Ecology of the Malay Civet (*Viverra tangalunga*) in a Logged and an Unlogged Forest in Sabah, East Malaysia

by

Christina Paulette Colón

B.A. Drew University, 1988
M.A. New York University, 1990

Dissertation submitted in partial fulfillment of the requirements for
the degree of Doctor of Philosophy
at Fordham University

New York

May, 1999
Royal Society of London Publication A/255

FORDHAM UNIVERSITY

GRADUATE SCHOOL OF ARTS AND SCIENCES

April 9 19 99

This dissertation prepared under my direction by

Christina P. Colon

entitled Ecology of the Malay Civet (Viverra Tangalunga) in a Logged and an Unlogged Forest in Sabah, East Malaysia

has been accepted in partial fulfillment of the requirements for the

Degree of Doctor of Philosophy

in the Department of Biological Sciences

(Mentor)

(Reader)

Craig L. Frank

(Reader)

This dissertation and all the work it represents is dedicated with respect and gratitude to
Elvis (MP1).
This project could never have been completed had it not been for you. You represent the
reason I embarked upon this journey, and you gave me the strength to see this project
through to the end. You were my finest subject and my greatest teacher. You continue to
be a source of tremendous inspiration.
May you and your kind live forever.

TABLE OF CONTENTS

1. GENERAL INTRODUCTION

2. RANGING BEHAVIOR

3. ACTIVITY AND MOVEMENT

4. DIET AND PARASITES

ABSTRACT

VITA

ACKNOWLEDGEMENTS

I would like to extend my gratitude to the many people and agencies who made this project possible. To start, I'd like to thank my committee chairman, Dr. David Burney, who has offered logistical, academic and moral support, often from such far reaching locations as Hawaii and Madagascar. My mentor, Dr. Alan Rabinowitz is owed a debt of gratitude for his patience, support and unyielding faith in me. Over the years, he has been a continual source of guidance and encouragement. Dr. Berish Rubin, Chairman of the Biology Department, has provided the administrative support necessary to keep me moving forward at all times during the course (and courses) of my degree. I thank Dr. George Dale and Dr. Craig Frank, for their time and input as committee members. Thanks to Dr. John Wehr, for teaching me biostatistics, and reminding me how to apply them properly.

This project would not have been possible without the generous support of the J. W. Fulbright Foundation, administered through the Institute of International Education in New York, and The Malaysian-American Commission on Educational Exchange in Malaysia. In particular, Ms. Kalak Kovan, Grant Administrator, provided assistance and friendship during and after my stay in her country. I am indebted to Dr. Craig Brush, of Fordham University's Office of Graduate Prestigious Fellowships, who encouraged me to submit the Fulbright application and assisted me throughout the process. I acknowledge the generosity of Sigma Xi, the Scientific Research Society, for their continual funding during both years of field work.

I am grateful to The Wildlife Conservation Society, for a Research Fellowship, which allowed me to complete my field work. I am indebted to the Royal Society of

London's Southeast Asian Rainforest Research Programme, for support while in the field and for granting me the honor of being the first American to become a Research Associate of the RS SEARP Programme. Chairman, Dr. Tim Clutton-Brock, Coordinator, Dr. Steven Sutton and Senior Scientist, Dr. Andrew Davis, are all duly thanked for their kind assistance and interest in my research. Dr. Sharon Patton in the Department of Parasitology at the University of Tennessee, Knoxville, provided assistance by identifying internal parasites. Mr. Matthew Shaw at the Department of Parasitology, University of Queensland, is thanked for his identification of external tick parasites. Mr. John Sugau from the Forest Research Centre in Sandakan, East Malaysia assisted through identification of seeds from civet scats. Dr. Annelisa Kilbourn provided valuable assistance with necropsies.

Gratitude is extended to the Economic Planning Unit of Malaysia for issuing and renewing my research permits. I would also like to thank the Management Committee of the Danum Valley Field Center, Yayasan Sabah and Rakyat Brejaya for permission to conduct my study at the Danum Valley Field Center. The director and staff of the Sabah Wildlife Department were instrumental in facilitating my success. Rajan Rajanathan and his wife Lynette provided valuable field training, friendship and top notch civet traps.

I am thankful to all the people at Danum Valley, who made my experience enjoyable and memorable. A million thanks to my field assistants, Jamal bin Abd. Majid, Karim Kasil and especially Ismail bin Abd. Samat, without whose help I never could have succeeded. Thanks to Dr. Keith Martin-Smith, Dr. Jim Gibbons, Dr. Don Kennedy, Glen Reynolds, Hubert Petol, Sylvia Yorath, Elaine Campbell and Dr. Zimbo, for their friendship and their beer. (Thanks guys; the stuff I remember, I'll never forget.) I would

also like to thank those of my friends who, for reasons that still escape me, braved land leeches, fire ants and beef rendang to visit me in my jungle retreat. In particular, thanks to Terry Smithson, who started as a volunteer and left as a friend, Rob Wisdom, who started as a friend, and left (remarkably) as a friend, and Heidi Spangler, who left....

A world of thanks is due to my mother, Norma Colon-Oland, for her early interest in my education; she taught me to test every boundary, never accept limits, and never admit defeat. Likewise I am grateful to my grandmother, Mary Oland, who taught me self respect, independence and tenacity. I thank my brother Will, for teaching me to shoot, ride, spit and face all my fears, head on. I thank my dad, Willy, stepmother, Maria, half-sister, Felisa and half-brother, Rick, for their patience and understanding. Finally, I thank Tom O'Leary, who encouraged me, supported me, challenged me, and loved me.

LIST OF TABLES

1.

2.

3.

4.

LIST OF FIGURES

1.

2.

3.

1.

GENERAL INTRODUCTION

Detailed basic research on rain forest mammals of Southeast Asia is lacking. The need for more data from this area is evidenced by the many recent discoveries or rediscoveries of mammals from this region [eg. *Presbytis* spp., (Constable, 1989); *Pseudoryx nghetinhensis* (Schaller and Rabinowitz, 1995; Dung, *et al.*, 1993); *Pseudonovibos spiralis*, (Peter and Feiler, 1994; cited in Dioli, 1997); *Megamuntiacus vuquangensis,* (Tuoc, *et al.,* 1994; cited in Schaller and Vrba, 1996); *Tarsius dianae* (Niemitz *et al.*, 1994); *Muntiacus crinifrons* (Rabinowitz *et al.,* 1998); *Muntiacus putaoensis* (Rabinowitz, *et al.* in press)].

High diversity, low density and cryptic behavior all contribute to the paucity of data from this group. As a result, advancements in scientific knowledge are often overshadowed by human disturbance, resulting in a net loss of potential data, as ecosystems are permanently altered and sometimes destroyed by development activities. Thus, without an increase in basic ecological research on Southeast Asia's fauna, it is possible that many species will remain undiscovered or largely unknown even after their local or global extinction (Schreiber, 1989).

Among mammals, carnivores are often more severely impacted by disturbance than other species (Johnsingh, 1986), yet little data on their survival in disturbed forests exist, despite their importance as keystone species, their role in regulation of prey populations (Smuts, 1978) and their influence on prey behavior (Rice, 1986). Rabinowitz and Walker (1991) conclude that a better understanding of the function of carnivore communities in tropical forests is essential for effective management and conservation of these areas. Among carnivores, a noticeable gap in the literature exists for most species of civet, particularly Asian species (Schreiber *et al.*, 1990). Despite the fact that civets are thought to play important ecological roles in Old World rain forests, they remain largely unstudied.

The objectives of this project are therefore twofold; one is to study the ecology of the Malay civet (*Viverra tangalunga*) a little known member of Southeast Asia's viverrid assemblage, the other is to determine whether selective logging has an impact on this species.

The Malay civet is common throughout its range and inhabits disturbed as well as pristine habitat. Preliminary studies indicate that in selectively logged forests *V. tangalunga* undergoes a dramatic population decline in excess of those observed among other civets (Heydon and Bulloh, 1996). If this is the case, *V. tangalunga* may be an appropriate indicator species for the civet community as a whole. However, because *V. tangalunga* is considered an opportunist and dietary generalist (Macdonald and Wise, 1979), it is also possible that this species may adapt well to conditions in selectively logged forests and undergo a population increase. If this were to occur, it could out-compete less adaptable species and pose a threat to the community.

In addition, civets are thought to play an important role in forest regeneration through seed dispersal (Rabinowitz, 1991a), and may also help control rodent populations (R. Rajanathan, pers. comm.). It is clear that long-term data on this species' basic ecology and response to logging will lead to a greater understanding of small carnivore ecology and the process of rain forest recovery.

SELECTIVE LOGGING IN SOUTHEAST ASIA

Rain forests in Southeast Asia are subject to intense human pressure. Rapid development, increasing demand for timber and recent economic turmoil in Asia make these already fragmented forests increasingly vulnerable to further alteration.

Selective logging is one of the primary means of timber extraction in Southeast Asia (Whitmore, 1984). Although less destructive than clear cutting, it can dramatically alter forest structure and species assemblages so the remaining forest bears little resemblance to its undisturbed counterpart. These changes have different effects on members of the wildlife community, ranging from population explosions to local extinctions. An understanding of how different species are affected by selective logging is essential for sound management and conservation.

Malaysia is the world's second largest exporter of tropical timber (Malaysian Timber Council, 1998), and in the East Malaysian states of Sabah and Sarawak, selective logging is the primary economic activity (Collins *et al.*, 1991). The total value of Sabah's timber exports in 1984 equaled $650 million (Scott, 1986).

According to the Sabah Forestry Department, in 1986 Sabah possessed between 2.8 and 3.4 million hectares of commercially viable forests (Butler, 1987). Extraction rates at this time exceeded 10 million cubic meters per annum (Zainoor, 1986). Yet, a sustainable rate of extraction should not exceed three million cubic meters per year (Scott, 1986). Thus, although Malaysia has one of the best records of forest management and silvicultural treatments in Asia (Scott, 1986), it does not yet practice sustainable selective logging.

The term 'selective logging' is misleading; although only a small fraction of the trees are commercially valuable, extensive alteration of the forest can result from extraction of these few trees. Many trees in the immediate vicinity of the timber tree are removed, pulled down or damaged during extraction. Studies in Malaysia have shown that when only 3.3% of the timber was harvested, over 50% of the trees were removed (Johns, 1983). When the extraction rate rises to 10%, only 35% of the remaining stand may be left undamaged (Burgess, 1971).

Immediately after logging, there is an increase in the survival and density of pioneer species, resulting in a very different floristic composition from that in an unlogged forest. There is also a flush of growth at the ground level that, combined with the mass of fallen trees, vines and debris from logging, adds to the increased incidence of fire, particularly during the dry season (Uhl, 1989; Collins *et al.*, 1991).

The practice of re-cutting can be even more damaging than the first cut. This interrupts the regeneration process and eliminates the remaining commercially valuable trees, leaving a severely depleted forest which lacks many old growth, shade-tolerant species characteristic of mature forests (Whitmore, 1984; Uhl, 1989).

Disturbance of an intermediate magnitude promotes high productivity (Thiollay, 1992) by increasing growth rates in gaps. These gaps result in the growth of both shade tolerant and shade intolerant seedlings as well as lateral growth of existing plants (Whitmore, 1989). According to Baskin (1994), ecosystems with such high diversity and productivity will in turn have more complex food webs and will tend to be more resilient to environmental changes.

However, commercial logging does not result in intermediate disturbance, but creates larger and more frequent gaps than most natural forces, which decreases diversity and lead to greater vulnerability to further disturbance (Skorupa and Kasenene, 1984). In the Kibale Forest Reserve in Uganda, selective logging created gaps ranging from 467 m^2 to 1307 m^2 which were much larger than natural treefall gaps, which averaged 256 m^2. Seedling regeneration was poor when gaps averaged more than 650 m^2 and even after 20 years, the density of saplings in logged areas was only 45% of that in unlogged forests (Kasenene, 1987).

Efforts to manage tropical forests based on the concept of gap dynamics have been made, but given the complex array of ecological, economic and political factors, few silvicultural management plans have succeeded (Mergen and Vincent, 1987). Low impact logging, which could mimic the rate of natural tree-fall patterns, would not likely produce enough timber to be economically viable (Mergen and Vincent, 1987). In order to work towards a commercially and environmentally sustainable means of forest utilization, more basic research on the interdependence of rain forest plants and animals is needed.

As the rate of human impact on tropical rain forests increases, researchers are beginning to recognize the need to look to disturbed areas as future refuges for wildlife (Johns, 1985; Skorupa, 1990). Although they may not support the same density and diversity of flora and fauna as undisturbed areas (Johns, 1983; Thiollay, 1992), their importance will continue to increase as unlogged forest areas decline (Johns, 1985). Accurate estimates of wildlife densities and carrying capacities in unlogged rain forests are necessary to replicate these conditions in disturbed areas (White, 1994).

Once the remaining timber supply in East Malaysia is exhausted, there will be strong economic and political pressures to log the remaining protected areas (Blockhus *et al.*, 1991). Therefore it is increasingly urgent to address two critical questions: What impact does selective logging have on the structure and function of rain forest ecosystems, and can they sustain the same density and diversity of biota as an area of undisturbed rain forest?

IMPACT OF SELECTIVE LOGGING ON WILDLIFE

The few studies which have examined the impact of logging on wildlife focus on a limited number of species, and come to tentative and often contradictory conclusions. Johns (1983) observed that immediately after a rain forest in peninsular Malaysia had been selectively logged, fruit resources became more clumped, due to habitat fragmentation. Most resources become concentrated in patches such as valley bottoms, where timber extraction is not possible. Shortly after, there is a noticeable increase in new growth from surviving trees, but although some new leaves, fruit and flowers are observed, it is not clear whether this compensates for the overall loss of vegetation.

In Sabah, most commercially valuable tree species are members of the family Dipterocarpaceae. Although not important fruit trees for rain forest animals, they often comprise up to 60% of the basal area of the forest (Waterman *et al.*, 1988), contributing to a large part of the canopy layer, and are thus of extreme structural importance. They provide a site of attachment for epiphytes, mosses and vines, which provide refuge for numerous reptiles, amphibians and invertebrates, many of which survive only in the highly controlled and stable microclimate of the understory (Wee Lek, 1977). Many of these are important food resources and their loss can lead to severe shortages for species dependent upon them.

Canopy trees also serve as hosts for strangler figs, which are a crucial food resource for many vertebrates including hornbills, primates and civets. Although not harvested, they are often lost from incidental damage due to their affinity for commercially valuable trees (Lambert, 1991). Leighton and Leighton (1983) reported that a decline in abundance of figs was the primary factor in the sharp decline of hornbills in logged forests. This food resource is not likely to regenerate to post-logging levels until the high canopy trees are re-established, which could take more than 70 years (Liew, 1978).

Chivers (1974) and Wilson and Wilson (1975) suggest that new growth of leaves after logging increases food availability for many species of folivorous primate, and thus logging has no negative impact on their populations. Some species of Asian primates, such as lars gibbons (*Hylobates lar*) and banded langurs (*Presbytis melalophos*) are able to increase leaf intake in the short term, to compensate for the decline in alternate diet items such as fruit. However, this requires a significant decrease in activity levels due to the reduced nutrient content and lower digestibility of leaves (Johns, 1986).

Others have found that logging leads to an increase in fruit availability. Fimbel (1994) found that frugivores on Tiwai Island of Sierra Leone, West Africa are attracted to disturbed forests due to an abundance of fruit produced by pioneer species. Wilson and Johns (1982) also report that fruit is more abundant in secondary than unlogged forests in East Kalimantan, Indonesia and both deer and pigs are attracted by this food resource. Thiollay (1992) concluded that among bird species in a Guianan rain forest, understory nectarivores and frugivores are more tolerant of selective logging than insectivores, but terrestrial frugivores are more adversely affected than arboreal ones. He suggests that this due to microhabitat factors, since understory growth becomes very dense and there is a high degree of litter after logging which can make locating fruit on the forest floor more difficult. Conversely, Lambert (1991) reported a large increase in the proportion of terrestrial frugivores after logging in the avian community of the Ulu Segama Forest Reserve, in Sabah, East Malaysia. However this may have been associated with a mast fruiting of *Macaranga* trees the following year, which led to an unusually high increase in fruit availability.

Although there may be a short term increase in leaves, fruit and flowers after logging, these may not comprise appropriate food resources. Wong (1986) found that in Malaysia, undisturbed forests had three times more plants with flowers visited by birds, and five times more plants with fruit dispersed by birds than forests logged approximately 25 years ago. Struhsaker (1973) observed that in Kenya, a reduction in plant food availability after disturbance led to a significant decrease in primate densities.

Insects appear to decline after logging. Lambert (1991) found that insectivores became the rarest guild in logged forests and Heydon (1994) also noted a 50% decline in the population density of the insectivorous western tarsiers (*Tarsius bancanus*) in the Ulu Segama Forest Reserve, East Malaysia, after logging. These findings are supported by Wong's (1985) conclusion that insects in a Malaysian rain forest were less abundant in forests logged 23 to 25 years previously, than in adjacent areas of unlogged forest. However, some researchers have noted a higher trap success of certain insect species after logging, (e.g. Korthals, 1990) which could be due to differences in activity levels rather than actual differences in population densities (DeVries, 1989).

