MICROHABITAT ANALYSIS AND POPULATION PARAMETERS OF SMALL CARNIVORES IN SARAWAK PLANTED FOREST, WITH EMPHASIS ON THE MALAY CIVET *VIVERRA TANGALUNGA*

By

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ABSTRACT

MICROHABITAT ANALYSIS AND POPULATION PARAMETERS OF SMALL CARNIVORES IN SARAWAK PLANTED FOREST, WITH EMPHASIS ON THE MALAY CIVET *Viverra Tangalunga*

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This study examined the microhabitat features of the small carnivores in the Acacia planted forest in Bintulu, Sarawak, with emphasis on the Malay civet *Viverra tangalunga*. Wire-cage trapping, camera trapping, and spotlight night surveys were used to sample the small carnivores at three sites of the planted forest: Tubau, Samarakan, and Kakus. There were 50 captures in total representing five species: the Malay civet *V. tangalunga* (71%), the common palm civet *Paradoxurus hermaphroditus* (12%), the masked palm civet *Paguma larvata* (6%), the leopard cat *Prionailurus bengalensis* (6%), and the small-toothed palm civet *Arctogalidia trivirgata* (4%). In Kakus, the survival and capture probabilities of the live-captured and subsequently the radio-collared *V. tangalunga* was estimated. The survival probability *V. tangalunga* was relatively high, with 89% of *V. tangalunga* survived through the last trapping session, suggesting that the planted forest may support this species. Capture probability was higher for animals that had been radio-tracked, whilst wire-cage trapping sessions yielded a lower estimate due to the low yield of recaptured animals. Twenty variables describing proximate habitat structure of the small carnivores were measured at each capture site, with the point of capture served as the centre of a quadrat of 25 m × 25 m. Variables that

associated with the microhabitat of *V. tangalunga* and other civets were defined by Principal Component Analysis (PCA) and Stepwise Discriminant Analysis (SDA). From the analyses, variable describing the crown closure of the microhabitat appeared to be the most important factor affecting the occurrence of *V. tangalunga*. Its occurrence was also associated with undergrowth and dead logs. Overall, these variables represented the openness and shadiness of the microhabitat, where a point of equilibrium was attained by *V. tangalunga*. Other than PCA and SDA, Hierarchical Cluster Analysis (HCA) was also used to examine the variables that affect the occurrence of civets. These analyses revealed that *V. tangalunga* and *P. hermaphroditus* use similar microhabitat features, indicating some degree of overlapping in their microhabitats. Microhabitat segregation of these species is possible, and the extent of this segregation could be investigated from resource partitioning.

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APPROVAL SHEET

This dissertation/thesis entitled "**MICROHABITAT ANALYSIS AND POPULATION PARAMETERS OF SMALL CARNIVORES IN SARAWAK PLANTED FOREST, WITH EMPHASIS ON THE MALAY CIVET *Viverra tangalunga***" was prepared by ENG I SUM and submitted as partial fulfilment of the requirements for the degree of Master of Science at Universiti Tunku Abdul Rahman.

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SUBMISSION OF THESIS

It is hereby certified that **ENG I SUM** **(ID No: 07UEM08773)** has completed this thesis / dissertation entitled "**MICROHABITAT ANALYSIS AND POPULATION PARAMETERS OF SMALL CARNIVORES IN SARAWAK PLANTED FOREST, WITH EMPHASIS ON THE MALAY CIVET *Viverra tangalunga*"** under the supervision of **DR. HAN KWAI HIN** (Supervisor).

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DECLARATION

I hereby declare that the dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and currently submitted for any other degree at UTAR or other institutions.

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LIST OF ABBREVIATIONS

AIC	Akaike's Information Criterion
dbh	Diameter at breast height
E	Ear length
GPS	Global Positioning System
ha	Hectare
HB	Head-and-body length
HCA	Hierarchical Cluster Analysis
HF	Hind foot
MCP	Minimum convex polygon
PCA	Principal Component Analysis
PFZ	Planted Forest Zone
SDA	Stepwise Discriminant Analysis
T	Tail
TL	Total length
Wt	Weight

CHAPTER 1

INTRODUCTION

1.1 Habitat Use

Habitat is the place where an animal occurs. Each habitat is characterised by a specific set of physical conditions such as topography, ambient temperature, sunlight intensity, moisture content, and soil type (Huggett, 2004). For terrestrial habitats, these ambient conditions will in turn affect its surrounding resources such as the coverage of vegetation, plant type, and water availability. Ecologically, each individual or population will have a specific set of preferred resources. For example, mammals constantly need water for their daily living and therefore they are more likely to nest and forage near the places where water may be easily accessible. In particular, the small- and medium-sized mammals prefer shady places to minimise the water loss and energy expenditure. The way an animal utilises the resources in the place where it lives is known as habitat use (Morrison, 2002). Because each habitat varies in resources such as food and water availability, places to avoid predators, foliage cover and other parameters, accessibility to the available resources is a major concern for an animal when it chooses which habitat to occupy (Lacher & Mares, 1996). Over a long run, this variability will affect the reproductive success of the wild animal.

Animals will respond to both exogenous and endogenous processes in spatial usage (Fortin & Dale, 2005). Disturbance such as forest logging and clearance, or the underlying environmental conditions such as the plant physiognomy are external processes a species will respond to. A species may respond positively or negatively towards the external process. For example, the common palm civet *Paradoxurus hermaphroditus* is more tolerant of fragmentation and disturbance of forest land; it responds somewhat positively to the changing of forested area to plantation because it also eats a large amount of fruits (Meijaard et al., 2005). Endogenous processes such as predatory risk, the presence of competitors, and inter- and intra-specific interaction will drive an animal to select its habitat. In other words, animals will occupy the habitat that maximises their reproductive gain and reduce the cost of energy (Pianka, 2000).

One primary question that will need to be answered when studying habitat use is: should an organism be thought as a member within its population? Or should it be considered as an individual? There are two approaches used to address this issue. The first one, used by Grinnell in 1932, assumes that the usage of microhabitat is generally similar over time and space within a population (Bowers, 1995). In contrast, the second approach advocates the individual level, rather than population, with the assumption that each species is largely morphologically and behaviourally distinct. Hence, an individual will maximise its benefit while reducing the cost based on its own perception on the ever-changing environment, but not on a particular set of patterns (Bowers, 1995). For example, the red squirrel *Sciurus vulgaris* in a mixed montane conifer forest in Lombardy Alps of Italy showed a large variation in home range size due to biological differences in size, sex, and age rather than a consistent pattern within the species (Wauters, Preatoni, Molinari, & Tosi, 2007).

Which approach to be used is closely related to the scale of study, the sample, and the sampling methods used to study the animals. For example, radio telemetry data will produce the home range size of an individual and gathering the data of the animals from the population allows us to construct the home range of a species. By contrast, other methods such as capture-recapture and spotlight night survey will yield population level data.

1.2 Habitat Fragmentation

Given the rapid rate of deforestation in the past few decades, most of the existing habitats in Malaysia are in fragmented form. Forest fragmentation converts the formerly continuous forests into patches of forests separated by open lands (Lindenmayer & Fischer, 2006). Fragmentation involves more than the loss of native vegetation. It is always accompanied by habitat degradation, habitat isolation, and eventually leading to the loss of habitat. Overall, it is related to the changes of vegetation patches across a landscape (Morrison, Marcot, & Mannan, 2006), leading to the degradation in the quality of habitat. Changes in the physical conditions (e.g., temperature and rainfall), vegetation structure, and plant demography of a habitat will alter the population size of the wildlife (Nakagawa, Miguchi, & Nakashizuka, 2006).

These changes may affect the breeding success, species interaction, food availability, and movements of a species (Lindenmayer & Fischer, 2006). Animals will have difficulties to adapt to such changes in habitat, especially if such changes happen rapidly. For example, the clearing of forested land for agricultural purposes in Peninsular Malaysia has been deemed as one of the major factors causing the loss of habitat for the Malayan tiger *Panthera tigris jacksoni*, which is now classified as endangered species by IUCN (2008).

Habitat loss is the primary cause that reduces the population of wildlife. It has greatly reduced the diversity of flora and fauna, especially in the species-rich tropical countries such as Malaysia. Massive clearance of land into agricultural or other development projects have altered, degraded, and destroyed the original habitat of many species, leading to the decline in number and driving them to become endangered or even to the point of extinction (Primack, 2002). For example, forest fragmentation has greatly restricted the movement of the Malayan sun bear *Helarctos malayanus*, changing their foraging habits and making them vulnerable to hunting. Consequently, the Malayan sun bear is declining rapidly in population size in Borneo (Meijaard et al., 2005).

The daily movement of an individual animal within its home range and territory can be negatively impaired by the isolation of habitat (Lindenmayer & Fischer, 2006). An individual that retreats to the remnant patches of habitat will create crowding effect while increasing inter- or intra-specific competition. Isolation of habitat may also affect the foraging behaviour of an organism. An animal may need to travel a longer distance from its nesting site to find food, using more energy to move between nesting site and foraging area. Also, fragmentation of habitat limits the potential of a species to disperse, thus increasing the chances for the population to inbreed (Primack, 2002). However, not all species are negatively impacted by habitat fragmentation, if the fragmented landscapes maintain some degree of terrestrial connectivity via the matrix of modified habitats (e.g., plantation) surrounding the fragments (Gascon et al., 1999). Gascon et al. (1999) found that the abundance of some vertebrates such as small mammals that are able to tolerate the matrix remains relatively stable or sometimes increase. Some larger mammals such as the Malayan sun bear *H. malayanus* may not persist in the planted forest without the embedded secondary forest blocks (McShea et al., 2009). It shows the importance of the connection of forests by modified habitat to the biodiversity of many terrestrial mammals.

Apart from the massive conversion of rain forest to fragmented forest, road construction also imposes potent effects on fauna. These impacts include changes of biotic and abiotic conditions along road edges, disturbances caused by vehicles, and road kills of animals (Goosem, 2007). The increase of light intensity and temperature along the road has altered the vegetation of the original habitat, promoting the growth of weeds and shrubs such as the *Melastoma* species (Meijaard et al., 2005). Vehicle disturbance such as gas, headlight, and noise may disturb the behaviour of some animals, especially those nocturnal mammals that have light-sensitive eyes (Goosem, 2007). Besides, roads have also increased the mortality of the animals. For example, eight civets' carcasses were found along the roads in a logged forest in Sabah during an 18 months survey (Colon, 2002), suggesting that these animals were at higher risk by using the roads. Chances of animals colliding with vehicles increase when there are more roads built for agricultural or other purposes. Undoubtedly, habitat fragmentation is one of the major threats to biological diversity.

1.3 Planted Forest

The establishment of planted forest, or plantation forest, is becoming common in most countries, mainly due to the increasing demand for wood and pulp, and sometimes for water or soil conservation or wind protection (Carnus et al., 2003). The conversion of the natural to monocultural forest has grown at a rapid pace for the last decade, particularly in the tropical forest. The land of planted forest has increased to an estimated 20 million hectares (ha) in tropical forest. In total, planted forest covers 187 million ha globally, where 62% of the planted forest is located in Asia (Carnus et al., 2003). In Sarawak, 5 million ha (41%) of the land is production forests (Stuebing, 2005), in which these forests are used for the production of various commodities, for example, timber (Fimbel, Grajal, & Robinson, 2001).

Planted forest has been referred to as a habitat that is less favourable to support a diverse range of species as compared to the natural forest (Hartley, 2002). Although planted forest has been criticised as a 'biological desert' (Hartley, 2002), it is not always true for some species, such as the generalist species. For example, a total of 25 species of mammals was trapped in the planted forest in the division of Bintulu, Sarawak, including the long-tailed giant rat *Leopoldamys sabanus* and the moonrat *Echinosorex gymnurus* (Giman, Stuebing, Megom, McShea, & Stewart, 2007). Also, the species richness of small mammals was found to be higher in the secondary and planted forests compared to the primary forest in Sabah (Stuebing & Gasis, 1989).

1.4 Objectives of Study

This study aims to identify the microhabitat features that affect the occurrence of small carnivores in Bintulu planted forest, particularly the Malay civet *Viverra tangalunga*. Despite the ubiquity and abundance of the Malay civet, only two previous studies had assessed the ranging behaviour (Jennings, Seymour, & Dunstone, 2006; Colon, 2002) and the day bed site (Colon, 2002) of this species. Both studies revealed that the day bed of the Malay civet was associated with some form of cover, such as fallen logs or tangled vines. Nonetheless, attempt has yet to be made to quantitatively describe the microhabitat features associated with the occurrence of this species. Because other civets such as the common palm civet have a similar diet as the Malay civet, they may share and utilise some portion of the microhabitat. As such, this study also investigated these two species to understand the habitat overlap among civets in the forest.

Although several recent studies (Jennings et al., 2006; Nowak, 2005; Colon, 2002) have shown that the Malay civet is capable of adapting to a wide variety of habitat, the resources used by the animal have yet to be identified, especially in the planted forest. Therefore this study also aimed to quantify the vegetation features and abiotic components of their microhabitats in order to understand the preferred habitat features of these animals.

In this study, the occurrence of the Malay civet is hypothesised to be non-random, that is, the selected site of the Malay civet would have a particular set of vegetation features. Parameters to be examined included the crown coverage, the undergrowth, and the number of understory trees, which manifest the extent of 'shadiness' of a site. In other words, it is hypothesised that the Malay civet prefers a shady site.

Other civets, such as the common palm civet, the masked palm civet, and the small-toothed palm civet (Colon, 2002; Heydon & Bulloh, 1996) may also use similar habitat features because of their frugivorous diet, but each species will have some distinctive or preferred habitat features that distinguish each of them. Since the Malay civet and the common palm civet are ecologically and behaviourally similar, these two species are hypothesised to show a substantial overlap in microhabitat features. On the other hand, as the small-toothed palm civet rarely descends to the ground and prefers the dense forest (Nowak, 2005), it is expected to have the least overlap in microhabitat features with the Malay civet.

This study is also aimed at estimating the population parameters of the Malay civet, such as the survival probability and the capture probability, which may indicate the extent of the habitat being used while providing insight on the habitat quality that the animal occupied. Although the Malay civet is regionally widespread, little is known on its population parameters. Survival probability will show the proportion of the captured Malay civet that would persist after the first trapping session, whilst the capture probability indicates the trappability of the Malay civet. These population parameters may serve as a baseline data for assessing the conservation status of the Malay civet.

CHAPTER 2

LITERATURE REVIEW

2.1 Small Carnivores: The Need to Conserve Them

Small carnivores are an ecological assemblage comprising taxa with an adult body weight of less than 20 kg and possessing sharp teeth and claws. They are lumped together as a group simply because they share some ecological features in common, mainly in diet and habit. Although they mostly eat meat, their diet also consists of a large proportion of fruits and invertebrates (Payne, Francis, & Phillipps, 2005). Regionally, there are 29 species of small carnivores recorded in Peninsular Malaysia (Medway, 1983) and 25 in East Malaysia (Payne et al., 2005), representing all the four families, i.e., Viverridae, Felidae, Herpestidae, and Mustelidae.

Little is known on the ecology, distribution, and conservation status of small carnivores given that most investigations usually focus on the charismatic large carnivores such as the tiger and the sun bear. Also, carnivores are difficult to study because their occurrence is somewhat elusive with a relatively low trap yield. Nonetheless, small carnivores may serve as a biological indicator for the integrity of an ecosystem (Nowak, 2005). They play significant roles in structuring populations and communities in an ecosystem by occupying the top or middle trophic level in the food chain.

Their abundance is therefore important in regulating the population size of other prey species. Small carnivores such as the leopard cat *Prionailurus bengalensis* and the Malay civet sampled in this study are among the largest predators in Borneo. These carnivores need a relatively large area to forage and survive. For example, the estimated home range size for the Malay civet can reach up to 110 ha (95% minimum convex polygon) in Ulu Segama Forest Reserve in Sabah (Colon, 2002). Conserving these small carnivores will require the preservation of their habitat, thus indirectly protecting other animals. Because small carnivores also consume fruits, they play an important role in dispersing the seeds and pollinating the fruit-bearing trees in the tropical forests (Cuarón, 2000).

Some small carnivores such as the common palm civet *Paradoxurus hermaphroditus* has been hunted for food or kept as pets in rural areas in Malaysia, especially in Borneo (Giman et al., 2007; Meijaard et al., 2005). Others, such as the masked palm civet *Paguma larvata* and the Malay civet, are considered as pests to the villagers for the reason that they prey upon livestock and destroy fruits in orchards. Since their ecological roles vary, their microhabitat requirements will therefore need to be investigated in detail for wildlife and forest management.

The conflict between human and small carnivores becomes increasingly critical when more lands are cleared for development and agricultural purposes. This conflict often leads to animal mortality, negatively impacting the populations of small carnivores. The loss and degradation of the habitats of small carnivores in Malaysia is a major threat to many of these animals such as the small-toothed palm civet *Arctogalidia trivirgata* and the binturong *Arctictis binturong*, which are believed to depend almost entirely on mature forests to build their nests because of their arboreal behaviour (Meijaard et al, 2005). Understanding the distribution pattern and ecological impacts of small carnivores in disturbed habitats is thus important to provide baseline data for long-term monitoring of their population dynamics and the effects of deforestation on these animals.

