Bat Species Diversity and Feeding Intensity in Intact Forest and Rubber Plantations in Southern Thailand

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ABSTRACT

Generally, large areas of tropical rain forest in Southeast Asia have been replaced by rubber plantations. There is little information on the impact of this on bat populations. The objective of this study is to compare bat diversity, bat activity and feeding intensity between intact tropical rain forest and nearby rubber plantations, using acoustic sampling and trapping. This study was conducted in Ton Nga Chang Wildlife Sanctuary (WS), and nearby rubber plantation in Songkhla Province, and Khao Ban That WS, Trang Province and Phattalung Province in Southern Thailand. Findings show that bat activity and insect biomass were significantly higher in intact forest compared to rubber plantations. Twenty species were acoustically recorded in forest while ten species were found in rubber plantations acoustically. Bat passes and feeding buzz in rubber plantations were, respectively, 58% and 33% lower than in forest sites. While 355 bats of 24 species were captured in forest, 16 individuals of eight bat species were trapped in rubber plantations. Bats found in forest have lower wing loading and lower aspect ratios than those found in rubber plantations. Based on the projection of wing morphology, bats were then divided into two groups; forest dependent (those found only in forest) and forest independent group (found both in forest and rubber plantations). Bats in the forest dependent group have much higher call frequency, low wing loading and low aspect ratio compared to bats in the forest independent group. These results can be used to identify and predict bat species that are likely to be seriously affected by forest disturbance, especially, when forest is replaced by plantation, agricultural and shifting cultivation.

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CHAPTER 1

INTRODUCTION

1.1 General introduction

Generally, tropical rain forest in Southeast Asia has been rapidly lost due to various human activities including shifting cultivation, and other agricultural practices, railways, road and industrial construction (Whitmore, 1984; Hutson *et al.*, 2001). Habitat loss and forest fragmentation may be subjected to factors leading to species loss, including deforestation-related disturbance, restriction of population size, reduction of immigration rates, forest edge effects, breakdowns in the ecological web, and the invasion of exotic species (Bernard and Fenton, 2006). In larger parts of South East Asia, primary forests are being modified by selective logging or cleared and replaced with plantations of exotic trees such rubber (*Hevea brasiliensis*) and oil palm (*Elaeis guineensis*), conversion of primary forest to rubber and oil palm plantations led to simple, species poor, less complex, lower canopy, less stable microclimate than natural forest, and greater human disturbance (Fitzherbert *et al.*, 2008). There is little information available concerning the responses of tropical forest animal to these changes.

That deforestation has been also identified as the major cause of forest loss in Thailand. The habitat changes essentially affect the availability of bats foraging and roosts sites and thus inevitably results in bat population decline. Some bats will be disappeared from its present habitat if level of clutter is changed (Hutson *et al.*, 2001). An increasing human population brings with it extra demand for land, resources, and food, which often results in the degradation or destruction of certain habitat types with a concomitant effect on bat populations (Hutson *et al.*, 2001). Diversity of species and trophic roles, abundances of individuals, mobility and sometimes relative ease of capture make bats natural candidates for ecological studies, especially, those on the effects of forest fragmentation (Bernard and Fenton, 2006, Struebig *et al.,* 2008). Furthermore, if bats are strongly affected by fragmentation, important ecological processes involving them (e.g. pollination and seed dispersal) will also be affected, compromising the forest dynamics and regeneration (Bernard and Fenton, 2006).

The insectivorous bat community can be broadly divided into three guilds, defined by the degree of clutter as narrow-space, edge and gap and open-space bat (Altringham, 1996; Schnitzler and Kalko, 1998; Kingston *et al*., 2003). The degree of negative effect of habitat disturbance may vary between bat species and bat guild. Prey abundance in forests can also be influenced by vegetation density and harvesting regimes. In some cases, forest insects are more abundant than in harvested areas (Patriquin and Barclay, 2003). Some bat species can forage in un-cluttered condition, while most of them forage in highly cluttered space. The habitat choice of foraging bats depends on the local food supply, bat activity increase with insect increase (Anthony and Kunz, 1977; Barclay, 1991; Kusch *et al*., 2004; Bartonicka and Rehak, 2004). Because insects are the major prey of most bat species and changes in the activity level of insects should also influence foraging behavior and activity level of bats (Lang *et al*., 2006). Most of insectivorous bat prey on insect, such as those in these order Homoptera, Lepidoptera, Coleoptera, Hemiptera, Hymenoptera, Odonata, Diptera, Orthoptera, Trichoptera, Blattodea, Neuroptera, Collembola, Araneae, Psocoptera and Psocoptera (Agosta, 2002; Tibbels and Kurta, 2003; Lumsden, and Bennett, 2005; Leelapaibul *et al*., 2005). Thus, difference in habitat structure or density of resources may significantly influence on feeding success of foraging bats (Anthony and Kunz, 1977).

Bat foraging strategy is constrained by wing morphology and echolocation call design (Aldridge and Rautenbach, 1987; Altringham, 1996; Schnitzler and Kalko, 1998; Bogdanowicz *et al*., 1999). Body mass and wing morphology of bat influence its wing loading and aspect ratio. Bats with low body mass, low wing loadings, low aspect ratios, low flight speeds, and high manoeuvrable can forage in cluttered space (Aldridge and Rautenbach, 1987; Altringham, 1996; Jacobs *et al*., 2005). Bats with short and broad wings are better adapted to maneuver in cluttered habitat because their body size and wing dimensions allow the species to fly and forage efficiently in cluttered environments. Bats with a larger body mass, average wing loadings and aspect ratios are less maneuverable and effectively forage in more open vegetation (Aldridge and Rautenbach, 1987).

Bats locate and capture their prey by the aid of their echolocation calls (Altringham, 1996; Schnitzler and Kalko, 1998; Fenton, 1999). The hunting bats emit echolocation calls to get information of their surroundings and search for their prey in search phrase, but when the hunting bat detects an insect or another kind of food, they increase their pulse. Most bats emit calls at a high repetition rate (feeding buzzes) to localize their prey during attacking phrase (Jung *et al.,* 1999; Arlettaz *et al.*, 2001; Menzel *et al*., 2002). Bat echolocation call may include constant frequency (CF), frequency modulated (FM) and Quasi Constant Frequency (QCF) depends on habitat and bat species (Aldridge and Rautenbach, 1987; Waters and Walsh, 1994; Kunz and Racey, 1998; Fenton, 1983; Fenton, 1985; Schnitzler and Kalko, 1998; Kingston *et al.*, 1999). Bat produce low frequency and long duration associate with open space or un-clutter space while bat produce higher frequency and short duration prefer highly clutter space. Gernaerally, call frequency increase when bat body size decrease (Zhang *et al*., 2000) Consequently, large bat species are generally limited to more open habitat whereas more manoeuvrable species can forage in more cluttered habitat (Schnitzler and Kalko, 1998; Ross and Jones, 2002). Bats forage in each foraging site for relative short duration (Kusch *et al.,* 2004) and not far from roost (Crampton and Barclay, 1998; Zahn *et al.,* 2004) but some bat species forage in large home range such as *Tadarida* forage at high altitude up to several kilometers, and as far as 25 km from caves (William *et al*., 1973)

Currently, large areas up to 2.72 million ha of rubber plantations are present in southern Thailand. Southern Thailand was the single largest rubber plantation region in the world (Krukanont and Prasertsan, 2004). The large track of tropical rain forest has been changed to be rubber plantations especially when the price of rubber is high. As a result, soil erosion, shortage of water supply, and biodiversity losses are currently observed in this exotic monoculture plantation. Only a few studies have been done on the effect of rubber plantations to biodiversity lost. As there are growing concerns on the lost of biodiversity, reliable data on suitability of land management for wildlife species, including bats are needed (Elmore *et al.,* 2005). For conservation of insectivorous bats, protecting their foraging habitats and their roosts are vital (Carmel and Safriel, 1998). In some cases, the fragmentation process leads to a decrease in species richness, diversity and abundance. In other cases there are no sharp differences in species richness and abundance between forest fragments and continuous forests, so small fragments can be ecologically important and rich bat species (Bernard and Fenton, 2006). However, little information on the impact of habitat disturbance from large rubber plantations to bat populations is available. Thus, the objective of this study is to compare bat species diversity, bat activity (feeding activity) and feeding intensity, based on acoustic techniques, between intact forest and nearby rubber plantations. Consistently, these results will be used to identify and predict bat species that are likely to be seriously affected by forest disturbance, especially, when forest is replaced by monoculture tree plantations, agricultural and shifting cultivation. Thus, this present study will help to identify areas important for bat and forest conservation.

1.2 Research questions

Are bat species diversity and feeding intensity significantly lower in rubber plantations as compared to intact forest nearby?

1.3 Research objective

To compare bat species diversity and feeding intensity in the intact forest and rubber plantations.

1.4 Research hypothesis

More bat species diversity and feeding intensity in intact forest than rubber plantations.

CHAPTER 2
LITERATER REVIEW

Order Chiroptera

Bats are the only mammals with the capacity for powered flight. Bats are found throughout greater part in of the world as tropical or subtropical, limestone, and island (Lekagul and McNeely, 1977). Bat in order Chiroptera includes 2 suborders Megachiroptera and Microchiroptera. Most of Megachiroptera are usually larger than Microchiroptera (insectivorous bat) and exclusively plant-eating such fruit, flowers, nectar and pollen, and confined to Africa, tropical Asia and Indo-Australasia. They are about 175 living species, all belonging to one family, the Pteropodidea. The Microchiroptera are usually smaller than Megachiroptera (1.5 - 150 g). Most of them prey on insect and other arthropods and also fruit nectar by using echolocation call. Microchiroptera consists of 17 families about 790 species. These families are the Rhinopomatidae, Craseonycteridae, Emballaonuridae, Rhinolophidae, Hipposideridae; Nycteridae, Megadermatidae, Mystacinidae, Noctilionidae, Mormoopidae, Phyllostomidae, Vespertilionidae, Natalidae, Furlipteridae, Thyropteridae, Myzopodidae, and Molossidae.

Bat species in study area

Thailand has very rich fauna in order Chiroptera include 2 suborders Megachiroptera and Microchiroptera. Lekagul and McNeely (1977) referred 10 families, 92 species. Subsequently; Corbet and Hill (1992) referred 10 families, 108 species that include endemic species while some bat species was endangered species and rare species. Up to the present, a total of 119 bat species; include 18 Megachiroptera and 101 Microchirotera have been recorded by Bumrungsri *et al*., (2006). Bumrungsri (1997) studied on roosts selection of cave dwelling bats in Songkhla and Satun Province found 2 Suborders, 6 Families, 20 species in 40 caves, These species were *Hipposideros bicolor, H. cineraceus, H. larvatus, H. diadema, H. armiger, H. lekaguli, H. galeritus, Rhinolophus lepidus, R. affinis, R. stheno, R.*

coelophyllus, Megaderma lyra, M. spasma, Miniopterus magnater, Miniopterus schreibersii, Taphozous melanopogon, Emballonura monticola, Rousettus amplexicaudatus, Cynopterus sphinx, and *Eonycteris spelaea*. Most Rhinolophid and Hipposiderid bats were common.

Echolocation and foraging strategy

In simple definition, echolocation is the analysis by an animal of echoes of its own emitted sounds waves, which it builds a sounds-picture of its immediate environment. In common with mammals, sounds are generated in the larynx. The larynx in Microbats is proportionally larger than Megabats and most other mammals. Microbats have heard as well, as large external ears or pinnae, noseleaf and tragus are accord to work (Altringham, 1996). Man is more sensitive to sounds below 15 kilohertz (kHz) but both bats and moths can hear ultrasonic in audible sound over 20 kHz. The frequencies used by bats are higher and cover a range from about 10 kHz to more than 200 kHz. Although, most insectivorous bat uses echolocation to detect obstacles and insect prey, only *Rousettus*, a fruit bat that use echolocation (Fenton, 1985).

Call of microchiropteran bat can be described as constant frequency (CF), quasi constant frequency (QCF) and frequency modulated (FM). Bat emits echolocation sounds in pulses. These pulses are usually described as being FM or CF, but many, perhaps most species of micro bat use combination of the two. The constant frequency (CF) call is used by many bats. They are typically 10 - 50 ms in duration, and are rarely entirely CF, since they often have brief, narrowband FM at one or both ends. CF pulse shower a lot of inter-specific variation and are more accurately referred to as CF/FM or even FM/CF/FM pulse. In broadband frequency modulated (FM), pulse is charecterised by short, sweep down the frequency from high to low frequency (Fenton, 1985; Altringham, 1996). Narrowband signals (as CF and QCF) are well advantage for target detection and classification but less suit for precise target localization. In contrast, broadband FM signals less suited for detection but allow more precise target localization (Schnitzler and Kalko, 1998).

When bat forage, changes in pulse pattern can be divided in to four phases: (1) search, (2) approach, (3) terminal and (4) capture (Altringham, 1996). The last one is called the "feeding buzz". Most of the hunting bats emit one of these pulses of sound each wing beat, for a small bat they would usually produce about 5 call per second and when the hunting bat detects an insect or another kind of food, they increase their production to more than 200 per second (Fenton, 1985). Generally, call can be heard on bat detector (Fenton, 1985) at distances of 10 to 15 metres when bat is facing the microphone (Fenton, 1985). However, most aerial insectivores use high-intensity echolocation calls, which can be identified and monitored with relative efficiency by acoustic methods (Aldridge and Rautenbach, 1987; Kingston *et al.*, 1999; Ross and Jones, 2002; Rydell *et al.*, 2002; Patriquin and Barclay, 2003).

Foraging habitat and echolocation

Within insectivorous bat community, it can be divided into three guilds based on foraging strategy. The first guild, narrow-space bats: bat species forage in highly cluttered space within the forest interior, second guild, edge and gap bats: bat species forage in small clearing in forest, over small streams or at the forest edge where its clutter is in the background and the third guild, open-space bats: bat species forage in open spaces above the forest, or in large clearings that are clear of clutter (Altringham, 1996; Schnitzler and Kalko, 1998; Kingston *et al.*, 2003). Narrow space CF bat, mostly found in horseshoe bat such as Hipposideridae and Rhinolophidae and narrow space FM bat was included Megadermatidae, Nyteridae and Vespertilionidae. Background clutter space bat was those in some Vespertilionidae (as *Eptesicus* and *Pipistrellus*) and uncluttered space bat are those Molossidae, Rhinopomatidae, Emballonuridae (as *Peropteryx* and *Taphozous*) and some Vespertilionidae such as *Nyctalus* and *Lasiurus* (Schnitzler and Kalko, 1998). Several studies have reported that, open space bat used long signals of low frequency that can detect prey on large insect in long distances but edge and gap (background cluttered space) bat use shorter signals and high frequency that can detect insect in smaller size and short distances (Schnitzler and Kalko, 1998; Zhang *et al.*, 2000). The echolocation interact with flight, food and foraging habitats. Thus, the degree of negative effect of habitat disturbance may vary between bat species, and the variation in habitat selection among species related to differences in body size, wing morphology (Patriquin and Barclay, 2003), echolocation call (Altringham, 1996; Schnitzler and Kalko, 1998) and food availability (Anthony and Kunz, 1977; Rydell *et al.*, 1996; Tibbels and Kurta, 2003).

Wing morphology and habitat selection

Flight modes and behavior vary among flying animal and depend on habitat structure, choice of food, foraging behavior and many factors (Norberg and Rayner, 1987). Flights at high or low speeds are related to manoeuvrability, referring to the minimum space required for turn at given speed and agility, relating to the rate at which a turn can be initiated. High flight speed correlates with high wing loading, good manoeuvrability is favored by low wing loading and turning agility should be associated with fast flight and with high wing loading (Norberg and Rayner, 1987). Bats have wings of different shapes and sizes, the differences largely influence foraging strategy of the bat as where they feed, how they feed and what they feed on. There are two main ways in which wings can vary. First, wing area can be large or small relative to the size of the bat; so called wing loading (Wl). High wing loading means a large bat with relatively small wing. Second, wing span square divide by wing area, called aspect ratio (AR). Low aspect ratio means wings is short and broad and high aspect ratio means long and narrow wing (Altringham, 1996).

Bat ecologists proposed four combination of bat wing morphology these are:

(1) Low Wl and low AR are found in many bats which feed among vegetation. These bat species fly slowly without stalling, make tight turns and even hover. Low speed profile power is low even with large wing area. All of bat in this part are gleaner and hoverers such as Nycteridae. *Plecotus* are typically ground gleaners, and have the lowest AR/Wl. The low Wl also enables them to carry heavy prey, and take off prey easily. Broad wings are also useful when taking off from the ground and moving in cluttered environments, because it has high manoeuvrability.

(2) High Wl and low AR, long wing would be aerodynamically more efficient for hovering, since induced power decrease with increase wingspan, but they are a hindrance in cluttered environment and limit manoeuvrability. These bats are principally nectar and pollen feeders and found among the phyllostomids such as *Glossopaga anoura, Leptonyteris, Choeronnyteris* and the small Megabats (*Macroglossus* spp.). The high Wl give them high flight speeds, an important factor when food supply is patchy and commuting time between patches must be minimized, and some of these bats dart from flower to flower like hummingbird. The long wing for hovering has been compromised by the need for speed and possibly access to flowers.

(3) Low Wl and high AR are also found in fish-eating bats such *Noctilio leporinus* and *Myotis vive*si. These species flying in the open over water, with no need to make tight turns, they have long and efficient wing. Wl is low so that they can carry heavy pay loads of the fish they feed on.

(4) High Wl and high AR are those species need to fly in open space, since their long wings would be a hindrance in vegetation. These bat species have high speed and long foraging distance such as *Tadarida brasiliensis* (Altringham, 1996).

For that reason, bat foraging strategy is constrained by wing morphology and echolocation call design (Aldridge and Rautenbach, 1987; Altringham, 1996; Schnitzler and Kalko, 1998; Bogdanowicz *et al*., 1999). Body mass and wing morphology of bat influence its wing loading and aspect ratio. Bats with low body mass, low wing loading, low aspect ratio, low flight speed, and low manoeuvrable can forage in cluttered space (Aldridge and Rautenbach, 1987; Norberg and Rayner, 1987; Altringham, 1996; Jacobs *et al*., 2005). Bats with short and broad wing are better adapted to maneuver in cluttered habitat because their body size and wing dimensions allow the species to fly and forage efficiently in cluttered environments and thus, these are sensitive to the effects of forest fragmentation. Bats with a larger body mass, average wing loading and aspect ratio are less maneuverable and effectively forage in more open vegetation (Aldridge and Rautenbach, 1987).