Some small mammals appear to thrive in selectively logged forests. Isabirye-Basuta and Kasenene (1987) conducted small mammal trapping in selectively logged and virgin forests in Kibale Forest, Uganda. They found that rodent density, species richness and diversity were higher in the logged forest, even 20 years after logging. Delaney (1971) also reported an increase in sympatric rodent species after human-induced habitat modifications were carried out in Mayanja Forest, Uganda. Harrison (1969) reported that although the numbers of small mammals increases in secondary forests in a lowland of Malaysia, the species present are physically smaller. Thus, not only does the species composition change after logging, but the animal biomass and productivity may also differ. Walker and Rabinowitz (1992) report that rodent populations in Huai Kha Khaeng Wildlife Sanctuary, Thailand were higher in areas of mosaic forest which can resemble a logged forest (Howlett, in prep.). L. Rajaratnan (pers. comm.)found that an oil palm plantation in Sabah had a significantly higher population density of rodents than the surrounding forest.

Because rodents pose health threats to humans, natural control mechanisms must remain intact subsequent to forest disturbance. Because the Malay civet often feeds on small mammals (Payne, *et al.* 1985) it may play an important role in this process.

Organisms that are highly sensitive to change, or have very specific needs, are more vulnerable to disturbance. Species that are more flexible in their requirements are usually less adversely affected by environmental change. Because *V. tangalunga* is an opportunistic feeder and survives well in areas altered by human activities, it should survive after logging. The reported increase in fruit and rodents indicates that the food base for this species may increase after logging. However, this may be tempered by the apparent decline in invertebrate abundance (Burghouts, *et al.*, 1992), which comprise a significant portion of their diet (Macdonald and Wise, 1979).

IMPACT OF SELECTIVE LOGGING ON CIVETS

Studies that quantify the impact of selective logging on small carnivores are limited. In 1993, Heydon and Bulloh collected data on civet densities in logged and unlogged forests in the Ulu Segama Forest Reserve, Sabah, East Malaysia, while walking nocturnal transects. They noted all sightings of civets and recorded the species and distance from the transect. A total of 32 civets were sighted in the unlogged forest and only 12 in the logged forest. *V. tangalunga* was the most abundant species observed, and also showed the greatest apparent population decline in the logged forest (Heydon and Bulloh, 1996).

These findings are however based on a small sample size and resulted from methodology not appropriate for sampling small carnivores (A. Rabinowitz, pers. comm.). In addition, because forest structure is altered by logging, visibility can differ dramatically in a logged forest. In unlogged forests, the ground layer remains fairly open, while after logging dense undergrowth and debris from tree felling could contribute to the lower sighting frequency of terrestrial civets. Although Heydon and Bulloh (1996) report no difference in sighting distance, Skorupa (1987) reported that line transect density estimates of mammals in logged forests are biased due to decreased visibility, which leads to systematic underestimates of their true densities.

Although Heydon and Bulloh (1996) conclude that the more carnivorous civets are more adversely affected by logging than the more frugivorous palm civets, no actual data on dietary intake or resource availability of food items after logging was reported to support this conclusion. In addition, *V. tangalunga* is common in both forests and cultivated areas near human settlement (Payne *et al.*, 1985) so it should have a high rate of survival after disturbance. It could also be predicted that this more terrestrial civet species would be less adversely affected by removal of canopy trees than the more arboreal members of this group.

If *V. tangalunga* is unable to survive in logged forests, the likelihood that other more sensitive carnivore species will also survive is questionable. Although some civets thrive in disturbed areas (L. Bennett, pers. comm.), further research into their response to disturbance is warranted. *V. tangalunga* is one of the most visible members of the carnivore community in Malaysia, which makes it an appropriate study species to begin a broader understanding of the composition, structure and ecology of the entire small carnivore community.

PREVIOUS EFFORTS TO RADIO-TRACK CIVETS

Heydon radio-collared a single *V. tangalunga*, in Danum Valley, East Malaysia, but was unable to relocate the animal subsequent to release (pers. comm.). Macdonald and Wise (1979) radio-collared two *V. tangalunga* in Gunung Mulu National Park in Sarawak, East Malaysia, however only the male was successfully followed for two months.

The first comprehensive study of civets took place in 1978 when Charles-Dominique radio-tracked several African palm civets (*Nandinia binotata*) in Gabon. In 1985, a female common palm civet (*Paradoxurus hermaphroditus*) was radio-collared in Royal Chitwan National Park, India and followed for less than a month (Dhungel and Edge, 1985). In 1987, Rabinowitz radio-tracked one individual each of five species of civet in Huai Kha Khaeng Wildlife Sanctuary in west central Thailand. These individuals were radio-tracked for up to one year, during which time basic ecological data on civet behavior was obtained. Due to insufficient sample size, only general conclusions could be made, with no specific data on individual species (Rabinowitz, 1991a). In 1990, two female and three male *P. hermaphroditus* were radio-collared and followed in Royal Chitwan National Park, Nepal (Joshi *et al.*, 1995).

Rajaratnan completed a study of small carnivores in Tabin Wildlife Reserve, Sabah. His focus was on the leopard cat (*Felis bengalensis*), but several Malay and common palm civets were also followed. The study area consisted of logged forest and an adjacent oil palm plantation and will provide a valuable comparison to data from this study.

OVERVIEW OF THIS STUDY

To determine whether logging has an impact on *V. tangalunga*, two populations were radio-tracked: one in an unlogged forest, the other in an area selectively logged eight years prior to this study. Because direct observations were not possible, data was obtained through radio-tracking and scat collection. A sample of six individuals were radio-tracked in each area. An equal sex ratio would have been desirable however, logistical constraints did not allow for this level of refinement.

Ranging patterns, including home range size and overlap, are discussed in Section two. Differences in home range size, overlap and seasonal changes were quantified and compared between sites and sexes. A discussion of trap success, morphometry and life history is included here.

Section three focuses on activity levels and behavior patterns, as a means to detail daily movements and energy budgets. Attraction and avoidance behavior are also examined, in order to explore social interactions. Because all of these may differ between genders, or between forest types, comparisons are made. Data are also included on day bed sites. Efforts to identify key habitat features that animals actively select were made in order to identify important or limited resources.

Diet is examined in Section four. Stomach contents examination and scat analysis were used to quantify diet intake. The effects of parasites on the host is often a function of diet, nutrition and stress and can affect survival, reproduction and movement patterns (Scott, 1988). Parasites can also provide insight on the health of a population (Patton and Rabinowitz, 1994; Dobson and Hudson, 1986). To assess parasites, internal and external parasites are included in Section four. Conclusions and conservation implications are contained in Section five.

This research explores the fundamental ecology of the Malay civet, a little known member of a rarely studied group of carnivores. An understanding of its population density home range, activity, parasites and diet are necessary to understand its basic ecology, and crucial for appropriate management. In addition, data on these parameters are necessary to quantify the effects of selective logging.

STUDY SITE

The Danum Valley Field Center (4°58'N, 117°48'E) is located in the East Malaysian state of Sabah, on the northern coast of Borneo. Elevation in this area ranges from 245 to 610 m above sea level. It is situated on the edge of the Danum Valley Conservation Area (DVCA), a 438 km^2 protected area within the Ulu Segama Commercial Forest Reserve (See Figure 1-1). Designated as a Class One Forest Reserve in 1995 (Marsh, 1995), DVCA harbors the largest remaining stand of unlogged lowland rainforest in the state (Collins *et al.*, 1991). On the other side of the Field Center is a logging concession, comprising nearly a million hectares of forest where selective logging has been carried out for the past 22 years (Marshall, 1992).

The Field Center and Conservation Area are the result of a joint effort on the part of the logging community, represented by Innoprise, Yayasan Sabah and the Sabah Forestry Department, and the conservation and research community, represented by the Royal Society of London's Southeast Asian Rainforest Research Programme, the Sabah Wildlife Department and the Sabah Society.

The area is suitable for the examination of ecological changes that occur when a rainforest is subjected to selective timber extraction, and is considered one of the premier locations for tropical rainforest research in Southeast Asia (Marsh and Greer, 1992). This is not only due to its optimal location, but the long-standing accumulation of data from a wealth of research carried out since its inception in 1986. These supplemental data provide valuable background information on the forest characteristics, plant community, climate, soil, hydrology and many other aspects of the surrounding area.

The wildlife community of Danum Valley is both rich and varied, yet few studies of the fauna have been conducted. Appendix I contains a preliminary list of non-volant, terrestrial mammals recorded in the Danum Valley Conservation Area. The representation of carnivores in Danum is particularly diverse, with records from 21 species from four families. Of these, 10 are members of the family Viverridae, eight of which are civets. The relative abundance of civets in Danum Valley makes it an ideal location to study one of the more common members of this group. *V. tangalunga* lends itself well to intensive study, due to its predominately terrestrial activity, relatively high frequency of sighting and ease of capture.

The Segama River, which is approximately 20 to 30 m wide, physically separates the field center from the unlogged forest. Human settlement in the area is limited to the field station and a temporary logging site nearby. There has been no evidence of shifting cultivation in this area in recent times (Wright, 1975), although the discovery of ancient coffins indicates that the area may have been inhabited or at least visited by humans several hundred years ago (Marsh and Greer, 1992). Most wildlife in this area [except the Sumatran rhinoceros (*Dicerorhinus sumatrensis*)] has experienced very little recent pressure from hunting, making the area somewhat anomalous in the virtual lack of current human impact (Marsh and Greer, 1992).

The geology of the Conservation Area and surrounding concession is a complex mosaic, but the immediate area of concern is the Kuamut Formation, comprised mainly of slump breccia, sandstone, mudstone, chert, tuff and tuffite. The soil association is Bang, derived from sandstone, shale and assorted rocks (Marsh and Greer, 1992). An ecologically important component of this soil type is the presence of mineral sodium sources, such as mud volcanoes, that are thought to have a significant influence on the distribution of large mammals (Payne, 1992).

Climate

The climate is typical of a wet equatorial region in terms of showing little variability in either temperature or relative humidity. The area lies within the relatively aseasonal core of Southeast Asia, where there is no regular wet and dry season and any patterns observed are unpredictable and often weak (Corlett and LaFrankie, 1998). The mean annual temperature is 26.7 °C, (range = 22.5 to 30.9 °C). Temperature data from September, 1985, to May, 1990, show little variability, with an average annual temperature of 30.9 °C. For this period, average monthly temperature ranged only from 29.0 to 32.5 °C. Relative humidity showed an annual mean of 94.5% at 08:00, and 72% at 14:00 (Walsh, 1990).

The area receives a mean of 2,822 mm of rainfall each year and is influenced by the edge effect of two monsoons: from November to March from the northeast, and from May through August from the southwest. The timing of the onset of both monsoon seasons is highly variable in this area (Marsh, 1995). Weather patterns during this study did not exhibit clear seasonal patterns. The study site also experiences no regular seasonal burning although seasonal flooding of low-lying areas did occur. Mean monthly rainfall data for the logged forest and unlogged forest study sites for 1996 and 1997 indicate some seasonal trends, but also illustrate their wide variability (see Figure 1-2 and Table 1-1). Mean annual rainfall in the unlogged forest for 1996 was 2988.7 mm compared to 2350.2 mm in the selectively logged forest. Similarly, the mean total rainfall from January to May, 1997, in the unlogged forest was 737.3 mm, while the mean rainfall in the logged forest during this time was only 551.4 mm. Out of 17 months for which data were available, there were 13 months where mean values were higher in the unlogged forest, and in 10 out of 17 months there were more rain days in the unlogged site. These differences were probably due to natural spatial variability (N. Chappell, pers. comm.).

Primary Forest Site

Whitmore (1984) defines the forests in DVCA and the surrounding area as lowland evergreen dipterocarp forest, which is also the most extensive forest type in Borneo. Prior to logging, the two research sites selected for this study were considered part of the same contiguous forest type, barring the inherent variability of rainforest micro-sites. Both sites are situated on uneven terrain at moderate elevations and show little difference in slope and topography when compared to the surrounding areas (See Figure 1-3.). The unlogged (and currently undisturbed) site and the logged site (Coupe 1988- selectively logged in 1988 and 1989) are separated by a minimum linear distance of two km and the physical barrier of the Ulu Segama River.

The unlogged forest is dominated by trees belonging to the family Dipterocarpaceae in the upper and emergent canopy (Newbery *et al.* 1992) which make up 88% of the total volume of large trees (Marsh, 1995). The forest is unique in its virtual lack of large palm species. The tree assemblage consists of 59 families of trees in 164 genera and a total higher plant diversity of 1,295 species in 562 genera and 139 families (Newbery *et al.*, 1992). Among the better represented tree species present along riparian strips are *Parashorea malaanonan* and members of the genera *Saraca*, *Eugenia*, *Pterospermum*, *Leea* and *Dillenia.* In drier regions and on ridges, there is a predominance of red seraya (*Rubroshorea* spp.) and keruing (*Dipterocarpus* spp.).

Newbery *et al.* (1992) identified and enumerated all trees (≥10 cm gbh) in two, four-hectare plots in the unlogged forest site. Data from these plots reveal that 82% of species are rare, of which >1% were represented by one individual. The Dipterocarpaceae were the most abundant family and contributed 43.7% of total basal area for trees greater than 10 cm gbh. Euphorbiaceae contributed 10.2% to basal area, followed by Lauraceae, which contributed 5.8%. Euphorbiaceae contributed the highest percentage (21%) to overall density, for trees ≥30 cm gbh. They were followed by Dipterocarpaceae, which contributed 16%.

Crown size is considered large, averaging 18 m in diameter, which may indicate the forest is in a late stage of recovery from past disturbance (Newbery *et al.* 1992). However, pioneer species make a very low contribution to density, which indicates a lack of recent disturbance in the area. Kennedy and Swaine (1992) found that pioneer species have a low seed bank in undisturbed sites. This may be due to the unusually low density of near-ground canopy gaps in the Danum forest, which was estimated to be between 0.3 and 0.5% of the total canopy cover. The observed rate of recruitment of pioneers under both artificially created gaps and intact canopy was only 5%, and appeared to be relatively unaffected by the presence or size of gaps.

Logged Forest Site

Coupe 1988 represents an intermediate stage of recovery from selective logging. The forest in this area was extremely abundant in commercially valuable timber and yielded an average extraction level of 12-15 trees per hectare (Sabah Forestry Department, 1989; cited in Howlett, in prep.). Timber extraction was carried out according to regional practices. After the completion of major access roads into the area, it was divided into 50 ha blocks, which were cut successively. Commercially valuable trees greater than 60 cm dbh were cut with chainsaws and dragged with a bulldozer to central yarding points, where they were loaded onto trucks and taken to the mill. This method of logging results in a seemingly random mosaic of skid trails interspersed with patches of undisturbed forest. According to Johns (1992), this method results in mortality of up to 70% of the original stand.

Howlett (in prep.) conducted a study of the distribution of pioneer trees and degree of recovery in the Coupe 88 site seven years after it was logged. His data indicate that disturbance in the logged forest was patchy, creating a mosaic of disturbed and undisturbed areas. Within these sites, there was a dramatic difference in the relative number of pioneer species present, with undisturbed patches containing more than 2,000 dipterocarp seedlings ha^{-1} and fewer than five pioneer trees per hectare. On highly disturbed sites such as skid tracks, there were fewer than 50 dipterocarp seedlings ha^{-1} and more than 1,000 pioneer seedlings ha^{-1}. It was estimated that 10% of the area in the logged forest was converted to roads, while 12% of all random sample locations fell into areas of severe disturbance. Only about 25% of random sample points fell into areas that showed no signs of disturbance.

Howlett's data (in prep.) indicate that 62% of the canopy was comprised of residual trees, while pioneer trees made up 28%, vines added another 6% and the remaining 4% was open canopy. Dominant pioneer species present included members of the genus *Macaranga* (Euphorbiaceae), *Ficus* (Moraceae) and *Bruinsmia styraoides* (Styracaceae). *Neolamarckia cadamba* was commonly found in severely disturbed sites such as on skid trails and road edges. *Macaranga hypoleuca* was abundant in the disturbed sites as well as along streams and in gaps in undisturbed sites. It was also the most abundant pioneer tree species (≥ 2.5 cm dbh) recorded. *Macaranga gigantea* was the second most abundant pioneer, and the two together comprised more than 60% of all pioneer trees counted. These two species had mean diameters of 13.5 cm and 13.9 cm respectively. Mean dbh of pioneer trees ranged from 25.3 cm for *M. pearsonii,* to 5.4 cm for *Ficus* spp. and *Xylophia* spp. combined.

Howlett (in prep.) concludes that canopy openness was strongly correlated with degree of disturbance. There was also a positive correlation between the presence of vines in the canopy and the number of pioneer trees present. Vines were present in the canopy in 30% of all sample sites, even though they dominated only 6% of the canopy as a whole.

A study of the effect of selective logging on a dipterocarp forest in West Kalimantan revealed that eight years after being logged, there was only limited evidence of canopy recovery (Cannon, *et al.*, 1994). They also found a higher density of dead residual canopy trees in recently logged sites as compared to unlogged, indicating that many trees not killed immediately may eventually die as a result of damage during logging.