2.2 Diversity

The fossil record reveals that small carnivores are relatively stable in diversity, with little changes in species richness over the past 44 million years (Gittleman, Funk, MacDonald, & Wayne, 2001). Nevertheless, they occupy a diverse ecological niche of environments ranging from terrestrial, arboreal, to aquatic habitats. Ecologically, small carnivores can be further grouped into habitat generalists (e.g., the common palm civet *P. hermaphroditus*), forest specialists (e.g., the Hose's civet *Hemigalus hosei*), and semi-aquatic species (e.g., the smooth otter *Lutra perspicillata*). In Malaysia, small carnivores are represented by four taxanomic families: Viverridae (the civets), Felidae (the wild cats), Herpestidae (the mongooses), and Mustelidae (the martens, weasels, badgers, and otters).

2.2.1 Family Viverridae

Members of the family Viverridae are represented by nine genera in Malaysia, namely *Arctogalidia, Arctictis, Cynogale, Diplogale, Hemigalus, Paguma, Paradoxurus, Prionodon,* and *Viverra*. Viverrids are small and medium-sized carnivores with adult weight varying from 0.6 to 20 kg (Nowak, 2005). They either have stripes and spots or uniform colouration on their bodies. The tail of viverrids is often banded or ringed in some genera, such as members from the genus *Viverra*. Most viverrids have a unique perineal scent gland which serves as intra-specific communication and scent-marking tool (Feldhamer, Drickamer, Vessey, & Merritt, 2004). Interestingly, the secretion from the scent gland of *Viverra* spp. is extracted for perfumery and medicinal purposes (Nowak, 2005).

Viverrids adopt ecologically dichotomous strategies and habits to minimise inter-specific competition. These strategies include terrestrial vs. arboreal, carnivorous vs. frugivorous, and nocturnal vs. diurnal habits (Wells, Biun, & Gabin, 2005). They prey upon small vertebrates and invertebrates, and sometimes small livestock. However, the diet of the common palm civet *Paradoxurus hermaphroditus*, the masked palm civet *Paguma larvata,* the binturong *Arctictis binturong*, and the small-toothed palm civet *Arctogalidia trivirgata* is composed of large portion of fruits (Payne et al., 2005). Civets are usually nocturnal, although binturong and masked palm civet are occasionally active during the day time (Payne et al., 2005). The otter civet is the only semi-aquatic civet in Malaysia. It is different from others as it has a short tail and a broad muzzle (Nowak, 2005).

Morphologically, the Malay civet or tangalung *Viverra tangalunga* is distinct from other viverrids by having black and white stripes on its neck and throat. This species is widespread in the Sundaic region and has been introduced to several nearby islands, including Pulau Pinang, for its civetone, a substance used in perfume production, and to control rodent populations (Nowak, 2005). There are two recent studies on the morphometric variation and ranging behaviour of the Malay civet in Southeast Asia (Jennings et al., 2006; Colon, 2002). In the tropical reserve forest in Danum Valley of Sabah, the male Malay civet was found to be significantly heavier and had larger neck circumference and longer hind foot length than the female (Colon, 2002). The introduced population on Buton Island of Sulawesi was also sexually dimorphic on these morphological characters (Jennings et al., 2006).

V. tangalunga is nocturnal and terrestrial in habit. In the day time, it stays in the dense cover and it comes out to the open area to search for food at night (Nowak, 2005). The day bed of the Malay civet seems to be associated with dense vegetation cover, vines, and fallen logs (Meijaard et al., 2005; Colon, 2002). They can persist in disturbed forest, although their density was found to be lower in the logged forest than in the unlogged ones in Sabah (Colon, 2002; Heydon & Bulloh, 1996). They were sighted near the human settlement in the planted forest in Bintulu (Giman et al., 2007).

The Malay civet has a relatively wide home range size. The adult male generally has a slightly larger home range size, with 159 ± 111 ha (95% minimum convex polygon, or MCP method) in logged forest as compared to

105 ± 20 ha (95% MCP) of an adult female (Colon, 2002). In Buton Island, the home range size (95% MCP) for male and female adults are 86 ± 71 ha and 50 ± 23 ha respectively (Jennings et al., 2006). Because the home range size is affected by the resource and the presence of competitors (Giuggioli, Abramson, Kenkre, Parmenter, & Yates, 2006), the difference in home range size of the Malay civet in Sabah and Buton Island may also be due to these two reasons. As only three civet species are found in Buton Island (Suyanto, Yoneda, Maryanto, Maharadatunkamsi, & Sugardjito, 1998), the competition may not be as great as in Sabah that has eight civet species (Payne et al., 2005). Because many of the civet species in Sabah have a similar diet, the Malay civet may need to forage a larger area for food to meet its energy requirement. In comparison, the Malay civet in Buton Island may not encounter such intense competition, and thus would require a smaller home range size (Jennings et al., 2006).

The common palm civet *Paradoxurus hermaphroditus* also forages widely, probably because of its frugivorous diet. It consumes a variety of plants and fruits, which may force it to venture into secondary forests, plantations, gardens, and places near to human settlements (Payne et al., 2005). It climbs efficiently, spending most of its time on the tree and in the tree cavities. Although *P. hermaphroditus* is a protected species under Sarawak Wildlife Protection Ordinance 1998 (State of Sarawak, 1998), individuals of this species are often killed when raiding fruits in the orchard and prey upon livestock.

The small-toothed palm civet *Arctogalidia trivirgata* has a similar appearance as the common palm civet, except that the tail of the small-toothed palm civet is generally longer than the head-and-body length with teeth that are relatively widely-spaced (Payne et al., 2005). Also, the perineal gland is absent in the male small-toothed palm civet, which is different from other civets of the subfamily Paradoxurinae (Patou et al., 2008). This strictly arboreal animal feeds on small animals such as birds and squirrels, and eats fruits occasionally. Due to its arboreal and nocturnal habit, it is difficult to either live-trap or camera-trap this species. Consequently, the biological and ecological data on the small-toothed palm civet are very scarce.

Another species has a similar appearance as *Paradoxurus hermaphroditus* is the masked palm civet *Paguma larvata* (Payne et al., 2005). Stripes or spots are absent from the body of *Paguma larvata*. It has a distinct facial marking which appears as a 'mask'. It occurs in lowland dipterocarp and lower montane forests, in both primary and disturbed forests, and sometimes enters plantations to forage (Meijaard et al., 2005). It occurs in mixed evergreen forest in Thailand, botanic garden in Java, and montane forest in Assam of India (Grassman, Tewes, Silvy, & Kreetiyutanont, 2005; Azlan, 2003; Choudhury, 1997).

2.2.2 Family Felidae

There are five wild cat species in East Malaysia: the clouded leopard *Neofelis nebulosa*, the leopard cat *Prionailurus bengalensis*, the marbled cat *Pardofelis marmorata*, the flat-headed cat *Prionailurus planiceps*, and the bay cat *Catopuma badia* (Payne et al., 2005). Among these species, the clouded leopard and the marbled cat are vulnerable or endangered (IUCN, 2008). Except for the widely distributed leopard cat, the ecology and behaviour of most wild cats in Malaysia are still poorly known.

The clouded leopard is the largest cat among the Bornean felids, probably serving an important ecological role as one of the top predators in the food chain. Its body weight ranges from 11 to 20 kg, with short legs, an exceptionally long tail, and cloud-like marking on its body (Nowell & Jackson, 1996). Due to the demand for its decorative pelt and meat for traditional Asian medicinal uses, the clouded leopard has been targeted by poachers for decades (Nowell & Jackson, 1996). It can be found in various kinds of forests (Payne et al., 2005) and has been recorded travelling by roads (Wilting, Fischer, Bakar, & Linsenmair, 2006). In Thailand, the clouded leopard was seen foraging in closed forest, open forest, and abandoned orchard, with the majority in the closed forest (83.9%) in a mixed evergreen forest (Grassman et al., 2005). Its home range size ranged from 22.9 to 45.1 km^2 with 95% MCP method (Grassman et al., 2005). In contrast, the marbled cat mainly uses tall forest (Nowak, 2005). It is nocturnal and partly arboreal, preying mostly upon birds and sometimes on rats and squirrels. It is perhaps one of the most mysterious felids in Southeast Asia. Only one marbled cat was reported in Jerangau Forest Reserve in Terengganu over a 21-month study (Azlan & Sharma, 2006) and one was captured in the mixed evergreen forest in Thailand (Grassman et al., 2005). The distribution of the flat-headed cat in forest is associated with water source because it feeds mainly on fish and frogs. Water pollution and deforestation seem to be the major threats to this rare animal (Nowak, 2005).

Among all the Southeast Asian wild cats, the leopard cat is the most common felid, probably because it adapts better to deforestation and other disturbance (Nowak, 2005). In Sabah, it uses the forest edge, oil palm estate, and garden more frequent than the interior forest (Rajaratnam, Sunquist, Rajaratnam, & Ambu, 2007). The use of these habitats is closely related to the diet of this species. They prey upon small mammals, herpetofauna, and large insects, and rat is the most favourable food of the leopard cat (Rajaratnam et al., 2007; Payne et al., 2005). This species was camera-trapped in an Acacia plantation in Bintulu of Sarawak (Giman et al., 2007). In a selectively logged dipterocarp forest, the overall mean home range of the leopard cat was 3.0 km^2 with 95% MCP (Rajaratnam et al., 2007). This relatively small home range size was probably due to the abundance of murids in the study area and the absence of larger predators such as tiger and leopard to compete for resource.

As predators, felids are crucial for maintaining the stability and integrity of the communities of the prey. Although felids may benefit from the increase of herbivores and rodents followed by selective logging, their sensitivity toward logged forest remains unclear (Meijaard et al., 2005).

2.3 Resource Use

A study on the habitat of an animal with various methods such as camera trapping and radio telemetry often aims to provide insights on resource utilisation of the animal (Erickson, McDonald, Gerow, Howlin, & Kern, 2001). A habitat comprises all the resources needed for the survival and reproduction of an animal and thus the quality of the habitat is a core factor for an animal to choose when deciding which place to occupy. For example, an open habitat that lacks vegetation cover may expose the animal to predators but at the same time reduces its energy expenditure to forage. Therefore, all of the features or resources within a microhabitat have an immediate effect on the fitness of the animal (Pianka, 2000). Nevertheless, the resources are seldom identified and quantified for most of the species (Morrison & Hall, 2002).

Habitat includes not only the vegetation or vegetation structure but also the specific resource that a species will need to fulfil its basic needs such as to gain enough food and to minimise predator risk. However, vegetation is the core component of the habitat of terrestrial animals and it plays a vital role in determining the habitat of a species (Morrison et al., 2006). In this study, the physiognomic approach is used to analyse the vegetation because it includes the description and measurement of the form and appearance of the vegetation, and it consists of at least six important features that affect the habitat. These six features are the dominant species, life form, stratification, foliage density, vegetation coverage, and plant dispersion, all of which will provide a somewhat comprehensive description on the habitat (Brower, Zar, & von Ende, 1998).

A large variety of animals, from insects to small carnivores, feeds on fruits or leaves of trees in tropical rain forest. Besides, branches and broad leaves of some trees are used by small carnivores such as the small-toothed palm civet to build nest on the trees (Nowak, 2005). There is clear evidence that the coverage of vegetation will affect the animal's survival. For example, the forest-dwelling small-toothed palm civet prefers habitats with dense vegetation to avoid predators and perhaps also containing more food. Classifying the physiognomy and plant type of the vegetation within the microhabitat of an organism will therefore help to determine which resources are frequently accessed by the animal (Morrison et al., 2006).

Other than vegetative resources, animals also use non-vegetative features surrounding their habitat. Abiotic resources such as the topology, water availability, and rocky outcrop may be important for the survival and reproductive success of an animal (Morrison et al., 2006). For example, fossorial species such as the Malay badger will occur in areas covered with soft soil but not stones because they feed on worms or other animals that live underground (Nowak, 2005). Also, the presence of water is important for most mammals when inhabiting an area as they cannot survive without water.

As the resources that animals used will affect their occurrence, survival, and reproduction ability, sorting out these resources may help us to understand their distribution pattern and their ecological impact to the ecosystem. However, determining which features to be included for assessment may need the understanding of the background information on the animal of interest, such as the activity pattern and feeding habit. Sometimes, a smaller set of variables is usually tested in prior study to generate some confirmatory variables. This is because when the number of variables is large, the result becomes rather exploratory and the possibility of including false variables may increase (Erickson et al., 2001). Nonetheless, listing all the potentially possible resources used by the animal may be useful to sort out the preferred resources of the animals, especially for those less studied species.

2.4 Microhabitat

To effectively measure the resources used by a species, the scale of the habitat will need to be quantified on a species-specific basis. Large-scale macrohabitat parameters such as Simpson's diversity index only gives an overview of the species constitution of an area without providing detailed information on habitat preference of a specific animal. In contrast, small-scale microhabitat analysis can refine the habitat parameters to individual level. Microhabitat encompasses the fine-scale ambient conditions such as vegetation cover and distance to the nearest tree of a species (Moura, Caparelli, Freitas, & Vieira, 2005). These fine-scale parameters may reveal the habitat use of an organism. For example, measuring the plant diameter at breast height (dbh) provides information on plant biomass and foliage cover around the point of capture.

Uncovering the specific vegetation structures and the abiotic conditions that are important to a species provides ecological data on the habitat occupied by an animal, such as the microhabitat features and resources it utilises when foraging. These data are useful when implementing conservation programmes for the animal, especially in altered habitats such as the planted forest. This is because the habitat features such as soil nutrient and vegetation cover of these altered habitats are completely different from the original conditions (Giardina, Sanford, Døckersmith, & Jaramillo, 2000). To examine if the distribution of a species is related to a specific set of microhabitat features, detailed characterisation of the microhabitat variables (e.g., vegetation structure) is needed. The observation from Lambir Hill National Park in Sarawak suggested that, in general, the selection of microhabitat of small mammals depends on a specific set of microhabitat features regardless of the forest type they occupy (Nakagawa et al., 2006). The utilisation of different sets of microhabitat features may suggest that these microhabitats serve different purposes for the small mammals as the selection of microhabitat is driven by resource availability and the risk of predation (Bowyer, Kie, & Van Ballenberghe, 1998). All of these studies show that animals exhibit a certain degree of microhabitat preference; either the selection is general regardless of forest type or specific in different forest types.

In this study, Stepwise Discriminant Analysis (SDA), Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA) were used to explore the relationship of the small carnivores with their microhabitats. SDA is used to determine the microhabitat variables which separate the habitats used by small carnivores. Dendogram constructed using HCA indicates the ecological similarities among the animals by clustering them into groups and sub-groups. Animals that belong to the same cluster show substantial similarity in their microhabitat features. PCA performs a simultaneous analysis on multiple independent and dependent microhabitat variables, depicting the relative importance of these variables. It generates the smallest number of factors to explain the total variance of the original variables with a minimal loss of information (Bryant & Yarnold, 1995).

2.5 Population Parameters

Although there are some records on sighting or capturing of small carnivores (Azlan, 2003; Wells et al., 2005; Giman et al., 2007), the population size of these animals remains unclear in Malaysia. One of the useful and widely used methods to estimate the population size of such carnivores is the capture-recapture sampling. To obtain a somewhat decent result, a large number of animals need to be trapped and marked. This method also allows us to assess the underlying causes that affect the population trend, such as the movement pattern and the survival rate (Elzinga, Willoughby, Salzer, & Gibbs, 2001).

There are several underlying assumptions in the capture-recapture method. First, the sample needs to be collected randomly from the targeted population because all the individuals within the population are assumed to have an equal chance of being captured. Second, each of the marked individual is presumed to be distributed homogeneously to its habitat and sufficient time is given to the marked animals to redistribute before a second sample (recaptured) is taken. Third, several sampling and re-sampling of the targeted animals are required to be carried out within a relatively short period of time (Brower et al., 1998).

There are two classes of models in the capture-recapture method: the closed and open models. The most general method in the closed model is the Lincoln-Peterson method (Lukacs, 2009). The main assumption for the closed model is that the population of a species is constant (i.e., the numbers of death, birth, and migration remain unchanged) during the period of study, the capture probability is uniform for all the individuals within the population and it is typically useful for short-term study. There are two types of closed models, i.e., the discrete-time and the continuous-time models. In the discrete-time model, the targeted population are sampled several times using traps or nets and the trapped animals are only counted once. These animals will be tagged for recapture purpose (Chao, 2001). For the continuous-time model, only one animal is captured for one occasion and the time of capturing the species is accurately recorded.

In contrast, the open model estimates that the population changes over a longer period where the parameters of births, death, and migration become important. The basic model for the open population is the Jolly-Saber model (McDonald & Amstrup, 2001). This model has some crucial assumptions, i.e., individual of a species have equal probability of being caught and survive for a particular sampling time, and it requires at least three sessions of capture or recapture of the targeted population (Elzinga et al., 2001). Similar to the closed model, the open model does not take into account the different catching probability of the animal. The open model provides a more accurate estimation as the emigration and immigration of the animals are taken into account (Elzinga et al., 2001).

Many factors affect the catching probability of a species (Mao, 2007). The heterogeneity (e.g., sex, age, and size) and the prior experience of the animal cause the individual to respond differently to the trap. Also, the probability of catching an individual animal may change over time due to the changes of the environment, such as the weather. The unequal chances of the animals to be caught make the estimation of their populations become more difficult. Nevertheless, there is a series of models such as the binomial mixture model to cope with this problem (Mao, 2007).