Bat activity and prey selection

Most of insectivorous bats prey on insects. The habitat choice of foraging bats depends on habitat quality (Agosta, 2002), local food supply, bat activity increase with insect increase (Barclay, 1991; Kusch *et al*., 2004; Bartonicka and Rehak, 2004). Thus, changes in the activity level of insect should also influence foraging behavior and activity level of bats. The highest peak of bat activity was occurred on early hours after sunset (Rydell *et al.*, 1996: Mayer *et al.*, 2004) and second peak was about 3 hour before sunrise (Mayer *et al*., 2004). The highest abundance of bats after sunset that because, it provide more insect availability (Rydell *et al.*, 1996). The moon phase can affect animals differently depending on whether they are predators, prey, or both (Lang *et al*., 2006). For example, bat is predators that prey on insect at night time, which may benefit from bright moonlight because their prey is easier to detect. Bats usually active during the night around new moon, but not around full moon. Several studies noted that bat activities differ within the night (Rydell *et al.*, 1996).

Equipments used for studying bat activity with bat detector

Bat detector

Many insectivorous bats use echolocation call (ultrasonic sound) for foraging (Schnitzler and Kalko, 1998; Francis and Habersetzer, 1998) and many studies, the researchers use bat detector for their research. Bat researchers using bat detectors to identify flying species (Fenton, 1983) or to compare bat activity between areas or among habitats (Law *et al*., 1999; Taylor *et al*., 2005). There are many methods to convert ultrasonic signals into audible sounds including heterodyne, frequency division and time expansion detector. Which one is best one to use depends on the purpose and the budget (Fenton, 2000).

Recorder

Echolocation call of bat can be recorded with recorder. There are many different types of recorder such as tape recorder, minidisk recorder, and MP3 or wave recorders. Each recorder models have different memory level, the memory level indicate, how long it can record. Recorders often connect with bat detector via line in line.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study area

The study was conducted in tropical rain forest and rubber plantations close to Ton Nga Chang Wildlife Sanctuary (WS), Songkhla Province, and Khao Ban That WS, Trang Province and Phattalung Province, Southern Thailand (6 to 7 degree North and 99 to 101 degree East) (Figure 1). A study was conducted between June – December 2007. Common stand types included lowland moist evergreen forest, hill forest, and forest on limestone area (Figure 2-7). Khao Ban That WS was 27 kilometers from Phatthalung city. This WS cover 126, 696 ha. The major vegetation is lowland moist evergreen forest. Ton Nga Chang WS covers about 18, 195.4 ha (Department of National Park, wildlife and Plant Conservation, 2006); it is 28 kilometers from Hatyai city. The forest mainly consists of primary and secondary lowland forest. There are limestone and caves surround this WS. The altitude of these area ranges between 100 to 1, 350 m. The average annual temperature varies between 25 - 30 C°. The rainy season is from May to December, and dry season from January to April. The annual rain fall is more than 2, 000 mm (Bickel and Watanasit, 2005).

Site selection:

The sampling sites for intact forest were selected at the oldgrowth tropical rain forests in these wildlife sanctuaries and the sampling sites in rubber plantations were selected in the large rubber plantation nearby (Figure 8-9), 25 pairs of sampling sites were sampled. A sampling site in rubber plantation was selected based on the criteria:

(1) Rubber plantations are larger than 2 hectares

(2) Each pair of forest and rubber plantation is within 2 km distance.

(3) The rubber plantation is older than ten year.

(4) The acoustic sampling sites are at least 150 m from the edge between forest and rubber plantations (appendix 1).

Figure 1. Map of paired sampling site sampled at the Ton Nga Chang Wildlife Sanctuary and Khao Ban That Wildlife Sanctuary.

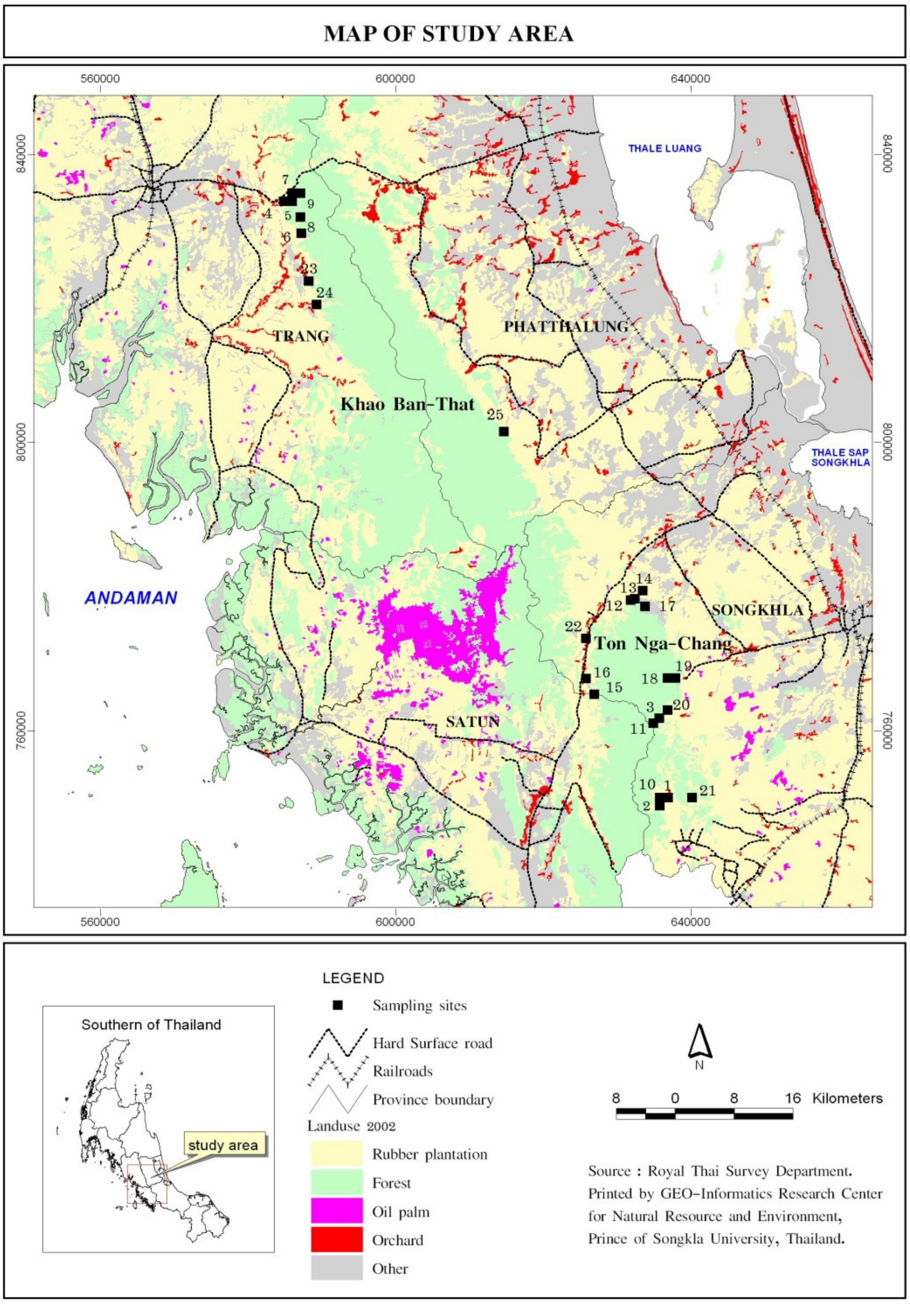


Figure 2-3. Forest sampling sites at the Ton Nga Chang Wildlife Sanctuary, Songkhla Province.

(Figure 2)

(Figure 3)

Figure 4-7. Forest sampling sites sampled at the Khao Ban That Wildlife Sanctuary, Trang and Phattalung Province.

(Figure 4)

(Figure 5)

(Figure 6)

(Figure 7)

Figure 8. Rubber plantation sampling sites close to Ton Nga Chang Wildlife Sanctuary.

Figure 9. Forest sampling sites in Ton Nga Chang Wildlife Sanctuary.

3.2 Acoustic studies

Bat activity was monitored at each site by an ultrasound detector model Petterson D-240x, frequency range 10-120 kHz connected with digital recorder (Figure 10). The acoustic sampling in each pair of habitats was undertaken on the same time each night. Bat detector was kept in box at 1.2 m above the ground, and tilted approximately 15° up from horizontal, stand in forest (forest gap and trail) and rubber plantation (space between row) (Figure 11). The heterodyne mode was set at 59 - 60 kHz. Bat detector was setting up to record in automatic mode and 17 seconds play back, normal gain: high, trigger type: low, Source: HF. In each sampling site, echolocation calls were recorded for 3 hours, between 18.30 h - 21.30 h (5 to 35 minutes after sunset, http://aa.usno.navy.mil/data/docs/RS_OneYear.php). Sampling sites were sampled in rain season (June - November 2007). The sampling was not conducted in heavy rain as bat activities are reduced.

Figure 10. Bat detector connected with recorder.

(a) (b)

Figure 11. Bat detector boxes in forest (a) and rubber plantation (b).

3.3 Bat trapping

Harp traps and mist nets were set in each sampling sites during or after acoustic sampling has been conducted. Direct capture by harp trap and mist net were an alternative way to confirm bats species presence. The capture method was conducted between June to December 2007. In two habitats, 25 pairs of sampling sites were sampled. Nets (6 x 12 m) were opened between 18.30 to 21.30 (5 to 35 minutes after sunset). Capture effort among habitats varied, with 1 harp trap used in forests, 1 harp trap and 2 mist nets in rubber plantation. Harp trap and mist nets were checked at 15-20 minutes intervals and all captured bats were placed in individual cloth bags for later identification and measurement including body mass (W), forearm length (FA), sex, reproductive status (Figure 12 - 23). Echolocation calls were recorded from hand released captured bats. Identification of all species was based on Corbet and Hill (1992), Bates and Harrison (1997), Douangkhae (2007), Payne et al. (1998), Kingston *et al*. (2006), and Francis (2008). For bat species that was unable to identify in the field, vouchers were collected and then preserved in 70% alcohol and deposited in Princess Maha Chakri Sirindhorn Natural History Museum, PSU.

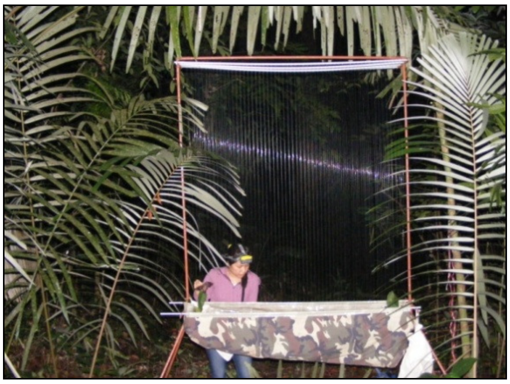


Figure 12. Harp trap in forest.

Figure 13. Harp trap in rubber.

Figure 14. Bats caught with harp trap.

Figure 15. Mist net in rubber.

Figure 16. Bat captured with mist net.

Figure 17. Bat processing.

Figure 18. Bat processing.

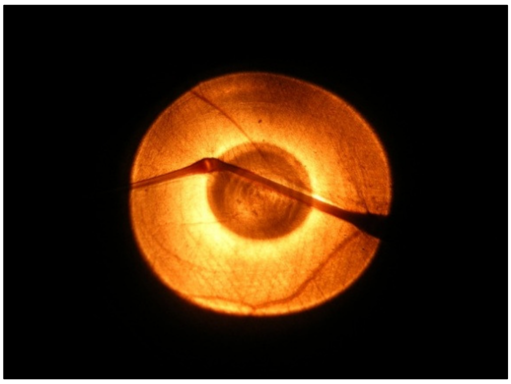


Figure 19. Age determination.

Figure 20. Measured forearm length.

Figure 21. Echolocation calls recorded.

Figure 22. Echolocation calls recorded in hand released.

3.4 Insect trapping

Insect was sampled simultaneously in intact forest and rubber stands using suction traps. The suction trap was set at least 50 m from ultrasonic monitoring sites and at 3 m high in gap in both sites (Figure 23). Suction traps were sampled insects 30 minute in each hour (19.00-19.30, 20.00-20.30 and 21.00- 21.30 h). The capture insects were put to a jar of 70% alcohol.

(a)

(b)

Figure 23. Suction trap in forest site (a) and rubber plantation (b).

3.5 Habitat structure

3.5.1 Forest and rubber plantation vertical stratification

The vertical stratification of a selected acoustic sampling site in forest and rubber plantation was made. Diameter and height of all trees and shrubs within 10 × 30 m were measured. In these plots, tree with diameter greater than 5 cm were measured in an area of 10 × 10 m, and for those greater than 15 cm were measured in an area of 10 × 20 m. The total height and the height at the first branch of all of trees were measured with rangefinder. Canopy widths were recorded.

3.5.2 Habitat clutter measurement

The habitat clutter was quantified (Brockelmen, 1998) as the percentage frequency of vegetation of 'hit' and 'misses' in 8 sites in each habitat (Hodgkison *et al.*, 2004). A 22 m-height vertical metal pole was set at 1, 2, 3, to 10 meters of North, South, East and West from a select central point. The hit or miss was scored at each 2 meters height from 2 to >22 meters height of vegetation.

3.6 Wing tracing

For each captured bat, photograph of each right wing (1/2 wing area) laid on a graph sheet was taken with Fuji S5700 camera. Head and tail of bat were placed in straight line of a graph sheet (Figure 24). Carefully, bat's head was not swing to avoid making it angry when taking their wing photo. The tip of wing was push straightly and firmly. The taken image was saved in jpg files in each species folder.

Figure 24. Taking a wing photograph on a graph paper.

3.6 Analysis

3.6.1 Sound analysis

Calls were analysed with Bat-Sound Pro 3.1 (Pettersson Elektronik, Sweden). Bat pass (at least 2 calls continuous) was counted. Number of bat feeding buzz or terminal buzz (call signals of bat were produced for captured flying insect) was counted in both forest and rubber plantations. Outliner (similar and bats produced continuous calls for more than 15 minutes) were counted as 1 bat pass.

Five parameters were measured from the harmonic containing most energy of call (Figure 25 - 26). To calculate minimum, maximum and peak frequency, -55 dB was used as the criterion for identifying minimum and maximum frequencies in any call (Taylor *et al.*, 2005):

(l) Start frequency (SF): the start or minimum frequency, measured from the power spectrum, obtained for each selected call.

(2) End Frequency (EF): The end or maximum frequency, measured from the power spectrum

(3) Most Energy Frequency: The frequency containing maximum energy, obtained from the power spectrum

(4) Call Duration (D): The duration of a single pulse, obtained by measuring the pulse envelope from the the oscillogram

(5) Inter-Call Interval (ICI): The time from the start of one pulse to the start of the next pulse, measured from the oscillogram

Recorded calls were compared with call reference collection from known bat species that was established in the present study and those already available in the Bat Research Unit, PSU. The echolocation calls were identified to species or genus based on call shape and most energy frequency. The echolocation calls were analyzed for only those bats producing CF calls (Rhinolophidae and Hipposideridae). Since species identification based on CF calls are highly accurate in these group. Some FM bats are also identified especially; those produce typical call characters show as *Embollonula monticola*.

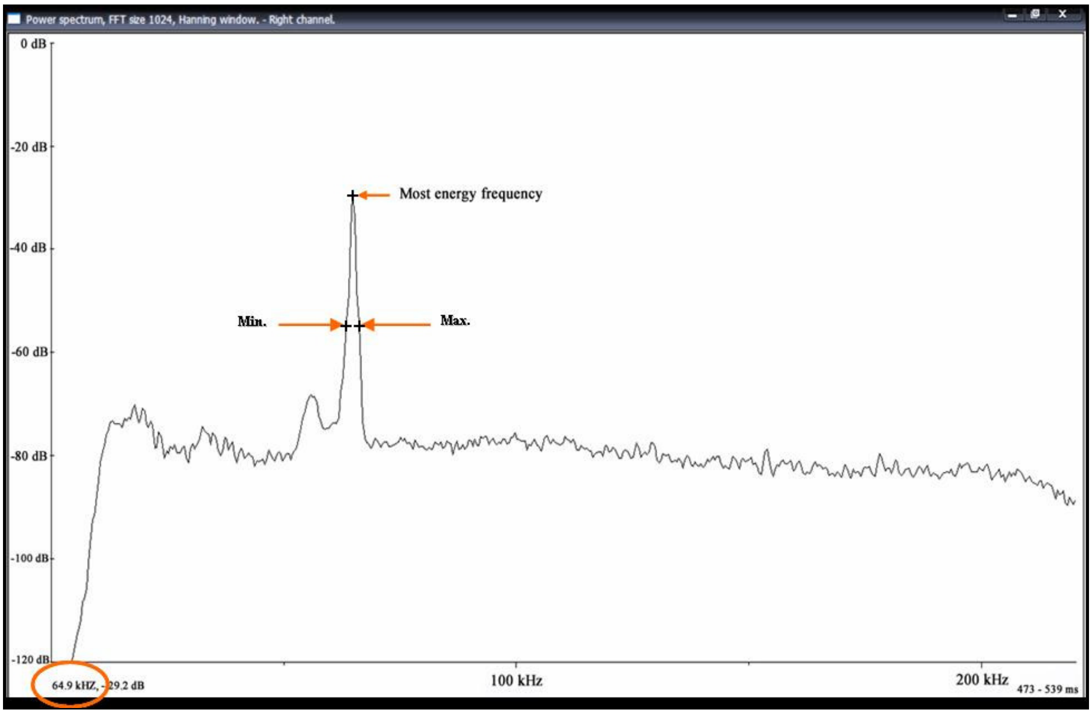


Figure 25. Power spectrum of call of *Rhinolophus robinsoni*, (Most energy frequency = 64.9 kHz, Minimum frequency = 63.3 kHz and Maximum frequency = 66.5 kHz).