Table 1-1. Annual rainfall for an unlogged and a logged forest site in Sabah, East Malaysia 1/96 to 4/97

UNLOGGED FOREST	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL 1996	Jan.	Feb.	Mar.	April	May	TOTAL PORTION OF 1997
Mean monthly rainfall[1]	590	424	43	245	274	162	153	166	180	390	138	225	**2989**	189	363	85	101	106	**843**
Rain days	26	23	9	19	25	19	18	23	21	23	22	22	**250**	19	25	18	15	12	**89**
Dry days	5	6	22	11	6	11	13	8	9	8	8	9	**116**	12	4	13	15	19	**63**
LOGGED FOREST																			
Mean monthly rainfall[1]	445	379	49	184	245	91	167	74	120	297	76	225	**2350**	183	208	77	83		**552**
Rain days	25	21	10	17	24	17	18	19	21	23	17	27	**239**	18	21	23	14		**76**
Dry days	6	8	21	13	7	13	13	12	9	8	13	4	**127**	13	7	8	16		**44**

1 = Rainfall measured in mm.

Data provided by Centre for Research on Environmental Systems and Statistics, Institute of Environmental and Natural Sciences, Lancaster, UK.

All rainfall data in mm.

Figure 1-1. Map of Southeast Asia, East Malaysia and location of study site.

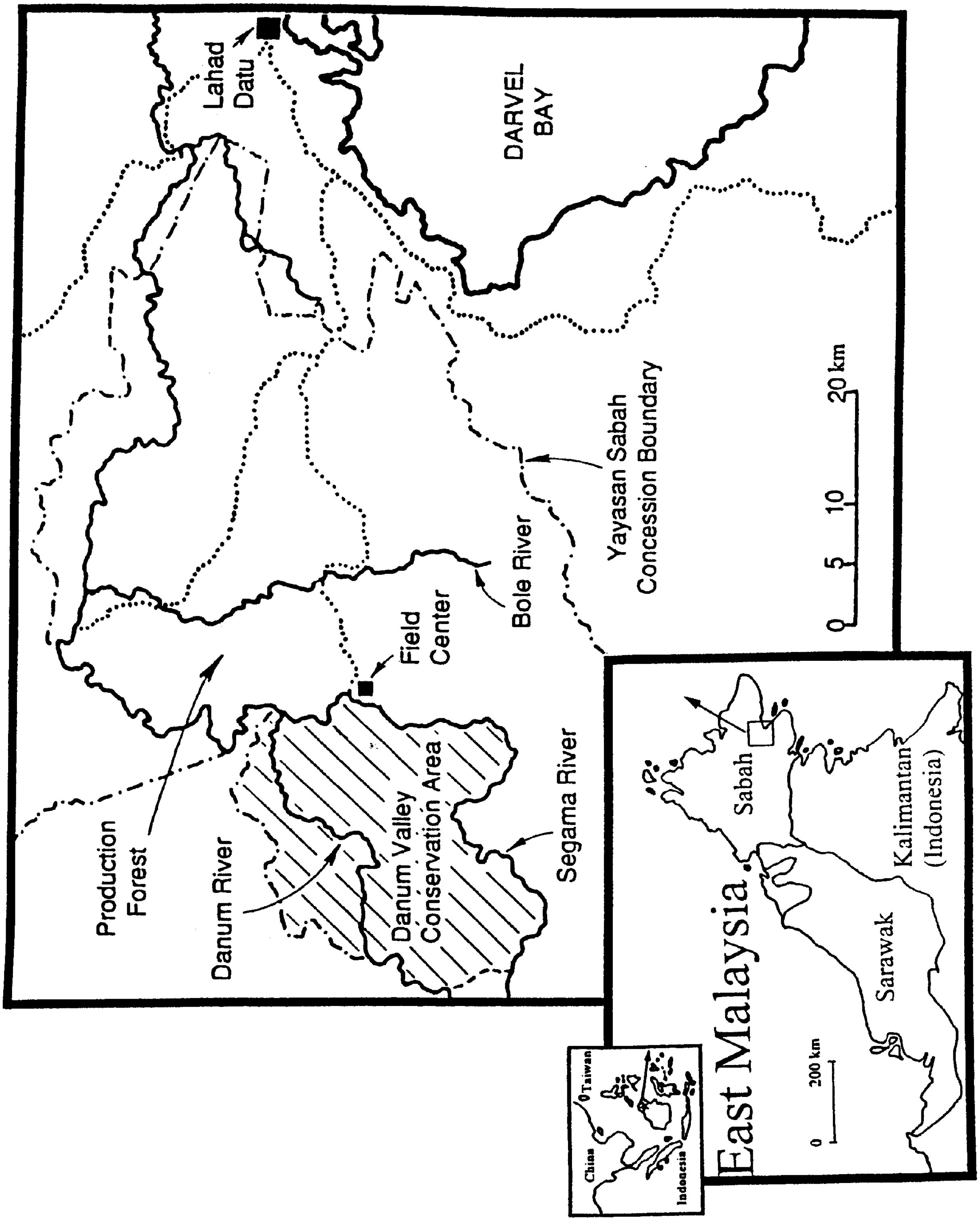
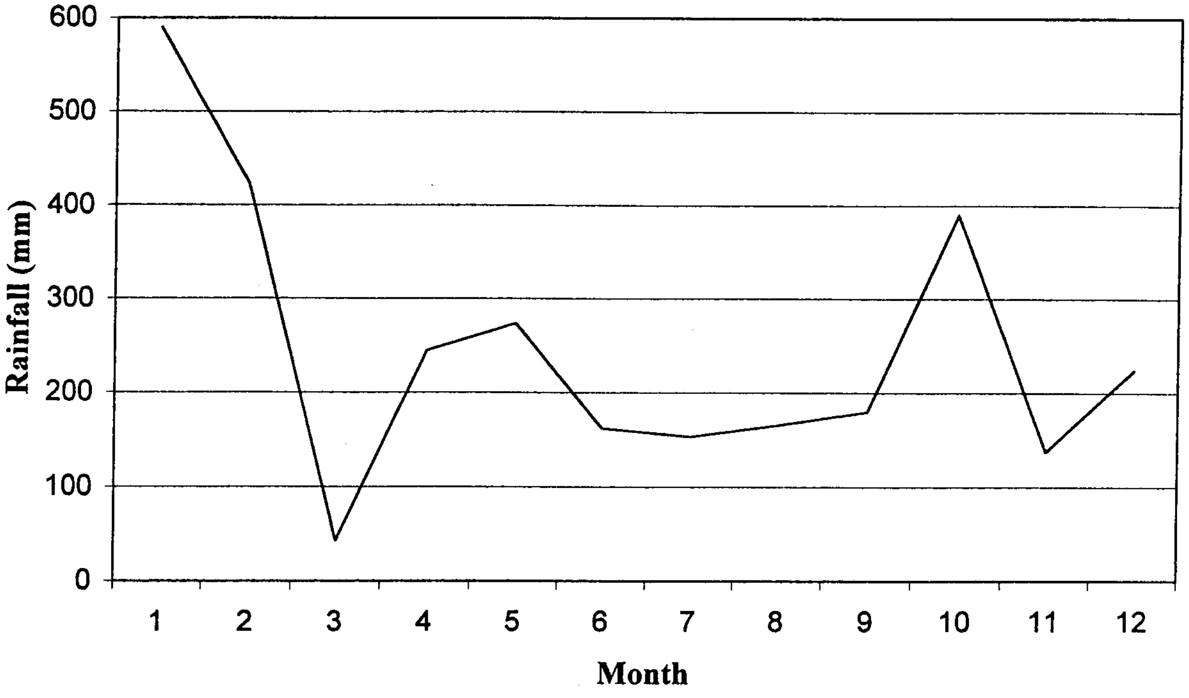
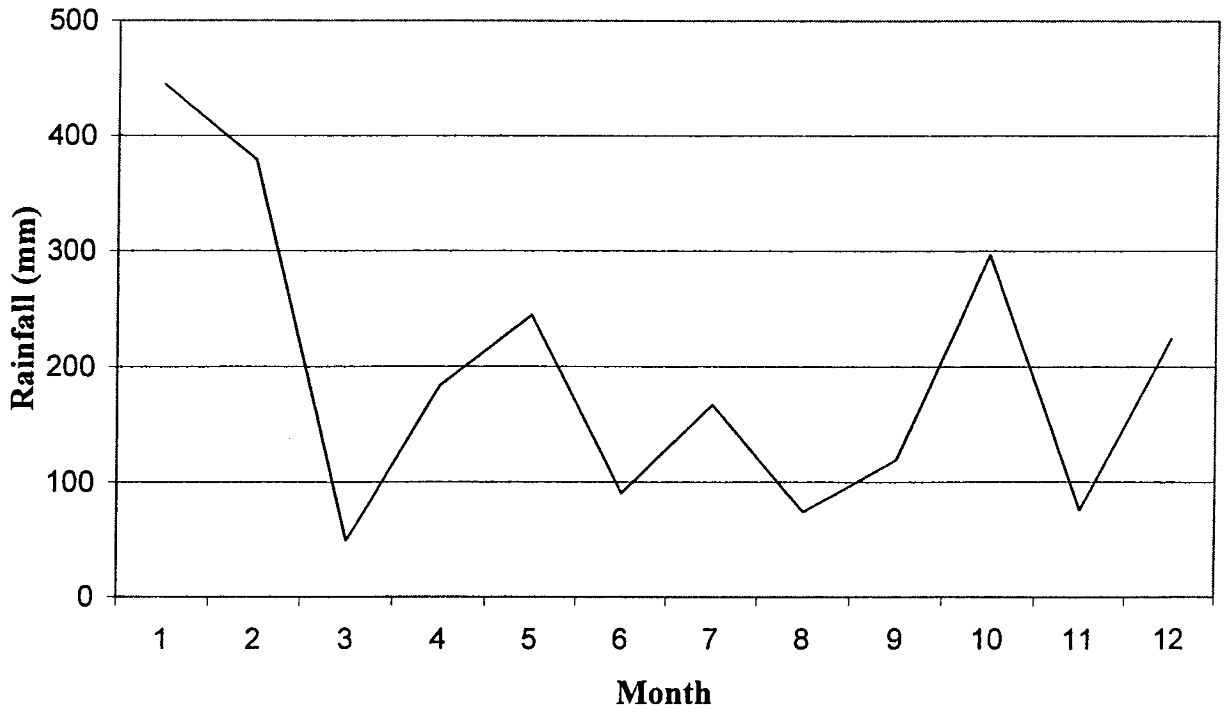

Lahad Datu
DARVEL BAY
Yayasan Sabah Concession Boundary
0 5 10 20 km
Bole River
Field Center
Segama River
Danum Valley Conservation Area
Danum River
Production Forest
East Malaysia
Sabah
Sarawak
Kalimantan (Indonesia)
0 200 km
China
Taiwan
Indonesia

Figure 1-2. Mean monthly rainfall, 1996, at the Danum Valley Field Center and in a logged forest in Sabah, East Malaysia (Data provided by Centre for Research on Environmental Systems and Statistics, Institute of Environmental and Natural Sciences, Lancaster, UK).

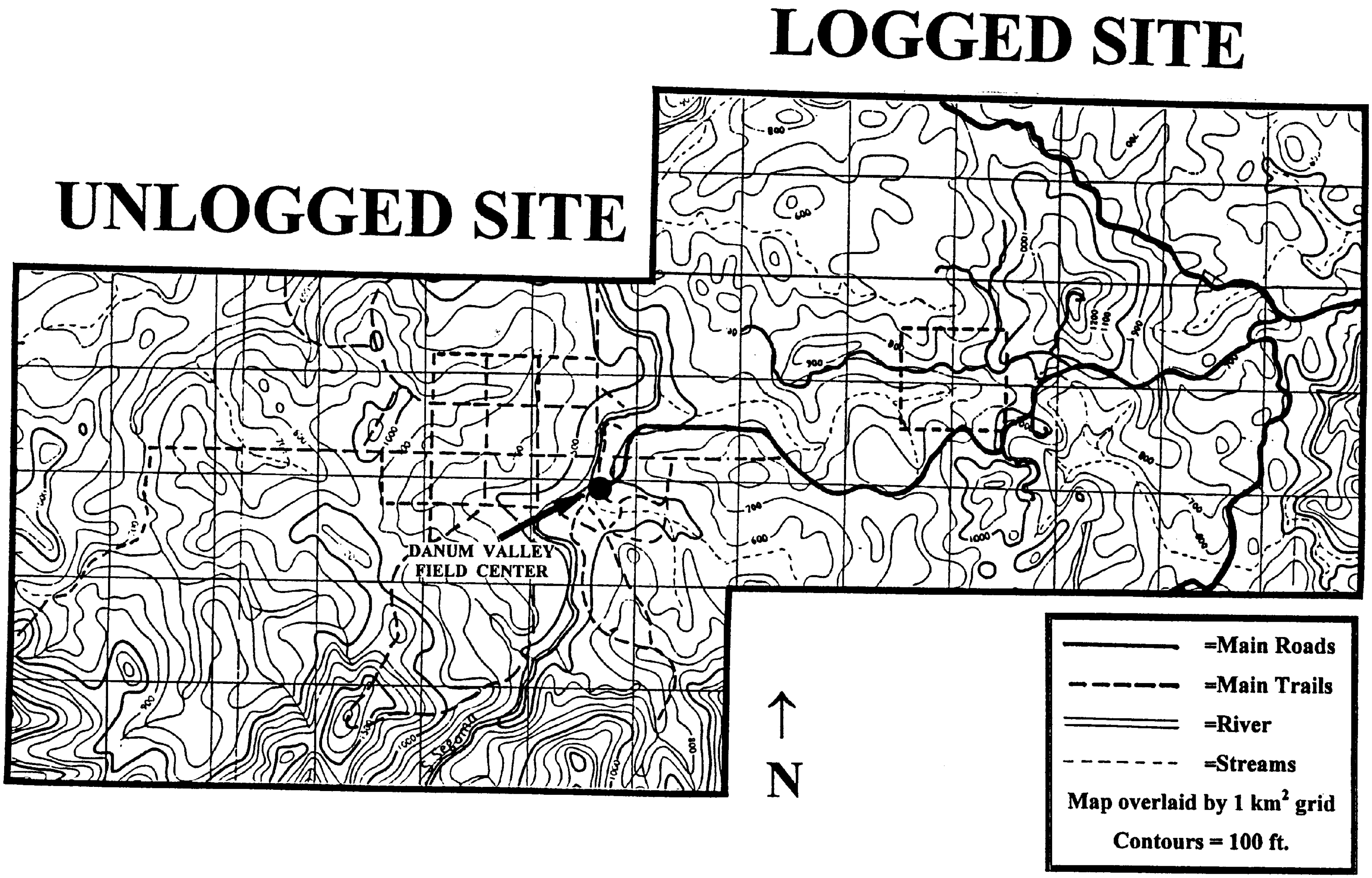


Danum Valley Field Center



Logged Forest

Figure 1-3. Topographic map of study sites.


LOGGED SITE
UNLOGGED SITE
DANUM VALLEY
FIELD CENTER
↑ N
=Main Roads
=Main Trails
=River
=Streams
Map overlaid by 1 km² grid
Contours = 100 ft.

2.

RANGING BEHAVIOR

INTRODUCTION

Viverrids are the most ecologically diverse, yet least understood family in the order Carnivora. There are over 70 species of viverrids worldwide (Grzimek, 1991), and with approximately 350 subspecies recognized (Schreiber *et al.*, 1990), they are considered one of the most important mammals in many Asian forest communities (Rabinowitz, 1991b). Among these, civets are perhaps the most ecologically diverse, occupying almost every habitat type in their range and filling a wide variety of ecological niches. Civet diets are equally varied, with some being specialized as carnivores, frugivores or insectivores, but many are considered dietary generalists (Eisenberg, 1989), and are thought to be important agents of seed dispersal (Rabinowitz, 1991b). Despite the species richness and ecological diversity of this group, very few taxa have been studied in the wild (Sandell, 1989).

The Malay civet (*Viverra tangalunga*) is one of 19 species contained within the subfamily Viverrinae. It is distributed throughout Borneo, the Philippines and parts of Indonesia (Macdonald, 1984). It appears to thrive in a variety of habitats, and under various environmental conditions. It is sympatric with the eight other civet species in Borneo, all of which differ considerably in morphology, feeding ecology and behavior. The paucity of field research on this group is probably due to their nocturnal habits and solitary behavior (Schreiber, 1989). Information on even the more common species is lacking in the scientific literature and represents a significant gap in our understanding of carnivore ecology.

In an effort to learn more about *V. tangalunga,* radio-tracking was employed in this study because it is the only feasible way to follow solitary, nocturnal, forest dwelling animals for a sufficient time to gain an in-depth understanding of their distribution, movement and activity (Worton, 1987).

Morphology

Morphologic data were collected and used to provide baseline parameters for this species, to determine whether it exhibits sexual dimorphism, and to investigate possible correlations between home range size and body mass. Among some carnivores, home range size is directly related to metabolic needs, that correlate with body mass (Mace *et al.* 1983). Thus, given equal habitat productivity, larger individuals will tend to have larger home ranges (Knick, 1990; Gompper and Gittleman, 1989). This is because their basal metabolic rates are higher (McNab, 1995) and their food resources are less abundant so they require a larger home range to satisfy minimal energy requirements. This assertion was supported by Rabinowitz (1991a), who reported that mean monthly home range size for members of the civet community of a forest in Thailand [the small Indian civet (*Viverricula malaccensis*), common palm civet (*Paradoxurus hermaphroditus*), large Indian civet (*Viverra zibetha*) and small-toothed palm civet (*Arctogalidia trivirgata*)] was directly correlated with an increase in size among species. Palomares (1994) also demonstrated a direct correlation between home range size and body mass in Egyptian mongooses (*Herpestes ichneumon*). Species with a more insectivorous diet tend to have smaller home ranges (Gittleman and Harvey, 1982) and lower basal metabolic rates (McNab, 1995). Because *V. tangalunga* is omnivorous it is not predicted that home range size will show a direct positive correlation with body mass.