Another similar approach to estimate the population size is the mark-resight method. This method allows the data from initial marked and subsequently resighted animals to be used for the estimation of population size (Elzinga et al., 2001). It is particularly useful when the yield of the recaptured animal is low but the species is sighted by other means, for example, spotlight night survey. This method is often used in conjunction with other methods, such as radio-telemetry.

The software MARK (White & Burnham, 1999; URL: http://www.warnercnr.colostate.edu/~gwhite/software) is used to analyse data from marked animals. It provides population parameter estimation for different types of re-encounter data: dead recoveries (e.g., the animal is harvested), live recaptures (e.g., the animal is re-trapped or re-sighted), radio tracking, or from some other combinations of these sources of re-encounters. This increases the flexibility of the experimental design. These re-encounter data can be modelled using the Cormack-Jolly-Seber (CJS) models, band or ring recovery models, joint live and dead encounters, known fate models, and some closed capture-recapture models such as Huggins closed model (Cooch & White, 2009). MARK also allows the combination of several models, such as the robust design model (combines CJS and closed capture) and joint live and dead encounters to estimate the population parameters such as probabilities of survival, capture, recapture, immigration, emigration, and fidelity, as well as the population size for the targeted organism.

Using a maximum likelihood approach, MARK implemented Akaike's Information Criterion (AIC; Akaike, 1985) to provide a quantitative method for model selection, in which model selection is treated within an optimisation rather than a hypothesis testing framework. A derivative of AIC, the small sample AIC (AIC_c) is used when the sample size (n) is small and the number of parameters in the model (K) is large. AIC_c should be used when the n/K is less than 40 (Burnham & Anderson, 2001). Variables associated with individual encounter history, or covariates, are modelled in MARK using design matrices (Cooch & White, 2009).

2.6 Camera Trapping: A Non-invasive Approach

Identifying the resources used by an animal species is not an easy task in the tropical rain forest because of its dense vegetation. The behaviour of small carnivores, which are secretive, nocturnal, and generally avoiding human contact, makes it even more difficult to study them in the tropical rain forest. The limitations of trapping or netting the animals are overcome with camera trapping, which is efficient and reliable in detecting the presence of wild animals with the least human disruption. This method has been widely used over the last decade to assess the presence of animals, including small carnivores in many types of forests (Moen & Lindquist, 2006; Numata et al., 2005; Silveira, Jacomo, & Diniz, 2003).

To enhance the chance of photographing an animal, baits are commonly used in most of the studies involving camera traps. However, bait should be replenished within a short interval especially during rainy seasons because the bait will deteriorate or be washed off by the rain. Camera trapping is particular useful in studies of inventories and population estimation for animals with unique pelt markings such as the tiger (Silveira et al., 2003). However, because it is difficult to identify the small carnivores up to the individual level based on only the pelt markings, camera trapping in this study is used for quadrat marking. Since microhabitat analysis requires the validation of the 'presence' of the animal, camera traps can provide photographic evidence of the animals that are present in a particular area. This is an advantage over direct observation with no physical evidence. With this technique, small carnivores that inhabit inner or dense forests which are difficult to be observed can now examined (Goldman & Winther-Hansen, 2003).

Although there are some limitations to the use of camera traps, i.e., high maintenance fees, studies have shown that camera trapping is useful in mammalian research because the camera trap method had proven to be efficient in almost any field conditions (McShea et al., 2009; Azlan & Lading, 2006). Apart from using camera trapping for inventory, species abundance, and activity pattern surveys, it can also be used to identify the presence of terrestrial mammals due to its ease in handling and low environmental disturbance (Silveira et al., 2003).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Sites

This study was conducted in the planted forest of the Tatau area of Bintulu, Sarawak. This planted forest consisted of a total area of 490,000 ha. It was established by the government of Sarawak to cater to the increasing demand for industrial softwood. This study site included three planted zones under the Sarawak Planted Forest Project (Figure 3.1): Tubau (N3º09’30”, E113º42’47”), Samarakan Nursery (N2º56’12”, E113º07’27”), and Kakus Nursery (N2º44’47”, E113º09’51”).

The planted forest zones (PFZ) comprised lowland forests with an elevation generally below 200 m. Approximately 150,000 ha or 30% of this area was planted with the fast-growing *Acacia mangium*, whereas 35% of the land area consisted of remnants of tall forest and secondary forests (Giman et al., 2007). The characteristic features of tall forest such as big trees with diameter at breast height (dbh) greater than 30 cm and relatively dense crown were still retained in these remnants. Commercially important hardwood species such as *Shorea* spp., *Dipterocarpus* spp., and *Dryobalanops* sp. were also found here (McShea et al., 2009). However, these remnant patches were small, with an area up to a few square kilometres only. The secondary

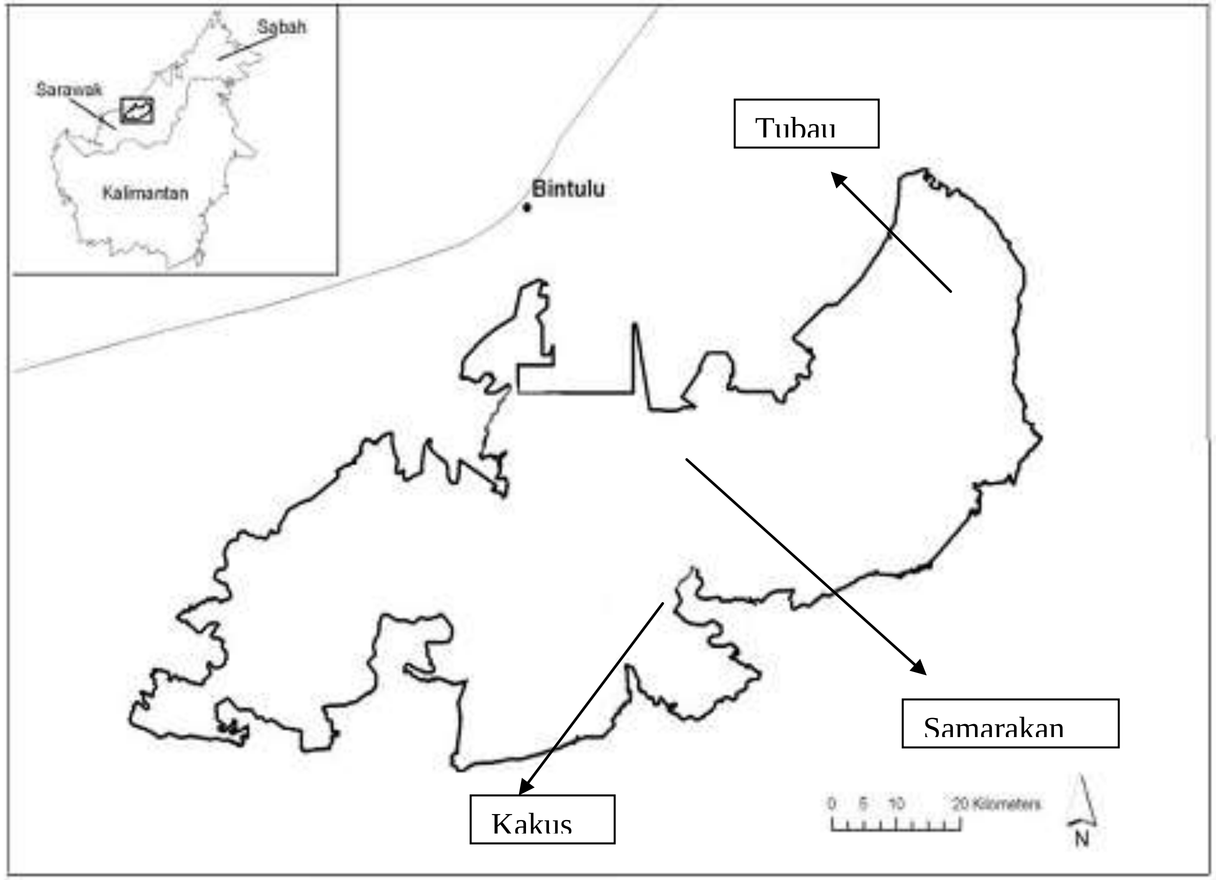

Figure 3.1: Map of the study sites within the Sarawak Planted Forest Zone (PFZ).

forests had been selectively logged since 30 to 40 years ago (McShea et al., 2009). These forests usually occurred between the interface of the Acacia forest and the remnants of tall forest. *Macaranga* spp., *Melastoma* spp., and *Calamus* spp. were the dominant plant species in these forests. In addition, these areas were widely covered by the ferns *Blechnum orientale* and *Dicranopteris* sp., with wild gingers growing within the dense undergrowth. Areas with steep slopes, streams, or rivers were left undisturbed in the PFZ to serve as buffer zones of the natural vegetation, functioning as the corridors where the wild animals could travel. Species such as the sun bear and the otter-civet using the primary habitats were reported in the remnants of tall forest during inventory studies within the PFZ (Giman et al., 2007).

The planting of Acacia forest was divided into blocks, allowing different ages of *A. mangium* to grow so that the forest would not be cleared simultaneously and that the logged forests would have sufficient time to regenerate. Aged trees of *Ficus* spp. and *Koompassia* spp. were retained in the Acacia forest to maintain a certain degree of plant diversity within the plantation. Understory vegetations remained uncut in both the mature Acacia forest and the remnants of tall forests (Stuebing, 2005). Since *A. mangium* tends to burn vigorously, artificial ponds were created for the purpose of fire-fighting, which, incidentally, become the water source to the animals.

3.2 Sampling Procedures

Several sampling methods were used in this study to locate the small carnivores. Although wire-cage trapping was the primary method used, camera trapping and spotlight night survey were also employed to increase the sample size of the small carnivores. This was because wire-cage trapping generally gave a relatively low trap yield. However, wire-cage trapping allowed us to examine the animals closely and to tag the individual animals, whilst camera trapping and spotlight night survey only permitted the detection of secretive and nocturnal species without close examination. Due to these reasons, this study only focused on animals from the family Viverridae (civet).

A total of eight sessions of wire-cage trapping was conducted in Sarawak planted forests in 2008 and 2009 (Table 3.1). Among these trapping sessions, five of them comprised 168 trap nights each, whilst the remaining surveys were carried out with an effort of 126, 210, and 210 trap nights, respectively. Although the trap effort varied among the study sites, a low trap yield rendered the difference in trap effort negligible when making comparison among the trapping sites.

3.2.1 Wire-cage Trapping

Trapping was carried out using wire-cage traps measuring at 32 cm × 32 cm × 64 cm each to catch the small carnivores, especially the civets. In

Table 3.1: Trapping effort of small carnivores in Sarawak Planted Forest.

Trapping site	**Date**	**Forest block**	**No. of traps**	**Trap night**
Tubau	May 6-14 , 2008	E2L, E2N	18	126
	October 14-21, 2008	E2L, E2M, E2N	24	168
	March 10-18, 2009	E2M, E2N	24	168
Samarakan	September 26 - October 3, 2008	T2A, T1C, T1F	24	168
	October 5-12, 2008	T2A, T1C	24	168
	August 13-23, 2009	T1F, T1Q	30	210
Kakus	April 21-28, 2009	K2C, K2D	24	168
	November 5-14, 2009	K1D, K2C, K2D	30	210

each survey, four to five transects were set (except for the first survey in Tubau which had three transects) and the distance of two adjacent transects was at least 2 km apart. Each transect consisted of six traps, which were placed at 50 m intervals. Given this setup, the placement of each trap within transect was not exactly independent from each other. Hence, each transect (instead of each trap) was considered as a 'site' as the distance between two transects was substantial. The traps were set along the pre-existing trail, usually not far (< 20 m) from the roadside at areas that comprised the interface of the Acacia forest and the secondary forest or the tall forest. The locations of each transect for the surveys in Tubau, Samarakan, and Kakus were shown in Figures 3.2, 3.3 and 3.4.

All traps were treated equally, where they were baited with a combination of different lures, such as cat food, chicken gut, banana, scent bait, and liquid essence. The scent bait consisted of either pheromone of mammals or rotten meat i.e., Carman's Magna-Glan lure and O'Gorman's Powder River Cat Call lure (Montgomery Fur, Ogden, Utah, USA), whilst the liquid essence comprised the flavours of banana, sweet corn, or durian. The traps were set on the ground, alongside a tree, fallen log, or within the shrub. To prevent the reflection of light which might frighten the animals, the traps were covered with dead leaves. They were checked on a daily basis for seven nights and baits were replenished every two days.

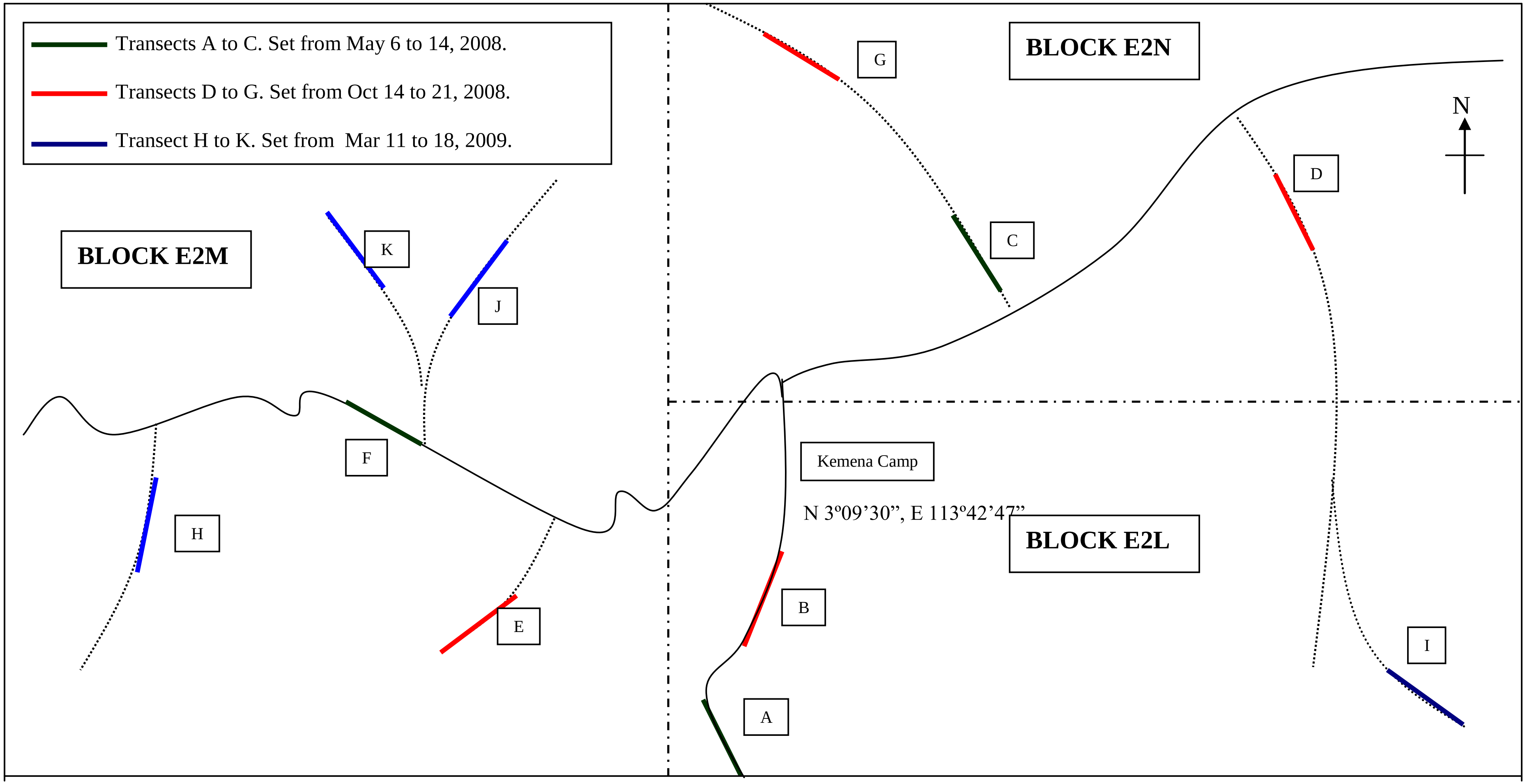

Figure 3.2: Trap sites in Tubau.