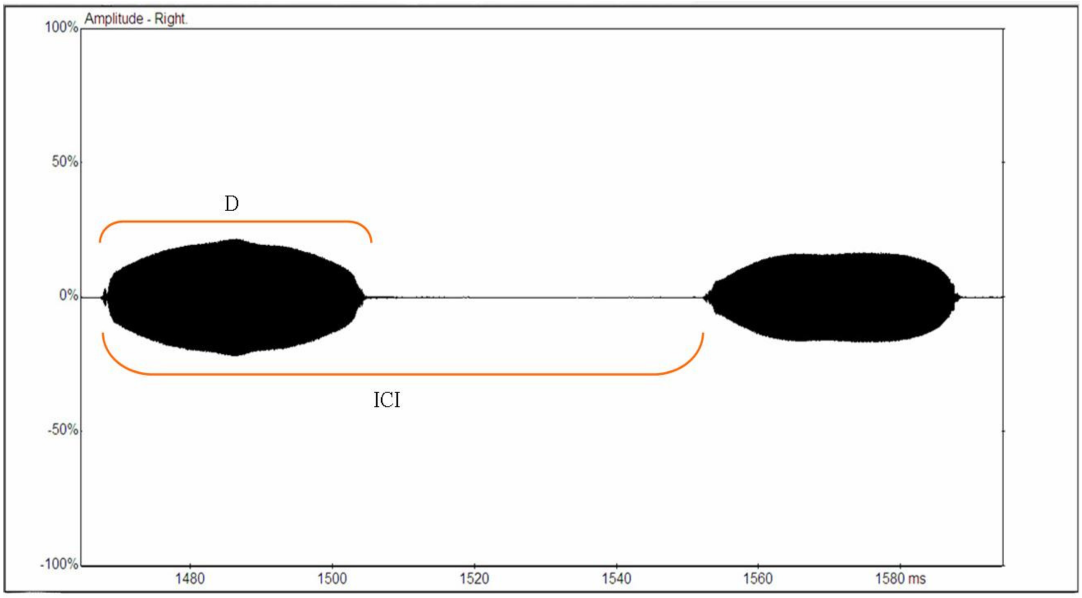


Figure 26. Oscillogram of calls of *Rhinolophus robinsoni*, (Call duration (D) = 50.2 ms and Inter-Call Interval (ICI) = 80.8 ms).

3.6.2 Wing morphology analyses

Wing morphometic were measured from image photo including wing area (S), area of armwing (*Saw*), handwing (*Shw*), length of arm wing (*law*) and length of handwaing (*lhw*) with Photoshop CS2, version 9. Area was carefully approximated by the tpsDig2 program (tpsSuper-digitized program). A number of different conventional character have been used to define wing morphometric of bat (Figure 27), these are:

(1) Wing loading: body mass divided by wing area (Wl=Mg/ S), M is body mass, g the acceleration due to gravity and (S) is wing area.

(2) Aspect ratio: wing span square divided by wing area (AR= B^2/ S), B is wing span.

(3) Wing shape index: relative between hand wing length and the arm wing length contribute to the total wing (I = Ts / Tl – Ts), (Ts) is the ratio of the handwing to the area of the armwing (Ts = Shw/Saw) and (Tl) is the ratio of handwing length and armwing length (Tl = *lhw* /*law*).

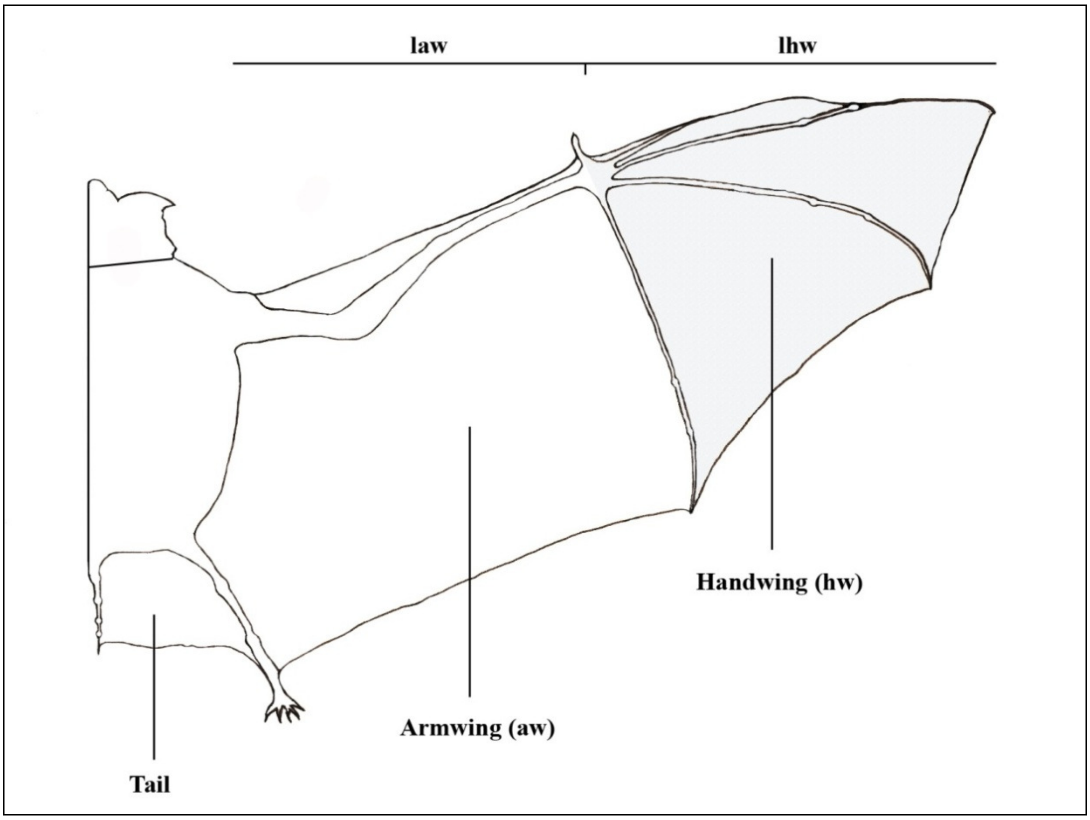


Figure 27. Wing drawing used to define wing morphology of bat.

3.6.3 Insect biomass

Captured insects were identified to order (Borror *et al*., 1989). Insects were sorted into categories based on the length of the body (0.1–2.0, 2.1–4.0, 4.1–6.0, 6.1–8.0, 8.1–10.0, 10.1–12.0, 12.1–24.0, 14.1–16.0, 16.1–18.0, 18.1–20.0, 20.1–22.0 and 22.1–24.0 mm). Captured insect were calculated for its biomass following Rogers *et al*., 1976 and Lumsden and Bennett, 2005:

$W = 0.0305L^{2.62}$

Where W is dry mass (mg) and L is length (mm).

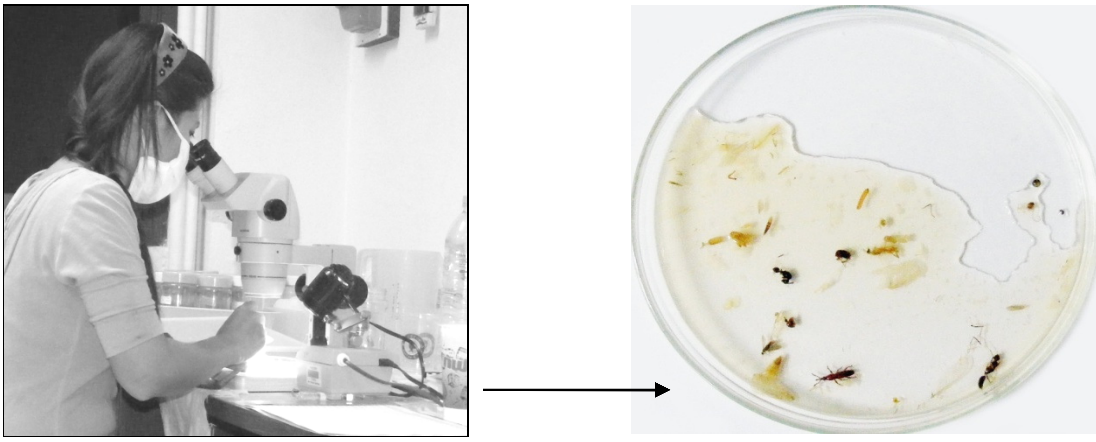


Figure 28. Insect identification in laboratory.

3.6.4 Habitat Structure:

The habitat clutter was quantified as the percentage frequency of vegetation of 'hit' and 'misses' in 8 sites in each habitat. A 22 m-height vertical metal pole was set at 1, 2, 3, to 10 meters of North, South, East and West from a select central point. The hit or miss was scored at each 2 meters height from 2 to >22 meters height of vegetation.

3.7 Statistic analysis:

Wilcoxon signed ranks test was applied to test for variation in relative use of habitat and feeding activity of bat and insect biomass in each habitat. Spearman's correlation was used to investigate the relationship between bat activity and insect biomass. A correlation between wing morphologys and call characters was examined by Spearman's test. One-way ANOVA test was applied to test for variation between forest dependent and forest independent group. These tests were run in SPSS 14.0 for Windows (SPSS Inc.). The cluster analysis and the Principle Component Analysis (PCA) were run in PC-ORD for Windows version 4.17 (McCune and Mefford, 1999). Graphs and diagram were made in windows excel, Microsoft office excel 2003. Species richness was estimated with EstimateS version 7.52 (Magurran, 2004). The species richness estimators were selected including Chao1 and Bootstrap. Margalef's Index was applied to determine species alpha diversity.

3.7.1 Species alpha diversity index:

$$D_{mg} = \frac{(S-1)}{InN}$$

D_{mg} : Species alpha diversity index
S : Number of bat species
N : Total number of bat individual

CHAPTER 4

RESULTS

4.1 Acoustic studies

From 25 paired sampling sites in the rainy season, the number of bat passes in 20 forest sites was higher than in rubber plantations (Figure 29). A total of 925 bat passes sites and 149 feeding buzzes were recorded in both habitats. 326 bat passes in both forest and rubber plantations site were categorized as outlier. After outliers were excluded, there were 377 bat passes in forest in which 241 of them were CF (Constant Frequency), 110 bat passes were FM (Frequency Modulated), 26 bat passes were QCF (Quasi Constant Frequency, Figure 30), and 106 (2 CF and 104 FM) bat calls are belong to unknown species (see appendix 2). A total of 112 feeding buzzes (terminal buzz) (Figure 31) were found in forest sites. Nine teen species (*R. affinis, R. stheno, R. lepidus, R. trifoliatus, R. coeloplyllus, R. yunanensis, R. robinsoni, R. luctus, R. acuminatus, R. mayalanus, Coelops frithii, K. hardwickii, H. bicolor, H. diadema, Emballonura monticola, H. cineraceus, H. armiger, H. larvatus, and Nycteris tragata*) were acoustically recorded in forest sites. Bat passes and feeding buzz in rubber plantations were 58% and 33% respectively of those in forest sites. A total 222 bat passes, and 37 feeding buzzes were found in rubber plantations. There were 99 CF, 3 FM, 23 QCF bat passes while another 97 (2 CF and 95 FM) bat calls were belong to unknown species. Consistently, the number of bat species in rubber plantations was lower than forest sites, ten species (*R. trifoliatus, R. affinis, R. lepidus, R. luctus, R. robinsoni, R. stheno, H. bicolor, H. larvatus, Emballonura monticola* and *Taphozous longimanus*) were recognized acoustically.

The intensity of bat activity (i.e. bat passes) was significantly different (Wilcoxon signed rank test, T=241.5, n=25, N=25, P=0.009) between forest and rubber plantations. Bat passes in forest (Mean ± SE, 15.08 ± 1.72) was higher than rubber plantations (8.88 ± 1.23). However, bat activity was significantly different between them in the first hour after sunset (Wilcoxon signed rank test, T=280, n=25, N=25, P=0.002) but did not different significantly in the second (Wilcoxon signed ranks test, T=183.5, n=25, N=25, P=0.064) and the third hour after sunset (Wilcoxon signed ranks test, T=96, n=25, N=25, P=0.968, Figure 32).

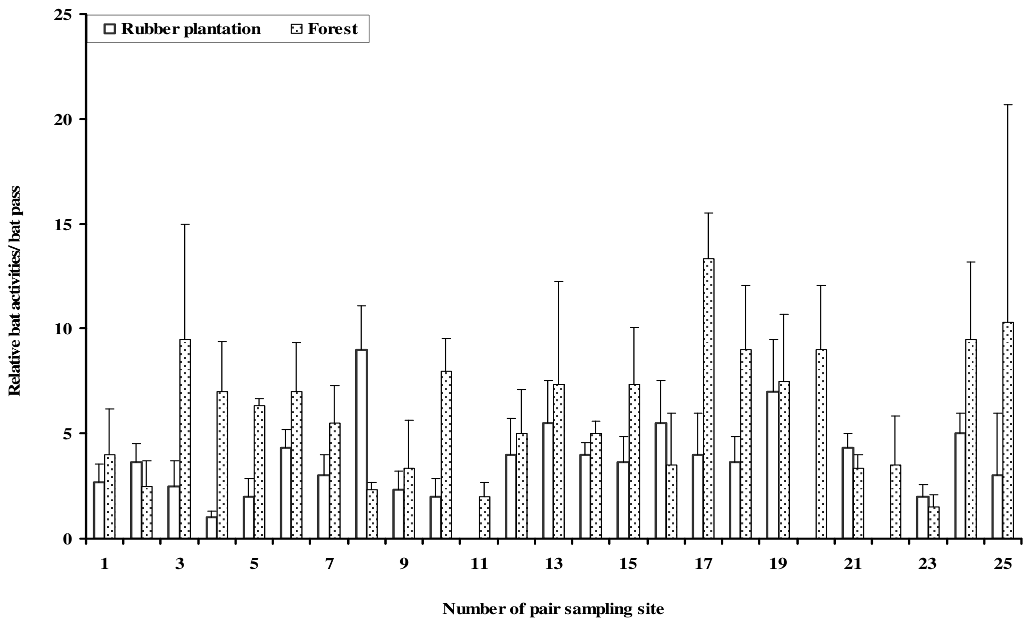


Figure 29. Mean (±SE) of bat pass in three hours after sunset in each pair sampling site in forest and rubber plantations.

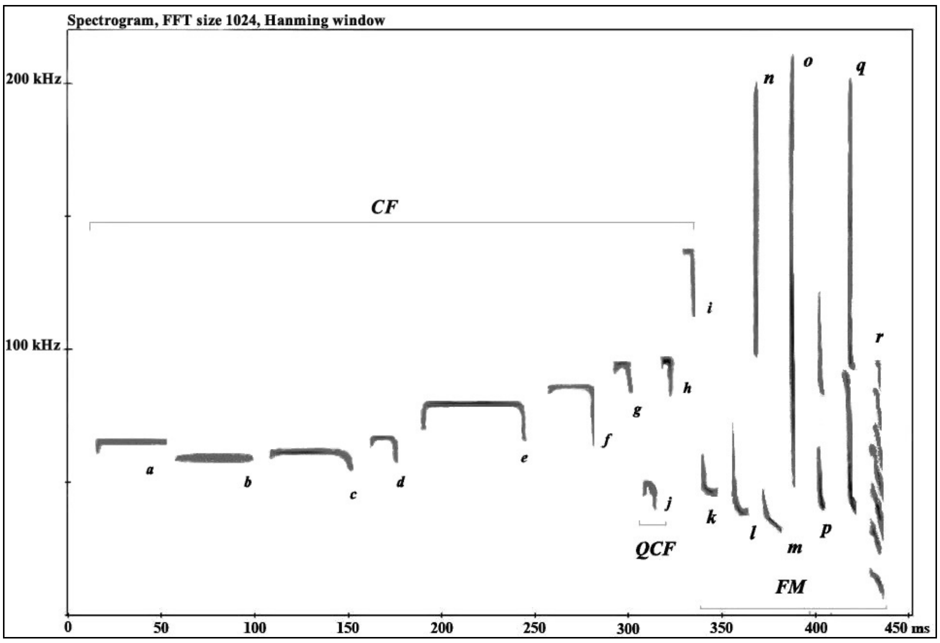


Figure 30. Echolocation calls presented in the present study (including known and unknown bat species).

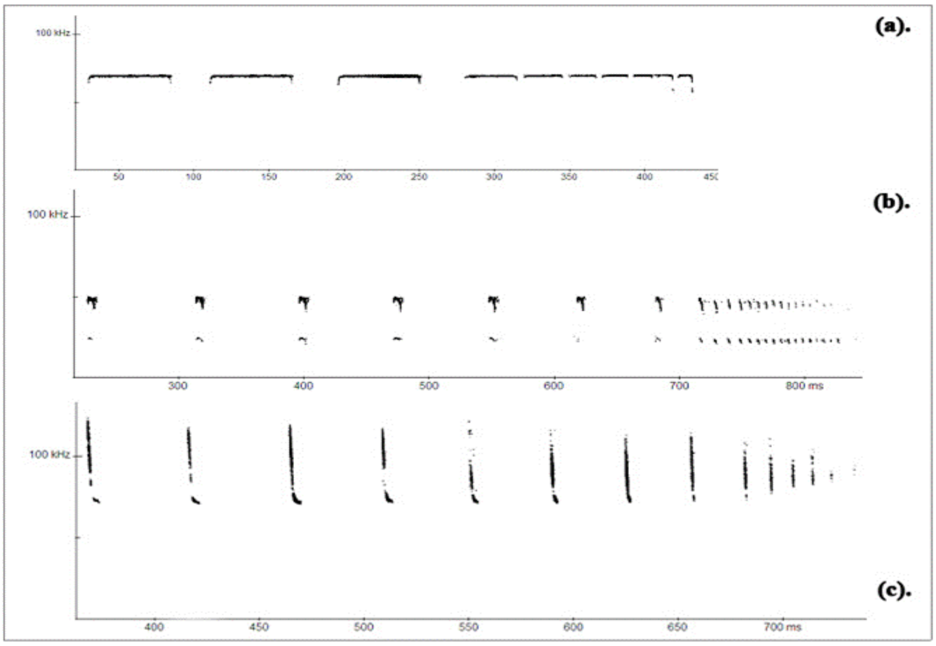


Figure 31. Feeding buzz of (a). *Rhinolophus affinis* (CF), (b). *Enbollonura monticola* (QCF) and (c). *Unknown bat species* (FM).