Home Range

Among carnivores, males frequently have larger home ranges than females (Livaitis, *et al.,* 1986; Buskirk and McDonald, 1989) that often overlap the ranges of several females (Kitchner, 1993). This pattern was reported for African palm civets (*Nandinia binotata*), where up to three females reside within the range of a single male, who regularly passes through each one's range and remains therein for several days (Macdonald, 1984). Therefore, in this study, home range size was expected to be larger for males.

Food resources clearly have an effect on home range size. Specialized feeders such as carnivores and frugivores tend to have larger home ranges because their food resources are rare and patchily distributed (Sandell, 1989). This trend was found to be true among frugivorous primates, which range further on a daily basis than folivores and have larger annual home ranges (Milton and May, 1976; Clutton-Brock and Harvey, 1975). Thus, clumped and scarce resources can be associated with larger home ranges than evenly distributed and relatively abundant resources. Because *V. tangalunga* is reported to eat some fruit, similar patterns could emerge, although its omnivorous tendencies may result in very different patterns. In this study, it was predicted that home range size between forest types will be different if one site contains resources that are more abundant and more evenly distributed than in the other site. If the logged forest contains fewer resources than the unlogged site (or *vice versa*), animals in this area would need to cover a larger range in order to satisfy their ecological requirements.

Because there is often a correlation between home range size and population density (Sandell, 1989), a change in density of *V. tangalunga* in the selectively logged forest could contribute to a change in home range size in the logged forest site.

Because food levels will often change in a seasonal habitat, territorial behavior, and/or home range size may change in response. Nel *et al.* (1984) found a strong correlation between invertebrate abundance and rainfall, that in turn affects spacing patterns of bat-eared foxes (*Otocyon megalotis*). Because *V. tangalunga* consumes invertebrates, it may show similar patterns. Rabinowitz (1990b) reported that among civets in Thailand, home range size expanded due to range shifts during dry season fires and in the wet season due to flooding, but contracted in the early rainy season, when fruit was readily available. So seasonal shifts in home range size may be a reflection of seasonal changes in the availability of resources, or they may be a response to seasonal disturbance such as evacuation of flooded or burned habitat.

Home Range Overlap

Home ranges of adjacent individuals may overlap to different degrees (Pianka, 1978). Among many solitary carnivore species, exclusive territories from which other individuals are actively excluded may be contained within a larger home range area (Gorman and Trowbridge; 1989, Kaufmann, 1983). Because it is usually impossible to directly observe territorial defense or active exclusion in the field, in this study, a lack of home-range overlap among neighboring individuals is considered an indication of territoriality. Because there are some forms of active exclusion in areas of overlap (e.g. Charles-Dominique, 1978), another indirect means to test for territorial behavior is by examination of affiliative and avoidance behavior between adjacent animals. If radio-collared individuals are more widely spaced in areas of overlap than predicted by chance, it could indicate that active exclusion may be taking place. Because it is not possible to be certain that all *V. tangalunga* in the area were collared, the results from this test must be viewed with caution.

The most common type of territory is a feeding territory, which will only be advantageous when the energy gained from the increased access to food outweighs the cost of its defense (Pianka, 1978). If food is evenly distributed in time and space, as is often the case with insects, it is usually defended. If resources are widely spaced, clumped and ephemeral, such as fruit and small mammals, territorial defense is a less likely strategy (Sandell, 1989). However, the opposite pattern has been observed among insectivorous bats in Tennessee (A. Rabinowitz, pers. comm.).

Home range overlap will tend to increase during periods of food abundance or in areas with greater food availability, because territorial exclusion is no longer energetically advantageous when food is not limiting (Carpenter and MacMillen, 1976). Crab-eating foxes (*Cerdocyon thous*) exhibit an increase in home range overlap during the rainy season when fruit and insects are abundant and comprise the bulk of the diet. In the dry season, when they shift to a diet of vertebrates and crabs, overlap of adjoining home ranges declines and they become less tolerant of conspecifics (Brady, 1979). Thus, territorial behavior will occur when resources are limited, but still exist in sufficient densities to be defensible (Oates, 1986). Because the diet of *V. tangalunga* is similar to that of *C. thous*, it may exhibit the same pattern. If *V. tangalunga* in either forest exhibit larger areas of exclusive use, it may result from a higher level of territorial behavior in response to limited resources.

Effects of Rainfall on Home Range

In comparison to other regions of Southeast Asia, Malaysia, Borneo, and Sumatra are relatively aseasonal. Sabah experiences the effects of two monsoon seasons, but these trends are usually highly irregular. As a result, fruiting and flowering of plants are unpredictable and subject to mast fruiting episodes that occur at intervals of from two to nine years. In non-mast years, fruit is rare for most of the year (Corlett, 1998). Thus, strong seasonal changes in behavior are not expected for

V. tangalunga. However, because animals will nonetheless react to climatic effects such as rainfall or drought, efforts were made here to look for changes in ranging behavior that correlate with different levels of rainfall.

Diurnal Versus Nocturnal Ranges

If *V. tangalunga* is nocturnal, it would be expected to use a greater portion of its home range during this period of peak activity. Diurnal ranges (equivalent to ranges during inactivity) are expected to be small if the animal selects one or a few day bed sites that it uses with high frequency. If multiple day beds are selected with low site fidelity, and/or if the animals relocate frequently over the course of a day, these might be reflected in a larger diurnal range. If nocturnal ranges, representing foraging sites, are disjunct from day ranges (measured through a comparison of degree of overlap between the two), the individual is selecting very different segments of its range for foraging than for resting. This could result from specific habitat features pertinent to either foraging or resting that are not evenly distributed within their range and may thus be somehow limiting or restricted.

Home Range Use

The distribution of point locations within an animal's home range will vary depending on the pattern of range use exhibited by an animal. Areas of high use often contain important resources such as food or shelter. However, these do not always correlate directly with exclusive use; some limiting resources may be contained in areas of high overlap if they are not defensible or are so superabundant as to be shared. This would be the case for a mineral resource such as a salt lick or mud volcano for ungulates (Payne, 1992). Areas of high use may also include important resources such as den sites, roads, trails or streams. Thus, examination of range use patterns can be informative in terms of identifying areas of high use and if possible, correlating them with habitat features. This provides insight into what features are important to the animal and if they are used exclusively or by multiple animals.

METHODS

Trapping

Trapping in the unlogged forest commenced December 1, 1995 and terminated May 26, 1997. Trapping in the logged forest began on February 19, 1996 and was completed on May 1, 1997. A total of 36 trap sites in the unlogged forest covered 98.5 ha, and 41 trap sites in the logged forest covered 199.5 ha, based on a 100% minimum convex polygon (see section on home range estimators). In the unlogged forest, trapping was carried out for six relatively dry months and eight relatively wet months. In the logged forest, trapping was done for four relatively dry months and six relatively wet months. Once all radio-collars were deployed, trapping ceased. When some animals prematurely shed their transmitters, trapping was recommenced in an effort to recapture and re-collar these individuals. Trapping also resumed at the end of the study in order to recapture study animals to remove their collars.

Two portable Tomahawk brand box traps (Tomahawk, WI) and 10 additional locally made traps were used for all trapping. These were designed with a single door and foot-activated trigger pad, and ranged in size from 114 x 38 x 51 cm to 76 x 38 x 51 cm. Traps were set at a minimum of 100 m intervals along the main west trail in the unlogged forest and along the main logging road in the logged forest. Exact trap sites were determined by the presence of trails, tracks, scrapes, scent marks, scat or any other signs of civet activity. Traps were situated on level, dry ground, near a tree or other source of cover, and were staked to the ground and anchored securely. The trap floor was covered with a thin layer of substrate to minimize detection of the spring mechanism and maintain substrate continuity.

Traps were set between 16:00 and 18:00 and baited with canned sardines, mackerel, or local freshwater fish left in the sun for 24 hours. Traps were checked in the mornings between 07:00 and 09:00 and were closed during the day to minimize the time captured animals spent in traps and to eliminate catching non-target diurnal species. All traps were situated below dense foliage to prevent exposure to direct sun and heavy rain.

Physical examinations and morphologic data from all *V. tangalunga* captures allowed for an assessment of the health of the population, as well as quantification of the body size of adults, sub-adults, males and females. Recapture and repeated measurements of young individuals gave an index of growth rate for this species in the wild. Capture records of different age groups provided an indication of breeding seasonality. Comparisons of trap success between males and females made it possible to test for gender bias in capture success. Comparisons of male and female morphometry also permitted tests of sexual dimorphism.

All trapping in the unlogged forest was carried out on the opposite side of the Segama River from the Field Center, in order to eliminate the effect of human settlement on the behavior of the study animals. With the exception of a single reported sighting (female FP 3), no radio-collared animals were located on the same side of the Segama River as the Field Center. All trapping in the logged forest was carried out at least 300 m from the main access road to minimize disturbance from vehicular traffic. Trails in both study areas were loosely based on a grid system with additional trails or roads used and/or cut as needed. Trap sites and study grids were selected to minimize variability among sites. However, trap locations were also selected based on signs of civet presence or wildlife trails in order to maximize trap success.

Immobilizing and Collaring Study Animals

Once captured, civets were left in the trap until all immobilizing materials and tracking equipment were ready. The trap was covered with a wet burlap sack or leaves to reduce stress and risk of overheating. The animal was immobilized in the back of the trap with a wooden plunger that pressed the animal against the cage bars.

A dose of 5 mg kg^{-1} Zoletil (Vibrac Laboratories, Carros, France) was administered through the cage bars based on an estimate of the animal's weight. Time to reach full sedation ranged from five to 40 minutes, during which the cage was covered and noise minimized to reduce resistance to the immobilant. Drug effects lasted between 30 minutes and one hour.

Once fully sedated, the animal was removed from the trap and weighed. The animal was laid out on a tarp in the shade and its eyes were covered. Two drops of Solcoseryl eye gel (Solco Basel Ltd, Switzerland) were placed in each eye to maintain eye moisture while immobile. A general examination was conducted to determine health, gender, age and reproductive condition. Pelage and ears were checked for external parasites (ticks, mites and fleas). Age was determined by body size, tooth wear and reproductive condition. Age categories included juvenile (not full size, still have milk teeth); sub-adult (almost full size young of the year, but not yet reproductive); young adult (probably second year, still not sexually mature); adult (full size, showing signs of reproductive activity, moderate tooth wear); and old [showing signs of decline in weight and health, pronounced tooth wear (Larson and Taber, 1980)]. Reproductive status was determined by checking nipples on females for signs of lactation and testicle size on males (Rabinowitz, 1997).

Measurements were taken of head-body length, tail length, head and neck circumference, height at shoulder, girth at upper thorax, ear length (right) as well as foot length (right rear) foot width (right front), and length of upper right canine. A photographic record of each animal's neck markings was created as a backup means of identification. Unusual markings, scars and injuries were recorded. All *V. tangalunga* captured were marked by fur clipping, which although not permanent, was visible for at least six months.

Only mature animals in good physical condition were selected for study and fitted with radio-collars. All healthy adult and sub-adult *V. tangalunga* were tranquilized, examined and measured (Table 2-1). Juvenile animals were not drugged, but were marked by fur clipping through the trap bars before being released.

Radio-collars (Advanced Telemetry Systems (ATS), Isanti, MN) were constructed from one inch wide two-ply Teflon and fitted with a three v transmitter (151-152 MHz). Antennas were composed of a 0.25 mm diameter flexible wire whip, sewn between the two layers of the collar and extended out the end to a total length of 41.25 cm. Battery life was warrantied for 270 days with an expected duration of 444 days (Chris Cochanny, ATS, pers. comm.). Mean collar and transmitter weight was 57.4 g (range = 48 - 62 g). Radio-collars were only 1.6% (range = 1.3 to 1.8%) of the total body weight of study animals. This value is at the low end of percent body weights for transmitters on birds (Cochran, 1980), which are considered more sensitive to the effects of transmitter weight than mammals (White and Garrott, 1990).

Once examined and when appropriate, radio-collared, the animal was placed back in the cage. The door was closed and locked to prevent exit before full recovery from the drug and to protect the animal from predators. The cage was covered and shaded during recovery. At dusk, the animal was checked, and when fully alert and healthy, it was released. The cage door was locked open and left, permitting the animal to exit on its own.

Morphology

Differences in size and weight between sexes were evaluated using a two-sample t-test. A Kendall's coefficient of rank correlation (Sokal and Rohlf, 1987) was run in order to test for any effects of body weight on home range size. Morphologic data on repeated captures of sub-adults was used to calculate growth rate of this species in the wild. By examining the time of year and the age of immature animals captured, it was possible to estimate breeding seasonality.

Radio-Tracking

Radio-tracking in both study sites was done concurrently from February, 1996 through June, 1997, on foot and by vehicle. Most data from the unlogged forest were collected on foot using trails, while most data from the logged forest were collected along logging roads using a vehicle. In the presence of a vehicle, all readings were taken with the engine off at a minimum distance of 10 m from the truck to eliminate magnetic interference from the vehicle. The presence of roads along ridges in the logged forest allowed readings to be taken from a slightly higher relative elevation in the logged forest, while in the unlogged forest, most readings were taken below the canopy.

Study animals were not observed to move between study sites. The only known means for study animals to traverse the river was via a suspension bridge near the field center. A camera trap was set at the foot of the bridge and did not record any study animals crossing the bridge. FP 3 was recorded via camera trap apparently moving past the bridge, in the direction of the river edge and was at another time reported to have been observed on the road at the far side of the bridge. However, no radio locations were ever recorded on the far side of the river for any study animal in the unlogged site.

All radio-tracking was done by the investigator and two trained field assistants, with additional help from a volunteer with extensive experience radio-tracking small carnivores. All data were collected using two identical TR-2 receivers (Telonics, Mesa AZ) and a single backup CE-12 receiver (Custom Electronics, Urbana, IL). All readings were taken with David Clark headphones (Worcester, MA) and two or three-element antennas held horizontal to the terrain using a Recta sighting compass (Biel, Switzerland).

To calculate bearings, the null method was employed in all cases, as this method gives sharper directivity than the peak method (Cochran and Lord 1963). Once nulls were located, the peak was calculated by splitting the arc to produce the estimated bearing. When locating each animal, a minimum of four bearings were taken if possible. This allowed for elimination of outliers, defined as bearings which appeared highly inconsistent with the remaining bearings, probably resulting from signal bounce.

Monitoring radio-collared animals was attempted at least once per week for each individual. Table 2-2 summarizes radio-tracking efforts for each animal. Diurnal readings were taken to estimate resting site locations and night readings to locate the animal during periods of activity. Day readings were taken by a single observer with each bearing taken with an attempted maximum of 5 minutes between successive bearings. Night readings were taken simultaneously by two trackers, with an acceptable minimum of 45° and maximum of 135° between bearings, in order to minimize error (Springer, 1979).

Standard error of compass bearings, based on the average value of 20 readings, taken on concealed transmitters before data collection commenced, was approximately ± 2.5° for the investigator and volunteer, and ± 2.0° for the field assistants. In order to account for both human and environmental error, the maximum value was doubled (or ± 5°). To determine a maximum acceptable error ellipse size, the largest mean animal-to-observer distance was doubled and rounded up to one km. The size of error ellipse that would result from a distance of one km using a bearing error of ± 5° was slightly less than one ha. In consideration of the inherent difficulty associated with radio-tracking in this habitat, climate and terrain (Mac Komnick, Telonics, pers. comm.) this value was selected as the maximum acceptable level. This value was also comparable to error selected for radio-tracking similar sized animals (Arthur *et al.* 1989; Kitchings and Storey, 1984; Voight, and Timline, 1980; Verts, 1963). Mean error ellipse radius in the unlogged forest was

39.6 m (range = 14.3 – 59.6 m) and 39.4 m (range = 31.5 – 49.4 m) in the logged forest.

Signal Range

Transmitter range varied from 400 m to > three km in both study areas and was determined by planting radio-collars in the forest and recording distance of reception at 100 m intervals. These tests were carried out prior to data collection. Mean observer-to-animal distance in the logged forest was 261.3 m (range = 178.7 – 288.4) and 207.1 m (range = 174.7 – 247) in the unlogged forest. These differences were largely a function of forest structure and elevation. Forest cover and canopy height were higher in the unlogged forest and trails were all located below the canopy; in the logged forest, roads were situated on ridges and peaks.