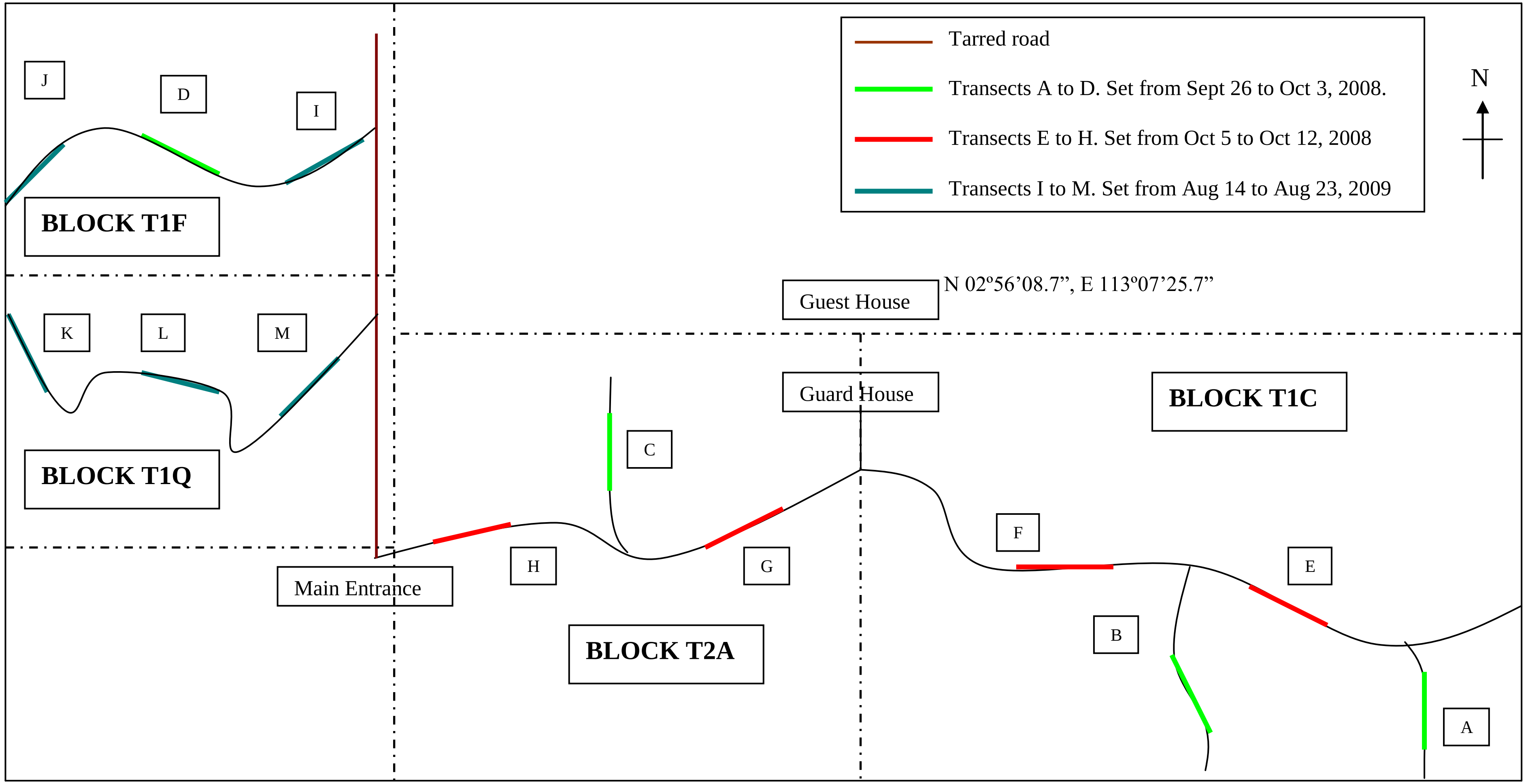

Figure 3.3: Trap sites in Samarakan.

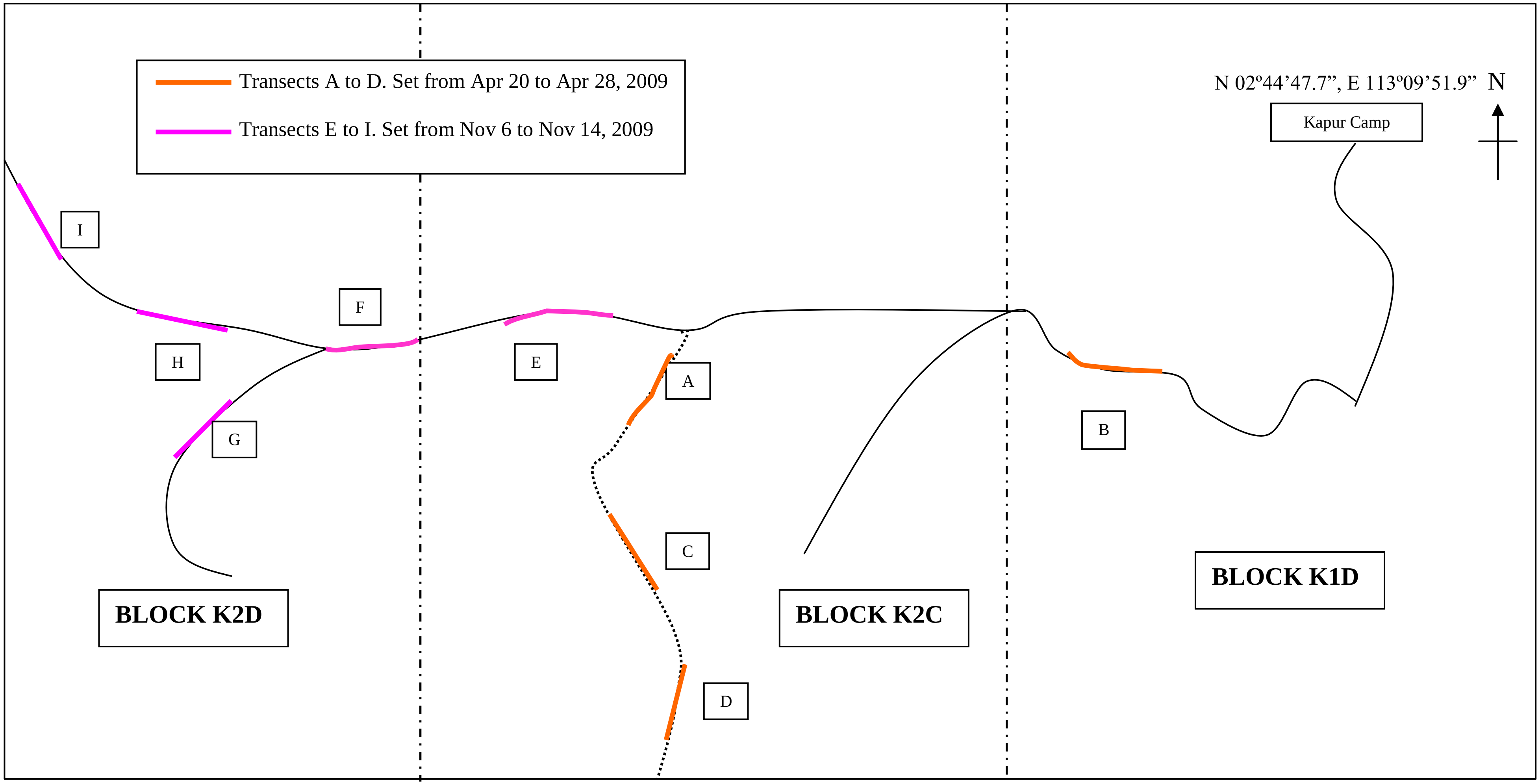

Figure 3.4: Trap sites in Kakus.

3.2.2 Camera Trapping

The camera trapping was conducted from March 2008 to October 2009 in Sarawak planted forest with 15 digital cameras (Trail Watcher 2035, Sharpsburg, USA) set either in the Acacia forest or the remnants of tall forest (Figure 3.5). Each camera, operating on a Sony rechargeable battery pack, had a 2" LCD screen with an ultra wide angle detection range to view the animals on the field. The built-in motion sensor was powered by a 9-volt battery that could last for 6-12 months. Each camera was mounted at about 0.5 m from the forest floor, along a path, trail or tract where animal signs such as footprints or evidence of debarking were detected. Sites close to a water source or underneath fruit trees were also chosen for setting the cameras. The cameras, set on sites that were not visible from the road, were placed at about 250 m intervals and baited. A stick was placed at about 2.0 m in front of the camera and wiped with the commercially available scent baits to lure the animals (Figure 3.6).

One picture was taken each time when the camera was triggered, with a delay of 2 minutes between each exposure to avoid taking multiple pictures of the same animal. The date and time of each shot were recorded on the photograph. All camera sites were marked with a Garmin 76CS Global Positioning System (Kansas, USA). The cameras were checked once in every two weeks to ensure that the memory card and batteries were functioning. Bait was also replenished during the inspection. On the fourth week, all the

Figure 3.5: The camera trap was set in the remnant of tall forest.

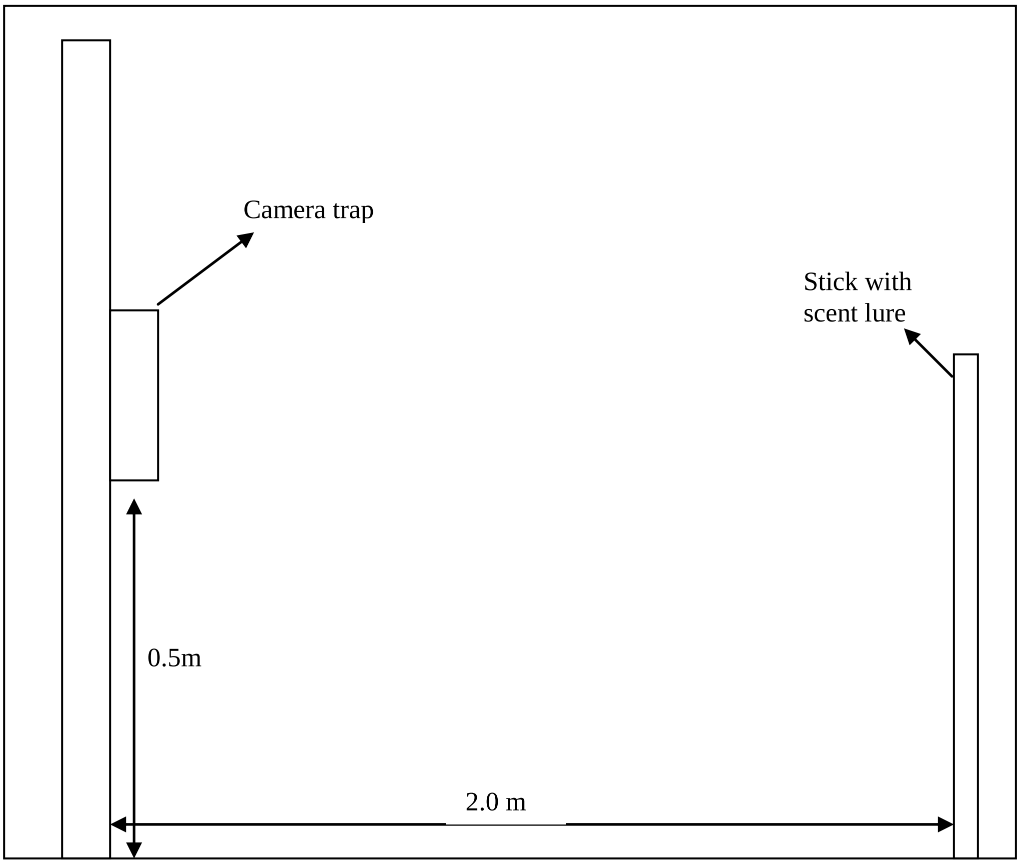

Figure 3.6: Setting of camera trap.

camera traps were removed. When the cameras were recovered, animals in the pictures were identified taxonomically.

3.2.3 Spotlight Night Survey

Because many small carnivores are nocturnal and arboreal (e.g., the masked palm civet and the small-toothed palm civet), spotlight night survey was carried out to increase the sample size for microhabitat analysis at interspecific level. Night-spotlighting was appropriate to be used because small carnivores have tapetum lucidum, a biological reflector system that is common in the eyes of carnivores to enhance visual sensitivity at low light levels (Ollivier et al., 2004). This created the phenomenon of ‘eye-shine’ and that the small carnivores would not look away from the light beam when the animal was beamed with a spotlight. The reflection of the small carnivores’ eyes then revealed their locations (Rudran, Thomas, Southwell, Jarman, & Smith, 1996).

On average, two night surveys were carried out during each trapping session. Each night survey was conducted from a moving motor vehicle for 5 to 7 km in distance, depending on the weather condition. A spotlight with intensity of 1,000,000 candle-light was used to scan above and on the ground of either side of the areas accessible to the vehicle at night. When sighted, a photograph was taken when the animal was somewhat stationary, either resting or grooming. The sighting spot was tagged with a ribbon and later the longitude and latitude was marked by GPS. Only individuals that were positively identified with photographic evidence were used for microhabitat analysis.

3.2.4 Animal Handling

The trapped animals were transferred into a net and held tight by two or three persons. Sex, weight, reproductive status, and morphometric measurements such as the total length (TL), head-and-body length (HB), tail length (T), hind foot length (HF), ear length (E), and the weight (Wt) of each individual were recorded. The animal was identified and ear-tagged on either side of the ear (Appendix). Each animal was fed with food and water, and released at the point of capture. The longitude and latitude of the point of capture was marked with GPS.

Animals caught for the first time, which were regarded as the first samples, would be released after they had been ear-tagged. Those caught more than once with ear-tags were categorised as recaptures (Brower et al., 1998). The population was re-sampled at least twice at the same site.

In Kakus, some selected individuals (five Malay civets and two common palm civets) in good physical conditions were fitted with a VHF transmitter (MOD-125, Telonics, Mesa, AZ, USA) on a collar. The transmitter, 53 g in weight with a sealed metal, had an operational life of two years under the standard power output at 25°C. Tracking was performed twice a day during the field survey for 11 days. The radio tracking data and the wire-cage data from the Malay civet in Kakus were converted into encounter history using the binary code ‘1’ and ‘0’. The value ‘1’ represented an encounter with a marked individual and ‘0’ indicated that a particular marked individual not detected on that particular occasion. The survival probability and the capture probability of the animals were estimated using the software MARK (White and Burnham, 1999; URL: http://www.warnercnr.colostate.edu/~gwhite/software).

3.2.5 Quadrat Sampling

The sites where animals were either trapped (wire-cage or camera trapping) or sighted (spotlight night survey) were analysed for microhabitat features. A quadrat of 25 m × 25 m was established with the point of capture or sighting as the centre of the quadrat for each sampled animal. To compare the variables of the quadrats with and without the captured Malay civet, one ‘blank’ quadrat (without capturing the Malay civet) was randomly selected to be measured for each transect. All quadrats were examined with respect to its vegetation and water availability, which were refined into 20 variables (Table 3.2; Appendix) and evaluated quantitatively in a consistent manner.

Table 3.2: Parameters and methods of quantifying 625 m^2 microhabitat.

No.	Variables	Methods
1.	Percentage of crown closure	Average percentage of points, sighting vertically with ocular tube (5 cm diameter) from 15 random points.
2.	Percentage of vegetation cover	Percentage of vegetation covered.
3.	Frequency of woody plant > 3 m height	Number of all live vegetation with woody stems > 3 m.
4.	Woody stem with 7.5-15.0 cm dbh	Live woody stem with 7.5-15.0 cm dbh counted at ground level.
5.	Woody stem with 15.1-23.0 cm dbh	Live woody stem with 15.1-23.0 cm dbh counted at ground level.
6.	Woody stem with 23.1-30.0 cm dbh	Live woody stem with 23.1-30.0 cm dbh counted at ground level.
7.	Woody stem with > 30.0 cm dbh	Live woody stem >30.0 cm dbh counted at ground level.
8.	Frequency of understory tree	Number of all live understory woody plant ≤ 3 m in height.
9.	Frequency of understory *Melastoma* spp.	Number of understory *Melastoma* spp.
10.	Frequency of herbaceous plant	Number of all live but unidentified herbaceous plant within the quadrat.
11.	Frequency of wild ginger	Number of live wild ginger.
12.	Frequency of rattan palm	Number of live rattan palm.
13.	Frequency of vine	Number of vine ≥ 1 cm dbh.
14.	Clump of *Blechnum orientale* (fern)	Clump of mature *Blechnum orientale*.
15.	Area covered by *Dicranopteris* sp. (fern)	Area covered by *Dicranopteris* sp. (m^2).
16.	Frequency of fallen-log	Number of fallen logs ≥7.5 cm dbh .
17.	Size of fallen-log	Average dbh (cm) of fallen log ≥7.5 cm dbh.
18.	Frequency of tree stump	Number of tree stumps ≥7.5 cm dbh.
19.	Size of tree stump	Average dbh (cm) of tree stump ≥7.5 cm dbh.
20.	Available water source within sight	Water source that could be sighted along the area nearby trap (Yes / No).

*dbh = diameter at breast height

3.3 Data Analysis

3.3.1 Trap Yield and Morphometric Variation

The trap yield, which was the total number of individuals caught over the number of trap nights expressed in percentage (Preatoni, Zilio, & Cantini, 1997), was calculated for samples collected from wire-cage trapping. Morphometric measurements of TL, HB, T, ratio of T to HB, HF, E, and Wt were recorded for animals captured with wire-cages. Differences in the morphometric measurements of both sexes of the Malay civet were evaluated using independent-sample t-test.

3.3.2 Microhabitat Analysis

Microhabitat variables of the Malay civet and other small carnivore species were examined using the multivariate statistics, i.e., Stepwise Discriminant Analysis (SDA) and Principal Component Analysis (PCA) followed by Hierarchical Cluster Analysis (HCA). SDA and PCA of the microhabitat variables were performed for the Malay civet, the civets (the Malay civet, the common palm civet, the masked palm civet, and the small-toothed palm civet), and all the captured small carnivores species (the Malay civet, the common palm civet, the masked palm civet, the small-toothed palm civet, and the leopard cat). HCA was conducted for the civets to examine the relatedness of the species in microhabitat features.

SDA was used to discriminate the quadrats with and without the Malay civet. The quantified microhabitat features were the independent variables, also known as discriminating variables or predictors, used to separate those quadrats. The distinctive microhabitat features of the three forest types, i.e., remnant of tall forest, open area, Acacia forest were also investigated using SDA. For the analyses of civets and small carnivores, SDA was used to group the species based on the unique characteristics of their microhabitat features in order to predict the membership of the small carnivore species. In addition, the sample size of the species was taken into account in these analyses because each species had a different sample size. A Wilk's lambda test (or F test) of significance was carried out to assess if the independent variables were significantly different in mean value across the groups (Hair, Black, Babin, Anderson, & Tatham, 2006).