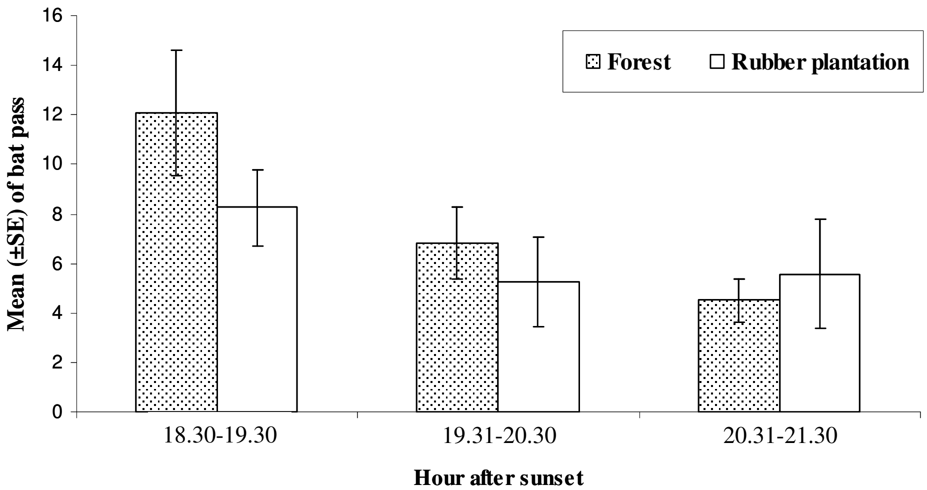


Figure 32. Mean (±SE) of bat passes in each hour after sunset in forest and rubber plantations.

4.3 Insect biomass

Based on trapping results from 12 paired sampling sites, Lepidopteran has the highest biomass among insect trapped in both forest and rubber plantations sampling sites (58-74%, see appendix 3 - 4). Diptera, and Coleoptera were moderately abundant and others insect order (Hemiptera, Homoptera, Hymenoptera, Isoptera, Tricoptera, Orthoptera, and Odonata) were relatively rare (Figure 33). Ten insect orders were found in forest (Lepidoptera, Diptera, Coleoptera, Hemiptera, Homoptera, Hymenopters, Isoptera, Tricoptera, Orthoptera, and Odonata (Figure 33a) and eight insect orders in rubber plantations (Lepidoptera, Diptera, Coleoptera, Hemiptera, Homoptera, Hymenoptera, Isoptera, and Tricoptera (Figure 33b). There was differed in number of insect size class between forest and rubber plantations. Every insect sizes had been found in forest (less than 2 mm to 24 mm) but fewer insect size claves had been found in rubber plantation (less than 2 to 12 mm).

Insect biomass was significantly different between forest (Mean ± SE, 849.7 ± 187.4) and rubber plantations (357.9 ± 88.8)(Wilcoxon signed ranks test, T= 69, N=12, N=12, P=0.019) in which Lepidoptera was proportionally much higher in the former than the latter. Within three hour sampling period, insect biomass was significantly different in the first hour after sunset between forest and rubber plantations (Wilcoxon signed ranks test, T=67, n=12, N=12, P=0.028) but not different significantly in the second (Wilcoxon signed ranks test, T=46, n=12, N=12, P=0.582) and the third hour after sunset between them (Wilcoxon signed ranks test, T= 61, N=12, N=12, P=0.084).

In any given sites, bat passes was not significantly correlated with insect biomass in forest site (r =0. 127, N=2, P =0.695) and in rubber plantation (r= 0.189, N=12, P=0.555). There were no correlations between bat pass and insect biomass in the first hour (r=0.228, N=12, P=0.367), the second hour (r=-0.134, N=12, P=0.677) and the third hour in forest site (r=-0.500, N=12, P=0.097). In rubber plantations there were no correlation between bat pass and insect biomass in the first (r=-0.275, N=12, P=0.385), the second (r=-0.109, N=12, P=0.734) and the third hour (r=0.294, N=12, P=0.353, Figure 34). There were no correlation (P>0.05) between biomass and bat passes in both types of call CF and FM.

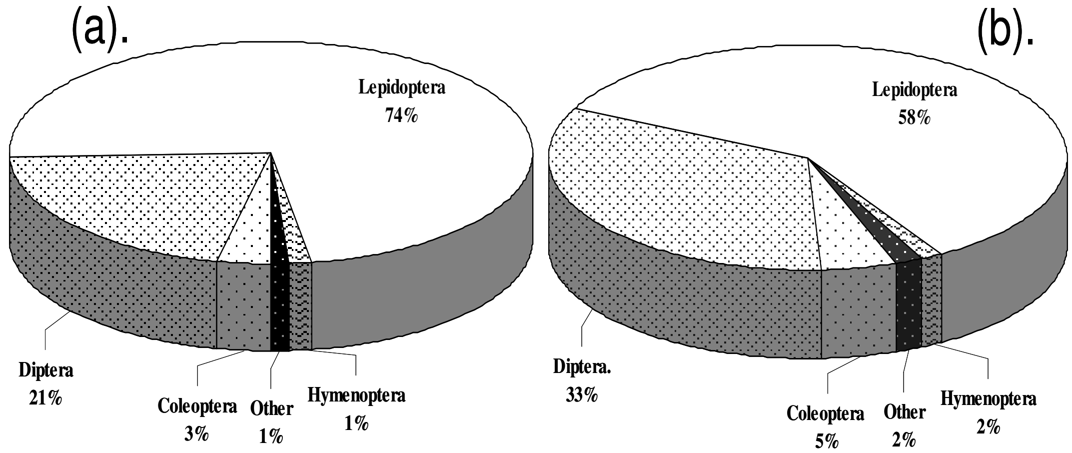


Figure 33. The percent of insect biomass. (a). insect biomass in forest and (b). insect biomass in rubber plantations.

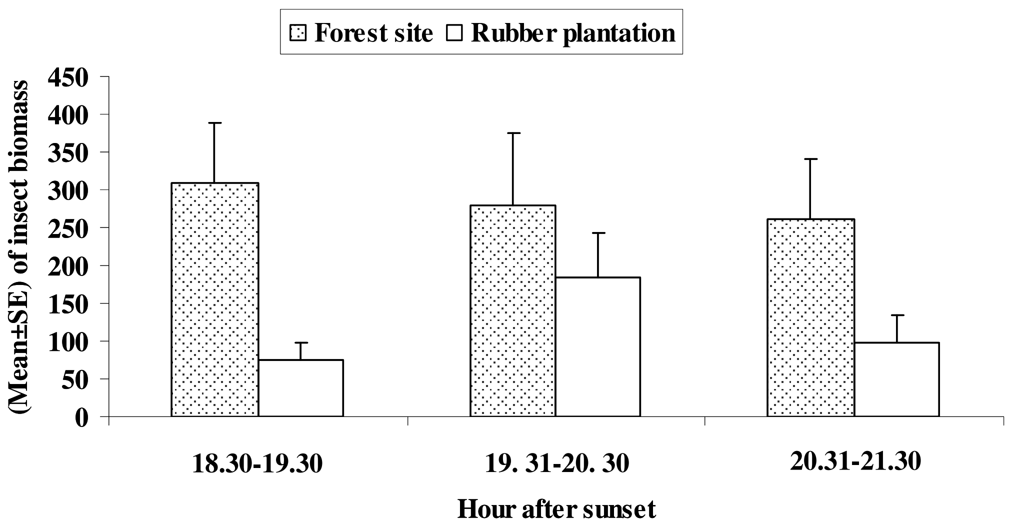


Figure 34. Comparison between mean (±SE) value of insect biomass in three hours after sunset in forest and rubber plantations.

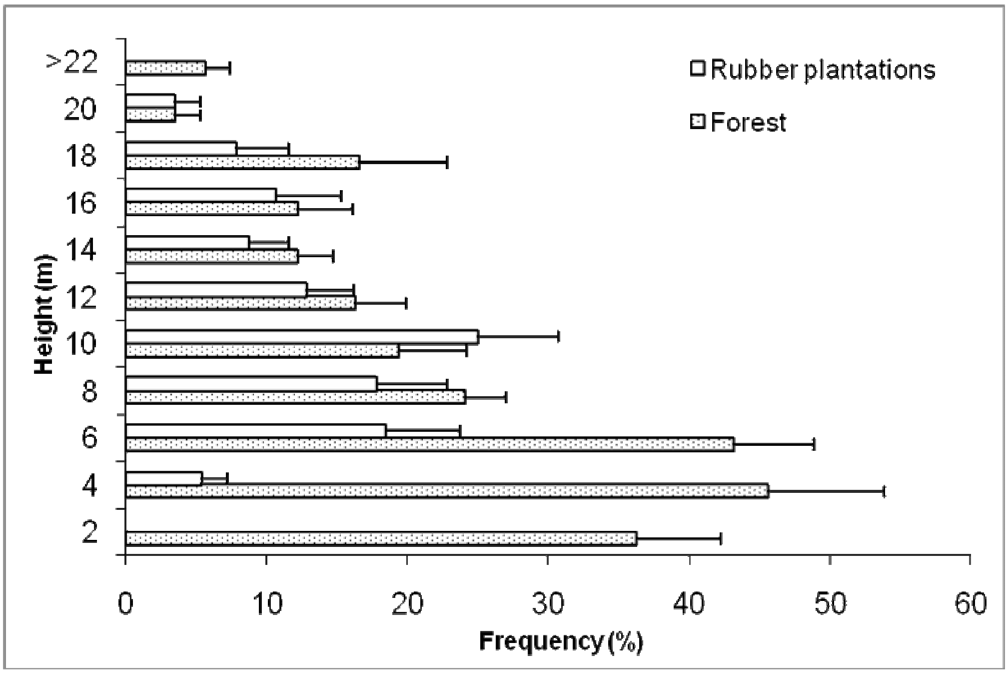
4.3 Habitat structure

Forest and rubber plantations profiles were strongly different. There was more complexity and tree density in forest than rubber plantations. There were 82 trees in forest sampling site but only 18 rubber trees in rubber plantation sampling site. There was more clutter of understorey of forest compared to rubber plantation (Figure 35). This was supported quantitatively with habitat clutter analysis. The highest clutter was at understorey (2 to 6 meters), intermediate at midstorey (8 to 20 meters) and less at canopy (>22 meters) level in forest. In contrast, there was much less clutter at 0-6 m height in rubber plantations compared to forest samples (4 times). The clutter level was comparable at 8-16 m height between both habitats while the canopy over 22 m was missed in rubber plantations (Figure 36).

Figure 35. The habitat structure of rubber plantation profiles.

Figure 36. The habitat structure of forest profiles.

Figure 37. The frequency of vegetation in forest and rubber plantations.



4.4 Bat trapping

In terms of species richness, there was a difference between forest and rubber sampling site from direct capturing. From estimated species richness based on sampling effort, no asymptote was reached in both habitats (Figure 38). It appears that more species could be found in each habitat, especially, in forest. In such habitat, bat accumulative species richness constantly increase when sampling effort increase. In rubber plantations, the number of bat species sharply increased in the first 20 hours effort then relatively stable after that (Figure 38).

There was difference in bat species richness between forest and rubber plantation. More bat species were found in forest than in rubber plantation (Figure 38). 355 bats of 24 bat species were captured in forest sampling sites (Table 1). These bats were mainly belonged to Rhinolophidae and Hipposideridae for example: *R. affinis, R. lepidus, R. mayalanus, R. stheno, R. robinsoni, R. trifoliatus, R. luctus, R. yunanensis, H. bicolor, H. diadema,* and *H. cineraceus* (Table 1 and Table 2). 16 individuals of 8 bat species (*R. stheno, Phoniscus jagorii, H. bicolor, H. larvatus, R.*

affinis, R. luctus, Miniopterus magnator and Magaderma spasma) were found in rubber plantation sampling. Additionally, fruit bats such as *Cynopterus sphinx, C. brachyotis, Rousettus amplexicaudatus, Balionycteris maculata, Megaerops ecaudatus and Eonycteris spelaea* were common in rubber plantation (appendix 5). The number of species observed closed to a prediction of Chao1 and Bootstrap in both forest and rubber plantations (Table 3).

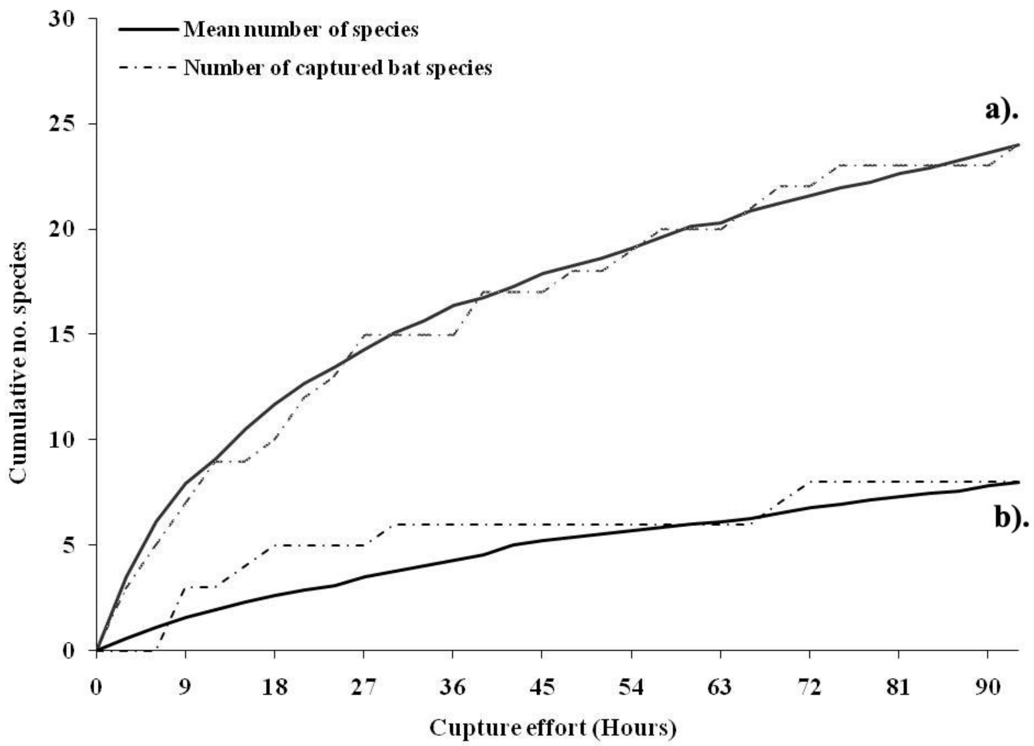


Figure 38. Bat species richness from direct capture in (a). forest and (b). rubber plantations (not included fruit bat species).

Table 1. Species richness in forest and rubber plantations.

Suborder	Family	Species	Forest	Rubber
Microchiroptera	Hipposideridae	*Hipposideros bicolor*	85	4
		Hipposideros cineraceus	4	-
		Hipposideros diadema	4	-
		Hipposideros larvatus	16	1
		Coelops frithii	2	-
	Megadermatidae	*Megaderma spasma*	4	1
	Nycteridae	*Nycteris tragata*	1	-
	Rhinolophidae	*Rhinolophus acuminatus*	6	-
		Rhinolophus affinis	99	6
		Rhinolophus coelophyllus	1	-
		Rhinolophus lepidus	29	-
		Rhinolophus luctus	3	1
		Rhinolophus malayanus	13	-
		Rhinolophus robinsoni	4	-
		Rhinolophus stheno	32	1
		Rhinolophus trifoliatus	3	-
		Rhinolophus yunanensis	3	-
	Vespertilionidae	*Kerivoula hardwickii*	21	-
		Kerivoula minuta	3	-
		Miniopterus magnator	7	1
		Murina cf. cyclotis	9	-
		Murina cf. suilla	2	-
		Myotis muricola	3	-
		Phoniscus jagorii	-	1
		Pipistrellus cf. tenuis	1	-
Number of bat species			**24**	**8**
Number of total bat species			**355**	**16**
Diversity index			**3.93**	**2.52**

Table 2. Bat species and call frequency from direct captured in forest and rubber plantations.

Species	n	Frequency (kHz) Most energy	Min.	Max.	D	ICI	Type
*Emballonura monticola**	2	48.9	45.3	51.9	3.6	64.7	QCF
*Hipposideros armiger**	4	67.2	64.13	68.9	12.3	51.9	CF
Hipposideros bicolor	15	140.4	124.1	141.2	5.3	14.4	CF
Hipposideros cineraceus	4	148.1	147.1	160.6	5.3	15.4	CF
Hipposideros diadema	3	57.8	49.5	58.9	11.9	30.4	CF
Hipposideros larvatus	4	96.2	87.3	90.4	5.1	29.3	CF
Coelops frithii	2	120.3	114.8	125.6	0.65	12.9	FM
Megaderma spasma	5	85.4	74.7	91.8	0.9	34.4	FM
Nycteris tragata	4	100.3	96.6	111.9	0.3	11.9	CF
Rhinolophus acuminatus	4	89.6	83.2	91.1	39.7	69.6	CF
Rhinolophus affinis	15	71.3	66.9	73.5	29.2	59.4	CF
Rhinolophus coelophyllus	4	79.23	71.7	80.3	25.8	53.9	CF
Rhinolophus lepidus	7	101.8	92.6	102.7	35.9	66.3	CF
Rhinolophus luctus	6	32.1	23.3	33.3	64.3	141.9	CF
Rhinolophus malayanus	5	86.7	82.4	87.9	31.6	55.3	CF
Rhinolophus robinsoni	5	66.9	62.1	67.8	42.2	86	CF
Rhinolophus stheno	10	86.1	83.5	87.2	38.8	68.6	CF
Rhinolophus trifoliatus	4	50.3	47.4	51.6	42.6	76.9	CF
Rhinolophus yunanensis	2	51.5	43.2	52.9	38	120	CF
Kerivoula hardwickii	6	114.8	104.5	125.7	0.6	16.1	FM
Kerivoula minuta	2	125.4	109.2	134.7	0.7	9.6	FM
Miniopterus magnator	4	47.1	38.2	97.9	4.5	66	FM
Murina cf. cyclotis	4	105.7	83	116.2	1.5	46.9	FM
Murina cf. suilla	6	112.8	97.9	129.6	1.1	51.1	FM
Myotis muricola	7	89.3	65.4	110.6	2.8	62.9	FM
Phoniscus jagorii	1	86.2	85.7	86.9	2.1	63.6	FM
Pipistrellus cf. tenuis	1	-	-	-	-	-	-

* Bat Research Unit

Table 3. The averages and species richness of several predictions (not included fruit bat species but included 6 pair sampling sites replication capture).