Data Analysis

All point locations were estimated with the Lenth Maximum Likelihood Estimator (MLE) using the program Locate II (Pacer Co., Truro, N. S., Canada). Bearings that appeared erroneous due to signal bounce, movement of the animal between bearings, or other sources of error, were eliminated from the data set. Because the MLE weighs each bearing equally, this step is necessary in order to insure accuracy of the estimate. For a full description of all Lenth estimators, see Lenth (1981). All other radio-tracking analyses were done using Ranges V (Institute of Terrestrial Ecology, Wareham, Dorset, UK)

In order to eliminate bias resulting from autocorrelation of successive radio locations, a test of independence was carried out (Swihart-Slade, 1985). Time to independence represents the time after which the location of the animal between consecutive readings is no longer dependent upon its location in the previous reading. Independence may never be reached for some animals if their movements are fairly routine on a daily basis. In these cases, the time interval with the least dependence was used (Kenward and Hodder 1996). Because each animal exhibited different patterns of movement, a separate test was carried out for each animal. Table 2-3 shows the time to reach statistical independence, Figures 2-1 and 2-2 contain graphs of the tests for each site. If sufficient continuous data were not available for an animal, the greatest time to independence developed for all other individuals was applied.

To determine if the number of data points available for home range estimation is sufficient to represent the animal's true home range, an asymptote can be calculated by plotting home range area against number of data points. The curve levels off where the home range size no longer increases significantly. Such plots were generated for each study animal based on a 95% minimum convex polygon (see Figures 2-3 and 2-4). All graphs reach an asymptote, except FP 6 (a female in the unlogged forest) and FL 16 (a female in the logged forest) which appeared to reach a plateau, but may have shown an increase in home range size given more data points.

Home Range Estimators

There are numerous probabilistic and non-probabilistic methods of calculating home range, each with associated advantages and disadvantages. In light of the widespread disagreement over which is best, and considering the vastly different results that can be attained using different methods, data from this study were analyzed using four of the most frequently cited home range estimators.

The most widely used non-parametric estimator is the minimum convex polygon method (MCP) (Mohr, 1947) and was included in this study for its consistency with other studies and simplicity of calculation and interpretation. It can overestimate true home range size, and because it makes no assumptions about the distribution of point locations within the selected polygon, it often includes areas that are not used or are inaccessible to the animal. It is also heavily influenced by outliers, a problem partially corrected by selecting a 95% isopleth. However, 100% MCP was also included to detect occurrence and extent of forays.

The Jennrich Turner Ellipse (JTE) (Jennrich and Turner, 1969) is a highly theoretical home range estimator, which makes some unrealistic assumptions about normality, such as that the movement of an animal is random (White and Garrott, 1990). However, it does allow for more consistent comparisons among separate individuals than most other estimators. This is in part because whereas sample size can heavily influence estimated home range size with other estimators, the effects of sample size lead to less variability with a JTE (White and Garrott, 1990).

The harmonic mean (HM) (Dixon and Chapman, 1980) is a non-parametric estimator that gives a fair representation of the true home range. There is no predetermined or artificial shape criteria which often include areas of little use and the calculated center of activity is located in a biologically relevant place: the area of highest concentration of point locations.

The kernel method (Worton, 1989) is an extension of the harmonic mean approach but gives more consistent results because it is mathematically more robust (see Kenward and Hoddard, 1996 for details). Of the two approaches to kernel analysis, Kenward and Hoddard (1996) advocate use of the fixed kernel (FK) to the adaptive kernel, because it provides more acceptable expansions of the outer contours. THUS, fixed kernel estimator was used in this study.

Density

Minimum density was determined by several means. A conservative estimate was derived by adding all the point locations for all study animals in a given site, generating a single area estimation using a 100% MCP, then dividing by the number of animals. This approach gives an accurate value for the largest area known to contain the entire home range of a minimum number of animals. An additional means was to divide the total number of individuals captured by the effective trap area, and a final method involved the same calculation based only on adults captured.

Home Range Overlap

An exclusive range was defined as one which showed mean overlap of less than 10% (Sandell, 1989). In order to quantify areas of overlap, overlap matrices were generated using Ranges V. in order to detect areas where all home ranges overlapped, which may represent convergence on essential resources, home range maps were overlaid and scanned visually.

Effects of Rainfall on Home Range

Because seasonality is not well defined in this area, dry and wet months were utilized instead of dry and wet seasons. These were selected on the basis of rainfall records from each site, collected during the interval that radio-tracking was carried out. Relatively wet months were defined as those in which more than 180 mm of rainfall were recorded and relatively dry months were those for which less than 180 mm fell. This value was selected because it represents a natural division between months of very high rainfall (up to 590 mm) and very low rainfall (as low as 42.9 mm). It resulted in an even split of six wet and six dry months per year. Although rainfall differed slightly between sites, months classified as wet or dry corresponded between sites.

There was a period of relatively low rainfall from June through September of 1996 and from March through May, 1997. This did not correspond well with the reported monsoon seasons, both of which normally fall within the periods this year when rainfall was lowest, rather than highest. This is not surprising in light of the fact that the area is known to be unpredictable in its weather patterns (Marsh, 1995). It is of interest to note that there were more rain days and higher overall rainfall in the primary forest.

Point location data for each animal for dry and wet months were plotted separately to test for changes in home range size, location and overlap that may have resulted from differences in the amount of rainfall. Only animals that had sufficient data points to reach an asymptote for each interval were considered valid for comparisons. Percent overlap was calculated for each seasonal range as an indication of home range shift between intervals, and compared between sites with a two-sample t-test. A paired t-test was used to identify differences in home range size. A two-sample t-test was used to compare the seasonal ranges in the logged and unlogged forests. Linear distance between dry and wet range centers was not computed since the distance was negligible.

Diurnal Versus Nocturnal Ranges

For this analysis, point locations taken between 08:00 and 18:00 were considered day locations; those taken from 18:00 to 08:00 were defined as night locations. This division was based on observations of the circadian patterns of the animals, who generally became active after nightfall around 18:00 and retired shortly before 08:00. Although the terms active versus inactive ranges could equally be applied, the close correlation with photo-period and the variation in activity levels during both intervals made the use of diurnal versus nocturnal ranges more appropriate although somewhat arbitrary.

Because there was an uneven distribution of point locations for day and night readings, statistical comparisons were made based only on ranges that contained sufficient numbers of points to reach an asymptote. The same statistical comparisons used for seasonal ranges were also used on this data.

Home Range Use

One means to examine patterns of home range use is to generate a cluster analysis which detects areas of disproportionately high use (Kenward, 1987). In this study, a cluster analysis was run for each animal at 5% intervals from 20 – 100% on Ranges V, using the nearest neighbor rule with 100% MCP. For these, the range center was defined using the Gaussian kernel estimator, a robust and biologically relevant definition of the home range center, based upon the highest density of point locations (Worton, 1989). Clusters were generated by connecting three points closest to one another, then locating the next nearest point. New clusters were formed if the distance between any three points was less than the distance to a new point in an existing cluster. For each cluster analysis, a utilization distribution was then graphed with total area on the y axis and percent of total point locations on the x axis. These were scanned visually for a sharp discontinuity in slope which is indicative of the presence of range nuclei (Kenward and Hoddard, 1996). The proportion of data points that corresponded with that point of inflection was then used to plot these clusters for each animal. Clusters were then mapped for all animals in each study site and visually examined for correlation with clusters for other individuals as well as overlap or intersection with habitat features such as roads, trails and streams.

Statistics

All two-way tests of home range size between study sites and gender were carried out with a two-way ANOVA. Tests for differences in range size between season and time of day were made with a paired t-test. Percent data from overlap comparisons were arc-sine transformed (Sokal and Rohlf, 1987) before performing a t-test. A χ^2 test was used to compare trap success and density between forest sites. All statistics were carried out with an alpha level of 0.05 using Systat 7.0 for Windows (SPSS Inc., Chicago, IL).

RESULTS

Trap Success

A total of 38 animals belonging to nine species were captured (Table 2-4), of which 24 were *V. tangalunga*, representing 63.2% of all captures. In the unlogged forest, 77% of all captures were *V. tangalunga* (n = 10) as were 56% of all captures in the logged forest (n = 14). Viverrids were represented by 30 individuals from four different species, or 78.9% of all captures, and carnivores represented 84.2% of all animal captures (n = 32).

Trap effort in the unlogged forest totaled 421 trap nights and resulted in a total trap success of one capture for every 32.4 trap nights. For carnivores, trap success equaled one capture for every 38.2 trap nights. Because the only carnivores captured were in the Viverridae, trap success for viverrids was also one capture per 38.2 trap nights. For *V. tangalunga*, trap success decreased to one capture every 42.1 nights.

In the logged forest, there were a total of 766 trap nights that resulted in one capture for ever 29.4 trap nights. For carnivores, trap success equaled one capture for every 34.9 trap nights and for viverrids, it equaled one capture for every 36.7 trap nights. For civets, trap success was one capture per 43.2 trap nights, for *V. tangalunga*, it decreases to one capture every 52.4 nights. Based on an assumption of equal trapability in both forest sites, a χ^2 test of observed versus expected trap success was not significantly different for any category above (Table 2-5).

The male to female ratio for *V. tangalunga* captured in the logged forest (3:8) showed an opposite trend to that in the unlogged site (8:2). However, neither ratio differed significantly from expected ($\chi^2 = 0.00309$, $p = 0.9556$ and $\chi^2 = 0.0085$ $p = 0.926$ respectively). Despite the disproportionate sex ratio in each site, the overall sex ratio was very close to parity. Mean recapture rates were approximately equal for males (31 recaptures among seven animals) and females (22 recaptures among five animals), indicating no gender-based difference in re-trapability ($\chi^2 = 0.000103$, $p = 0.9919$). Mean frequency of recapture for *V. tangalunga* was 3.55 (range = 1-10)

Reproductive Activity

All sub-adults were captured between 25 September and 2 February. The young adults were captured between 4 March and 26 June. All juveniles were captured between 30 March and 31 May. The smaller two of these were captured in the logged forest on 30 March, 1996 and 25 April, 1997, while the largest were captured on 30 May, 1996 in the unlogged forest and 31 May, 1996 in the logged forest. On 4 May, an additional juvenile was observed waiting outside the trap containing female FP 3 in the unlogged forest, which may have been her offspring. Similarly, the juvenile captured in the logged forest on 25 April, 1997 was assumed to be the offspring of female FL 14. Her presence was detected in a clump of nearby vegetation where she remained until the juvenile was released and subsequently ran directly into the same clump of vegetation. Continual follows of her during a six week interval prior to the capture date of the juvenile showed highly clumped and restricted movement and were all located in the same immediate area to the trap site (see section on Movement).

Morphology

Measures for all *V. tangalunga* are contained in Table 2-1. Mean values are based on highest values when a single animal was measured more than once. Mean body weight for adult males was 3.79 kg (range = 3.45 - 4.30 kg) and mean body weight for females was 3.60 kg (range = 3.12 - 3.95 kg). Mean head-body length for males was 66.7 cm (range = 59.0 - 77.3 cm), and for females was 64.3 cm (range = 62.0 - 67.0). Mean tail length for males was 32.8 cm (range = 30.0 - 34.4 cm), and 31.8 cm (range = 30.0 - 33.0 cm) for females. Mean girth (upper thorax) was 32.2 cm (range = 30.5 - 35.2 cm) for males and 31.1 cm (range = 29.2 - 33.0 cm) for females. Mean hind foot length (right) was 10.4 cm (range = 9.8 - 11.0 cm) for males and 10.0 cm (range = 9.4 - 10.5 cm) for females. Mean height at shoulders was 26.5 cm (range = 25.0 - 2.0 cm) for males and 25.9 cm (range = 24.0 - 28.0) for females. Mean head circumference was 21.7 cm (range = 20.3 - 22.9 cm) for males and 20.5 cm (range = 19.8 - 21.0 cm) for females. Mean neck circumference was 20.5 cm (range = 19.8 - 22.0 cm) for males and 18.9 cm (range = 18.1 - 19.8 cm) for females. Mean ear length (right) was 3.6 cm (range = 3.2 - 4.1 cm) for males and 3.6 cm (range = 3.3 - 3.9 cm) for females. Mean canine length (upper right) for males was 0.92 cm (range = 0.96 - 1.20 cm) for males and 0.96 cm (range = 0.60 - 1.10 cm) for females.

A two sample t-test on all parameters (when a single animal was measured on more than one occasion, the largest measurement taken was used in statistical tests) revealed significant differences between males and females in hind foot length ($p = 0.046$) head circumference ($p = 0.007$) and neck circumference ($p = 0.001$). In all three cases, males were found to be larger than females in these parameters. No significant differences were revealed for any other parameters measured (Table 2-6). There was also no significant correlation observed between body mass and home range size for males or females (see Table 2 -7).

It was possible to quantify growth rates based on consecutive captures of two individuals. A sub-adult male (MP 5) was captured on February 2, 1996 in the unlogged forest, then 50 days later, and another 32 days later. Over this time, he increased in all physical parameters measured except ear length and hind foot length (Table 2-8). Overall the animal increased in weight by 0.98 kg, (28.5%), girth increased by 4.1 cm (13.6%), neck circumference by 2.6 cm (13.2%) and head-body length increased by 5.2 cm (7.9%). Rate of growth decreased in the second interval for all categories except head circumference.

A juvenile male (ML 13) was captured in the logged forest on March 30, 1996, then 92 days later, and again 65 days later. Although no measurements were taken at the first capture due to the young age of the animal, it is estimated that the animal doubled in size over this time. Between the second and third capture, the animal increased in every parameter measured except hind foot length, ear length, tooth length and tail length. He showed the greatest increase in weight, adding 0.45 kg (12.6%) in 65 days, followed by head-body length increase of 2.0 cm (3.1%) and an increase in girth of 0.7 cm (2.3%).

Radio-Tracking

Of the 24 *V. tangalunga* captured, 17 were radio-collared: six males and two females in the unlogged forest, three males and six females in the logged forest. The signal was lost almost immediately from male MP 4 in the unlogged forest and female FL 12 in the logged forest. MP 8 and FL 11 were tracked briefly before their signals were also lost. The latter was relocated approximately two km away down an old logging road and tracked in this area briefly before she shed her radio-collar. She was not re-trapped. Considerable effort was made to recapture animals who shed their collars or whose collars may have stopped transmitting.

When a radio signal was lost, the entire study area was searched, then the search was systematically extended outward from the core study area. In the unlogged forest, all trails and ridges were regularly hiked during searches because signal range was up to three km from some high points. In the logged forest, searches were carried out along all roads, trails and stream beds. Lost signals from either study area were searched for in both forest sites. A thorough search was executed at approximately two week intervals in the event that lost animals moved out of the study area then returned at a later date. In addition, no lost signal was ever eliminated from the list of frequencies searched for on a daily basis.

Three additional females (FL 12, FL 14 and FL 16) and one male (ML 15) in the logged forest also shed their collars, but females FL 14 and FL 16 were recaptured and their collars re-deployed. An additional female in the unlogged forest (FP 6), was also able to shed her collar before sufficient data was collected, but she was also recaptured and re-collared.

All collars that were shed were retrieved. In no case did it appear as though the animal had been killed or injured rather than simply slipping the collar off. In most cases, the collar was located on the ground, with the exception of female FL 11, whose collar was found inside the hollow trunk of a fallen tree. In the cases of the male ML 15, the collar was found in association with some vine roots, which could have been used to aid in removing the collar.

The fact that so many animals were able to shed their collars is probably due to the relatively small difference in circumference between their head and neck (See Table 2-1). Based on reports of injury and death from collars being attached either too tightly or too loosely, great care was taken when fitting collars to reduce the risk of possible injury or death to the animal. Efforts to remove collars at the end of the study resulted in recapture and removal of collars from two individuals (MP 2 and FP 3). Both animals showed no sign of injury or irritation from the collar and no weight loss or external indications of decline in health.

Sufficient data for home range analysis was collected on six animals in each forest type: four males and two females in the unlogged forest and three males and three females in the logged forest. Although all animals were not radio-tracked concurrently, each was tracked for at least four months. Animals were relocated on average 74% of the time (62 - 97%) in the unlogged forest and 72% (range = 55 – 84%) in the logged forest (Table 2-2). There was no significant difference in rate of relocation between forest types ($t = 0.423$, $p = 0.683$). Animals that proved difficult to locate may have home ranges larger than reflected here.

Home Range Size

Table 2-9 shows home range sizes and means for all animals using all estimators selected. Figures 2-5 through 2-9 show home range polygons in the unlogged and logged study sites respectively. Mean overall home range was 135.3 ha (range = 69 - 329 ha) for 100% minimum convex polygon (MCP), 110.3 ha for 95% MCP (range = 56 - 284 ha), 144.7 ha for 95% harmonic mean (HM) (range = 68 – 446 ha), 208.1 ha for 95% Jennrich Turner ellipse (JTE) (range = 115 – 439 ha), and 148.8 ha for 95 % fixed kernel (FK) (range = 89 – 448 ha). Male ML 13 in the logged forest displayed an unusually large home range, which could be considered an outlier, but due to small sample size, it was retained in the analyses.

Mean home range size in the unlogged site was 105.2 ha (range = 69 - 139 ha) for 100% MCP, compared to 165.7 ha (range = 97 - 329 ha) in the logged site. Ninety five percent MCP range size in the unlogged forest was 88.5 ha (range = 56 - 111 ha) compared to 132.0 ha (range = 70 - 284 ha) in the logged forest. Using 95% HM, mean home range in the unlogged site was 109.5 ha (range = 68 - 151 ha) and 179.8 ha (range = 91 - 446 ha) in the logged site. Jennrich Turner ellipse (95%) was 163.2 ha (range = 115 - 234 ha) in the unlogged site and 253.0 ha (range = 171 - 439 ha) in the logged site. Finally, 95% FK home range size averaged 121.0 ha (range = 89 - 170 ha) in the unlogged site and 176.7 ha (range = 97 - 448 ha) in the logged forest.