HCA was used to investigate the degree of similarity and difference in the microhabitat features for the civets using squared Euclidean distance to construct a dendogram. In PCA, only components with eigenvalue greater than 1.0 were extracted to explain the variance. Orthogonal factor rotation Varimax was used to maximise the variance to facilitate interpretation on the analysis and at the same time maintaining the independency among the factors (Hair et al., 2006). When the loading of the variable was greater than 0.63 or less than -0.63, the variable was considered significantly important to explain the variance (Tabachnick & Fidell, 2007). Therefore, only high loading variables (> 0.63 or < -0.63) were used to explain the function.

All the statistical analyses of microhabitats were generated using the software SPSS 17.0 (SPSS Inc., Chicago, IL). All microhabitat data were log-transformed before the analyses were conducted to meet the assumptions (e.g., normal distribution) of parametric test and to improve the interpretability.

3.3.3 Estimation of Population Parameters

In this study, the software MARK (White & Burnham, 1999; URL: http://www.warnercnr.colostate.edu/~gwhite/software) was used to estimate two parameters of the wire-cage trapping data of the Malay civet from Kakus. These parameters were the survival probability and the capture probability. The survival probability, denoted by S, is the probability that an individual animal or groups of individuals surviving an interval among the primary sampling occasions, whilst the capture probability (p) or recovery probability is the likelihood that an individual animal or groups of individual being captured at a given period of time (Bradshaw, Barker, Harcourt, & Davis, 2003). The robust model of Huggins heterogeneity was used to analyse the data of four primary sessions conducted in April, July, November 2009, and January 2010 respectively. They included two sessions of wire-cage trapping and radio tracking each. Robust model (Pollock, 1982) allowed the modelling of a combination of closed and open populations. Open-population models were applied at the primary sessions to estimate the survival probabilities. Within the primary sessions, there were secondary capture occasions that were closed together in time, assuming no mortality or emigration occurred during this short period. These secondary sessions were 7, 4, 7, and 7 days, respectively. This yielded a detection history of 25 occasions. Individual covariates can also be incorporated into Huggins robust model (Cooch & White, 2009), but they were not included in this analysis as the sample size was small. After all the possible models were constructed, the best model was selected based on the lowest small sample Akaike's Information Criterion (AIC_c) value (Cooch & White, 2009). AIC_c selected the models that fitted the data with less parameter. Only models with > 1% support were described, and the parameters were estimated using model average (Burnham & Anderson, 2001).

CHAPTER 4

RESULTS

4.1 Species Composition and Trap Yield

Overall, this study yielded 31 small carnivores from wire-cage trapping, 10 from camera trapping, and nine from spotlight night survey, representing 50 animals and five species (Table 4.1). These species were the Malay civet (72.0%), the common palm civet (12.0%), the masked palm civet (6.0%), the leopard cat (6.0%), and the small-toothed palm civet (4.0%). The civet was the largest component of the collection, comprising 94.0% of the total number of small carnivores sampled.

Wire-cage trapping was carried out for 1386 trap nights with a trap yield of 2.2% (Table 4.1). Among the 31 wire-cage trapped animals, the Malay civet comprised 87.1% (27 individuals), followed by the common palm civet with 12.9% (4 individuals) of the total captures (A). Meanwhile, the masked palm civet (three individuals) and the small-toothed palm civet (two individuals) were each sampled by camera trapping and spotlight night surveys (Appendix). The leopard cat was detected by both camera trapping and spotlight night survey.

Table 4.1: Species composition of small carnivores with different sampling methods.

Species	Common name	Sampling method (number of individuals)			Total	Composition (%)
		Wire-cage trapping	**Camera trapping**	**Spotlight night survey**		
Viverra tangalunga	Malay civet	27	5	4	36	72.0
Paradoxurus hermaphroditus	Common palm civet	4	1	1	6	12.0
Paguma larvata	Masked palm civet	-	3	-	3	6.0
Prionailurus bengalensis	Leopard cat	-	1	2	3	6.0
Arctogalidia trivirgata	Small-toothed palm civet	-	-	2	2	4.0
	Total	**31**	**10**	**9**	**50**	**100.0**
	Yield	**2.2%**				

A total of four Malay civets was recaptured during subsequent trapping sessions via both wire-cage trapping and camera trapping, with one and three individuals, respectively. However, camera trapping did not yield the identity of the tagged Malay civet because the tag number was too faint to be seen (Appendix).

4.2 Morphometric Variation

On average, the Malay civet had a total length of 996.1 ± 31.0 mm and a tail length of 324.1 ± 14.6 mm (Table 4.2). The Malay civet had a relatively shorter tail, which was only about half of its head-and-body length. In comparison, the common palm civet had a relatively longer tail, with a ratio of tail length to head-and-body length of 0.7. The Malay civet appeared to be larger than the common palm civet in the PFZ with a mean weight of 3.6 ± 0.6 kg ($n = 21$) whist the common palm civet weighed 2.4 kg ($n = 4$) on average. The mean weight of the Malay civet in Sarawak was similar to those reported by Colon (2002) in the logged forest in Sabah (3.6 kg).

The male Malay civet had a longer hind foot (average HF = 103.0 ± 2.4 mm) than the female (average HF = 97.4 ± 2.1 mm; $t = 6.4$, d.f. = 24, $p = 0.0$). Jennings et al. (2006) and Colon (2002) also found that the hind foot length of the male Malay civet was significantly longer than that of the female. The total length, head-and-body length, tail length, ear length, weight, and the

Table 4.2: Morphometric variation of *Viverra tangalunga* and *Paradoxurus hermaphrodites.*

Species	**n**	**Average ± Standard Deviation**						
		TL (mm)	**T (mm)**	**HB (mm)**	**T/ HB**	**HF (mm)**	**E (mm)**	**Wt (kg)**
Viverra tangalunga	26	996.1 ± 31.0	324.1 ± 14.6	672.0 ± 30.2	0.5	100.2 ± 3.6	34.0 ± 2.9	3.6 ± 0.6*
Paradoxurus hermaphroditus	4	900.0	370.5	504.5	0.7	72.0	32.5	2.4

TL= total length; T =tail; HB = head-and-body length; HF = hint foot length; E = ear length; Wt = weight

* only 21 individuals of *V. tangalunga* were weighed

ratio of tail length to head-and-body length were not statistically different between the sexes of the Malay civet (Table 4.3).

4.3 Microhabitat Analysis

4.3.1 Intraspecific Comparison: Stepwise Discriminant Analysis for *Viverra tangalunga*

The quadrats with Malay civet captured were compared against the quadrats without animal captured ('blank') using the Stepwise Discriminant Analysis (SDA). One function was produced ($p = 0.0$), consisting of seven microhabitat features which explained 100% of the variance among these two types of quadrats. The quadrats with captured Malay civet differed from the 'blank' quadrats primarily in the percentage of crown closure (loading value 0.4). The mean percentage of crown closure in quadrats with captured Malay civet was approximately two times denser than the 'blank' quadrats (40.7% vs. 22.1%). Also, the numbers of tree stumps, clumps of *Blechnum orientale* fern and understory *Melastoma* spp. were able to distinguish these quadrats, with discriminant loadings of 0.31, 0.26, and 0.21 respectively (Table 4.4). These features were all greater in the quadrats with captured Malay civet than that of the 'blank' quadrats. The remaining variables, namely, available water source within sight, frequency of wild ginger, and area covered by *Dicranopteris* sp. had loadings smaller than 0.2 and hence were not considered as substantive discriminators (Hair et al., 2006). Table 4.5 shows that 92.3% of the 'blank' quadrats and 97.2% of the quadrats with captured Malay civet were correctly

Table 4.3: Independent t-test of the morphometric variation between male and female Malay civet.

Parameter	t value	d.f.	p-value	Remark
Total length	0.5	24	0.6	Not significant
Head-and-body length	1.0	24	0.3	Not significant
Tail length	-0.8	24	0.4	Not significant
Ratio of tail to head-body	-0.9	24	0.3	Not significant
Hind foot length	6.4	24	0.0	Significant
Ear length	1.3	24	0.2	Not significant
Weight	1.3	19	0.2	Not significant

Table 4.4: Discriminant loadings of different quadrats for the Malay civet.

Microhabitat variables	**Function**
	1
Percentage of crown closure	0.44
Frequency of tree stump	0.31
Clump of *Blechnum orientale* (fern)	0.26
Woody stem with 15.1-23.0 cm dbh[a]	0.22
Frequency of understory sapling *Melastoma* spp.	0.21
Woody stem with 7.5-15.0 cm dbh[a]	0.20
Available water source within sight	0.19
Size of tree stump[a]	0.17
Frequency of woody plant > 3 m height[a]	0.16
Frequency of wild ginger	0.12
Frequency of fallen log[a]	0.11
Frequency of herbaceous plant[a]	0.09
Frequency of understory tree[a]	0.05
Area covered by *Dicranopteris* sp. (fern)	-0.05
Frequency of vine[a]	0.05
Size of fallen log[a]	0.02
Eigenvalue	1.91
Percentage of variance	100.00
Canonical correlation	0.81

[a] These variables were excluded from the analysis because they were not significant (F<2.7)

Table 4.5: Classification of the quadrats of Malay civet based on Stepwise Discriminant Analysis.

Microhabitat	**n**	**Predicted Group Membership**	
		Without captured animal	With captured animal
Without captured animal	26	24 (92.3%)	2 (7.7%)
With captured animal	36	1 (2.8%)	35 (97.2%)

Note: 95.2% of the original grouped cases were correctly classified.

classified using the above predictors, indicating that the variables in function one were able to distinguish these two types of quadrats.

Although the SDA yielded two functions, only the first one was able to statistically discriminate ($p = 0.0$) the forest type of the Malay civet, in which the understory tree frequency explained 98.9% of the total variance (Table 4.6). The remnant of tall forest was clearly separated from Acacia and open area based on the high number of understory tree (Figure 4.1). All quadrats of the remnant of tall forest were correctly classified (100%) whilst the grouping of the Acacia and the open area of the secondary forest was ambiguous (Table 4.7). A high number of the Acacia quadrats (73.3%) had a similar number of understory tree as the open area, with only 58.3% of the quadrats correctly classified.

4.3.2 Intraspecific Comparison: Principal Component Analysis for *Viverra tangalunga*

Among the 20 variables quantified, only 17 of them were analysed using PCA due to the high cross-loading of the variables in more than one Principal Component (Hair et al., 2006). The eigenvalue and the explained variance of the truncated data were identical to the full data set. Analysis of the microhabitat features of the Malay civets produced five components that explained 91.0% of the total variance.

Table 4.6: Discriminant loadings of the microhabitat variables of different forest types of the Malay civet.

Microhabitat variables	**Function**	
	1	**2**
Frequency of understory tree	0.73	0.69
Percentage of crown closure[a]	0.48	0.40
Woody stem with 15.1-23.0 cm dbh[a]	0.43	0.16
Frequency of understory sapling *Melastoma* spp.[a]	-0.31	0.23
Clump of *Blechnum orientale* (fern)[a]	0.24	-0.13
Area covered by *Dicranopteris* sp. (fern)[a]	-0.20	-0.14
Size of tree stump[a]	0.17	0.03
Frequency of fallen log	-0.03	1.00
Frequency of vine[a]	0.30	0.77
Frequency of woody plant > 3 m height[a]	0.33	0.70
Frequency of herbaceous plant [a]	0.03	0.67
Size of fallenlog[a]	-0.20	0.60
Woody stem with 7.5-15.0 cm dbh[a]	-0.02	0.40
Percentage of vegetation cover[a]	0.30	0.38
Available water source within sight[a]	0.14	-0.18
Frequency of wild ginger[a]	0.00	0.17
Frequency of tree stump[a]	0.01	0.16
Eigenvalue	3.40	0.04
Percentage of variance	98.90	1.10
Canonical correlation	0.88	0.19

[a] These variables were excluded from the analysis because they were not significant (F<2.7)

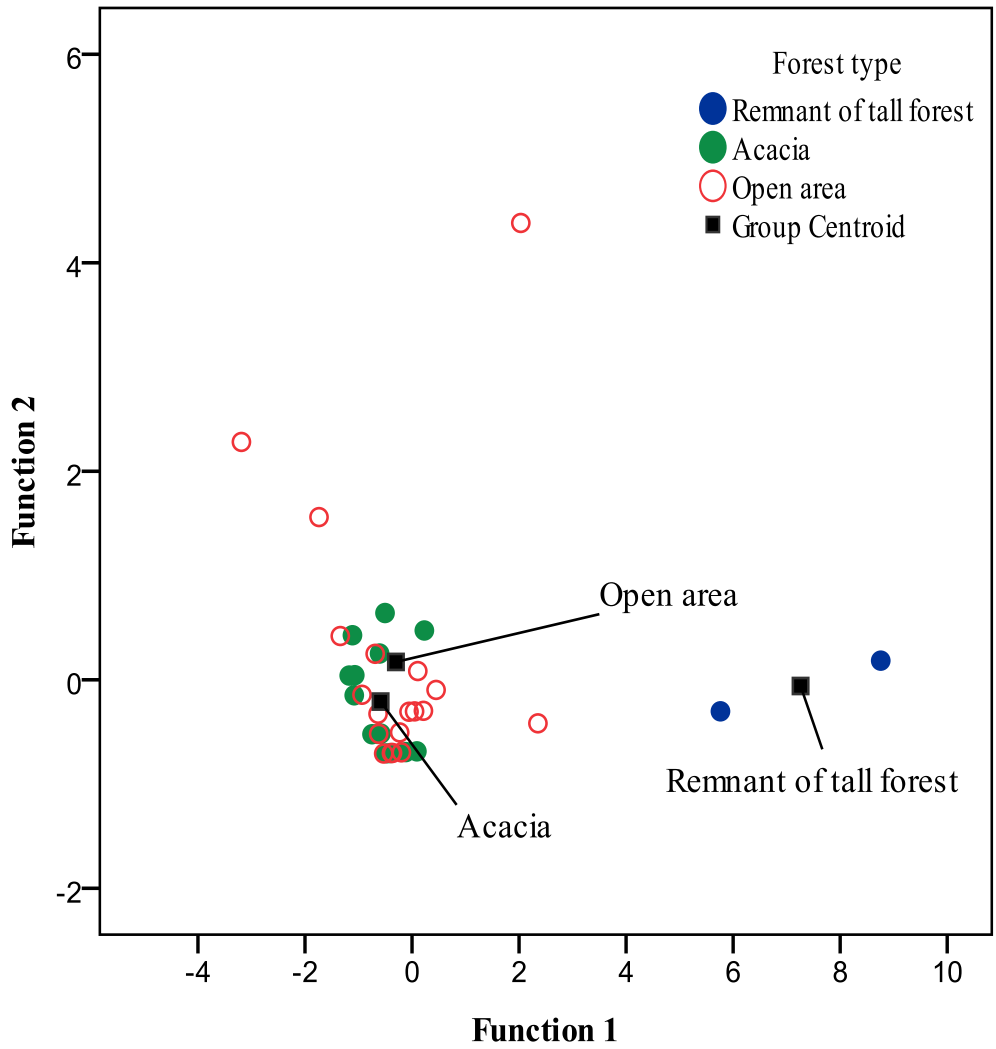

Figure 4.1: Canonical Discriminant Functions of the forest type of the Malay civet.

Table 4.7: Classification of the forest type of Malay civet based on Stepwise Discriminant Analysis.

Study sites	n	Predicted Group Membership		
		Remnant of tall forest	**Acacia**	**Open area**
Remnant of tall forest	2	2 (100.0%)	0	0
Acacia	15	0	4 (26.7%)	11 (73.3%)
Open area	19	0	4 (21.1%)	15 (78.9%)

Note: 58.3% of the original grouped cases were correctly classified

Principal Component one (PC1) comprised five microhabitat variables, i.e., frequency of tree stump, frequency of understory tree, area covered by the fern of *Dicranopteris* sp., frequency of fallen log, and the percentage of crown closure (Table 4.8). The frequency of tree stump had the highest loading value in PC1 (0.96), suggesting that the occurrence of the Malay civet was strongly correlated with the number of tree stumps present in the quadrat. However, the size of the tree stump had minimal influence on their quadrats (loading value -0.12). The frequency of understory trees had the second highest loading value in PC1 (0.85). Only the number of understory trees seemed to be influencing the occurrence of the Malay civet in the microhabitat but not the species of the understory tree, as suggested by the low loading value (-0.05) of the number of understory *Melastoma* spp.

The frequencies of tree stump and understory tree, both with positive loading values, were negatively correlated with the coverage of *Dicranopteris* sp. (-0.81) in PC1. Such a negative correlation was likely to be the result that the increment of the frequencies of tree stump and understory tree in a quadrat would reduce the space for *Dicranopteris* sp. to grow (less coverage). Interestingly, the frequency of tree stump and the coverage of *Dicranopteris* sp. were positively correlated with each other (both had negative loading value) but negatively correlated with the frequency of understory tree in PC2 (Table 4.8). These three features seem to be interrelated with each other, manifesting the ‘shadiness’ and the ‘openness’ of the quadrats. Surprisingly, the crown closure was highly loaded in both PC1 and PC2, suggesting that ‘shade’ was the most important variable to attract the Malay civet to use a site. Incidentally,

Table 4.8: Varimax-rotated Principal Components Analysis of microhabitat variables of the Malay civet.