Habitat	Site	Sobs	Mean average of species richness (%) Chao 1	Bootstrap	Mean
Forest	31	24	27	28	28
(%)			88.9	85.7	87.3
Rubber	31	8	11	10	11
(%)			72.7	80	76.4

4.5 Wing morphology

Wing morpholocial data from 107 individuals of 25 bat species in 5 families were obtained. When compile information from both direct capture and acoustical encounter, bat can be divided into two groups: first, the bats found in forest only (Figure 39) and second, the bat found in forest and rubber plantation. 13 bat species have been found in forest only including *H. armiger, H. cineraceus, H. diadema, Coelops frithii, N. tragata, R. acuminatus, R. coeloplyllus, R. mayalanus, Kerivoula hardwikii, K. minuta, Murina cf. cyclotis, M. suilla* and *Myotis muricola*. However, some bats in forest only group such as *H. diadema* that was also captured in rubber plantation during the field study but was excluded since trapping in forest in that night was missed. 11 bat species have been found in both forest and rubber plantation including *Emballonura monticola, Hipposideros bicolor, H. larvatus, Megaderma spasma, Rhinolophus affinis, R. lepidus, R. luctus, R. robinsoni, R. stheno, R. trifoliatus, Miniopterus magnator*. *Phoniscus jagorii* was found in rubber plantation only. From the present study, bats found in forest only have relatively lower wing loading and aspect ratio compared to those found in forest and rubber plantation (Table 5-6). Call frequency of bats in former were higher than the latter (Table 7-8).

From PCA overlay of wing morphology of those bats in forest and rubber plantation group including *H. diadema*, *H. armiger* and *N. tragata* on those forest only groups, several species of bat in forest only group fall in no-overlap zone. These bats were name as forest dependent bats and those found in overlap zone, called forest independent bats. Forest-dependent group including *H. cineraceus*, *Coelops frithii*, *Kerivoula hardwikii, K. minuta, Murina cf. cyclotis,* and *M. suilla*. These bats have very low wing loading and aspect ratio and their calls frequency were very high compared to forest-independent group (Table 9-10). The forest-independent groups included *Hipposideros bicolor, H. diadema, H. armiger, H. larvatus, Rhinolophus affinis, R. lepidus, R. luctus, R. robinsoni, R. stheno, R. trifoliatus, R. acuminatus, R. coelophyllus, R. mayalanus*, *Miniopterus magnator, Myotis muricola,* *N. tragata* and *Phonicus jagorii*.. These bats have high wing loading and higher aspect ratio (Table 11) and their calls frequency were relatively low (Table 12).

There was no significantly different in wing morphology between forest only and forest and rubber plantations (P>0.05). There were significantly different between bats found in forest only and forest and rubber plantations such as most energy frequency (Mann-Whitney U, P=0.026), maximum frequency (P = 0.039) and interval call interval (P=0.012). There was significantly different in wing loading between forest dependent group and forest independent group (One-way ANOVA test, P=0.003) but no significantly in other character (P>0.05). There was significantly different in call frequency (P<0.01) between forest dependent group and forest independent group.

A correlation between wing morphology and call character was examined by Spearman's test. There was correlation between wing morphology and call character. Wing loading was negatively correlated with most energy frequency (r= -0.886, N= 24, P=0.019) (Figure 40) and minimum frequency (r= -0.943, N= 24, P= 0.005) between forest dependent group and forest independent group (Figure 41).

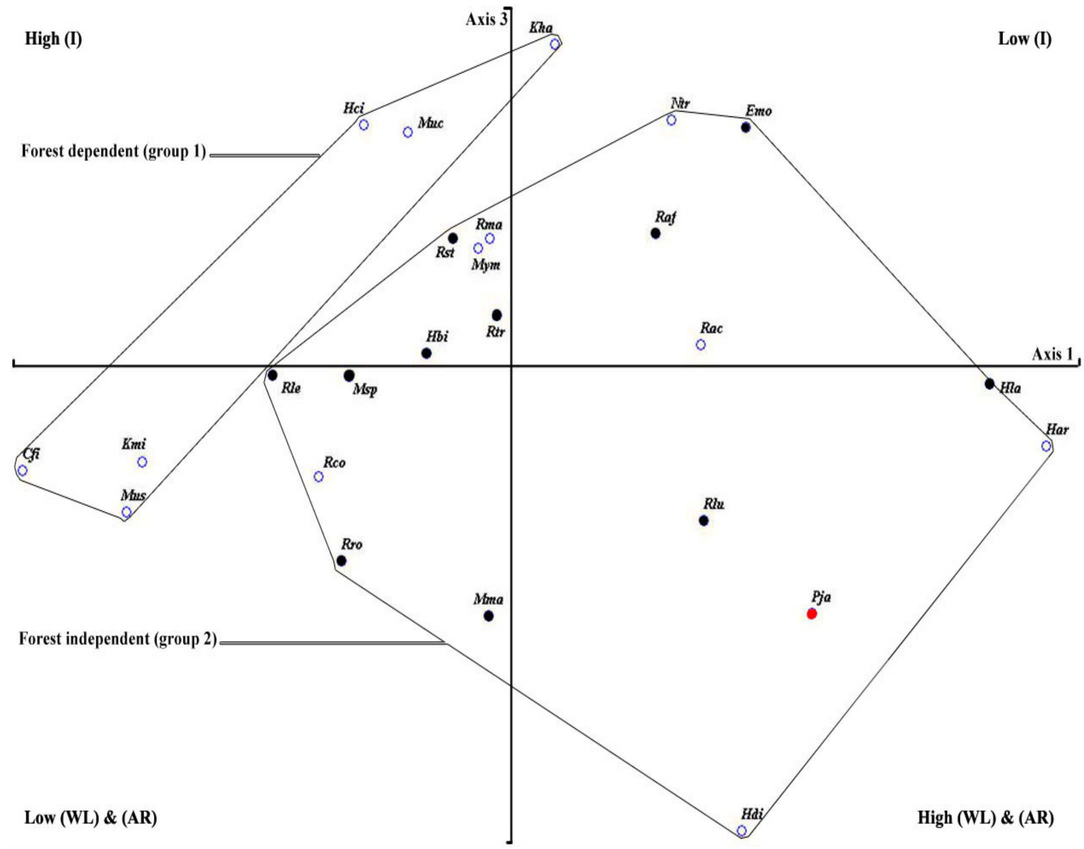


Figure 39. Principal components analysis (PCA) of twenty five insectivorous bat species based on wing morphology (loading, aspect ratio and wing shape index). Bat species found in forest only refer to (open circles), bat species found in ruber plantation (red circles) and bat species found in both forest and rubber plantation refer to (filled circles). Group them in terms of its captured location. Forest dependent group refer to (group 1) and forest impendent group refer to (group 2) (see appendix 6 - 7).

Table 4. The average of wing morphology of bats captured in forest only.

Species	n	Body mass (Kg)	Wing area S (m²)	Wing span B (m)	WL Mg/S (Nm⁻²)	AR A=B²/S	Tl	Ts	I
*Hipposideros armiger**	4	0.0456	0.04297	0.5929	10.42	8.180	1.095	0.578	1.118
Hipposideros cineraceus	3	0.0039	0.00906	0.2548	4.223	7.169	0.732	0.523	2.499
Hipposideros diadema	4	0.043	0.03551	0.5184	11.88	7.568	0.732	0.564	3.366
Coelops frithii	2	0.006	0.01324	0.281	4.446	5.963	0.885	0.734	4.885
Nycteris tragata	1	0.015	0.02258	0.4167	6.517	7.689	1.009	0.555	1.225
Rhinolophus acuminatus	3	0.0125	0.01374	0.3087	8.925	6.934	0.85	0.522	1.597
Rhinolophus coelophyllus	3	0.0075	0.01187	0.2893	6.200	7.05	0.94	0.749	3.913
Rhinolophus malayanus	3	0.0064	0.01057	0.2787	5.942	7.349	0.847	0.595	2.371
Kerivoula hardwickii	6	0.0043	0.00896	0.2673	4.707	7.975	0.996	0.615	1.613
Kerivoula minuta	1	0.003	0.00658	0.216	4.473	7.090	1.13	0.932	4.71
Murina cf. cyclotis	2	0.009	0.01457	0.286	6.06	5.614	1.066	0.675	1.73
Murina cf. suilla	2	0.0047	0.00991	0.265	4.652	7.086	0.756	0.629	4.96
Myotis muricola	1	0.0068	0.01007	0.2567	6.627	6.544	1.11	0.759	2.159
Average		**0.0129**	**0.0161**	**0.326**	**6.5433**	**7.093**	**0.935**	**0.649**	**2.780**

Table 5. The average of wing morphology of bat captured in forest and rubber plantations.

Species	n	Body mass (Kg)	Wing area S (m²)	Wing span B (m)	WL Mg/S (Nm⁻²)	AR A=B²/S	Tl	Ts	I
*Emballunura monticola**	2	0.005	0.0092	0.3005	5.332	9.812	1.057	0.665	1.696
Hipposideros bicolor	18	0.0079	0.01247	0.3006	6.214	7.246	0.936	0.704	3.039
Hipposideros larvatus	2	0.0162	0.01874	0.4465	8.480	10. 64	0.787	0.502	1.762
Megaderma spasma	2	0.0185	0.02577	0.3831	7.043	5.695	1.054	0.784	2.906
Rhinolophus affinis	15	0.0132	0.01683	0.3442	7.696	7.042	0.965	0.573	1.458
Rhinolophus lepidus	6	0.0052	0.01034	0.274	4.933	7.260	0.866	0.688	3.850
Rhinolophus luctus	2	0.034	0.03185	0.459	10.472	6.614	0.867	0.582	2.049
Rhinolophus robinsoni	5	0.008	0.01164	0.2912	6.7423	7.285	0.764	0.617	4.189
Rhinolophus stheno	16	0.0076	0.01383	0.324	5.392	7.591	0.802	0.582	2.638
Rhinolophus trifoliatus	2	0.0129	0.01712	0.33	7.392	6.360	0.965	0.667	2.238
Miniopterus magnator	1	0.0067	0.00882	0.272	7.452	8.388	1.077	0.866	4.107
Phoniscus jagorii	1	0.0094	0.00676	0.246	9.868	8.952	0.968	0.712	2.782
Average		**0.0121**	**0.0153**	**0.331**	**7.251**	**7.478**	**0.926**	**0.662**	**2.726**

Table 6. The average of call frequency of bats captured in forest only.

Species	n	Frequency (kHz) Most energy	Min.	Max.	D (ms)	ICI (ms)	Type
*Hipposideros armiger**	4	67.2	64.13	68.9	12.3	51.9	CF
Hipposideros cineraceus	4	148.1	147.1	160.6	5.3	15.4	CF
Hipposideros diadema	3	57.8	49.5	58.9	11.9	30.4	CF
Coelops frithii	2	120.3	114.8	125.6	0.65	12.9	FM
Nycteris tragata	4	100.3	96.6	111.9	0.3	11.9	CF
Rhinolophus acuminatus	4	89.6	83.2	91.1	39.7	69.6	CF
Rhinolophus coelophyllus	4	79.23	71.7	80.3	25.8	53.9	CF
Rhinolophus malayanus	5	86.7	82.4	87.9	31.6	55.3	CF
Kerivoula hardwickii	6	114.8	104.5	125.7	0.6	16.1	FM
Kerivoula minuta	2	125.4	109.2	134.7	0.7	9.6	FM
Murina cf. cyclotis	4	105.7	83	116.2	1.5	46.9	FM
Murina cf. suilla	6	112.8	97.9	129.6	1.1	51.1	FM
Myotis muricola	7	89.3	65.4	110.6	2.8	62.9	FM
Average		**99.79**	**89.96**	**107.85**	**10.32**	**37.53**	

Table 7. The average of call frequency of bat captured in forest and rubber plantations (included one bat was found in rubber plantation only).

Species	n	Frequency (kHz) Most energy	Min.	Max.	D (ms)	ICI (ms)	Type
*Emballonura monticola**	2	48.9	45.3	51.9	3.6	64.7	QCF
Hipposideros bicolor	15	140.4	124.1	141.2	5.3	14.4	CF
Hipposideros larvatus	4	96.2	87.3	90.4	5.1	29.3	CF
Megaderma spasma	5	85.4	74.7	91.8	0.9	34.4	FM
Rhinolophus affinis	15	71.3	66.9	73.5	29.2	59.4	CF
Rhinolophus lepidus	7	101.8	92.6	102.7	35.9	66.3	CF
Rhinolophus luctus	6	32.1	23.3	33.3	64.3	141.9	CF
Rhinolophus robinsoni	5	66.9	62.1	67.8	42.2	86	CF
Rhinolophus stheno	10	86.1	83.5	87.2	38.8	68.6	CF
Rhinolophus trifoliatus	4	50.3	47.4	51.6	42.6	76.9	CF
Miniopterus magnator	4	47.1	38.2	97.9	4.5	66	FM
Phoniscus jagorii	1	86.2	85.7	86.9	2.1	63.6	FM
Average		**76.06**	**69.26**	**81.35**	**22.88**	**64.29**	

Table 8. The average of wing morphology of bats in forest dependent group.

Species	**n**	**Body mass (Kg)**	**Wing area S (m²)**	**Wing span B (m)**	**WL Mg/S (Nm⁻²)**	**AR A=B²/S**	**Tl**	**Ts**	**I**
Hipposideros cineraceus	3	0.0039	0.0090	0.2548	4.223	7.166	0.732	0.523	2.499
Coelops frithii	2	0.006	0.0132	0.2810	4.446	5.964	0.885	0.734	4.885
Kerivoula hardwickii	6	0.0043	0.0089	0.2673	4.707	7.975	0.996	0.615	1.613
Kerivoula minuta	1	0.0030	0.0066	0.216	4.473	7.091	1.13	0.932	4.709
Murina cf. cyclotis	2	0.009	0.0146	0.2860	6.059	5.614	1.066	0.675	1.730
Murina cf. suilla	2	0.0047	0.0099	0.2650	4.653	7.086	0.756	0.629	4.961
Average		**0.0052**	**0.0104**	**0.2617**	**4.7601**	**6.8156**	**0.928**	**0.685**	**3.399**

Table 9. The average of call frequency of bats in forest dependent group.

Species	**n**	**Frequency (kHz)** Most energy	Min.	Max.	**D (ms)**	**ICI (ms)**	**Type**
Hipposideros cineraceus	4	148.1	147.1	160.6	5.30	15.4	CF
Coelops frithii	2	120.3	114.8	125.6	0.65	12.9	FM
Kerivoula hardwickii	6	114.8	104.5	125.7	0.60	16.1	FM
Kerivoula minuta	2	125.4	109.2	134.7	0.70	9.6	FM
Murina cf. cyclotis	4	105.7	83	116.2	1.50	46.9	FM
Murina cf. suilla	6	112.8	97.9	129.6	1.10	51.1	FM
Average		**121.18**	**109.41**	**132.06**	**1.64**	**25.33**	

Table 10. The average of wing morphology of bats in forest independent group.

Species	n	Body mass (Kg)	Wing area S (m²)	Wing span B (m)	WL Mg/S (Nm^{-2})	AR A=B²/S	Tl	Ts	I
*Emballonura monticola**	2	0.0050	0.0092	0.3005	5.332	9.815	1.057	0.665	1.696
*Hipposideros armiger**	4	0.0456	0.0429	0.5929	10.412	8.180	1.095	0.578	1.118
Hipposideros bicolor	18	0.0079	0.0125	0.3006	6.214	7.246	0.936	0.704	3.039
Hipposideros diadema	4	0.0430	0.0355	0.5184	11.880	7.567	0.732	0.564	3.366
Hipposideros larvatus	2	0.0162	0.0187	0.4465	8.480	10. 638	0.787	0.502	1.762
Megaderma spasma	2	0.0185	0.0258	0.3831	7.043	5.695	1.054	0.784	2.907
Nycteris tragata	1	0.015	0.0226	0.4167	6.517	7.689	1.009	0.555	1.225
Rhinolophus acuminatus	3	0.0125	0.0137	0.3087	8.925	6.934	0.850	0.522	1.597
Rhinolophus affinis	15	0.0132	0.0168	0.3442	7.696	7.043	0.965	0.573	1.458
Rhinolophus coelophyllus	3	0.0075	0.0118	0.2893	6.200	7.055	0.940	0.749	3.913
Rhinolophus lepidus	6	0.0052	0.0103	0.2740	4.934	7.260	0.866	0.688	3.850
Rhinolophus luctus	2	0.0340	0.0319	0.4590	10.472	6.615	0.867	0.582	2.049
Rhinolophus malayanus	3	0.0064	0.0106	0.2787	5.942	7.349	0.847	0.595	2.372
Rhinolophus robinsoni	5	0.0080	0.0116	0.2912	6.742	7.285	0.764	0.617	4.189
Rhinolophus stheno	16	0.0076	0.0138	0.3240	5.392	7.592	0.802	0.582	2.638
Rhinolophus trifoliatus	2	0.0129	0.0171	0.3300	7.392	6.361	0.965	0.667	2.239
Miniopterus magnator	1	0.0067	0.0088	0.2720	7.452	8.388	1.077	0.866	4.108
Myotis muricola	1	0.0068	0.0100	0.2567	6.627	6.544	1.110	0.759	2.159
Phoniscus jagorii	1	0.0094	0.0067	0.246	9.868	8.952	0.968	0.712	2.782
Average		**0.0147**	**0.0174**	**0.349**	**7.553**	**7.420**	**0.931**	**0.645**	**2.550**

Table 11. The average of call frequency of bats in forest independent group.

Species	n	Frequency (kHz) Most energy	Min.	Max.	D (ms)	ICI (ms)	Type
*Emballonura monticola**	2	48.9	45.3	51.9	3.6	64.7	QCF
*Hipposideros armiger**	4	67.2	64.13	68.9	12.3	51.9	CF
Hipposidero. bicolor	15	140.4	124.1	141.2	5.3	14.4	CF
Hipposideros diadema	4	57.8	49.5	58.9	11.9	30.4	CF
Hipposideros larvatus	3	96.2	87.3	90.4	5.1	29.3	CF
Megaderma spasma	4	85.4	74.7	91.8	0.9	34.4	CF
Nycteris tragata	2	100.3	96.6	111.9	0.3	11.9	FM
Rhinolophus acuminatus	5	89.6	83.2	91.1	39.7	69.6	FM
Rhinolophus affinis	4	71.3	66.9	73.5	29.2	59.4	CF
Rhinolophus coelophyllus	4	79.23	71.7	80.3	25.8	53.9	CF
Rhinolophus lepidus	15	101.8	92.6	102.7	35.9	66.3	CF
Rhinolophus luctus	4	32.1	23.3	33.3	64.3	141.9	CF
Rhinolophus malayanus	7	86.7	82.4	87.9	31.6	55.3	CF
Rhinolophus robinsoni	6	66.9	62.1	67.8	42.2	86	CF
Rhinolophus stheno	5	86.1	83.5	87.2	38.8	68.6	CF
Rhinolophus trifoliatus	5	50.3	47.4	51.6	42.6	76.9	CF
Miniopterus magnator	4	47.1	38.2	97.9	4.5	66	FM
Myotis muricola	7	89.3	65.4	110.6	2.8	62.9	FM
Phoniscus jagorii	1	86.2	85.7	86.9	2.1	63.6	FM
Average		**78.043**	**70.738**	**83.463**	**20.994**	**58.284**	

*** Bat Research Unit**

Figure 40. Correlation between wing loading and most energy frequency.