In the unlogged forest among males, mean home range size was 110.3 ha (range 69 - 139 ha) using 100% MCP, 93 ha (range 56 - 111 ha) with 95% MCP, 117.8 ha (range = 68 - 151 ha) with 95% HM, 175.3 ha (range = 115 - 234 ha) with 95% JTE and 131.8 ha (range = 93 - 170 ha) with 95% FK. Among females in the same site, mean home range size was 95.0 (range = 92 - 98 ha) with 100% MCP, 79.5 ha (range = 78 - 81 ha) with 95% MCP, 93.0 ha (range 91-95 ha) with 95% HM, 139.0 ha (range = 136 - 142 ha) with 95% JTE and 99.5 ha (range = 89 - 110 ha) with 95% FK.

In the logged forest among males, mean home range size was 210.3 ha (range = 124 - 329 ha) with 100% MCP, 159.0 ha (range = 70 - 283 ha) with 95% MCP, 231.0 ha (range = 101 - 446 ha) with 95% HM, 317.3 ha (range = 171 - 439 ha) with 95% JTE and 240.3 ha (range = 97 - 448 ha) with 95% FK. Among females in the same site, mean home range size was 121.0 ha (range = 97 - 123 ha) with 100% MCP, 105.0 ha (range = 93 - 128 ha) with 95% MCP, 128.7 ha (range = 91 - 151 ha) with 95% HM, 188.7 ha (range = 172 - 199 ha) with 95% JTE and 113.0 ha (range = 96 - 134 ha) with 95% FK.

Table 2-10 shows the results of a two-way factorial ANOVA with forest type and gender as dependent variables. In no case was statistical significance attained and p values varied widely for different estimators. However, raw values were consistently smaller for females and for animals in the unlogged forest, which could indicate an effect of gender and/or selective logging on home range size. Small sample size and high variance within the sample may have contributed to the lack of significance.

Mean difference between a 100% MCP and 95% MCP is an indicator of the extent to which individuals exhibit forays beyond their normal range. For *V. tangalunga* the difference was 16% in the unlogged site (range = 6 – 20 %) and 21% in the logged site (range = 3 – 44 %). There was no statistically significant difference between the extent of range expansion between forest types ($t = 0.842$, $p = 0.216$).

Despite indications that minimum convex polygon tends to overestimate the area of utilization more than other techniques (Mykytka and Pelton, 1988; White and Garrott, 1990), in this study, 95% MCP resulted in smaller home range estimates than those from all other 95% estimators used. Mean home range sizes were 20% smaller when calculated with a 95 % MCP than those based on a 95% HM, 22% smaller than estimates using 95% FK and 47% smaller than estimates using 95% JTE. The home range estimator that gave the largest values was 95% JTE, resulting in home range estimates approximately twice the size of those based on 95% MCP.

Both MCP and JTE included areas in the unlogged forest that could not be used by the animals, such as portions of the Segama River, that resulted in overestimation of ranges for animals close to the river. Thus, some ranges in this study site may be smaller than reflected by the calculated values.

Density

Minimum density estimates indicate that the density of *V. tangalunga* in the unlogged forest is 1/0.46 km^2, compared to 1/1.07 km^2 in the logged forest. These value are based only on the six radio-collared individuals in each forest type using their combined home ranges estimated by 100% MCP divided by the number of individuals. There was no significant difference in density between sites (χ^2= 0.655, p = 0.418). Another means used to estimate density was to include all Malay civets captured and divide this into the total trap area (again estimated by 100% MCP). Using these values, the total density was 1/0.1 km^2 in the unlogged forest and 1/0.14 km^2 in the logged site (χ^2 = 0.681, p = 0.409). Finally, if only adults are considered in the above calculations, the density is 1/0.16 km^2 in the unlogged forest and 1/0.25 km^2 in the logged forest (χ^2 = 0.513, p = 0.474). Although the difference in density is not significant, the consistent trend in the above estimates support the conclusion that overall density is from 29% to 57% higher in the unlogged forest.

Home Range Overlap

There was extensive home range overlap in both study sites. Table 2-11 contains all mean overlap values. Mean overlap for both sites combined was 39.6% using 100% MCP (30.7% using 95% MCP, 34.0% using 95% HM, 44.4% using 95% JTE, and 35% using 95% FK). Mean overlap in the unlogged forest was 44.4%, versus 34.7 % in the logged site using 100 % MCP (45.7% versus 28.4% using 95% MCP, 39.8% versus 28.2% using 95% HM, 49.2% versus 39.6% using 95% JTE and 41.6% versus 28.4% using 95% FK). Table 2-12 shows results of a t-test comparing all overlap in the unlogged forest with that in the logged forest, and shows no significant difference in the degree of overlap between sites.

Appendix II shows home range overlap among individuals within the same gender for each study site. Overlap among males in the unlogged forest was 38.1% for 100% MCP, versus 36.1% for females, (33% versus 27.3% for 95% MCP, 28.9% versus 24.9% for 95% HM, 42.3% versus 36% for 95% JTE, and 32.1% versus 23.8% for 95% FK). Within this site, three males (MP 1, MP 2, MP 5) exhibited extensive overlap with the other males. One male (MP 7) showed little home range overlap with other males, however, his range was on the border of the study area, and may have overlapped extensively with home ranges of males not radio-collared. The two females in the unlogged forest exhibited only moderate overlap with one another. Table 2-13 shows the results of a t-test comparing home range overlap between males and females in the unlogged forest. No significant difference was detected between genders in this site.

In the selectively logged forest, mean overlap for males was 16.8% for 100% MCP versus 23.7% for females (see Table 2-11 for values based on remaining estimators). Within the logged forest, again, one male (ML 13) showed considerably less overlap, perhaps due to his position on the periphery of the study area. Two females in the logged forest overlapped extensively, while one female (FL 14) showed little overlap. Table 2-14 shows the results of a t-test comparing overlap between genders in the logged forest; again, no significant difference was detected. When data from both forest types was combined, and a t-test was run, there was also no significant difference detected in overlap between males compared to overlap between females (See Table 2-15).

Overlap between genders for both sites combined, averaged 44.8% for 100% MCP, while overlap within genders was 31.4% (41.4% versus 31.4% using 95% MCP, 38.8% versus 25.9%, for 95% HM, 47.5% versus 40.4% for 95% JTE, and, 40.3% versus 29.6% for 95% FK). Table 2-16 shows the results of a t-test comparing inter-gender overlap (combining data for males and females) between forest sites, and shows no significant difference. Finally, Table 2-17 shows results of a t-test comparing inter-gender home range overlap (between males and females) between forest sites. Again, there was no significant difference observed between sites. Thus, there is no difference in degree of overlap between males and females, nor is there a difference in overlap between logged and unlogged forest sites.

In order to detect areas of exclusive use, home range was calculated at 50% MCP 40% 30% 20% and 10% of data points. Even at 10% MCP home range, overlap was still extensive among some individuals in both forest types. In addition, home range overlap between individuals was evident when ranges were divided into seasonal ranges based on 100% MCP (Figures 2-10 and 2-11) as well as day and night ranges (Figures 2-12 and 2-13). Thus, there was no indication in this study that *V. tangalunga* actively exclude other individuals from the boundaries of their home range. However, animals may still actively avoid direct interactions in these areas of overlap. To test for this, analyses of dispersion of concurrent point locations were carried out (see section on Dynamic Interactions).

When home ranges were mapped using 100% MCP, there was a distinctive area of overlap for all animals in both the unlogged forest and logged forest (see Figures 2-5). In the unlogged forest, this coincided with one trap site approximately 700 m along the main west trail, near the center of the study area, where trap success was unusually high for civets. In the logged forest, the area of heavy overlap also corresponded with a trap site, but one that was less frequently visited. If these trap sites were a factor in the heavy overlap in these areas, and if they were viewed as a resource by the animals, it would indicate that key resources are not defended for exclusive use in either forest area.

Home Ranges During Wet and Dry Months

Data from six animals (three males and one female in the unlogged forest and two females in the logged forest) contained sufficient information for both wet and dry months to make comparisons of home ranges for both intervals. Table 2-18 shows wet and dry month home ranges and percent overlap, along with mean values based on ranges that contained sufficient numbers to reach an asymptote. Figure 2-10 shows both dry and wet month home ranges for each animal in the unlogged forest, and Figure 2-11 shows the same data in the selectively logged forest site.

Mean dry interval home range size in the unlogged forest based on a 100% MCP was 77 ha (range = 43 - 86 ha). In the logged forest it was 159.7 ha (range = 57 - 327 ha). Mean wet interval home range size in the unlogged forest was 75 ha (range = 42 - 103 ha). In the logged forest it was 110.5 ha (range = 86 - 135 ha). See table 2-18 for home range sizes based on other estimators.

When data from both sites were pooled, and a paired t-test was run, home ranges were not significantly larger for the cumulative wet months than for the dry months (Table 2-19). There was also no significant difference in home range size between forest type for either the cumulative dry months (Table 2-20) or the cumulative wet months (Table 2-21). Wet and dry month home ranges, based on pooled data for both sites, showed no significant difference in size between males and females (Tables 2-22 and 2-23, respectively). Finally, there was no significant difference in the extent of overlap of dry and wet month home ranges in the unlogged and the logged forest site (Table 2-24).

Diurnal Versus Nocturnal Home Ranges

Diurnal and nocturnal range areas and percent overlaps are shown in Table 2-25. Figure 2-12 shows both diurnal and nocturnal home ranges for each animal in the unlogged forest, and Figure 2-13 shows the same data in the selectively logged forest site. Sufficient data for a statistical comparison of diurnal versus nocturnal ranges were available from six animals; three males and one female in the unlogged forest and one male and one female in the logged forest. Due to small sample size, data from both forest types were combined to test for differences in range size from day to night.

Mean diurnal ranges for all animals based on a 100% MCP was 101.1 ha (range = 37 – 184 ha) while nocturnal ranges averaged 126.0 ha (range = 57 – 294 ha). In the unlogged forest, diurnal ranges averaged 85.8 ha (range = 37 – 134 ha), while nocturnal ranges averaged 69.7 ha (range = 57 – 88 ha). Overlap between these ranges was high, with a mean value of 97.3% (range = 94 – 100%). In the logged forest, mean diurnal range was 119.6 ha (range = 89 – 184 ha) and nocturnal ranges averaged 210.5 ha (range = 127 – 294 ha). Mean overlap was 89.0% (range = 87 – 91%). See Table 2-25 for values based on the other home range estimators.

A t-test comparing diurnal and nocturnal range size in both sites combined showed no significant difference (see Table 2-26). In order to test whether either diurnal or nocturnal ranges differed between sites, two separate t-tests were run; the first compared diurnal range size in the logged forest to those in the unlogged forest (Table 2-27), the other compared nocturnal range size between sites (Table 2-28). In both cases, there was no significant difference between forest sites, with the anomalous exception of a 95% JTE which showed a difference in the size of nocturnal ranges in the logged and unlogged forest (p = 0.035). Finally, a t-test was run to compare the amount of overlap between diurnal and nocturnal ranges in the unlogged forest versus that in the logged forest (Table 2-29). There was also no significant difference between forest sites in the extent that diurnal and nocturnal ranges overlapped, indicating that there is no perceptible shift in home range location.

Home Range Use

Figure 2-14 and 2-15 show habitat use clusters for all animals in the logged and the unlogged forest respectively. All animals had multiple clusters which were distributed throughout their home ranges (see Table 2-30). In the unlogged forest, the mean number of clusters for males was 6.8 (range = 4 - 9) and for females, it was 4.5 (4 and 6). In the logged forest, mean number of clusters for males was 4.0 (range = 3 -5) and for females was 5.3 (range = 4 - 6). The mean percentage of points in clusters was 77.9 (range = 65 to 95) and mean total area was 14.5 ha (range = 4.2 ha).

Based on a paired χ^2 test, there was no significant difference in the frequency that clusters overlapped among females ($p = 0.655$), or males ($p = 0.727$) or the number that overlapped with roads and/or trails ($p = 0.631$).

DISCUSSION

Trap Success

Trap success for *V. tangalunga* as well as for civets as a group was higher in the unlogged forest despite a larger trapping area, higher number of trap sites, and longer trapping period in the logged forest. Among civets, a greater diversity of species were captured in the logged forest [masked palm civets (*Paguma larvata*) and binturong (*Arctictis binturong*)]. Because both species were more arboreal, the higher trap success may have resulted from disruption of the canopy after logging (Howlett, in prep.), which increased their terrestrial movement and their encounter rate with ground traps. This could also explain the higher encounter rates for *A. binturong* in the logged forest observed by Heydon and Bulloh (1996).

Trap success for *V. tangalunga* was high compared to rates reported for other carnivores. Arthur *et al.* (1989) reported a trap success of one new capture for every 207.5 trap nights for adult fishers (*Martes pennanti*). Ray (1997) reported a trap success of one long-nosed mongoose (*Herpestes naso*) for every 464 trap nights. Maddock (1993) reported a trap success ranging from one capture for every 3,663 trap nights for the banded mongoose (*Mungos mungo*) to one capture every 333 trap nights for large grey mongoose (*H. ichneumon*) and the genet (*Genetta tigrina*). Thus, among carnivores, the Malay civet is a readily captured and/or abundant species, particularly in comparison to the other terrestrial carnivores present in the study area, which rarely entered traps.

In this study, new captures usually occurred in the first week of trapping; when traps were situated near a home range border, area of overlap, or frequently used trail, several civets would be captured at that site in rapid succession. This was similar to the experience of Rowe-Rowe and Green (1981) who captured black-backed jackals (*Canis mesomelas*) with the highest success in the first four nights when traps were s*et al*ong trails near fresh signs. In this study, *V. tangalunga* captured in a trap opened for longer than ten days often proved to be repeat captures or transient animals which quickly moved out of the immediate area. Thus, an appropriate protocol for future trapping regimes would entail limiting the trap effort to ten days or less before relocating the trap. In addition, pre-baiting is not a necessary step in a successful trapping effort for this species.

Recapture rates among *V. tangalunga* were high, indicating that *V.*

tangalunga do not appear to develop an aversion to traps, or become trap-shy. The higher recapture rate for males in the unlogged forest was similar to the findings of King (1975), who found that the recapture ratio for male to female weasels (*Mustela nivalis*) was 83%. She proposed that females learn more quickly to avoid traps or are less willing to risk capture than males.

Trap success from the logged forest showed a bias towards females and data from the unlogged forest was biased towards males. These data could represent a true sex bias in either or both forest types, or could simply represent a bias in trapability. Studies of carnivores indicate that the sex ratio may favor males (e.g. Weckwerth and Hawley, 1962, King, 1975, Packer and Pusey, 1987, Conforti, 1996), which was the case in the unlogged forest. Some of the reported male trap bias among mustelids appears to be a function of sexual dimorphism of home range size and overlap (Buskirk and Lindstedt, 1989). Because three of the four male home ranges were larger than the two female ranges in this site, it is possible that among *V. tangalunga* there is a sexual dimorphism of home range size, which was not detected statistically due to low sample size. This would not however explain the lower trap success among males in the logged forest.

Trap data from the logged forest were in concordance with trapping data of viverrids on the south coast of Natal, where captures of five species was biased in favor of females (Maddock, 1993). If the bias towards females in the logged forest was a trapping bias, it could be an indication that food resources are more limiting in this site, because among solitary carnivores, it is often the case that females are more limited by food than males (Sandell, 1989), thus females may be more prone to enter a trap under conditions of resource limitation. Although data from pit traps indicated that prey levels are similar, scat analysis indicated that fruit resources may be lower in the selectively logged forest. The trap bias could also represent a true sex bias of fewer males in the logged forest. The higher observed rate of road mortality among males seems to support this conclusion.

Density

Density estimates were based on several values, including total number of *V. tangalunga* captured, adults captured, and only animals for which home range estimates were generated. Although not statistically significant, density based on each set of values were consistently higher in the unlogged forest. These values were not directly comparable to estimates developed by Heydon and Bulloh (1996) since their values are based on transect data and were pooled for all civet species. However, if sighting data for *V. tangalunga* are extracted and density estimates are generated from these (1/0.082 km^2 in the unlogged forest, 1/0.32 km^2 in the logged forest), they are considerably higher in both forest types than values based on this study. Density estimates from this study represent an accurate minimum density based on a known number of individuals inhabiting a unit area, as well as a known number trapped in the same area. It is possible that Heydon and Bulloh's values may be somewhat inflated if count data from the same transect, walked at the same time interval on different occasions were used in density estimates, because these may contain repeated sightings of the same individuals.

Despite the above mentioned disparity in density estimates for *V. tangalunga*, there does appear to be some decline in density subsequent to selective logging. This would be consistent with data from studies of other species in logged forests elsewhere, that have similar diets to the Malay civet. Among primates in a logged forest in Kenya, an observed decrease in population density was attributed to a reduction in plant food availability (Struhsaker, 1973). The reduction in numbers of hornbills in a Bornean rainforest was also attributed to a decline in fig abundance after selective logging (Leighton and Leighton, 1983). Heydon (1994) also observed a decline in population density of insectivorous tarsiers (*Tarsius bancanus)* in the same selectively logged forest studied here. Because *V. tangalunga* feeds extensively on fruit and insects (see section on Diet), any decline in density may also be the result of a similar decline in food resources.