Microhabitat Variables	**Eigen-value**	**Component**				
		1	**2**	**3**	**4**	**5**
Frequency of tree stump	1.18	**0.96**	-0.03	0.08	0.13	0.05
Frequency of understory tree	1.29	**0.85**	0.44	0.06	-0.07	0.02
Area covered by *Dicranopteris* sp. (fern)	-0.73	**-0.81**	-0.37	0.40	0.08	-0.04
Frequency of fallen log	1.64	**0.69**	0.27	0.09	0.59	0.01
Percentage of crown closure	1.36	**0.68**	**0.67**	0.04	0.05	-0.08
Woody stem with 15.1-23.0 cm dbh	0.68	0.48	0.41	-0.43	0.07	0.16
Woody stem with 7.5-15.0 cm dbh	1.30	0.17	**0.96**	0.01	0.15	0.01
Frequency of woody plant > 3 m height	1.52	0.31	**0.89**	0.03	0.32	-0.03
Percentage of vegetation cover	1.35	0.20	**0.79**	0.45	-0.28	0.19
Frequency of vine	0.44	0.49	0.61	-0.09	0.04	-0.60
Available water source within sight	0.76	0.19	-0.18	**0.90**	0.06	-0.20
Frequency of wild ginger	1.07	-0.19	0.31	**0.85**	-0.05	0.14
Frequency of understory *Melastoma* spp.	-1.36	-0.05	-0.41	**-0.75**	-0.16	0.02
Size of tree stump	1.06	-0.12	-0.10	**0.71**	-0.05	0.62
Frequency of herbaceous plant	1.31	0.15	0.23	-0.04	**0.90**	0.07
Clump of *Blechnum orientale* (fern)	0.62	-0.33	-0.28	0.54	**0.64**	0.04
Size of fallen log	1.55	0.51	0.22	-0.17	0.20	**0.79**
Percentage of variance	-	25.57	24.81	20.68	11.10	8.85

Note: loading values ≥ 0.63 or ≤ -0.63 for each component were in bold

the percentage of crown closure was positively correlated to four categories of plants, namely trees with 7.5 to 15.0 cm dbh and 15.1 to 23.0 cm dbh, understory trees and woody plants > 3 m in height, in both PC1 and PC2. These features contributed to an average of 40.7 ± 2.9 % foliage cover within the quadrat.

The percentage of vegetation coverage on the ground loaded 0.79 in PC2 (Table 4.8). It was negatively related to the fern of *Dicranopteris* sp. and *Blechnum orientale* in both PC1 and PC2. These three features also reflected the extent of 'openness' in the microhabitat. When the ferns were abundant in the Acacia and the open area of secondary forest, the overall vegetation coverage in the microhabitat was reduced. In other word, the 'openness' of the site was another important factor that influenced the selection of the Malay civet in microhabitat use.

The occurrence of the Malay civet was also affected by the number of fallen logs (0.69 in PC1). Water source was somewhat important for the Malay civet as it loaded 0.90 in PC3 (Table 4.8). The water source was not located within the microhabitat, but it was found at places near the quadrats. As indicated in PC3, when the frequency of the wild ginger increased, the number of *Melastoma* spp. decreased. The size of the tree stump loaded 0.71 in PC3 (Table 4.8), suggesting that the dead log was rather important to the Malay civet.

4.3.3 Interspecific Comparison: Stepwise Discriminant Analysis and Hierarchical Cluster Analysis for Civets

Stepwise Discriminant Analysis was used to examine the microhabitat features that were important to four civet species, namely the Malay civet *V. tangalunga*, the common palm civet *Paradoxurus hermaphroditus,* the masked palm civet *Paguma larvata,* and the small-toothed palm civet *A. trivirgata*. Two statistically significant functions ($p = 0.0$) were generated, with eigenvalues of 1.7 and 0.3 respectively (Table 4.9). The frequency of herbaceous plants had a loading value of 0.96 in function one and it separated the small-toothed palm civet from other civets. The frequency of vines in function two with a loading value of 0.80 was also able to distinguish the small-toothed palm civet from the masked palm civet. The quadrats of the Malay civet and the common palm civet shared substantially similar features (Figure 4.2), suggesting that SDA did not detect substantial difference in the quantified variables between the Malay civet and the common palm civet. As shown in Table 4.10, all of the quadrats of the common palm civet were grouped as the quadrats of the Malay civet when using SDA. As for the masked palm civets, their quadrats shared about 33.3% similarity with the Malay civet and the small-toothed palm civet each. Only the small-toothed palm civet was 100.0% correctly classified.

In the Hierarchical Cluster Analysis (HCA), the Malay civet and the common palm civet were grouped closely to each other with substantial overlap (Figure 4.3). This result agreed with that of SDA, suggesting that the

Table 4.9: Discriminant loadings of microhabitat variables for different civet species.

Microhabitat Variables	Function	
	1	**2**
Frequency of herbaceous plant	0.96	-0.27
Frequency of fallen log[a]	0.61	0.30
Percentage of vegetation cover[a]	0.34	0.26
Size of fallen log [a]	0.28	0.05
Frequency of wild ginger[a]	0.26	0.21
Size of tree stump [a]	-0.10	0.07
Frequency of vine	0.60	0.80
Frequency of understory tree [a]	0.28	0.52
Frequency of woody plant > 3 m height[a]	0.36	0.48
Woody stem with 15.1-23.0 cm dbh[a]	0.18	0.44
Clump of *Blechnum orientale* (fern)[a]	-0.18	-0.39
Woody stem with 23.1-30.0 cm dbh[a]	-0.10	0.38
Percentage of crown closure[a]	0.23	0.37
Woody stem with 7.5-15.0 cm dbh[a]	0.25	0.32
Frequency of rattan palm[a]	0.06	0.27
Area covered by *Dicranopteris* sp. (fern)[a]	-0.03	-0.26
Frequency of tree stump[a]	0.07	0.25
Available water source within sight[a]	0.03	-0.17
Frequency of understory sapling *Melastoma* spp. [a]	0.07	-0.14
Eigenvalue	1.65	0.29
Percentage of variance	85.30	14.70
Canonical correlation	0.79	0.47

[a] These variables were excluded from the analysis because they were not significant (F<2.7)

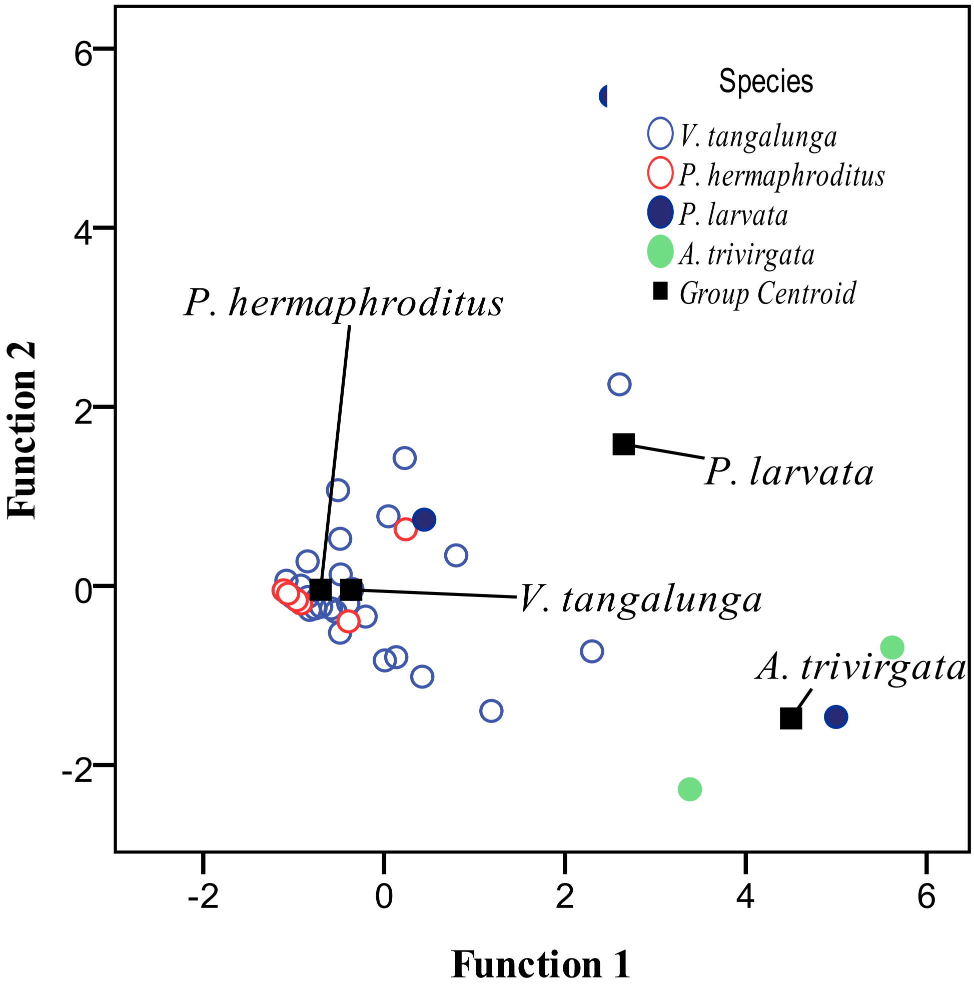

Figure 4.2: Canonical Discriminant Functions of the different species of civets.

Table 4.10: Classification of the civet species based on Stepwise Discriminant Analysis.

Species	n	Predicted Group Membership			
		V. tangalunga	***Paradoxurus hermaphroditus***	***Paguma larvata***	***A. trivirgata***
V. tangalunga	36	35 (97.2%)	0	1 (2.8%)	0
P. hermaphroditus	6	6(100.0%)	0	0	0
P. larvata	3	1 (33.3%)	0	1 (33.3%)	1 (33.3%)
A. trivirgata	2	0	0	0	2 (100.0%)

Note: 80.9% of the original grouped cases were correctly classified

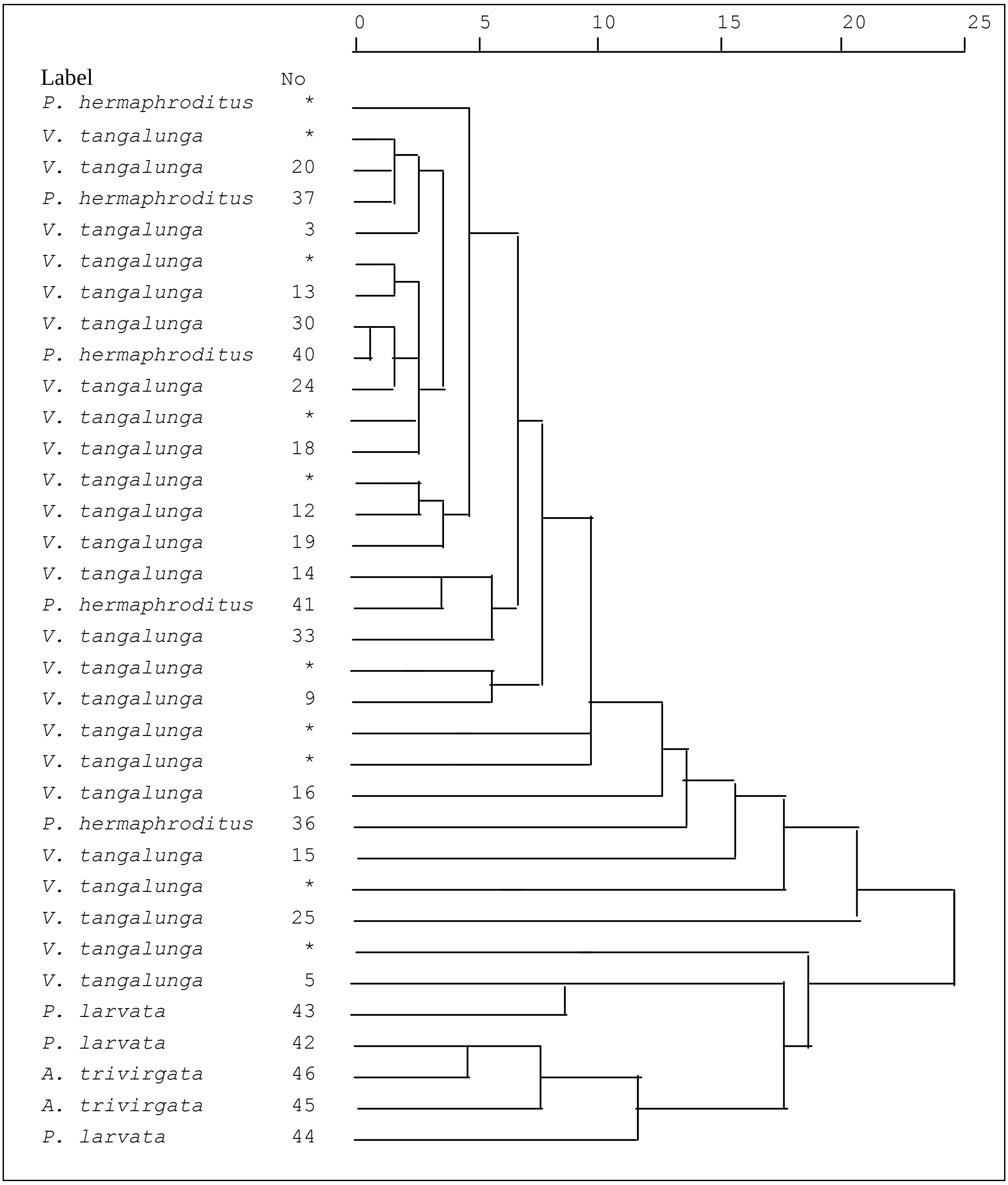

Figure 4.3: Clustering of civets by Hierarchical Cluster Analysis.
* Those without number consisted of ≥2 individuals

quadrats of both Malay civet and common palm civet shared somewhat similar microhabitat features. Conversely, the masked palm civet and the small toothed palm civet were grouped in the same cluster, indicating overlapping in microhabitat features.

4.3.4 Interspecific Comparison: Principal Component Analysis for Civets

Four components were retained to describe the quadrats of different civet species (Table 4.11). The number of wild ginger appeared to be the most important feature of the quadrats for all the civets, with a loading value of 1.0 in PC1. However, the frequency of herbaceous plants associated with wild ginger had little effect (-0.04) in the quadrats of the civets. Civets constantly need water, as indicated by the high loading value (0.94) of the available water source within sight from the quadrat. The number of understory *Melastoma* spp. had a negative loading value in PC1 (-0.84). Increased vegetation cover, *Blechnum orientale*, and tree stump on the forest floor decreased the number of understory *Melastoma* spp.

PC2 described the fallen log, woody plants, crown closure, herbaceous plants, and vines of the quadrats of the civet. Only the number of the fallen log (loading value 0.90) was important to the civet but not the size of the fallen log (loading value 0.21; Table 4.11). The crown closure gave a load of 0.83 in PC2, which was mainly contributed by woody plants > 3 m height (loading value 0.88) and woody stems with dbh between 7.5 cm to 15.0 cm (loading value 0.78). The herbaceous plants and vines also had high loading values in

Table 4.11: Varimax-rotated Principal Component Analysis of microhabitat variables for different civet species.

Microhabitat Variables	Eigen-value	Component			
		1	2	3	4
Frequency of wild ginger	0.99	**1.00**	0.02	-0.06	0.03
Available water source within sight	1.09	**0.94**	0.10	0.26	-0.21
Frequency of understory *Melastoma* spp.	-1.66	**-0.84**	-0.44	-0.08	-0.30
Percentage of vegetation cover	1.81	**0.78**	0.29	0.25	0.49
Clump of *Blechnum orientale* (fern)	1.06	**0.77**	0.59	-0.15	-0.16
Frequency of tree stump	1.86	**0.64**	0.19	0.41	0.62
Frequency of fallen-log	1.47	0.39	**0.90**	-0.02	0.20
Frequency of woody plant > 3 m height	1.65	0.14	**0.88**	0.24	0.39
Percentage of crown closure	1.47	0.05	**0.83**	0.56	0.04
Woody stem with 7.5-15.0 cm dbh	1.60	0.30	**0.78**	-0.03	0.55
Frequency of herbaceous plant	0.84	-0.04	**0.77**	-0.40	0.50
Frequency of vine	1.83	0.61	**0.69**	0.19	0.34
Size of tree stump	0.43	-0.25	0.07	**0.91**	-0.31
Frequency of rattan palm	1.22	0.40	-0.09	**0.91**	0.00
Frequency of understory tree	1.54	0.09	0.45	**0.88**	0.12
Woody stem with 23.1-30.0 cm dbh	1.25	0.46	-0.25	**0.82**	0.22
Area covered by *Dicranopteris* sp. (fern)	-1.03	0.47	-0.39	-0.62	-0.49
Size of fallen log	1.11	0.00	0.21	-0.07	**0.97**
Woody stem with 15.1-23.0 cm dbh	1.43	0.05	0.48	0.02	**0.88**
Percentage of variance	-	29.02	28.05	23.13	19.80

Note: loading values ≥ 0.63 or ≤ -0.63 for each component were in bold

PC2 (0.77 and 0.69) respectively. They increased the structural complexity on the ground and might be an important feature used by the civet.

4.3.5 Stepwise Discriminant Analysis for Small Carnivores

The membership of the five small carnivore species was predicted based on 19 microhabitat features, generating two discriminating functions ($p = 0.0$). Each was explained by one microhabitat variable. These variables were the frequencies of herbaceous plants and the vines, which yielded the same result when used to predict the membership of the civets.