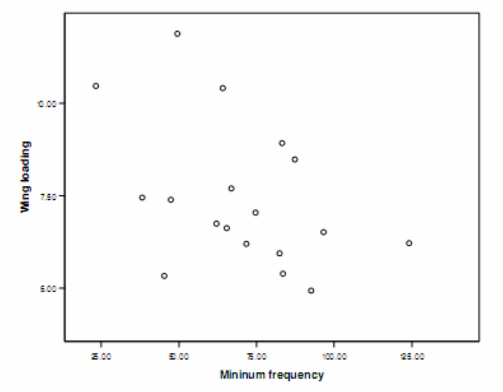
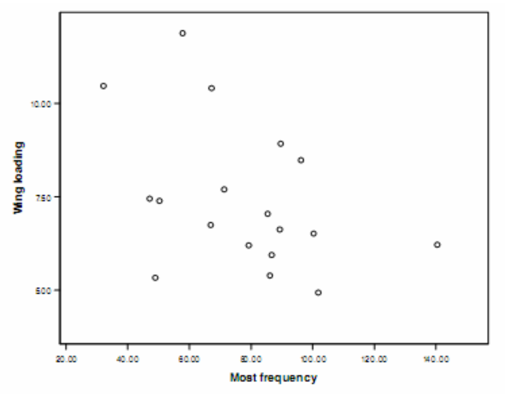


Figure 41. Correlation between wing loading and minimum frequency.



CHAPTER 5

DISCUSSION

5.1 Bat activity variation between habitats

Bat activity and insect biomass

Bat activity in forest was nearly two times higher than in rubber plantations. Insect biomass in forest was also found to be much higher than rubber plantations. It is strongly suggested that bat activity positively relate to insect biomass. Previous study indicate that the insect availability was control foraging behavior and activity of bat (Lang *et al*., 2006), and bat activity increase when prey increase (Agosta *et al*., 2003; Bartonicka and Rehak, 2004; Jones *et al*., 2000). It also suggested that bat select foraging site based on insect availability.

As the results showed that bat activity was highest in the first hour after sunset in this study. It was similar to those reports in *Pipistrellus pipistrellus* and *Myotis daubentonii* (Rydell *et al*., 1996), *Plecotus townsendii ingens* (Clark *et al*., 1993), *Myotis velifer* (Kunz, 1974), and *Chalinolobus tuberlatus* (O'Donnell *et al*., 2000). Insect biomass in forest was also highest in the first hour after sunset. Several researches reported that insect avilalability was higher in the early evening than other period (Rydell *et al.,* 1996; Hayes, 1997; Meyer *et al*., 2004; Bartonicka and Rehak, 2004). Thus, these results strongly indicate that the temporal variation in bat activity can be explained by the variation in food availability.

It the present study, the bat detection microphone can receive a maximum number of bat activities at ground-level but relatively limited for calls from canopy and above canopy level. Whereas the bats that forage in open space can be found at or above the canopy. Since forest canopy is thicker than in rubber plantations. So, bat activity in forest could be more under represent than that in rubber plantation. The number of receiving calls also depend on the angle of horizontal

(Weller and Zabel, 2002), the frequency range, intensity of emitted signal and the sensitive of microphone as well (Limpens *et al.,* 2004).

On the other hand, this data showed that there was not correlation between bat activity and insect biomass in a given night. Whereas previous studies have published the correlation between bat activity and insect activity within night. The lack of correlation between bat activity and insect biomass in a given night in the present study may be influenced by a strong variation in bat activity and insect activity between sites within each habitat.

Insect biomass and plant diversity

Moths, the major insect captured are herbivore that selectively feed on plants (Takacs *et al.*, 1997). Its biomass as well as other insect biomass may be influenced by plant diversity. From this study area, forest had obviously higher plant diversity than rubber plantation (Figure 35 - 37). Thus, insect biomass was high in forest compared to rubber plantations. The forest canopy is more complex cluttered than that in rubber plantations. These may result in less wind, earlier darkness (Rydell *et al.*, 1996) and more shelter from predator in forest (Patriquin and Barclay, 2003; Lumden and Bennett, 2005). So, it may be resulted in higher insect biomass in forest than in rubber plantations. Several researches reported that the highest percentage of moths caught by bat (Waters, 2003; McWilliams, 2005).

5.2 Variation in bat species diversity between habitat

Wing morphology

Bat species richness in forest was three times higher than in rubber plantations. That group of bats found in forest only has relatively lower wing loading and aspect ratio compared to those found in forest and rubber plantations. These results strongly suggest that bats found in highly cluttered space have relatively low wing loading and aspect ratio than those found in background cluttered space (Aldridge and Rautenbach, 1987; Norberg and Rayner, 1987; Altringham, 1996). Narrow space bat characterise with high manoeuvrability, slowly flight and short movement in clutter or highly clutter space (Altringham, 1996). High wing loading and aspect ratio was characterise those bats found in open space. These bats need to fly in the open, catching insect on wing, fast flight but can not turn as circle, since their long wing would be hindrance in vegetation (Altringham, 1996).

In the present study, bats found in forest belong to Hipposideridae, Rhinolophidae, Nyteridae, Megadermatidae and some Vespertilionidae. Previous studies indicated that these bats forage in cluttered space (Kingston *et al*., 2003). Some of them has been found in both forest and rubber plantations (Table 1). The represent results suggest that these narrow space bats also adapt to forage in more open space (Norberg and Rayner, 1987) or background cluttered space such as rubber plantations.

Bats forage in open space has relatively long narrow wing, small wing area (Altringham, 1996) and high aspect ratio (Aldridge and Rautenbach, 1987; Norberg and Rayner, 1987; Altringham, 1996). Thus, these bats may not be effect by rubber plantations. The good example was *E. monticola*, this bat has intermediate wing loading and high aspect ratio that foraged in forest edge (Kingston *et al*., 2003), trees top of canopy between background cluttered and open space (Altringham, 1996; Schnitzler and Kalko, 1998; Schnitzler and Kalko, 2001).

On other hand, some bats forage specifically in forest such as forest-dependent bats (Table 9). These bats have very low wing loading and aspect ratio, its wing loading allow them to forage in highly cluttered space. They have low speed flight (Altringham, 1996). So, these bats could much more effect when forest was cleared. Consequently, bats of forest dependent group can be seriously effected by rubber plantations than the bats in forest independent group. This result strongly suggested that habitat selection by bats is influence by wing morphology.

Echolocation call

There were six bats in forest dependent group bats including *H. cineraceus*, *Coelops frithii*, *Kerivoula hardwikii, K. minuta, Murina cf. cyclotis,* and *M. suilla*. Most of them have FM calls except the CF-FM bat such as *H. cineraceus* (Table 10). Their call was characterized with high frequency short duration, low SPL (low intensity) which can prevent overloading with clutter echoes (Schnitzler and Kalko, 2001) and better adapted to feeding in clutter (Water, 2003). *Kerivoula* and *Murina* were whispering bats that emitted very low intensity call.

13 species was in forest-independent group including *Hipposideros bicolor, H. diadema, H. armiger, H. larvatus, Rhinolophus affinis, R. lepidus, R. robinsoni, R. stheno, R. trifoliatus, R. acuminatus, R. coelophyllus, R. mayalanus*, *N. tragata* and *Myotis muricola*. Most of these bats used narrowband CF. These bats emitted lower most energy frequency calls compared to forest dependent group. The lower of most frequency calls usually accompany with high sound pressure level (Schnitzler and Kalko, 2001). The higher intensity calls was better in detecting of echoes from distant targets than species using lower intensity (Fenton, 1983). Broadband FM signals were less suited for detection but more precise target localization and narrowband CF signals were suited for detection but less precise for target localization (Schnitzler and Kalko, 1998; Schnitzler and Kalko, 2001). The mixing CF-FM signal could facilitate in bats to forage in background cluttered space as rubber plantations. These results strongly supported that echolocation call design can explain the habitat selection by bats.

CHAPTER 6

CONCLUSION

A study of bat species diversity and feeding intensity in intact forest and rubber plantations was carried out in Khao Ban That and Ton Nga Chang WS in Southern Thailand between June - December 2007. It was found that number of bat passes in forest was nearly 2 times higher than in rubber plantations while number of feeding buzz in forest was 3 times higher than in rubber plantations. Insect biomass in forest was 2 times higher than in rubber plantations. Structurally, forest was more complex than rubber plantations. Bat species richness and diversity index in forest was much higher than rubber plantations.

The average call frequency of bat captured in forest only was higher than forest and rubber plantations while mean of wing loading and aspect ratio of bat captured in forest only lower than forest and rubber plantations. The average call frequency of bat in forest dependent group was much higher than forest independent group and the average wing loading and aspect ratio of bats in forest dependent group was lower than forest independent group.

The results from the present study strongly support the suggestion that habitat selection by bats is influenced by wing morphology and echolocation call design. Some bats forage in open space but some was very limit themselves in cluttered space. Thus, wing morphology and echolocation call character can be used to predict whether a certain species of bat will seriously affected by forest disturbance, especially, when forest is replaced by monoculture tree plantations such as rubber plantations.

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APPENDIXES

Appendix 1. Location of pair sampling site in forest and rubber plantations.

S1. Forest	N 06° 47' 738" E 100° 14' 675"
Rubber	N 06° 47' 483" E 100° 14' 511"
S2. Forest	N 06° 46' 767" E 100° 14'205"
Rubber	N 06° 46' 378" E 100° 14'035"
S3. Forest	N 06° 53' 806" E 100° 13' 999"
Rubber	N 07° 32' 507" E 099°14' 354"
S4. Forest	N 07° 32' 382" E 099° 46'387"
Rubber	N 07° 32' 507" E 099° 46' 376"
S5. Forest	N 07° 32' 904" E 099° 46' 709"
Rubber	N 07° 32' 675" E 099° 46' 677"
S6. Forest	N 07° 32' 098" E 099° 46' 320"
Rubber	N 07° 32' 333" E 099° 46' 270"
S7. Forest	N 07° 31' 789" E 099° 46' 678"
Rubber	N 07° 31' 616" E 099° 46' 583
S8. Forest	N 07° 32' 161" E 099° 47'064"
Rubber	N 07° 32' 157" E 099° 47' 309"
S9. Forest	N 07° 32' 939" E 099° 47' 317"
Rubber	N 07° 33' 633" E 099° 46' 763"
S10. Forest	N 06° 47' 777" E 100° 14' 092"
Rubber	N 06° 47' 607" E 100° 14' 151"
S11. Forest	N 06° 53' 501" E 100° 14' 056"
Rubber	N 06° 53' 891" E 100° 14' 288"
S12. Forest	N 07° 02' 483" E 100° 12'411"
Rubber	N 07° 02' 297" E 100° 12'320"
S13. Forest	N 07° 02' 777"E 100° 12'520"
Rubber	N 07° 02' 807" E 100° 12'540"
S14. Forest	N 07° 03' 290" E 100° 13'009"
Rubber	N 07° 02' 360" E 100° 13'102"
S15. Forest	N 06° 55' 450" E 100° 09'305"
Rubber	N 06° 55' 507" E 100° 09´038"
S16. Forest	N 06° 56' 718" E 100° 08' 725"
Rubber	N 06° 56' 557" E 100° 08' 505"
S17. Forest	N 07° 02' 397" E 100° 12' 961"
Rubber	N 07° 02' 487" E 100° 12' 095"
S18. Forest	N 06° 56' 899" E 100° 14' 420
Rubber	N 06° 56' 540" E 100° 15' 292"
S19. Forest	N 06° 56' 557" E 100° 16' 429"
Rubber	N 06° 56' 540" E 100° 16' 192"
S20. Forest	N 06° 54' 209" E 100° 14' 691"
Rubber	N 06° 54' 611" E 100° 14' 789"
S21. Forest	N 06° 47' 920" E 100° 16' 234"
Rubber	N 06° 48' 194" E 100° 16' 333"
S22. Forest	N 06° 59' 990" E 100° 08' 572"
Rubber	N 07° 00' 025" E 100° 08' 482"
S23. Forest	N 07° 26' 489" E 099° 48'067"
Rubber	N 07° 26' 228" E 099° 47' 946"
S24. Forest	N 07° 25' 006" E 099° 48' 607"
Rubber	N 07° 25' 147" E099° 48' 461"
S25. Forest	N 07° 15' 384" E 100° 02' 509"
Rubber	N 07° 15' 283" E 100° 02' 681"

Appendix 2. Acoustic study and bat identification from sound recording in forest and rubber plantations.

Date	F	Kn.	CF	FM	QCF	Species	Unkn.	CF	FM	QCF	R	Kn.	CF	FM	QCF	Species	Unkn.	CF	FM
2^{nd} Aug 2007	8	8	8			*Raf,Rst, Hdi*					8	1			1	*Emo*	7		7
3^{rd} Aug 2007	5	2	1		1	*Emo, Rst*	3		3		11	3	2	1		*Raf, Rst*	8		8
4^{th} Aug 2007	19	7	3	3	1	*Emo,Raf, Rlu, Rtr*	12		12		5	3	1		2	*Emo,Rst*	2		2
11^{th} Aug 2007	14	11	10		1	*Emo,Raf, Kha, Rlu, Rtr, Rle, Rco*	3		3		2	2	2			*Rlu, Hla*			
12^{th} Aug 2007	19	14	14			*Raf, Rle, Hbi, Rlu, Rco*	5	1	4		4	1	1			*Hla*	3	1	2
13^{th} Aug 2007	14	11	8	2	1	*Rtr, Raf, Hla,Hbi, Cfi Emo*	3		3		13	3	2		1	*Emo, Rle*	10		10
15^{th} Aug 2007	11	7	7			*Rst, Rco, Rro, Raf*	4		4		6	2	2			*Rle*	4		4
16th Aug 2007	8	8	8			*Rlu, Rst, Raf*					27	24	23		1	*Emo,Rlu*	3		3

17th Aug 2007	10	8	8			*Rtr, Raf, Hdi, Rco, Rle*	2		2		7	7	3		4	*Emo,Rle Raf*			
20th Aug 2007	24	8	8			*Rst, Raf, Rlu*	16		16		4	2	2			*Hdi, Rtr*	2	1	1
21st Aug 2007	4	4	3	1		*Raf, Ryu, Rtr, Ntr*													
22nd Aug 2007	15	9	6		3	*Emo, Hci Raf, Rro, Hbi, Hdi, Rst, Ryu*	6	1	5		12	11	9		2	*Emo,Rst*	1		1
23rd Aug 2007	22	14	12		2	*Rlu, Rst, Raf*	8		8		11	9	9				2		2
10th Sep 2007	15	5	2		3	*Emo, Rtr*	10		10		12	8	8			*Hdi,Rlu, Rle, Hla, Raf*	4		4
20th Sep 2007	22	12	6		6	*Emo, Raf, Rlu, Rle*	10		10		11	9	6	1	2	*Tlo, Rtr, Rlu, Rst, Emo,Hla*	2		2
30th Sep 2007	7	7	7			*Rle, Rst, Rtr*					11	10	7	1	2	*Tlo, Rtr, Rlu,Emo Hla*	1		1
4th Sep 2007	40	40	39		1	*Emo,Raf, Rlu, Rle, Rst, Hbi, Hdi*					8	7	4		3	*Emo, Hbi*	1		1

5th Sep 2007	18	17	13		4	*Emo,Raf, Rro*	1		1		11	6	6			*Raf, Rlu, Rro*	5		5
12th Sep 2007	14	10	8		2	*Raf, Rle, Hbi, Hla, Emo, Hdi*	4		4		21	6	1		5	*Emo,Hla*	15		15
13th Sep 2007	18	18	18			*Raf, Rle, Hbi, Hdi, Rst, Ryu*													
27th Sep 2007	10	10	9		1	*Rlu, Raf, Emo*					13	7	7			*Raf, Hla*	6		6
28th Sep 2007	7	7	7			*Rtr, Raf*													
11th Nov 2007	3	2	2			*Raf, Rst, Rma*	1		1		6	4	4				2		2
14th Nov 2007	19	14	14			*Raf, Rst*	5		5		10	9	9				1		1
15th Nov 2007	31	18	18			*Rlu, Raf, Rtr, Hbi*	13		13		9						9		9
Total	**377**	**271**	**239**	**6**	**26**	**19**	**106**	**2**	**104**	**0**	**222**	**134**	**108**	**3**	**23**	**10**	**88**	**2**	**86**

Appendix 3. Insect biomass in forest in three hours.