Data generated by Heydon and Bulloh (1996) indicate a significantly larger difference in density of civets between sites. This result may have been affected by the fact that some logged forest observations were made in areas logged much more recently than the logged area examined in this study. These areas, logged two and five years previous to the study, may have had dramatically lower densities of civets than the areas disturbed eight and 12 years previously. Therefore, combining data from these areas could have led to biased results. In addition, sightings are often considered more difficult in a logged forest (Skorupa, 1987), so although their sighting distance and effective transect width were not significantly different between forest sites, it is still possible that a higher proportion of individuals in the logged forest went undetected.

Reproductive Activity

Though not adequately explored, limited data from this study indicate that there may be a seasonal element to reproduction in *V. tangalunga.* Despite some overlap, there was a separate time interval when each age group was captured. Juveniles appeared more common in months from March through June. During the same interval there were numerous young adults, indicating that they may mature over the course of one year. Sub-adults were captured during months from September through April.

In the absence of documentation on the growth rate and gestation of *V. tangalunga,* data from related species were used in an effort to estimate the breeding season. The congeneric large Indian civet (*V. zibetha*) is considered independent at six months, the African civet (*Civettictis civetta*), within the same subfamily, is independent at four months (Fowler, 1986). The gestation period of *A. trivirgata* is reported to be 45 days (Medway, 1969; Lekagul and McNeely, 1977) and 60 days for *P. hermaphroditus* (Hayssen, *et al.*, 1993). These values would place the breeding season in November, around the start of the longer rainy interval (Marsh, 1995).

P. larvata is reported to have a breeding season that corresponds with the longer of two rainy seasons (Lekagul and McNeely 1977). The African genet

(*Genetta genetta*) and the black-tipped mongoose (*Herpestes sanguineus*) also have breeding seasons during each of the rainy seasons (Taylor, 1969). O'Connell (1989) observed a distinct reproductive peak with the onset of the rainy season among small neotropical mammals. In Indonesian Borneo, and a young *Cynogale bennettii* was found in May (Hayssen *et al.,* 1993), within the same time frame as young captures in this study, which suggests that other species of civet may breed at the same time of year.

The lack of distinct seasonal patterns in this forest makes it unclear what the possible advantages of having a breeding season would be. There are no reported indications that food resources vary seasonally and because the Malay civet is not a specialized feeder, it can presumably switch diet if necessary. Perhaps high rainfall make foraging logistically difficult and decrease visibility and hearing, which would make juvenile animals more vulnerable to predation than they would during a drier interval. Because rainfall tends to be low during April, (Marsh, 1995), and there was low rainfall from June through September of 1996 and from March through May of 1997, it is possible that the higher encounter rate of juveniles during this interval corresponded with a higher rate of survival for young that become independent during this time of year. The indications of breeding seasonality observed could also be a phylogenetic effect. Because related species live in more seasonal habitats, a common ancestor may have had a distinct seasonal breeding pattern. What is observed here may be a vestige of that breeding seasonality.

Morphology

Adult *V. tangalunga* captured, had morphological parameters that fell within the ranges reported for this species in Borneo, although data on weight in the literature varies. Body measures recorded here agreed with those reported by Payne *et al.* (1985), Harrison (1964) and Medway (1969). However, weights measured here were lighter than others reported. Harrison reported the weight of a single *V. tangalunga* as 10 kg, which is two to three times larger than those observed here and highly anomalous. The single weight reported by Medway (4.7 kg) was 0.4 kg larger than the heaviest animal captured in this study, and may have been a member of a mainland population, which would normally be larger than individuals from an island.

There is some sexual dimorphism detected in this study for *V. tangalunga*, but only in head and neck circumference and hind foot length, wherein males are larger than females. Mean values for all parameters, except canine length, were smaller for females. Sexual dimorphism has not been previously reported in the literature for this species, although Conforti (1996) reported sexual dimorphism for the small Indian civet (*Viverricula indica*) and *P. hermaphroditus* but no dimorphism was detected for the large Indian civet (*V. zibetha*). African palm civets (*N. binotata*) clearly exhibit sexual dimorphism (Charles-Dominique, 1978).

Daily weight gain for two male sub-adult *V. tangalunga* ranged from seven to 14 g, and was comparable to increase values for other similar sized carnivores. Juvenile leopard cats (*Felis bengalensis*) and European wild cats (*Felis sylvestris*) have a daily weight gain of 11 g, domestic cats and sand cats (*Felis margarita*) have a daily increase of 12 and 13 g, respectively (Kitchner, 1993). The rate of development appears to vary widely among many species of civet. Goldman (1982) reported that captive *P. hermaphroditus* reach adult body size at about 18 months, while among *P. larvata,* adult body size is reached at eight months. Louwman (1970) reported that young banded palm civets (*Hemigalus derbyanus*) are almost the same size as adults after only six months.

There was no significant correlation between home range size and body mass. Such a correlation is usually associated with limited resources and territoriality (Salsbury and Armitage, 1994). Because *V. tangalunga* does not appear to be highly territorial in this area (See section on Dynamic Interactions), this could account for the lack of correlation. In addition, Gompper and Gittleman (1991) found that only the carnivorous bobcat (*Felis rufus*) showed a positive and significant correlation between home range size and body mass, while the omnivorous coyote (*Canis latrans*) and the frugivorous-folivorous black bear (*Ursus americanus*) showed no correlation. Because *V. tangalunga* is trophically more similar to the latter two, the lack of correlation fit with their results. This implies that home range size is less dependent upon the metabolic needs of an omnivore/frugivore than a strict carnivore.

Home Range Estimators

Of the five home range estimators used in this study, 95% MCP yielded the most conservative results in terms of range size. The largest home ranges were those calculated with the Jennrich Turner Ellipse that yielded values which were almost twice as large. A utilization plot of estimated home range size versus percentage of points, revealed that for most ranges, the greatest reduction in range size occurred for the first 5% reduction in points. This indicates that use of 95% for home range estimators here is a biologically meaningful representation of the real area used by the animals.

Home Range Size

There was no statistically significant difference detected in home range size between sites in this study, although mean values were larger among animals in the selectively logged forest. Because there is often a positive correlation between home range size and resource availability among solitary carnivores (Sandell, 1989), the lack of difference in home range size between sites may be a function of no difference in resource availability for *V. tangalunga* between sites.

Home range size was larger than that previously reported for *V. tangalunga* as well as for other similarly sized civets in closed tropical forests. Macdonald and Wise (1979) radio-tracked a single male *V. tangalunga* in a secondary forest in Sarawak for two months and recorded a home range of 50 - 70 ha (100% MCP). The smaller size of this range could be due to the shorter duration of the study. Home range for a single female *P. hermaphroditus*, radio-tracked in Royal Chitwan National Park for 23 days was 1.2 ha and remained in close proximity to a single tree site where it was known to sleep (Dhungel and Edge, 1985). A male of the same species tracked over the course of seven months in the same area had a home range of 21 ha (Joshi *et al.*, 1995). In a relatively dry tropical forest in Gabon, a three year radio-tracking study of *N. binotata* revealed home ranges of 29 - 50 ha for females, and 34 and 153 ha for males (Charles-Dominique, 1978). The smaller home ranges for these species could be attributed in part to their more arboreal behavior, or to differences in resource availability and distribution in their habitats. Because *V. tangalunga* is generally considered terrestrial (Payne *et al.* 1985) and is not an agile climber (pers. obs.) the larger home range size observed for this species may be a function of decreased access to resources in strata above ground level.

Home ranges of civets in a dry tropical forest in Thailand were substantially larger than ranges observed here. A male *V. zibetha* had a home range of 12 km^2, while a male *V. malaccensis* had a range of 3.1 km^2 and a female *P. larvata* ranged over 3.7 km^2 (Rabinowitz, 1991a). These larger ranges could be attributable to the fact that the above species are found in a drier and more open habitat composed of a mosaic of forest types that may have fewer resources. In addition, this area is characterized by a marked seasonality and associated fires, which were shown to dramatically affect home ranges.

There was no significant difference in home range size between genders, although mean values were larger for males in both forest sites. Among some solitary carnivores, home ranges for females are determined by the availability and distribution of food and are always minimized, whereas male home ranges are determined by the availability of females and tend to be maximized (Sandell 1989).

Sex-specific differences in home range size have been reported for other civet species (e. g. Joshi, *et al.* 1995; Fuller *et al.*, 1990; Charles-Dominique, 1978) Sandell (1989) predicted that home range size for male carnivores would be 1.22 ± 0.10 times larger than female range size. When tested on existing data from 21 species, he found that observed male range size was 2.47 ± 1.06 times larger than females. In this study, three of the four calculated home ranges for males in the unlogged forest were larger than those of the females in that site, and two of the three home ranges in the selectively logged forest were larger than those of the females. In the unlogged site, mean range size for males was slightly less than the predicted 1.22 times larger than females. In the selectively logged site, mean range size was somewhat more. If male home range size is maximized, there may be fewer males in the logged forest. The observed lower trap success for males in this site and higher rate of road traffic mortality (see section on Movement) would support this conclusion.

Home Range Overlap

There was extensive home range overlap among individuals in both forest types. Joshi *et al.* (1995) reported a similar although less extensive degree of overlap among five common palm civets radio-tracked in Royal Chitwan National Park in Nepal, where overlap was highest when resources were scarce and clumped, and decreased when resources were most abundant. This led Joshi *et al.* to conclude that the lack of territoriality was due in part to the fact that food resources were either too abundant to require defense, or too clumped to be efficiently defended against numerous competitors. Because the Malay civet is a dietary generalist, it may be either unnecessary or difficult for it to actively defend food resources.

In this study, males showed more home range overlap than females. Although not significant, overlap within genders was less than overlap between, indicating that individuals may be less tolerant of individuals of the same gender. Results of Dynamic Interactions (p. 161) support this conclusion.

Exclusive home ranges will only be observed among solitary carnivores when food resources are evenly distributed and stable (Sandell, 1989). If food abundance and distribution varies in space and time, which is likely to occur in a rainforest environment, solitary carnivores can be expected to exhibit a system of overlapping home ranges.

Rabinowitz (1986) attributed home range overlap among adjacent male jaguars (*Panthera onca*) in part to the presence of roads and trails, which were used extensively by resident animals who may consider them a limited resource. The central location of roads and trails in the home ranges of all Malay civets, indicates that these may also be important to this species. Frequent sightings and high density of scat from *V. tangalunga* on roads support this conclusion. Male Malay civets appeared to use roads and trails with greater frequency than females and may have exhibited boundary marking with feces on a road (see section on Movement). Thus, some home range overlap observed in this study may have been a function of the presence of roads and trails.

Dry Versus Wet Month Home Ranges

Home range size or location did not appear to be dramatically affected by rainfall. This was probably the result of a lack of clear seasonal patterns in this area during the study and in general for this region. Although rainfall varied on a weekly and monthly basis, there was no single, well defined, dry or wet season. The wind dispersed Dipterocarpaceae that dominate these forests flower at supra-annual intervals of two to 21 years, with a few trees flowering sporadically during intervening periods (Appanah, 1993), apparently triggered by dry conditions rather than high rainfall (Toy *et al.,* 1992). In such aseasonal forests, figs are abundant and fruit continually throughout the year (Lambert and Marshal, 1991). These aseasonal patterns could explain the lack of response to rainfall variability observed for *V. tangalunga*. Changes in home range size of civets during intervals of high and low rainfall in Huai Kha Khaeng were correlated with differences in abundance of food resources, particularly fruit (Rabinowitz, 1991a). The lack of similar range shifts in this study may be due to a lack of seasonal changes in food abundance.

Rabinowitz (1991a) also noted that civets in a seasonally dry forest mosaic in Thailand showed large shifts in home range center during times of heavy flooding. Conversely, in a dry seasonal habitat in Venezuela, Sunquist *et al.* (1989) noted a decrease in home range size during the wet season among crab-eating foxes (*Credocyon thois*) due to flooding of low lying portions of their home range. The lack of any observed flooding within the Malay civet's home ranges in this study could in part explain the lack of any observed shifts in home range size.

Diurnal Versus Nocturnal Ranges

The fact that day ranges were not significantly different from night ranges in both forest types suggests that animals in both forests utilized most of their home range for both foraging and resting. Data from continual follows revealed that foraging and resting sites were often spatially separated, but both appeared to be distributed evenly throughout their home range. On a smaller scale, the habitat is a complex assemblage of diverse elements of apparent importance to *V. tangalunga* such as tree falls and vine tangles for day-beds (see section on Day-Beds), and roads and trails for travel and fecal deposition (see Movement section). Yet, on a macroscopic scale, the habitat was relative homogeneous and may contribute to the lack of distinct segregation of day and night ranges (or foraging and resting sites).

Home Range Use

Cluster analysis revealed that in both forest types, areas of high use were numerous and evenly distributed. The majority showed overlap or abutment with those of other individuals, the frequency of which did not differ between genders. A high number of clusters also intersected or abutted trails and/or roads; frequency of occurrence between site also did not differ. This observed parity in range use intensity in the selectively logged forest indicates that the mosaic pattern of disturbance in the logged forest (Howlett, in prep.) has no apparent effect on range use of *V. tangalunga.*

Among animals in the logged forest, roads were centrally located in all areas of high use, indicating their importance to *V. tangalunga.* In the unlogged forest, main trails were centrally located in core areas. Among large felids, roads and trails are used extensively and are considered a limited resource (Schaller, 1967; Sunquist, 1981; Rabinowitz: 1986). During this study, most scat collection and direct sightings of *V. tangalunga* and other terrestrial carnivores occurred along roads and trails (pers. obs.). Thus, roads and trails appear to be significant habitat features and important resources for *V. tangalunga.*

In the unlogged forest, there was an association of the Segama River with clusters, which may also be an important resource particularly for foraging (see section on diet).

Table 2-1. Body measurements of all *Viverra tangalunga* captured in an unlogged and a logged forest in Sabah, East Malaysia between 12/2/95 and 5/1/97

Study animal	Capture date	Sex	Age category	Weight [1]	Head-body length [2]	Tail length	Upper thorax girth	Right hind foot	Height at shoulder	Head circumf.	Neck circumf.	Right ear length	Upper right canine length	Physical condition
UNLOGGED FOREST														
MP 1	12/2/95	M	Adult	3.55	72.0	34.2	32.1	11.0	29.0	22.9	22.0	3.2	1.00	Very good
MP 2	12/10/95	M	Adult	3.65	66.0	31.5	31.5	10.6	25.0	19.5	19.0	3.4	1.20	Good; old cut on left ear
MP 2	5/15/97	M	Adult	4.30	66.0	32.5	34.0	10.7	27.0	21.5	20.0	4.1	1.00	Good; fat
FP 3	1/5/96	F	Adult	3.61	64.0	32.0	30.0	9.8	27.0	20.0	19.0	3.7	0.97	Good
FP 3	5/4/96	F	Adult	3.52	63.5	32.0	30.0	9.8	27.0	20.0	18.8	3.7	0.97	Good
MP 4	2/2/96	M	Sub-adult	2.67	60.3	34.1	27.0	10.3	25.1	19.0	17.2	3.5	0.80	Good; thin, cut above right eye from trap
MP 4	3/24/96	M	Young-adult	3.36	65.5	34.0	29.9	10.3	26.5	19.7	19.4	3.7	1.01	Fair; thin no sign of cut from prior capture
MP 4	4/25/96	M	Adult	3.65	65.4	34.4	31.1	10.3	27.0	20.3	19.8	3.9	1.02	Good
MP 5	2/5/96	M	Adult	3.45	62.4	34.3	30.5	10.6	26.5	20.5	20.5	3.6	0.90	Good
FP 6	3/4/96	F	Adult	3.03	62.0	31.0	28.0	10.5	26.5	19.6	18.0	3.6	1.10	Good; thin
FP 6	9/28/96	F	Adult	3.55	62.0	31.0	32.0	10.5	26.5	21.0	19.5	3.6	1.00	Good; fat, possibly pregnant
MP 7	3/6/96	M	Adult	3.60	65.0	32.1	29.9	10.9	26.5	21.0	20.1	4.0	1.01	Good; right pinnae gone, lip cut on trap
MP 7	12/10/96	M	Adult	4.10	67.0	31.6	35.2	9.8	26.1	22.0	21.0	3.9	1.00	Very good; scar on abdomen
MP 8	10/2/96	M	Old	3.90	59.0	30.0	33.0	10.0	26.0	22.0	20.0	3.7	0.60	Very good; some molars worn flat
MP 9	10/3/96	M	Sub-adult	2.45	57.0	31.0	26.8	10.0	23.9	18.4	17.3	3.7	0.70	Very good; fat, upper gum brown
MP 10	5/8/97	M	Sub-adult	2.80	61.0	33.0	28.0	10.2	22.0	18.5	17.0	3.6	0.80	Good

1 = Weight in kg.
2 = All measurements in cm.