In SDA, the first function accounted for 81.0% of total variance whilst the second one only explained 19.0% of it (Table 4.12). Adding another species (*P. bengalensis*) in the analysis yielded the same result as in the grouping of the civets in Table 4.9. The small-toothed palm civet was the only species that was clearly separated from the other small carnivores. Overall, about 78.0% of the civet species were correctly classified (Table 4.13).

4.3.6 Principal Component Analysis for Small Carnivores

PCA identified the key microhabitat features shared among the small carnivores based on 50 quadrats (36 *V. tangalunga*, six *P. hermaphroditus*, three *P. larvata*, three *P. bengalensis*, and two *A. trivirgata*). The result was identical to the analysis for civets, in which the variance could be explained with four functions (Table 4.14). Wild gingers and water source loaded

Table 4.12: Discriminant loadings of the microhabitat variables for various small carnivore species.

Microhabitat Variables	**Function**	
	1	**2**
Frequency of herbaceous plant	0.96	-0.29
Frequency of fallen log[a]	0.63	0.27
Percentage of vegetation cover[a]	0.32	0.25
Size of fallen log [a]	0.27	0.06
Frequency of wild ginger[a]	0.25	0.21
Size of tree stump[a]	-0.04	0.02
Frequency of vine	0.61	0.79
Frequency of understory tree [a]	0.29	0.51
Frequency of woody plant > 3 m height[a]	0.37	0.47
Woody stem with 15.1-23.0 cm dbh[a]	0.22	0.40
Clump of *Blechnum orientale* (fern)[a]	-0.18	-0.39
Woody stem with 23.1-30.0 cm dbh[a]	-0.07	0.36
Percentage of crown closure[a]	0.24	0.36
Woody stem with > 30.0 cm dbh[a]	0.04	0.35
Woody stem with 7.5-15.0 cm dbh[a]	0.26	0.31
Frequency of rattan palm[a]	0.07	0.27
Area covered by *Dicranopteris* sp. (fern)[a]	-0.04	-0.25
Frequency of tree stump[a]	0.09	0.23
Available water source within sight[a]	0.06	-0.19
Frequency of understory sapling *Melastoma* spp. [a]	0.06	-0.13
Eigenvalue	1.57	0.37
Percentage of variance	81.02	18.98
Canonical correlation	0.78	0.52

[a] These variables were excluded from the analysis because they were not significant (F<2.7)

Table 4.13: Classification of Stepwise Discriminant Analysis for various small carnivore species.

Species	n	Predicted Group Membership				
		V. tangalunga	***Paradoxurus hermaphroditus***	***Paguma larvata***	***A. trivirgata***	***Prionailurus bengalensis***
V. tangalunga	36	35 (97.2%)	0	1 (2.8%)	0	0
P. hermaphroditus	6	6 (100.0%)	0	0	0	0
P. larvata	3	1 (33.3%)	0	1 (33.3%)	1 (33.3%)	0
A. trivirgata	2	0	0	0	2 (100.0%)	0
P. bengalensis	3	2 (66.7%)	0	0	0	1 (33.3%)

Note: 78.0% of the original grouped cases were correctly classified

Table 4.14: Varimax-rotated Principal Component Analysis of microhabitat variables for small carnivores.

Microhabitat Variables	Eigen-value	Component			
		1	2	3	4
Frequency of wild ginger	0.99	**1.00**	0.02	-0.06	0.03
Available water source within sight	1.09	**0.94**	0.10	0.26	-0.21
Frequency of understory *Melastoma* spp.	-1.66	**-0.84**	-0.44	-0.08	-0.30
Percentage of vegetation cover	1.81	**0.78**	0.29	0.25	0.49
Clump of *Blechnum orientale* (fern)	1.06	**0.77**	0.59	-0.15	-0.16
Frequency of tree stump	1.86	**0.64**	0.19	0.41	0.62
Frequency of fallen-log	1.47	0.39	**0.90**	-0.02	0.20
Frequency of woody plant > 3 m height	1.65	0.14	**0.88**	0.24	0.39
Percentage of crown closure	1.47	0.05	**0.83**	0.56	0.04
Woody stem with 7.5-15.0 cm dbh	1.60	0.30	**0.78**	-0.03	0.55
Frequency of herbaceous plant	0.84	-0.04	**0.77**	-0.40	0.50
Frequency of vine	1.83	0.61	**0.69**	0.19	0.34
Size of tree stump	0.43	-0.25	0.07	**0.91**	-0.31
Frequency of rattan palm	1.22	0.40	-0.09	**0.91**	0.00
Frequency of understory tree	1.54	0.09	0.45	**0.88**	0.12
Woody stem with 23.1-30.0 cm dbh	1.25	0.46	-0.25	**0.82**	0.22
Area covered by *Dicranopteris* sp. (fern)	-1.03	0.47	-0.39	**-0.62**	-0.49
Size of fallen log	1.11	0.00	0.21	-0.07	**0.97**
Woody stem with 15.1-23.0 cm dbh	1.43	0.05	0.48	0.02	**0.88**
Percentage of variance		29.02	28.05	23.13	19.80

Note: loading values ≥ 0.63 or ≤ -0.63 for each component were in bold

high in PC1, with 1.0 and 0.94 respectively. This followed by variables that described the vegetation coverage on ground, where the number of understory *Melastoma* spp. was negatively correlated with percentage of vegetation cover and clumps of *Blechnum orientale*. PC2 described the crown closure within the quadrats, which positively related with number of woody plants (> 3 m height with dbh of 7.5 to 15.0 cm).

4.4 Estimation of Population Parameters for *Viverra tangalunga*

Parameters were set either constant over time (".") or varied through time ("t") to investigate the relationship of each parameter in a model. The survival and capture probabilities of the Malay civet in Kakus were estimated based on seven models, in which six of them had a constant survival probability throughout the study (Table 4.15). Conversely, as shown in the first two models, the capture probability of the Malay civet varied over the primary session. In addition, the movement of the animals during the trapping period was mostly constrained within the study area, as the parameters of immigration and emigration remained constant in most of the constructed models. The best model (first model) that weighted 0.55 had all the described characteristics.

The model-averaged survival probability of the Malay civet in Kakus was 0.89±0.11, with approximately 89.0% of them surviving through the last trapping session (Table 4.16). The capture probabilities for the radio tracking sessions (T2 and T4) were higher than the wire-cage trapping sessions (T1 and

Table 4.15: Models with AIC_c values.

No.	Model	AIC_c	Δ AIC_c	AIC_c weight
1	S(.) γ”(.) γ’(.) π(t) p(t)	105.57	0.00	0.55
2	S(.) γ”(.) γ’(t) π(t) p(t)	108.16	2.58	0.15
3	S(.) γ”(.) γ’(.) π(.) p(.)	108.18	2.60	0.15
4	S(t) γ”(.) γ’(.) π(t) p(t)	110.25	4.67	0.05
5	S(.) γ”(t) γ’(t) π(t) p(.)	110.25	4.67	0.05
6	S(.) γ”(.) γ’(.) π(t) p(t.)	111.50	5.93	0.03
7	S(.) γ”(.) γ’(.) π(.) p(t)	113.06	7.49	0.01

Parameter:
S = probability of an individual surviving from time *i* to *i*+1
γ”= probability that the marked individual has temporarily emigrated from the study area
γ’= probability that the marked individual has immigrated to the study area
π = probability that an individual occurs in one mixture due to heterogeneity of that individual
p= probability of an individual being captured

Table 4.16: Population parameters estimation of the Malay civet.

Parameter		Probability	Standard Error	95% Confidence Interval	
				Lower	Upper
Survival	(S)	0.89	0.11	0.46	0.99
Capture	(p)				
	T1	0.30	0.46	0.01	0.97
	T2	0.95	0.09	0.28	0.99
	T3	0.00	0.00	-0.01	0.01
	T4	0.58	0.30	0.11	0.94

Parameter:
S= probability of an individual surviving from time *i* to *i*+1
p= probability of an individual being captured
T= primary trapping session

T3). This was because that radio tracking had a higher 'return rate' as compared to wire-cage trapping of the animals. The capture probabilities of T2 and T4 were 0.95±0.09 and 0.58±0.30 whilst T1 and T3 were 0.30±0.46 and 0.0±0.0, respectively.

CHAPTER 5

DISCUSSION

5.1 Species Composition and Trap yield

The Malay civet formed the largest component of the captured small carnivore in the study sites, comprising 72.0% of the total captures. It had a trap yield of 2.2%, which was slightly higher than that of 2.0% of a previous live-trapping study in Danum Valley of Sabah (Colon, 1999). Although the effort for camera trapping was somewhat higher than that of wire-cage trapping (1,422 camera trap nights vs. 1,386 wire-cage trap nights), 75.0% of the captured Malay civets were contributed by wire-cage trapping whilst only 13.9% came from the camera trapping. Since all the wire-cage traps were placed near the road (< 20 m) whilst the cameras were deployed 'inside' the forest, the high composition of the Malay civet from the wire-cage trapping suggested that this species used the interfaces of the forest and the open area frequently. This observation could further be reinforced by the sighting of the Malay civet at the interfaces of the forests at night. This nocturnal animal was often sighted travelling along the road in the PFZ.

The common palm civet was also trapped along the forest edge, but the yield (12.0%) was much lower than the Malay civet, probably due to its semi-arboreal behaviour since all the wire-cage traps in this study were placed on the ground. The masked palm civet was only detected by camera, suggesting that this animal may not use the interfaces of the forest in the PFZ frequently. In this study, two small-toothed palm civets were sighted above the ground (> 7 m) in the remnants of tall forest in the spotlight night survey. However, wire-cage trapping did not catch any small-toothed palm civet, and neither did camera trapping (McShea et al., 2009; Giman et al., 2007).

Recapture of the civets was low; only one Malay civet was recaptured over 1,386 wire-cage trap nights (< 0.1% trap yield). In this study, recapture was also obtained by camera trapping. However, the photos from camera trapping did not allow the identification of the Malay civet at the individual level. Collared and tagged Malay civets were seen in the photos, indicating that the Malay civet survived the radio-tagging.

The use of lure raises an interesting possibility as to whether an individual animal would select or use the site in the absence of a lure. This issue could be addressed when we compared the results of trappings (wire-cage trapping and camera trapping) with spotlight night survey. However, since the trap yield for trappings was low and it was even lower for spotlight night survey, the effect of the lure could not be examined systematically. Nonetheless, because all traps were treated evenly and the selection of site to deploy the traps was random, the potential bias was minimal when establishing the traps and that the animal would need to be around the trapping area to be attracted by the lure. Moreover, this sampling issue is negligible when the scale of analysis is the area around the traps, where the structural variables are measured (Moura et al., 2005).

5.2 Morphometric Variation

The Malay civets caught in the PFZ weighed 3.6 ± 0.6 kg, which agreed with the findings of both Jennings et al. (2006) and Colon (2002). Other morphometric measurements were similar to that of Colon (2002) and were generally larger than the Malay civets in Buton Island (Jennings et al., 2006). The ratio of tail length over the head-and-body length of the Malay civet was 0.5, where the tail length was half of the body length. One of the important functions of the tail is to maintain the balance of the animal while it is climbing and jumping (King & Powell, 2007). The relatively short tail length of the Malay civet suggests that it uses the ground of the forest (Payne et al., 2005).

The hind foot length of the Malay civet appeared to be sexually dimorphic. In this study, all captured male Malay civets had a mean hind foot length of 103.0 ± 2.4 mm, whilst the hind foot length of the female was 97.4 ± 2.1 mm on average. This result was similar to the finding of Jennings et al. (2006) and Colon (2002). Sexual dimorphism usually occurs among carnivores (Nowak, 2005). This probably resulted from sexual selection or natural selection, where male and female have different ecological roles such as the female mammals would need to feed the offspring after giving birth (Janis, Scott, & Jacobs, 1998).

The morphometric measurements of the common palm civet fell within the range of those found in South East Asia (Francis, 2008), except that the head-and-body length in the planted forest was slightly longer. The common palm civet had a head-and-body length that ranged from 420 mm to 500 mm in South East Asia whilst those in the Sarawak planted forest had a head-and-body length of 490 mm to 518 mm. As compared to the ratio of tail over head-and body length with the Malay civet, the common palm civet had a generally longer tail, which facilitated the climbing activity for this semi-arboreal species (Francis, 2008).

5.3 Microhabitat Analysis

5.3.1 The Malay Civet *Viverra tangalunga*

In order to investigate if the Malay civet was selecting quadrats with specific microhabitat features, a comparison of the quadrats with and without (blank) the occurrence of the Malay civet was necessary. SDA shows that these two types of quadrats differed in microhabitat features especially in the crown closure. The crown closure for the quadrats with the Malay civet was 40.2% on average, whilst it was 22.1% for the ‘blank’ plot. The crown closure was related to the ‘shadiness’ of a particular quadrat, which in turn affected the undergrowth such as the understory trees, fern, and herbaceous plants within the quadrat.

The quadrat with the Malay civet was also characterised by a higher percentage (85.7%) of tree stumps. Only 19.2% of the 'blank' quadrats had tree stump, and the number of tree stumps in these 'balnk' quadrats were low, with an average of 0.3 tree stump. The fern *Blechnum orientale* and *Melastoma* sp. dominated the understory vegetation of these 'blank' quadrats. Except for *B. orientale,* all the microhabitat features describing the quadrats with the occurrence of the Malay civet were important features for the Malay civet to use, and were loaded in the first three components in the PCA.

In the PFZ, the Malay civet was caught in three different habitat types: the Acacia forest, the open area of secondary forest, and the remnant of tall forest. The Acacia forest and the open area of the secondary forest substantially overlapped, with 73.3% of the mature Acacia forest grouped as the open area of the secondary forest (Table 4.7), indicating that the Malay civet selected a particular set of microhabitat features within these forests.

Only two Malay civets were trapped in the remnants of tall forest, suggesting that this forest may just be the diurnal bed site for this animal. Meijaard et al. (2005) and Colon (2002) reported that the presence of vines may serve as an important feature of the diurnal bed site for the Malay civet. Although the frequency of vine was not the predictor of the habitat type in this study, both quadrats in the remnant of tall forest on average had higher number of vine as compared to quadrats in Acacia and open area (25 vs. 8 stems).

The occurrence of the Malay civet was best predicted by five microhabitat variables: low number of tree stumps, high number of understory trees, high coverage of *Dicranopteris* sp., high number of fallen logs, and moderate crown closure. These microhabitat features can be categorised as the dead log (tree stump and fallen log), undergrowth (understory trees and area covered by *Dicranopteris* sp.), and medium crown closure. There seemed to be an equilibrium attained among three of these microhabitat features: the coverage of *Dicranopteris* sp., frequency of tree stumps, and frequency of understory trees, as they were the first three variables had high loading values in PC1, and their relationships in PC1 and PC2 were different (Table 4.8). The coverage of *Dicranopteris* sp. and the frequency of tree stump expressed the extent of 'openness' of the quadrats, as both of them had negative loading values in PC2 and were negatively correlated to the frequency of understory trees. On the other hand, the frequency of tree stumps and the frequency of understory trees, which had positive loading values and negatively correlation to the coverage of *Dicranopteris* sp. in PC1 (Table 4.8), manifested the degree of 'shadiness'. The crown closure was the most important microhabitat feature in the quadrats of the captured animal, with high loading values in both PC1 and PC2 (0.68 and 0.67). When the crown closure was moderate, it allowed different types of undergrowth to grow whilst it remained shady (McShea et al., 2009). The undergrowth would attract the small mammals such as rats and tree shrews, and the Malay civet would prey on these animals (McShea et al., 2009; Nakagawa et al., 2006). Also, dense undergrowth provided cover to the Malay civet when it is hunting.

When the number of understory trees became substantial, the area covered by the fern *Dicranopteris* sp. was reduced. The number of understory trees was proportional to the percentage of crown closure. As the percentage of the crown closure increased, more understory trees grew within the quadrat. At the same time, the coverage of *Dicranopteris* sp. became reduced as the space on ground was occupied by the understory trees. The number of *Melastoma* spp., which belong to the category of understory tree, did not have a prominent effect on the quadrat of the Malay civet, suggesting that the Malay civet did not select any specific understory plant species but only chose the site where the undergrowth was abundant. This may allow the Malay civet to hide from predators in dense undergrowth while resting.

On average, there were two to three tree stumps present within the quadrats of captured Malay civets. The number of tree stumps was negatively correlated with the size of the tree stump (negatively correlated in PC1). Although the number of tree stumps found in the quadrat was low, the size of the tree stumps was big, with an average of 24.1 cm dbh. In quadrats with captured Malay civets, there was an increase in the number of fallen logs and log sizes (positively correlated in PC1). The Malay civet appeared to use the fallen logs and probably walked on the smooth fallen logs instead of the shrubby forest floor.

The occurrence of the Malay civet in PFZ was also associated with water source and the number of wild ginger. However, as water was readily available in the PFZ, it was not a strong predictor for the occurrence of the

Malay civet. The wild ginger present within the quadrat of the Malay civet might be a food source for the animal when food was scarce. The Malay civet might also eat the wild ginger within the quadrat to enhance digestion. Nonetheless, the effect of wild ginger to the Malay civet would need more evidence. On the other hand, other herbaceous plants minimally affected the occurrence of this animal in a site.