Insect biomass in 1st hour

Forest1	Coleop	Dip	Hemip	Homop	Hymenop	Isop	Lepidop	Orthop	Odonata	Tricop	Total
1	1.34014761	47.33875385	0	0	7.4609071	0	0	11.526488	0	0	67.66629694
2	9.230125527	104.7007514	0.1874988	19.8748698	0.9374939	0	618.935643	0	0	0	753.8663822
3	0	2.812481582	0	0	0.1874988	0	17.20186	0	0	0	20.20184036
4	41.16630098	284.0728291	0	1.12499263	2.3052977	0	256.793401	0	0	0	585.462821
5	0	4.527626736	0	1.15264884	0	0	0	0	0	0	5.680275573
6	0.187498772	105.2018406	0	0.37499754	3.334695	0	161.578037	0	0	0	270.6770686
7	4.020442829	206.7342717	0	0	16.435595	0	88.1048553	0	0	0	315.2951645
8	33.21493887	5.827491424	0	0	3.4579465	0	334.436318	0	0	0	376.9366943
9	3.334694977	22.8748502	0	0	0	0	44.6911823	0	0	0	70.90072749
10	0.562496316	19.31237353	0	0	1.1249926	0	33.3469498	0	0	0	54.34681225
11	0	26.65248185	0	0	0	14.171819	520.083901	0	0	0	560.9082016
12	5.237338903	65.4488234	0	0.74999509	12.714516	28.343638	520.229347	0	0	0	635.0289564
Total	**98.2939848**	**895.50458**	**0.1875**	**23.2775**	**47.95894**	**42.5155**	**2595.4015**	**11.52649**	**0**	**2.305298**	**3716.971241**

Insect biomass in 2nd hour

Forest2	Coleop	Dip	Hemip	Homop	Hymenop	Isop	Lepidop	Orthop	Odonata	Tricop	Total
1	3.61778908	98.3323252	0.1874988	0.56249632	7.0443875	0	134.418789	0	0	0	244.1632861
2	9.724682718	115.0347454	1.1526488	4.55528294	3.334695	0	762.110602	0	0	0	895.9126565
3	1.152648838	4.930280485	0	1.15264884	1.5276464	0	75.5273341	0	0	0	84.29055862
4	9.381033268	166.7014379	0	1.71514515	2.3052977	0	756.965256	0	0	0	937.0681697
5	0.374997544	7.52760709	0	0.18749877	0	0	39.6574518	0	0	0	47.74755522
6	0	14.65256043	0	1.3124914	0	0	5.36059044	0	0	0	21.32564227
7	160.673821	1.902643926	0	0	6.8568887	0	412.423201	0	0	0	581.8565548
8	10.60810331	12.18742019	0	0	0.1874988	0	12.2590012	0	0	0	35.2420235
9	1.715145154	55.52729275	0	0.18749877	11.573253	0	65.6290184	0	0	0	134.6322085
10	2.492796447	61.33975469	0	0	0.3749975	0	133.851077	0	0	0	198.0586257
11	0.187498772	24.27031022	0	0	0	0	51.5059245	0	0	0	75.9637335
12	4.020442829	40.6103596	0	0.37499754	23.957986	3.334695	23.9579863	0	0	0.3749975	96.63146509
Total	**203.948959**	**603.01674**	**1.34015**	**10.04806**	**57.16265**	**3.33469**	**2473.6662**	**0**	**0**	**0.374998**	**3352.89248**

Insect biomass in 3rd hour											
Forest3	**Coleop**	**Dip**	**Hemip**	**Homop**	**Hymenop**	**Isop**	**Lepidop**	**Orthop**	**Odonata**	**Tricop**	**Total**
1	0.187498772	140.5532998	0	0.18749877	0	0	816.992844	3.334695	0	0	961.2558365
2	2.680295219	97.48389462	0.1874988	2.43748404	2.4927964	0	327.014797	0	0	0	432.2967665
3	13.19156406	98.15092109	0	0.56249632	0	0	196.311154	0	3.334695	0	311.5508306
4	3.522193749	105.9705571	0	0	0.1874988	0	366.687253	0	0	0	476.3675028
5	0	16.02036424	0	0	0	0	13.8785511	0	0	0	29.8989153
6	0	8.305258383	0	1.49999018	0	3.334695	3.52219375	0	0	0	16.66213729
7	7.29089057	16.29083163	0	0	0	0	35.1885397	0	0	0	58.77026192
8	2.492796447	14.99990177	0	0	1.1526488	0	174.956502	0	0	0	193.6018489
9	1.34014761	41.20944694	0	0	4.6748426	0	80.6759631	0	0	0	127.9004002
10	1.34014761	89.83956805	0	0	0.9374939	0	288.794668	0	0	0.1874988	381.0993762
11	0	20.84001991	0	0.18749877	0	0	89.7357509	0	0	0	110.7632696
12	1.152648838	0	0	0	21.652689	0	3.33469498	0	0	0	26.14003244
Total	**33.1981829**	**649.66406**	**0.1875**	**4.874968**	**31.09797**	**3.33469**	**2397.0929**	**3.334695**	**3.33469**	**0.187499**	**3126.307178**
Total of insect biomass in three hours											**10196.171**

Appendix 4. Insect biomass in rubber plantation in three hours

Insect biomass in 1st hour										
Rubber1	**Coleop**	**Dip**	**Hemip**	**Homop**	**Isop**	**Lepidop**	**Hymenop**	**Odonata**	**Tricop**	**Total**
1	0	0	0	0	0	0	0	0	0	0
2	1.15265	14.3605315	0	0.18749877	0.18749877	72.8885606	0	0	0	88.7767385
3	0.1875	0	0	0	0	7.08590956	0	0	0	7.27340834
4	0	103.311823	0	0	0	1.87498772	0	0	0	105.186811
5	25.1256	27.110448	1.68748895	1.49999018	0	18.3243728	1.15264884	0	0	74.900586
6	19.0264	4.39544037	1.15264884	1.12499263	5.63999265	4.15262919	0	0	0	35.4921429
7	2.06249	11.4374251		0.18749877	1.15264884	11.3755806	0	0	0	26.2156398
8	1.90264	0	0	0	0	1.15264884	0	0	0	3.05529276
9	0.1875	7.68744966	0	0	0	144.335563	0	0	0	152.210512
10	1.52765	49.053899	0	0	14.0660498	18.9283912	0	0	0	83.5759864
11	47.9195	109.685907	0.93749386	6.18745948	0.18749877	115.249804	10.1273365	0	2.30529768	292.600332
12	0.1875	27.5960704	0	0	0	1.34014761	0	0	0	29.1237167
Total	**99.28**	**354.63899**	**3.7776316**	**9.1874398**	**21.233689**	**396.7086**	**11.279985**	**0**	**2.3052977**	**898.41117**
Insect biomass in 2nd hour										
Rubber2	**Coleop**	**Dip**	**Hemip**	**Homop**	**Isop**	**Lepidop**	**Hymenop**	**Odonata**	**Tricop**	**Total**
1	5.04984	103.213388	0	0	14.3995253	0	414.277251	0	0	536.940004
2	1.34015	65.6367596	0.18749877	2.30529768	3.33469498	0	556.79947	0	0	629.603869
3	0	0	0	0	0	0	12.7145162	0	0	12.7145162
4	0.1875	1.49999018	1.15264884	0	0	0	86.8940209	0	0	89.7341587
5	65.675	26.068424	0.18749877	0.37499754	4.67484259	0	94.5638986	0	0	191.544616
6	4.79809	21.8328262	0.37499754	0	0.93749386	0	44.3183814	0	0	72.2617931
7	1.34015	15.242713	0	0	0	0	30.4199151	0	0	47.0027757
8	0.1875	33.9925902	0	0.18749877	0.18749877	0	76.0834512	0	0	110.638538
9	0.1875	15.027558	0	0	5.33293423	0	60.9642472	0	0	81.5122382
10	0.1875	26.6248256	0	0	0.18749877	0	111.904013	0	0	138.903837
11	6.83292	195.843439	0	1.49999018	7.0443875	0	62.3142314	0	7.27340834	280.80838
12	0	21.9926687	0	0	0	0	0	0	0	21.9926687
Total	**85.786**	**526.97518**	**1.9026439**	**4.3677842**	**36.098876**	**0**	**1551.2534**	**0**	**7.2734083**	**2213.6574**

Insect biomass in 3rd hour										
Rubber3	**Coleop**	**Dip**	**Hemip**	**Homop**	**Isop**	**Lepidop**	**Hymenop**	**Odonata**	**Tricop**	**Total**
1	0.1875	76.5548114	0	0	4.00039378	63.1902194	0	0	0	143.932923
2	0.1875	116.768612	0	1.34014761	0.30949877	25.9247621	0	0	0	144.530519
3	0	3.3749779	0	0	2.30529768	48.7630379	0	0	0	54.4433135
4	0	7.34010832	0	0	0	0.18749877	0	0	0	7.52760709
5	3.45795	5.11777926	0	0	3.52219375	1.15264884	0	0	0	13.2505684
6	1.15265	86.1509997	3.02763656	0	0.18749877	205.473504	0	0	0	295.992288
7	0	0	0	0	0	0	0	0	0	0
8	0.1875	13.1525703	0	0	0	13.4645113	0	0	0	26.8045803
9	1.52765	1.90264393	0	0	0	12.3093826	0	0	0	15.7396729
10	3.05529	30.3255833	0	0.37499754	1.52764638	15.4704447	0	0	0	50.7539647
11	2.43748	187.335652	0	2.0901427	3.52219375	180.701679	0	0	3.33469498	379.421846
12	0.5625	20.4926786	0	0.37499754	3.33469498	14.088775	10.4206045	0	0	49.2742469
Total	**12.756**	**548.51642**	**3.0276366**	**4.1802854**	**18.709418**	**580.72646**	**10.420605**	**0**	**3.334695**	**1181.6715**
Total insect biomass in three hours										**4293.7401**

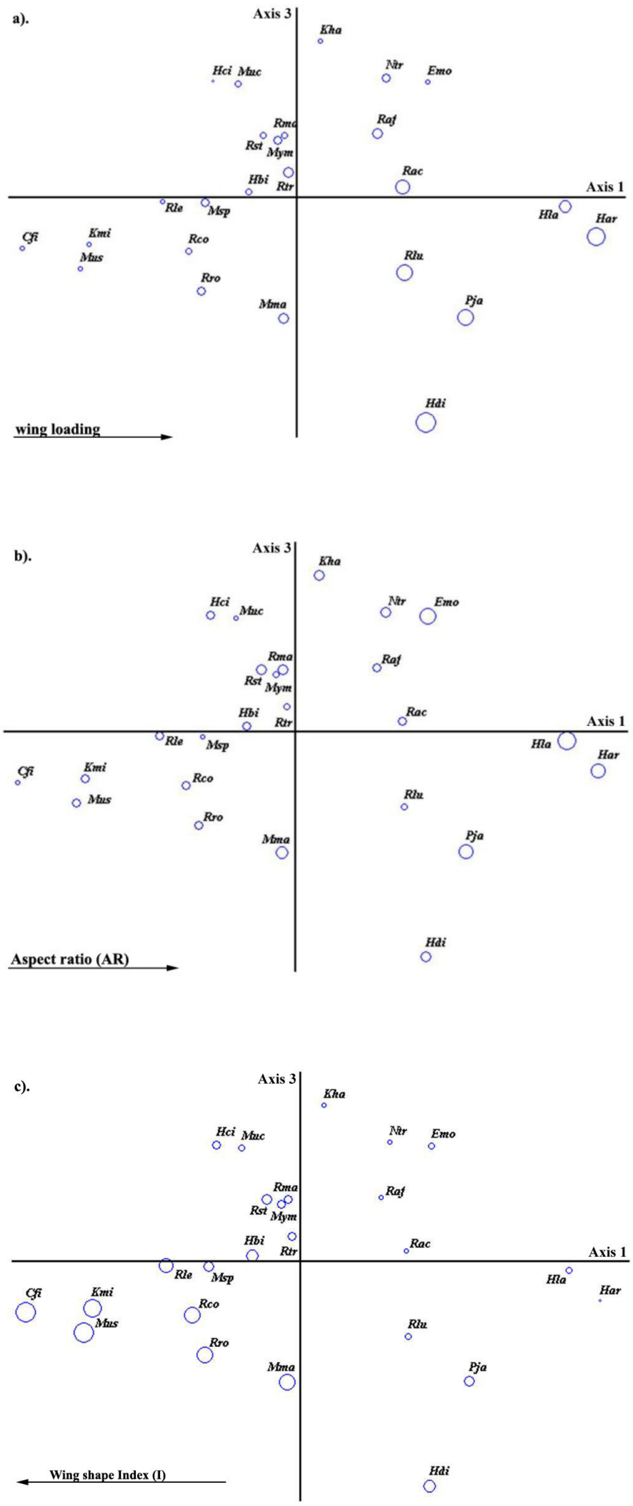
Appendix 5. Fruit bat captured in forest and rubber plantations.

Suborder	Family	Species	Forest	Rubber
Megachiroptera	Pteropodidae	*Balionycteris maculata*	-	2
		Cynopterus brachyotis	1	46
		Cynopterus sphinx	3	64
		Cynopterus horsfieldi	-	7
		Eonycteris spelaea	-	28
		Macroglossus sobrinus	-	16
		Megaerops ecaudatus	-	4
		Rousettus leschenaulti	-	4
Number of bat species			**2**	**8**
Number of bat species diversity			**4**	**171**

Appendix 6. Eigen values, eigenvector scores and variance explained resulting from Principal components analysis (PCA) of twenty-five insectivorous bat species based on wing morphology (loading, aspect ratio and wing shape index). Axis 1 is wing loading (WL), Axis 2 is Aspect ratio (AR) and Axis 3 is wing shape index (I).

		Eigenvector scores		
Species	**Species label**	**Axis 1 (WL)**	**Axis 2 (AR)**	**Axis 3 (I)**
Emballunura monticola	*Emo*	-1.1746	-1.7486	1.0354
Hipposideros armiger	*Har*	-2.6857	0.0894	-0.3447
Hipposideros bicolor	*Hbi*	0.4273	-0.0812	0.0557
Hipposideros cineraceus	*Hci*	0.7490	-0.2782	1.0443
Hipposideros diadema	*Hdi*	-1.1581	0.7445	-2.0077
Hipposideros larvatus	*Hla*	-2.4054	-1.7241	-0.0756
Coelops frithii	*Cfr*	2.4652	-0.0176	-0.4508
Megaderma spasma	*Msp*	0.8206	1.2440	-0.0425
Nycteris tragata	*Ntr*	-0.8006	0.1572	1.0665
Rhinolophus acuminatus	*Rac*	-0.9520	1.0884	0.0947
Rhinolophus affinis	*Raf*	-0.7237	0.7994	0.5744
Rhinolophus coelophyllus	*Rco*	0.9712	-0.1845	-0.4752
Rhinolophus lepidus	*Rle*	1.2060	-0.5728	-0.0364
Rhinolophus luctus	*Rlu*	-0.9673	1.5825	-0.6668
Rhinolophus malayanus	*Rma*	0.1118	-0.0276	0.5554
Rhinolophus robinsonii	*Rro*	0.8575	-0.3172	-0.8377
Rhinolophus stheno	*Rst*	0.2974	-0.3871	0.5538
Rhinolophus trifoliatus	*Rtr*	0.0750	1.0165	0.2237
Kerivoula hardwickii	*Kha*	-0.2132	-0.5220	1.3954
Kerivoula minuta	*Kmi*	1.8597	0.7784	-0.4141
Miniopterus magnator	*Mma*	0.1169	-0.9483	-1.0796
Murina cf. cyclotis	*Mcy*	0.5255	1.4259	1.0170
Murina cf. suilla	*Msu*	1.9413	-0.8078	-0.6297
Myotis muricola	*Mmu*	0.1683	0.7512	0.5121
Phoniscus jagorii	*Pja*	-1.5121	-0.5036	-1.0675
Eigenvalue		1.574	0.780	0.646
% of Variance		52.450	26.006	21.544
Cumunitive of variance %		52.450	78.456	100.000

Appendix 7. Principal components analysis (PCA) of twenty-five insectivorous bat species based on: a). wing loading (WL), b) Aspect ratio (AR) and c). Wing shape index.



Appendix 8. The average of call frequency of bat species in this present study (calls were recorded on hand release

No.	Species	n	Most Energy	Min Freq	Max Freq	D	Interval	Type
1	***H. bicolor***	1	142.9	117.9	144	4.5	11.2	
		2	143	118.9	144.4	5.2	11.4	
		3	140.2	118.3	140.9	3.9	10.6	
		4	139.7	112	139	5.6	17.1	
		5	137.7	122.5	138.6	5.8	18.5	
		6	137.8	111.7	139.1	8.4	21.7	
		7	138.8	133	139.3	6.1	15.8	
		8	141.8	141.3	142.9	4.8	13.1	
		9	141.7	141	142.4	3.5	9.8	
	Average		140.4	124.067	141.177	5.311	14.35	CF
2	***H. cineraceus***	1	152.4	150.9	156.7	5.6	18.4	
		2	153.1	152	155.4	4.3	14.7	
		3	145.1	144.6	163.3	5.9	14.5	
		4	141.9	1409	166.9	5.2	13.8	
	Average		148.125	464.125	160.575	5.25	15.35	CF
3	***H. diadema***	1	57.7	47.7	58.8	10.8	30.3	
		2	57.8	51.3	58.9	13	30.5	
	Average		57.75	49.5	58.85	11.9	30.4	CF
4	***H. larvatus***	1	95.6	87.4	96.8	5.5	30.7	
		2	95	79.4	76.3	5.2	27.4	
		3	97.9	95	98.1	4.5	29.7	
	Average		96.166	87.266	90.4	5.066	29.26	CF
5	***Coelops frithii***	1	125.6	120.6	131.1	0.7	11.8	
		2	115	109	120.1	0.6	14.1	
	Average		120.3	114.8	125.6	0.65	12.95	FM
6	***M. spasma***	1	88.7	83.4	93.4	1.7	35.6	
		2	83.6	64.4	89.4	0.7	32.8	
		3	86.9	62.9	92.9	0.6	35.2	
		4	84.3	81.8	92.1	0.88	35.6	
		5	83.4	80.8	91.2	0.75	32.2	
	Average		85.38	74.66	91.8	0.926	34.28	FM
7	***N. tragata***	1	99.8	102	115.9	0.3	12.3	
		2	104.3	92.3	117.2	0.3	11.3	
		3	96.7	95.6	102.8	0.3	12	
	Average		100.266	96.633	111.97	0.3	11.86	FM

8	***R. acuminatus***	1	93.6	82	95.3	29.3	51.4	
		2	85.7	84.4	86.9	50.1	87.8	
	Average		89.65	83.2	91.1	39.7	69.6	CF
9	***R. affinis***	1	71.1	67.1	73.1	26.8	32.2	
		2	71.5	66.8	73.9	31.6	86.5	
	Average		71.3	66.95	73.5	29.2	59.35	CF
10	***R. coelophyllus***	1	80.7	79.1	81.6	24.5	32.3	
		2	78.7	66.5	80.5	26.3	31.1	
		3	78.5	65.6	79.6	25.3	68.6	
		4	79.1	75.6	79.6	26.9	83.5	
	Average		79.25	71.7	80.325	25.75	53.87	CF
11	***R. lepidus***	1	107.1	95.6	101.4	40.1	111.3	
		2	99.7	91	101	48.6	80.6	
		3	100.1	99.6	101.6	34.4	77.6	
		4	104	102.8	105.6	24.5	38.9	
		5	103.9	97	105.6	38.5	73.3	
		6	98.7	75.3	100.8	33.6	40.2	
		7	99	86.7	102.8	32	42	
	Average		101.785	92.571	102.685	35.957	66.27	CF
12	***R. luctus***	1	31.4	29.8	32.9	69.5	152.2	
		2	32.1	15.4	32.4	62	159	
		3	32.3	18.5	33.9	69	152	
		4	32.3	15.8	33.7	70.3	154.2	
		5	32.1	28	33.3	62	86	
		6	32.1	25	33.5	64.5	180.9	
		7	32.3	30.5	33.4	53	109.3	
	Average		32.085	23.285	33.3	64.328	141.94	CF
13	***R. malayanus***	1	86.3	81.3	87.4	37.6	76.7	
		2	87.2	83.5	88.3	25.5	33.8	
	Average		86.75	82.4	87.85	31.55	55.25	CF
14	***R. robinsoni***	1	66.4	65.5	67.1	50.2	92.9	
		2	67.3	66.4	68.2	39.4	90.1	
		3	67.7	58.8	68.4	50.3	87.8	
		4	65.3	60.8	66.5	36.5	85.4	
		5	67.8	58.8	68.7	34.6	73.8	
	Average		66.9	62.06	67.78	42.2	86	CF
15	***R. stheno***	1	86	84.9	86.7	56.4	86.9	
		2	86.3	74.4	88	34.5	96.4	
		3	86.7	85.4	87.8	27	37	
		4	85.6	82.3	86.1	39.9	50.7	

		5	85.8	85.7	87.1	44	96	
		6	86.1	82.5	87.6	25.8	34.6	
		7	85.1	84	86.3	28.6	62	
		8	85.8	84	87.1	54.3	89.4	
		9	86.7	85.6	88.1	25.4	34	
		10	86.5	86	87.4	52	99.3	
	Average		86.06	83.48	87.22	38.79	68.63	CF
16	***R. trifoliatus***	1	50.6	49.3	51.7	57	86	
		2	50.2	48.6	51.3	40.8	69.9	
		3	50.6	44.6	51.7	32.4	75.7	
		4	49.7	47.2	51.8	40.1	76	
	Average		50.275	47.425	51.625	42.575	76.9	CF
17	***R. yunanensis***		51.5	43.2	52.9	38	120	
18	***K. hardwickii***	1	114.4	107.7	122.3	0.7	18.1	
		2	112.3	97.8	122.6	0.5	16.4	
		3	107.8	97.7	119.9	0.6	14.9	
		4	124.4	110	131.7	0.7	9.6	
		5	117.3	107.4	134.6	0.8	21.2	
		6	112.5	106.3	122.8	0.7	16.4	
	Average		114.783	104.483	125.65	0.666	16.1	FM
19	***K. minuta***	1	125.4	109.2	134.7	0.7	9.6	FM
20	***Mi. magnator***	1	46.6	34.7	98.3	4.2	81	
		2	48.8	38.4	98.8	5	56.4	
		3	47.1	39.2	99.9	5.1	70.1	
		4	45.9	40.6	94.9	3.8	56.5	
	Average		47.1	38.225	97.975	4.525	66	FM
21	***Murina cf. cyclotis***	1	87.6	62.7	122.1	1.1	26.4	
		2	86	90	113.5	1.3	16.3	
		3	103.4	60.9	134	1.9	43.5	
		4	103.2	74.4	131.1	1.2	38.6	
	Average		95.05	72	125.175	1.375	31.2	FM
22	***Murina cf. suilla***	1	90.1	85.6	95.8	0.9	38.8	
		2	115.4	78	137.7	0.6	54.6	
		3	112.4	75.1	137	0.7	40.6	
		4	88	79.7	91.8	0.6	52	
	Average		101.475	79.6	115.575	0.7	46.5	FM
23	***Myotis muricola***	1	105.2	82.2	114.4	7.7	87.4	
		2	96.6	67.5	107.7	2	53.5	
		3	84.9	61.8	120.1	1.9	68.7	

		4	85.1	59.8	109.6	2.1	68.8	
		5	89.9	62.7	104.3	2.2	68.7	
		6	73.4	56.6	117.2	2	46.7	
		7	90	66.9	100.7	1.8	46.8	
	Average		89.3	65.36	110.58	2.814	62.94	FM
24	***Phoniscus jagorii***	1	86.2	85.7	86.9	20.1	63.6	FM

Appendix 9. The average of wing morphology

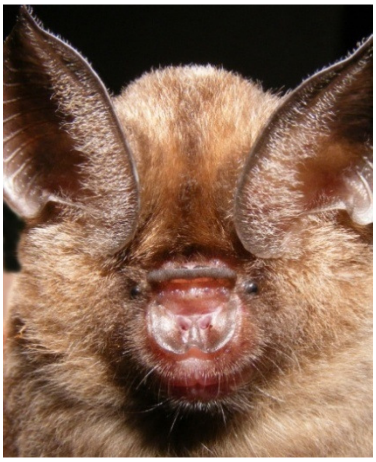
No.	Species	n	S	S_{aw}	S_{hw}	l_{aw}	l_{hw}	1/2B
1	*H. bicolor*	1	64.55	33.7	22.56	7.02	6.77	15.72
		2	51.56	22.5	25.13	5.8	5.6	13.45
		3	67.3	29.9	21.1	7.01	5.9	15.2
		4	63	26.4	20.8	6	6.3	15.2
		5	64	26	18.15	5.8	5.2	14.1
		6	60.7	24.9	17.72	6.01	5.7	14.8
		7	58	24.6	18.08	5.6	5.7	14.8
		8	68.8	33	18.2	6.7	5.5	15.1
		9	65.3	29	17.5	5.9	5.5	15
		10	63.5	28	19.3	6	5.9	15.9
		11	75.2	32	22.5	6.1	6.5	16.9
		12	49.4	25.6	16.2	5.8	5.7	14.2
		13	59.4	28.2	19.7	5.7	6.6	15.1
		14	58	23.8	16.9	7	5.8	14.3
		15	63	29	18.4	5.9	5.7	15.1
		16	66.7	33	22	7	5	13.8
		17	65.3	30.9	19.7	6.9	5.6	15.6
		18	59.8	24.6	21.7	5.4	5.5	16.3
	Average		62.4172	28.0611	19.7578	6.2022	5.8039	15.03
	Total		0.0125	0.0028	0.0020	0.0620	0.0580	0.150
2	*H. cineraceus*	1	45.3	27.25	14.25	6.8	4.9	12.74
	Total		0.00906	0.00273	0.001425	0.068	0.049	0.127
3	*H. diadema*	1	173.2	101.5	56.72	13.34	11.25	24.6
		2	178.2	113	58.5	16.15	10.75	26.9
		3	186.9	105.3	61.41	15.55	11.15	26.5
		4	171.8	95.7	57.9	14.92	10.75	25.67
	Average		177.525	103.875	58.6325	14.99	10.975	25.918
	Total		0.03551	0.01039	0.005863	0.1499	0.10975	0.2591
4	*H. larvatus*	1	93.5	57.3	26.6	11.75	7.5	19.25
		2	93.9	58.4	31.5	11.5	10.8	25.4
	Average		93.7	57.85	29.05	11.625	9.15	22.325
	Total		0.01874	0.00579	0.002905	0.11625	0.0915	0.2232
5	*Coelop fritii*	1	66.5	34.2	26.6	6.78	5.6	13.7
		2	65.9	35.4	24.5	6.9	6.5	14.4

	Average		66.2	34.8	25.55	6.84	6.05	14.05
	Total		0.01324	0.00348	0.002555	0.0684	0.0605	0.1405
6	*M. spasma*	1	130.1	62.2	46.9	9.45	9.7	19.15
		2	127.6	60.9	49.6	9.21	9.96	19.16
	Average		128.85	61.55	48.25	9.33	9.83	19.155
	Total		0.0258	0.0062	0.00483	0.0933	0.0983	0.1916
7	*N. tragata*	1	112.9	71.3	39.6	8.9	8.98	20.834
	Total		0.02258	0.00713	0.00396	0.089	0.0898	0.2083
8	*R. acuminatus*	1	58.4	42.2	20.5	6.9	5.6	13.1
		2	65.4	45.4	23.9	7.8	6.5	15.8
		3	82.3	46.4	25.6	7.9	7.1	17.4
	Average		68.7	44.6667	23.33333	7.53333	6.4	15.4333
	Total		0.01374	0.00447	0.002333	0.07533	0.064	0.15433
9	*R. affinis*	1	87.9	50.6	26.4	7.7	6.7	17.5
		2	87.9	49.7	27.7	7.8	7.2	17.6
		3	75.2	44.9	23.9	7.6	6.9	16.8
		4	86.6	49.6	28.9	7.9	8	17.2
		5	89.7	51.3	29.6	8	7.8	17.3
		6	85.4	50	28.8	7.6	7	17
		7	83.9	48	27.8	7.7	7.6	16.9
		8	86.8	49.3	30.5	7.9	7	17.4
		9	88.2	50.9	30	7	8	16.9
		10	79.6	47	27.7	7.6	7.3	17
		11	83.6	48	28	7.9	7.5	17.2
		12	81.3	48.5	29.4	7.6	6.9	17
		13	83.9	48.8	28.9	7	6.9	17
		14	78.5	43.7	27.3	7.6	7.4	16.8
		15	85.5	49	27	7.4	7.8	18
		16	87	50.1	26	7.7	8	18
		17	79.2	44.8	24	7	6	17
	Average		84.1294	48.4824	27.75882	7.58824	7.325	17.2118
	Total		0.01683	0.00485	0.002776	0.07588	0.07325	0.1721
10	*R. coelophyllus*	1	58.9	29.1	23.4	6.8	6.5	14.5
		2	61.7	32.3	21.5	6.7	5.8	14.4
		3	57.4	29.4	23.1	6.6	6.6	14.5
	Average		59.3333	30.2667	22.66667	6.7	6.3	14.4667

	Total		0.01187	0.00303	0.002267	0.067	0.063	0.14467
11	*R. lepidus*	1	50.3	25.3	17.8	6.4	5.8	13.7
		2	52.4	27	18.3	6.75	6.1	13.9
		3	52.7	26.4	18	6.8	5.7	14
		4	51.4	26	17.9	6.6	5.4	13.2
	Average		51.7	26.175	18	6.6375	5.75	13.7
	Total		0.01034	0.00262	0.0018	0.06638	0.0575	0.137
12	*R. luctus*	1	158.5	87.4	50.9	10.9	9.8	22.6
		2	165	87.9	51.2	11.6	9.7	23.3
	Average		161.75	87.65	51.05	11.25	9.75	22.95
	Total		0.03235	0.00877	0.005105	0.1125	0.0975	0.2295
13	*R. mayalanus*	1	51	25.3	16.7	6.4	5.5	13.6
		2	52.9	29	17	6.8	5.9	14.1
		3	54.6	29.5	16.2	7	5.7	14.1
	Average		52.8333	27.9333	16.63333	6.73333	5.7	13.933
	Total		0.01057	0.00279	0.001663	0.06733	0.057	0.1393
14	*R. robinsoni*	1	57.6	29.5	18.3	7.05	5.7	14.7
		2	55.6	29.4	18.1	6.8	5.9	14.5
		3	56.4	31.2	19.7	7.5	6.1	13.6
		4	55.6	31.6	17.7	9.4	5.6	15
		5	65.8	34	22.2	8.4	6.6	15
	Average		58.2	31.14	19.2	7.83	5.98	14.56
	Total		0.01164	0.00311	0.00192	0.0783	0.0598	0.1456
15	*R. stheno*	1	69.3	38.4	23.2	8.2	6.8	16.6
		2	70	38	20.4	8.3	6.1	16
		3	68.9	36	20.1	8	6.2	15.9
		4	70.1	37	22.6	8.4	6.7	15.9
		5	67.4	38.9	23.2	8	7	16.6
	Average		69.14	37.66	21.9	8.18	6.56	16.2
	Total		0.01383	0.00377	0.00219	0.0818	0.0656	0.162
16	*R. trifoliatus*	1	85.2	45.1	32.6	7.6	7.8	16.5
		2	86	46.53	28.5	7.95	7.2	16.5
	Average		85.6	45.815	30.55	7.775	7.5	16.5
	Total		0.01712	0.00458	0.003055	0.07775	0.075	0.165
17	*K. hardwickii*	1	44.14	26.1	14.7	5.95	5.9	14.1
		2	41.7	24	14.7	5.4	5.6	13.6

		3	46.9	26	14.8	5.8	5.8	14.2
		4	45.8	25.2	14.8	5.7	5.8	14.2
		5	47	25.3	15.9	6	5.7	14.5
		6	49.3	27	19.5	6.1	6	13.6
	Average		45.8067	25.6	15.73333	5.825	5.8	14.0333
	Total		0.00916	0.00256	0.001573	0.05825	0.058	0.14033
18	*K. minuta*	1	32.9	14.8	13.8	4.6	5.2	10.8
	Total		0.00658	0.00148	0.00138	0.046	0.052	0.108
19	*M. Magnator*	1	44.1	22.4	19.4	6.5	7	13.6
	Total		0.00882	0.00224	0.00194	0.065	0.07	0.136
20	*M. cyclotis*	1	78.9	39.4	28	7	7.4	14.6
		2	66.8	37	23.6	6.7	7.2	14
	Average		72.85	38.2	25.8	6.85	7.3	14.3
	Total		0.01457	0.00382	0.00258	0.0685	0.073	0.143
21	*M. suilla*	1	50.2	26.5	16.4	6.9	5.2	14.3
		2	48.9	22.8	14.6	6.6	5	13.2
	Average		49.55	24.65	15.5	6.75	5.1	13.75
	Total		0.00991	0.00247	0.00155	0.0675	0.051	0.1375
23	*M. muricola*	1	53.1	21.4	19.2	5.9	6.7	13.1
		2	49.5	22.2	12.1	5.6	6.1	12.9
		3	48.4	21.1	17.8	5.7	6.3	12.5
	Average		50.3333	21.5667	16.36667	5.73333	6.36667	12.8333
	Total		0.01007	0.00216	0.001637	0.05733	0.06367	0.12833

Appendix 10. Photo of insectivore bat and frugivorous bat in both forest and rubber plantations.



1. Hipposideros bicolor

2. Hipposideros cineraceus

3.1. Hipposideros diadema

3.2. Hipposideros diadema

4. Hipposideros larvatus

5. Coelops frithii

6.1. Megaderma spasma

6.2. Megaderma spasma

7. Nycteris tragata

8. Rhinolophus coelophyllus

9. Rhinolophus affinis

10. Rhinolophus robinsoni

11. Rhinolophus acuminatus

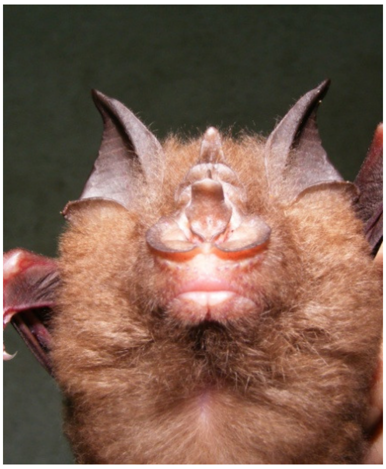
12. Rhinolophus lepidus

13. Rhinolophus luctus

14. Rhinolophus trifoliatus

15. Rhinolophus malayanus

16. Rhinolophus stheno



17. Rhinolophus yunanensis

18. Myotis muricola

19. Kerivoula hardwickii

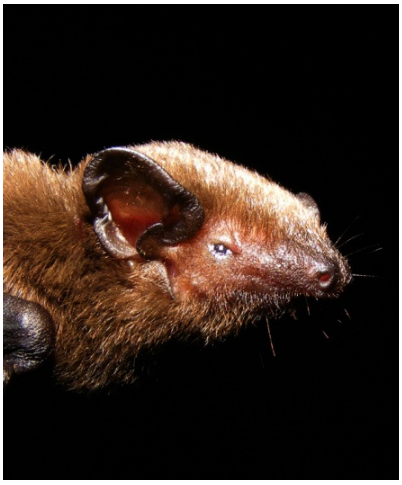
20. Kerivoula minuta

21. Miniopterus magnator

22. Phoniscus jagorii

23. Murina cyclotis

24. Murina suilla



25. Pipistrellus cf. tenuis

26. Cynopterus horsfieldi

27. Cynopterus brachyotis

28. Cynopterus sphinx

29. Megaerops ecaudatus

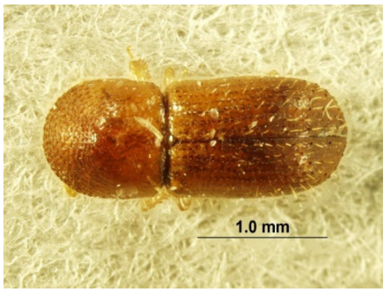
30. Eonycteris spelaea

31.1 Balionycteris maculata

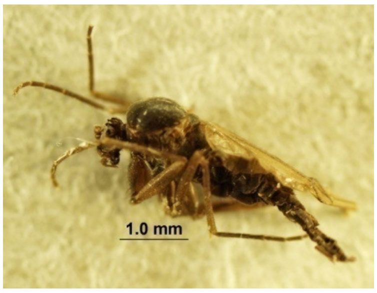
31.2 Balionycteris maculata

Appendix 11. Picture of insect order were trapping in forest and rubber plantations.

1. Coleoptera

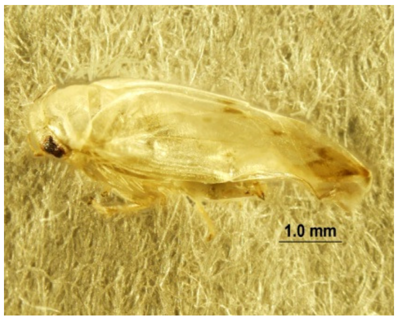


2. Diptera



3. Isoptera

4. Homoptera



5. ***Hemiptera***

6. ***Hymenoptera***

7. ***Lepidoptera***

8. Tricoptera

9. Odonata

VITAE

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Phommexay, P., S. Bumrungsri and P. J. J. Bates. 2007. Acoustic Study of Bat Species Diversity and Feeding Intensity in Intact Forest and Rubber Plantations, Southern, Thailand. Proceeding of the First International South-East Asian Bat Conference. Club Andaman Resort Beach Hotel, Patong, Phuket, Thailand, 7-10 May 2007. p 183.