Heydon and Bulloh (1996) reported that the Malay civet was negatively affected by the effects of timber harvest in Sabah as their density decreased from 31.5 individuals per km^2 in unlogged forest to 6.4 individuals per km^2 in logged forests. However, the occurrence of this animal in the Acacia forest and the open area secondary forest was substantial in this study as compared to the remnant of tall forests (34 vs. 2 individuals). About 75% of the Malay civets were caught in the interface of Acacia forest and the remnant forest, suggesting that this species may use both forests, as long as the essential microhabitat features, i.e., dead log (tree stump and fallen log), undergrowth (understory trees and area covered by *Dicranopteris* sp.), and medium crown closure, were present within the microhabitat. A camera trapping study conducted in PFZ found that the occurrence of the Malay civet in the secondary forest was twice higher than in the Acacia forest (McShea et al., 2009).

5.3.2 Civets

The occurrence of civets (the Malay civet, the common palm civet, the masked palm civet, and the small-toothed palm civet) in the PFZ could best be predicted by seven microhabitat features: moderate frequency of wild ginger, readily available water source, high frequency of understory *Melastoma* spp., high vegetation cover, moderate number of *Blechnum orientale* fern, and low number of tree stumps based on the results of PCA. Among these features, the most important predictor to the quadrat of the civets was the number of the wild ginger, which had the highest loading value (1.0) in the PCA. This herbaceous plant was especially abundant in the quadrat of the common palm civet and the masked palm civet (18 stems on average). Given that these two species are known to eat fruits (Payne et al., 2005), the soft stem and the fruits of the wild ginger may be one of the food sources of these animals.

According to the PCA, water was an important source to all the civets as it had the second highest loading value (0.94). As for the Malay civet, water source was an ambiguous indicator for the quadrats of the civets as artificial ponds were plentiful in the PFZ. The vegetation cover on ground was high (> 75%) in the quadrats of the civets. Unlike the quadrats with captured Malay civets in which the ground was covered by *Dicranopteris* sp. and understory trees, the ground of the quadrats for other civets was characterised by a higher number of *Blechnum orientale* fern and tree stumps, but a low number of understory *Melastoma* spp.

The quadrats with captured civets were also associated with several features, namely the high number of fallen logs, high number of woody plants (particularly those with 7.5 to 15.0 cm dbh), moderate crown closure, moderate number of herbaceous plants, and vines. Woody plants, fallen logs, and vines appeared to be important as structural material for nest-building. Colon (2002) reported that the day bed site of the Malay civet was associated with fallen logs and vines. Joshi, Smith, and Cuthbert (1995) also found that the common palm civet preferred to rest in the crown of vine-covered trees. A medium crown closure (46.3%) was another feature of the quadrats of the civets. This coverage was contributed by woody plants with a height of 3 m and above, particularly those with 7.5 to 15.0 cm dbh.

The results of SDA and HCA show that the Malay civet and the common palm civet appeared to use similar microhabitat features, indicating some degree of overlapping in their microhabitat used. Among the six sampled common palm civets, four of them were either captured or sighted near the site where a Malay civet was caught. Interspecific competition for the resources within the microhabitat could lead to niche segregation where some resources are shared and others are used exclusively by a particular species (Pianka, 2000). Co-occurrence of these two species was possible since the Malay civet consumed substantially more invertebrates than the common palm civet, which allowed for resource partitioning (Colon 1999). In Nepal, the common palm civet would only shift from a frugivorous diet to a carnivorous diet when fruits were scarce (Joshi et al., 1995). In addition, the Malay civet, with a relatively shorter tail, used the ground more often than the common palm civet given that the common palm civet has adapted to a semi-arboreal behaviour (Payne et al., 2005). There is increasing evidence showing that co-occurring species frequently display greater morphological difference and prefer different niches to reduce competition and permit co-existence (Dayan & Simberloff, 2005), which may be the case for the Malay civet and the common palm civet.

In this study, the common palm civet did not show an obvious preference on the forest type, as three of them were caught in the open area of secondary forests whilst three were captured or sighted in Acacia forest. However, it was neither captured nor sighted in the remnant of tall forest in the PFZ. Quadrats of the common palm civet showed one common feature: crown closure was relatively sparse (30.4%). In Borneo, this animal occurs in secondary forests, plantations, and gardens but is rarely seen in primary forests (Payne et al. 2005). Nonetheless, Wells et al. (2005) caught six common palm civets in a primary forest in Sabah at an elevation of ≥ 400 m and, they were reported to be primary forests in Laos (Meijaard et al., 2005). The common palm civet is known to feed on seeds and pulpy fruits, including those of *Ficus* spp. and palms (Nowak, 2005; Shanahan, Compto, & Corlett, 2004). Such *Ficus* spp. were frequently found in the quadrats of the common palm civet, either as sapling understory trees or mature trees. The common palm civet also used roads, but probably less frequently than the Malay civet in the PFZ because fewer common palm civets were sighted at the logging roads.

While the Malay civet and common palm civet could persist in the Acacia forest, the masked palm civet and the small-toothed palm civet seemed to use a mixture of the remnants of tall forest and secondary forest. Their quadrats were characterised by dense crown closure and vegetation cover (> 75%). All of the camera-trapped masked palm civets in the study site were found in the remnant of tall forest at an elevation ranging from 120 to 220 m. Previous studies showed that the occurrence of this species may be related to a certain elevation. In Laos, this species was found in large blocks of evergreen forest at 500 m above sea level (Duckworth, Salter, & Khounboline, 1999). In 2008, two masked palm civets were caught in the secondary montane forest at an altitude above 1000 m in Cameron Highlands (UTAR, unpublished data). Other than elevation, the quadrats of the masked palm civet were characterised by a steep slope, reaching about 45º in gradient.

The small-toothed palm civets were arboreal in habit and rarely descended to the ground (Payne et al., 2005). They depended on the canopy layers of the tall trees to survive (Duckworth et al., 1999). One small-toothed palm civet was sighted with two or three cubs on the same tree, suggesting that this animal may raise its young on the tree or in a hollow tree. Both quadrats of the small-toothed palm civets were characterised by a high number of herbaceous plants and vines, which were the typical features of the remnants of tall forest. Their quadrats were also closely related to the presence of the rattan palm (*Calamus* spp.), which are known to hold a considerable amount of starch in their young stem tips and the gelatinous pulp surrounding the seeds are edible (Evans & Sengdala, 2002). Whether the small-toothed palm civet would consume these plants still remains to be seen.

The small-toothed palm civet was never caught or sighted in the Acacia forest, suggesting that they may avoid using the Acacia forest. Several previous studies showed that the small toothed palm civet was only found in the primary forest (Wells et al., 2005; Heydon & Bulloh, 1996), and regenerated or unlogged forest (Syakirah et al., 2000). The sighting of two individuals of this species in the remnants of tall forest in PFZ suggested that the canopy was still in good condition.

5.3.3 Other Small Carnivores

The leopard cat was sighted or camera trapped in the Acacia forest. A total of 66.7% (n = 2) of the quadrats of the leopard cat had similar microhabitat features as the quadrats of Malay civet (Table 4.13). However, these quadrats differed from that of the Malay civet by the area coverage of two fern species: *Blechnum orientale* and *Dicranopteris* sp. The quadrats of the leopard cat was characterised by a higher number of *B. orientale* fern (29.3 clumps on average) whilst the coverage of *Dicranopteris* sp. within the quadrat was much reduced as compared to the Malay civet quadrat (4.2% vs. 19.7%). *B. orientale* fern may have provided some form of cover to the leopard cat when it was foraging. On the other hand, if the area covered by *Dicranopteris* sp. increased, it may prevent the leopard cat from moving easily around the forest.

All the leopard cats (n = 3) were sighted walking alongside the road of Acacia forest at night, suggesting that they used the road for their activities. The extensive network of roads in the Acacia forest may facilitate the movement of the leopard cats, allowing them to travel through the plantations to hunt for food (Acosta-Jamett & Simonetti, 2004). The leopard cat has a carnivorous diet. Small mammals such as rats and squirrels comprised 97.2% of its total diet (Rajaratnam et al., 2007). The well-spaced Acacia forest was an added advantage to the leopard cat when hunting for prey because the visibility in the Acacia forest was high. In contrast, the remnants of tall forests with dense undergrowth may hinder the vision of the leopard cat and provide an escape route for the small mammals.

Many of the terrestrial or semi-arboreal small carnivores such as the Malay civet, the common palm civet, and the leopard cat were frequently sighted along the roads at night. They seem to use the roads as alternative foraging areas and as corridors to move between favourable forest sites, including the planted forests. Foraging using the roads to travel from one patch of forest to another may reduce the energy spent because there is less vegetation on the road. However, these animals also face a higher risk of being preyed on or hunted. These animals continue using roads because there are only two potential predators in the PFZ: the clouded leopard (McShea et al., 2009) and the sun bear (Giman et al., 2007). Nevertheless, human posed a greater threat to these animals. The locals in Sarawak often consume the common palm civet and kept the Malay civet as pet (Giman et al., 2007). Also, because the roads in the planted forest are frequently used by the workers, these terrestrial animals have accounted for higher road kills. In this study, one common palm civet was found as a road kill at the study site.

Several features were important to both the Malay civet and other small carnivores, suggesting that resource partitioning may have segregated these small carnivores into using a different set of microhabitat. These features were the tree stumps, fallen logs, crown closure, and woody plants (Table 4.14). The extent of microhabitat segregation in resource partitioning between these animals needs to be further investigated.

Although multivariate analysis has been widely used to quantitatively describe the habitat of animals (Nakagawa et al., 2006; McDonald, 2002; Lamber and Adler, 2000; Martin, 1998), there are some limitations on the data transcription itself when using this approach. Multivariate analyses such as MANOVA and DFA are used to infer the characteristics of the microhabitat by comparing the presence or absence sites of the species. According to North and Reynolds (1996), such incidental data of the species provides little information on the habitat, as the species is only a subset of the samples and the absence site may not be avoided by the species. Apart from that, microhabitat data seldom meet the two main assumptions of multivariate analysis, which are, normal distribution of independent variables and constant covariance structure across all sites (North & Reynolds, 1996). One of the alternatives to these multivariate analyses for microhabitats would be Polytomous Logistic Regression, where the radiotelemetry data is used to generate use-intensity across sites of the species (Cross & Petersen, 2001). In this technique, the radiotelemetry data is ranked based on the ‘usage’ of the species and hence avoiding the assumption on the non-used sites.

5.4 Estimation of Population Parameters for *Viverra tangalunga*

The survival probability of the Malay civet in Kakus was considerably high (89.0%) over a 10-month trapping session (inclusive of wire-cage trapping and radio tracking). Since no Malay civet was recaptured using wire-cage trapping, the estimation of the survival probability of the Malay civet was mainly based on the radio tracking data, which gave higher precision on the estimation even though the sample size of the Malay civet was small (14 individuals). This allowed the examination of the status (dead or alive) of the animal during each sampling session (White & Burnham, 1999). Models in Table 4.15 indicated that the survival probabilities in four primary trapping sessions were somewhat consistent where the individuals that survived in the second and third intervals were still alive in the last trapping session. The probability that the Malay civets emigrated from or immigrated to the study area were quite consistent from the first trapping session to the last trapping session, probably because of the population of the Malay civet in Kakus was concentrated in the study area. However, this speculation would need extensive sampling to confirm.

Capture probability differed in all four primary sessions at 0.30, 0.95, 0.0, and 0.58, respectively (Table 4.16). However, there was no heterogeneity in the capture probability for different individuals in the same session. Factors that could affect the capture probability of the Malay civet were trap density, duration, definition of the trapping occasion, spatial arrangement of the traps, and trapping details such as the bait used (Trolle & Kery, 2003). In this study, another factor that could affect the capture probability was the method of recapturing the animals. The capture probabilities for the first and third primary sessions were concluded from wire-cage trapping, which was generally lower than radio tracking (second and forth primary sessions). The probability of the Malay civet being captured was relatively low when using wire-cage trapping, because wire-cage trapping was affected by weather during the trapping period as well as seasonality. For radio tracking, however, once the signal of the radio-tagged animal was detected, it was considered present in the study area. Therefore, a combination of different methods was essential to enhance the detection probability of the animals.

The standard error for the capture probability in the first primary session was relatively high (0.46). This was probably due to a small sample size and the low recapture rate of the Malay civet. No Malay civet was recaptured in the first trapping session, rendering a high standard error when estimating the capture probability. However, such a high standard error is by no means the problem of the data but rather, it is largely due to the fact that recapturing of small carnivores is rather difficult in tropical forest, let alone re-sighting the marked animals in the dense forest. This setback could be tackled using the radio tracking method, where the status (dead or alive) of all tagged animals is known at each sampling occasion (Cooch & White, 2009).

5.5 Future Outlook

The result shows that the Malay civet and the common palm civet use similar resources in the PFZ, where there might be niche segregation between these two species. The extent of microhabitat segregation between the Malay civet and the common palm civet would need further investigation and could probably be achieved by modelling, where environmental (e.g., weather) and individual covariates (e.g., body condition) could be incorporated (Cooch & White, 2009). In order to have decent population parameters estimations by the software MARK, the interval to re-sample the animals should be kept short and a larger sample size with extensive samplings would minimise the standard error. To enhance the sample size, more traps could be deployed. The different sampling protocols that outlined in this study have successfully enhanced the sample size of the animals, and could probably be used for future studies to increase the yield. In addition to conventional trapping methods, radio tracking of the Malay civets would serve as a continuous effort to discover their movement pattern and home range size in the PFZ.

Results from this study also suggested that the current forest management in PFZ, i.e., dividing forests into blocks and retaining buffer zones, is useful and effective, at least for civets. Generalist species such as the Malay civet was frequently sighted or captured at the interface of the Acacia forest and the remnants of tall forests and hence the incorporation of these remnants would help to maintain the population of civets in the PFZ at least over a short-term period. Although this study revealed that the civets were selecting particular microhabitat features instead of forest types, a broad-scale change in the forest cover type would inevitably affect the animals. Hence, only a long-term monitoring programme of the small carnivores' population in the PFZ could ensure that the planted forest is sustainable in maintaining its ecological functions (McShea et al., 2009).

CHAPTER 6

CONCLUSIONS

The PFZ supported several types of small carnivores, mainly the civets which comprised 94.0% (n = 47) of the total captures. The Malay civet was the most abundant animal among the captures (n = 27), suggesting that they could survive and persist in PFZ. The Malay civet seemed to adapt well in the PFZ, with approximately 89.0% of the captured individuals surviving through the last trapping session. Different methods of recapturing also affected the capture probability of the Malay civet. The capture probability was substantially higher with radio tracking as compared to wire-cage trapping (0.77 vs. 0.15 on average). Sufficient consideration is thus needed when designing the study to ensure that the data is consistent and can be efficiently used to model the population parameters.

In PFZ, the Malay civet did not show preference on the forest type. Instead, they selected particular features, such as medium crown closure, high frequency of undergrowth and low frequency of tree stumps within the quadrats. A point of equilibrium was attained between ‘openness’ and ‘shadiness’ within the quadrat of the Malay civet and the Malay civet seemed to prefer a relatively open quadrat with a medium crown closure.

The common palm civet and the Malay civet apparently showed a certain degree of overlap in microhabitat used although the number of captures was relatively low. These species may share similar microhabitat features, but their utilisation of resources may be different. The coexistence of these species may be the result of resource partitioning and microhabitat spatial selection, which drive the composition of civets in the PFZ. However, further verification is needed to confirm this observation

The undergrowth seemed to provide covers to the animals from predators whilst patches of forested area may act as a corridor for the animals to move between the remnants of tall forest and planted forest. Several small carnivore species such as the Malay civet, the common palm civet and the leopard cat were frequently sighted using the roads in the PFZ. The small-toothed palm civet and masked palm civet were found to use the remnants of tall forest and secondary forest within the planted forest, indicating that the remnants of tall forest and secondary forest embedded in the Acacia forest indeed support some of the forest-dwelling species, and that these remnants would also be important for the survival of large mammals in the planted forest. Hence the importance of the remnants of tall forest within the planted forest should be emphasised when devising conservation plan for the PFZ. Current conservation strategy and management indicated some success in retaining small carnivores in the PFZ. However, long-term monitoring of the population is the only effective way to investigate the status of small carnivores in this altered habitat. With the extensive network of roads within

PFZ, radio tracking and camera trapping are the suitable methods to monitor the population dynamic of small carnivores in the PFZ.

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Appendix

Photographic Plates

Plate 1a – Animal handling: the animal was trapped and secured in the wire-cage.

Plate 1b – Animal handling: the trapped animal was weighed.

Plate 1c – Animal handling: it was transferred into a net.

Plate 1d – Animal handling: it was then tagged after its morphometric measurements were recorded.

Plate 2a – Wire-cage trapping: wire-cage trapped Malay civet.

Plate 2b – Wire-cage trapping: the common palm civet was released on the point of captured.


Plate 3a – Spotlight night survey: the small-toothed palm civet was spotted on a tree.


Plate 3b – Spotlight night survey: the Malay civet was foraging along the road in the PFZ.

Plate 4a – Camera trapping: the tag number of the recaptured Malay civet could not be seen.

Plate 4a – Camera trapping: radio-tagged Malay civet was recaptured by camera trap.


Plate 5a – Microhabitat variables; crown closure.


Plate 5b – Microhabitat variables: understory *Melastoma* sp.


Plate 5c – Microhabitat variables: *Dicranopteris* sp.

Plate 5d – Microhabitat variables: a clump of *Blechnum orientale*