Study animal	Capture date	Sex	Age category	Weight [1]	Head-body length [2]	Tail length	Upper thorax girth	Right hind foot	Height at shoulder	Head circumf.	Neck circumf.	Right ear length	Upper right canine length	Physical condition
LOGGED FOREST														
FL 9	2/23/96	F	Adult	3.12	62.8	31.0	29.2	9.4	24.0	20.8	18.1	3.6	1.1	Good
ML 10	3/2/96	M	Old	3.75	77.3	32.9	31.4	10.6	25.0	21.0	20.8	3.3	0.7	Very good; 3 worn canines, nose scrape
FL 11	5/4/96	F	Adult	3.73	65.7	32.9	31.2	10.5	25.4	20.7	19.8	3.5	1.1	Good
FL 12	6/2/96	F	Adult	3.55	64.0	30.0	31.0	9.5	25.0	21.0	19.5	3.7	1.0	Good; front pads worn on trap
ML 13	7/1/96	M	Young-adult	3.25	62.0	32.5	29.9	10.4	26.4	22.0	20.9	3.8	1.2	Good; scrape on chin, left canines chipped
ML 13	9/4/96	M	Adult	3.70	64.0	32.5	30.6	10.5	27.0	22.2	20.6	3.7	1.2	Good; 3 chipped canines, from last capture?
FL 14	7/1/96	F	Adult	3.52	65.0	34.5	31.3	10.0	27.0	20.0	18.9	3.5	0.6	Good; missing 1st upper incisor
FL 14	9/27/96	F	Adult	3.75	67.0	33.0	32.5	10.0	28.0	20.0	18.5	3.5	1.0	Good; old cut at base of tail above anus
ML 15	9/3/96	M	Adult	3.75	67.0	33.0	32.2	10.1	25.0	22.5	20.1	3.1	0.9	Good; small scrape on nose
FL 16	9/11/96	F	Young-adult	3.79	64.0	34.0	32.0	10.3	27.0	21.0	19.0	3.9	1.0	Fair; cut on gum from trap, no blood
FL 16	5/1/96	F	Adult	3.95	65.0	33.0	33.0	10.3	27.0	21.0	18.5	3.9	1.0	Very good; claws worn down from trap
FL 18	9/25/96	F	Sub-adult	2.62	62.0	29.0	27.5	10.3	21.5	19.0	18.0	4.0	0.6	Very good
FL 17	12/17/96	F	Old	3.55	64.0	31.6	29.7	9.8	24.0	19.8	18.6	3.3	0.6	Good
BOTH SITES														
Mean adult males				3.79	66.7	32.8	32.2	10.4	26.5	21.7	20.5	3.6	0.9	
Mean adult females				3.60	64.3	31.8	31.1	10.0	25.9	20.5	18.9	3.6	1.0	

1 = Weight in kg.
2 = All measurements in cm.

Table 2-2. Radio-tracking summary for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia between 12/95 and 08/97

Radio-collared animal	Date of first capture	Date collared	Date signal lost	Days collared	Times sought	Times located	Independent locations selected	Times located in trap	Locations from follows	Independent locations from follows	All locations	Total independent locations	# locations to reach independence
UNLOGGED FOREST													
MP 1*	12/1/95	12/1/95	11/18/96	350	134	99	87	6	23	6	110	93	18
MP 2*	12/10/95	12/15/95	12/14/96	362	134	81	69	10	36	5	105	74	10
FP 3*	1/5/96	1/5/96	3/3/97	410	147	83	78	8	50	20	128	98	45
MP 4	2/5/96	2/3/96	2/13/96	8	7	3	-	2	-	-	3	3	-
MP 5*	2/2/96	4/24/96	11/9/96	198	75	47	45	3	-	-	45	45	14
FP 6*	3/4/96	3/4/96 ^{1}	3/13/97	257	66	42	49	2	-	-	49	49	37
MP 7*	3/6/96	12/9/96	7/18/97	197	71	64	64	5	153	15	217	79	43
MP 8	10/2/96	10/1/96	2/4/97	63	41	17	-	2	-	-	17	17	-
LOGGED FOREST													
FL 9*	2/23/96	2/22/96	12/8/96	288	89	67	65	8	-	-	65	65	20
ML 10*	3/2/96	3/1/96	1/14/97	318	87	44	43	4	17	3	60	46	24
FL 11	5/4/96	6/12/96	9/1/96 ^{4}	80	29	17	-	1	-	-	17	17	-
FL 12	6/12/96	6/12/96	9/10/96 ^{5}	128	47	12	-	1	-	-	12	12	-
ML 13*	6/30/96	9/3/96	8/8/97	338	125	78	62	5	77	13	139	75	15
FL 14*	6/30/96	6/30/96 ^{2}	8/28/97	352	129	85	75	6	124	14	202	89	15
ML 15*	9/3/96	9/3/96	3/30/97	208	63	43	41	3	65	11	106	52	30
FL 16*	9/11/96	9/11/96 ^{3}	5/13/97	138	49	38	38	3	94	12	132	50	38
ML 17	12/16/96	12/16/96	3/4/97	77	20	1	-	1	-	-	1	1	-

* = Study animals
1 = Collar shed 6/30/96, replaced 9/28/96
2 = Collar shed 7/19/96, replaced 9/27/96
3 = Collar shed 1/14/97, replaced 4/31/97
4, 5 = Date collar was retrieved

Table 2-3. Summary of time to reach statistical independence for radio-tracking data from *Viverra tangalunga* in Sabah, East Malaysia

Study animal	# consecutive locations	Time to independence[1]	Closest time to independence[2]
UNLOGGED FOREST			
MP 1	22	2.5	
MP 2	36	5.0	
FP 3 - 1	11	0.5	
FP 3 - 2	39		2.0
MP 7 - 1	27	3.0	
MP 7 - 2	45		6.3
MP 7 - 3	45		10.0
MP 7 - 4	36		8.3
LOGGED FOREST			
ML 10	18		3.3
ML 13 - 1	30	1.7	
ML 13 - 2	44		10.4
FL 14 - 1	45	9.5	
FL 14 - 2	48	6.5	
FL 14 - 3	38	3.0	
ML 15 - 1	20		4.2
ML 15 - 2	13		11.7
ML 15 - 3	32	4.5	
FL 16 - 1	46		3.7
FL 16 - 2	49		4.3

1 = Time in hours

2 = Did not reach full independence

Table 2-4. Trap success in an unlogged and a logged forest in Sabah, East Malaysia from 12/1/95 to 4/26/97

Species	Capture date	Sex	Age	Physical condition
UNLOGGED FOREST				
Malay Civet (*Viverra tangalunga*)	12/2/95	M	Adult	Very good
Malay Civet (*V. tangalunga*)	12/10/95	M	Adult	Good
Malay Civet (*V. tangalunga*)	1/5/96	F	Adult	Good
Malay Civet (*V. tangalunga*)	2/2/96	M	Sub-adult	Good
Malay Civet (*V. tangalunga*)	2/5/96	M	Adult	Good
Malay Civet (*V. tangalunga*)	3/4/96	F	Young-adult	Good
Malay Civet (*V. tangalunga*)	3/6/96	M	Adult	Good
Crested Fireback (*Copyschus malabaricus*)	4/10/96	M	Adult	Good
Short Tailed Mongoose (*Herpestes brachyurus*)	4/26/96	U	Adult	Good
Malay Civet (*V. tangalunga*)	5/8/96	M	Sub-adult	Good
Malay Civet (*V. tangalunga*)	5/30/96	U	Juvenile	Good
Malay Civet (*V. tangalunga*)	10/2/96	M	Old	Very good, high tooth wear
Burmese Brown Tortoise (*Manouria emys*)	11/25/96	U	Adult	Good
LOGGED FOREST				
Malay Civet (*V. tangalunga*)	2/23/96	F	Adult	Good
Malay Civet (*V. tangalunga*)	3/2/96	M	Old	Very good, three worn canines
Malay Civet (*V. tangalunga*)	3/30/96	M	Juvenile	Good
White-rumped Shama (*Lophura erthropthalma*)	5/16/96	F	Adult	Good
Short Tailed Mongoose (*H. brachyurus*)	4/12/96	U	Adult	Good
Malay Civet (*V. tangalunga*)	5/4/96	F	Adult	Good

Species	Capture date	Sex	Age	Physical condition
Tufted Ground Squirrel (*Rheitosciurus macrotis*)	5/31/96	U	Adult	Good
Malay Civet (*V. tangalunga*)	5/31/96	U	Juvenile	Good
Malay Civet (*V. tangalunga*)	6/2/96	F	Adult	Good, front claws worn from trap
Malay Badger (*Myadus javanensis)*	6/16/96	U	Juvenile	Fair
Malay Civet (*V. tangalunga*)	6/26/96	F	Young-adult	Fair
Malay Civet (*V. tangalunga*)	7/1/96	F	Adult	Good
Malay Civet (*V. tangalunga*)	9/3/96	M	Adult	Very good, scrape on nose
Masked Palm Civet (*Paguma larvata*)	9/4/96	M	Old	Good, three chipped canines
Short Tailed Mongoose (*H. brachyurus*)	9/9/96	U	Adult	Good
Malay Civet (*V. tangalunga*)	9/11/96	F	Adult	Fair, fresh cut on lower lip
Binturong (*Arctictis binturong*)	9/24/96	U	Adult	Good
Malay Civet (*V. tangalung*)	9/25/96	F	Sub-adult	Very good
Burmese Brown Tortiose (*M. emys*)	10/31/96	U	Adult	Good
Masked Palm Civet (*P. larvata)*	10/31/96	F	Old	Fair
Burmese Brown Tortoise (*M. emys*)	12/11/96	U	Adult	Good
Short Tailed Mongoose (*H. brachyurus*)	12/15/96	U	Adult	Good
Malay Civet (*V. tangalunga*)	12/17/96	F	Old	Good
Malay Civet (*V. tangalunga*)	4/13/97	U	Sub-adult	Good
Malay Civet (*V. tangalunga*)	4/25/97	U	Juvenile	Good

Table 2-5. X^2 test of observed versus expected trap success in an unlogged versus a logged forest in Sabah, East Malaysia

	Observed		Expected		p
Category	**Unlogged**	**Logged**	**Unlogged**	**Logged**	
All animals	12	25	18.5	18.5	0.0326
Carnivores	10	21	15.5	15.5	0.0482
Viverrids	10	20	15.0	15.0	0.0679
Civets	9	14	11.5	11.5	0.2971
Viverra tangalunga	9	14	11.5	11.5	0.2971

Table 2-6. Results of t-test comparing morphometry between sexes in *Viverra tangalunga* in Sabah, East Malaysia

Parameter	Gender	Mean	Variance	t	df	p
Weight[1]	Male	3.794	0.071	1.562	15	0.139
	Female	3.601	0.057			
Head-body length[2]	Male	66.678	28.484	1.203	15	0.247
	Female	64.313	2.506			
Tail length	Male	32.822	2.033	1.611	15	0.128
	Female	31.812	1.241			
Girth	Male	32.233	2.522	1.581	15	0.135
	Female	31.087	1.888			
Hind foot length	Male	10.400	0.145	2.171	15	0.046
	Female	10.000	0.182			
Height at shoulder	Male	26.510	1.488	0.988	15	0.339
	Female	25.860	2.208			
Head circumfrence	Male	21.660	0.810	3.100	15	0.007
	Female	20.540	0.270			
Neck circumfrence	Male	20.530	0.468	5.060	15	0.001
	Female	18.940	0.368			
Ear length	Male	3.610	0.118	0.082	15	0.936
	Female	3.600	0.031			

1 = Weight in kg.
2 = All other measurements in cm.

Table 2-7. Results of regression analysis of body weight and home range size for *Viverra tangalunga* in Sabah, East Malaysia

	100% MCP	95% MCP	95% HM	95% JTE	95% FK
Males (n = 7)					
r^2	0.0390	0.0030	0.0120	0.0710	0.0420
p	0.6710	0.9020	0.8110	0.5630	0.6580
Females (n = 5)					
r^2	0.4000	0.0860	0.4920	0.0001	0.1180
p	0.2520	0.6320	0.1870	0.9910	0.5710

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel

Table 2-8. Growth rate of two male *Viverra tangalunga* in Sabah, East Malaysia

Male MP 5	First capture	Second capture	Increase	% Increase	Average daily increase	Third capture	Increase	% Increase	Average daily increase
Days from first capture	0	50				81.00			
Weight	2.67	3.36	0.69	20.54%	0.0138	3.65	0.29	7.95%	0.0094
Head-body length	60.30	65.50	5.20	7.94%	0.1040	65.50	0.00	0.00%	0.0000
Tail	34.10	34.20	0.10	0.29%	0.0002	34.40	0.20	0.58%	0.0004
Girth	27.00	29.90	2.90	9.70%	0.0580	31.10	1.20	3.86%	0.0387
Hind foot	10.30	10.30	0.00	0.00%	0.0000	10.30	0.00	0.00%	0.0000
Height at shoulder	25.10	26.50	1.40	5.27%	0.0280	27.00	0.50	1.85%	0.0161
Head circumference	19.00	19.70	0.70	3.55%	0.0140	20.30	0.60	2.96%	0.0194
Neck circumference	17.20	19.40	2.20	11.34%	0.0440	19.80	0.40	2.02%	0.0129
Ear length	3.50	3.70	0.20	5.00%	0.0004	3.90	0.20	5.00%	0.0004
Canine length	0.80	1.00	0.20	20.00%	0.0040	1.02	0.02	1.96%	0.0006

Male ML 13	Second capture[1]	Third capture	Increase	% Increase	Average daily increase
Days from first capture	92	157			
Weight	3.25	3.70	0.45	12.60%	0.0069
Head-body length	62.00	64.00	2.00	3.13%	0.0308
Tail	32.50	32.50	0.00	0.00%	0.0000
Girth	29.90	30.60	0.70	2.29%	0.0108
Hind foot	10.40	10.50	0.10	0.10%	0.0002
Height at shoulder	26.40	27.00	0.60	2.22%	0.0092
Head circumference	22.00	22.20	0.20	0.90%	0.0031

1 = No measurements taken at first capture due to juvenile status of animal.

Weight in kg.

All other measurements in cm.

Table 2-9. Home range size for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Study animal	100% MCP	95% MCP	95% HM	95% JTE	95% FK
UNLOGGED FOREST					
MP 1	139	111	144	234	159
MP 2	100	94	108	153	105
FP 3	98	81	95	136	89
MP 5	69	56	68	115	93
FP 6	92	78	91	142	110
MP 7	133	111	151	199	170
Mean	**105.2**	**88.5**	**109.5**	**163.2**	**121.0**
Mean females	**95.0**	**79.5**	**93.0**	**139.0**	**99.5**
Mean males	**110.3**	**93.0**	**117.8**	**175.3**	**131.8**
LOGGED FOREST					
FL 9	97	94	91	199	96
ML 10	178	124	146	342	176
ML 13	329	283	446	439	448
FL 14	143	128	151	195	109
ML15	124	70	101	171	97
FL 16	123	93	144	172	134
Mean	**165.7**	**132.0**	**179.8**	**253.0**	**176.7**
Mean females	**121.0**	**105.0**	**128.7**	**188.7**	**113.0**
Mean males	**210.3**	**159.0**	**231.0**	**317.3**	**240.3**
BOTH FORESTS					
Mean	**135.4**	**110.3**	**144.7**	**208.1**	**148.8**
Mean females	**110.6**	**94.8**	**114.4**	**168.8**	**107.6**
Mean males	**153.1**	**121.3**	**166.3**	**236.1**	**178.3**

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
Ranges in ha.

Table 2-10. Results of two way ANOVA comparing home range size in an unlogged and a logged forest for male and female *Viverra tangalunga* in Sabah, East Malaysia

Home range estimator	Source of variation	SS	df	F-ratio	p
100% MCP	Gender	7764.945	1	2.311	0.167
	Habitat	11234.622	1	3.344	0.105
	Interaction	3825.555	1	1.139	0.317
95% MCP	Gender	3305.490	1	0.964	0.355
	Habitat	6031.764	1	1.759	0.221
	Interaction	1167.899	1	0.341	0.576
95% HM	Gender	11262.840	1	1.170	0.311
	Habitat	15628.026	1	1.623	0.238
	Interaction	4243.080	1	0.441	0.525
95% JTE	Gender	19142.020	1	3.381	0.103
	Habitat	25911.080	1	4.577	0.065
	Interaction	6042.970	1	1.067	0.332
95% FK	Gender	17958.574	1	1.967	0.198
	Habitat	10519.562	1	1.152	0.314
	Interaction	6405.000	1	0.702	0.427

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel.
SS = Sum of Squares

Table 2-11. Mean percent home range overlap for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

	100% MCP	95% MCP	95% HM	95% JTE	95% FK
UNLOGGED FOREST					
Mean overall	44.4	45.7	39.8	49.2	41.6
Mean male	38.1	41.4	35.0	44.7	37.5
Mean female	36.1	30.5	24.1	41.9	24.7
Mean among	50.2	50.9	45.4	54.5	46.7
Mean within	37.8	39.8	33.5	44.3	35.6
LOGGED FOREST					
Mean overall	34.7	28.4	28.2	39.6	28.4
Mean male	16.8	16.3	16.8	37.6	21.4
Mean female	23.7	26.8	25.2	34.0	23.7
Mean among	40.0	33.0	32.9	42.1	34.2
Mean within	25.6	21.5	16.3	35.8	22.5
BOTH SITES					
Mean overall	39.6	30.7	34.0	44.4	35.0
Mean male	29.4	33.0	28.9	42.3	32.1
Mean female	26.8	27.3	24.9	36.0	23.8
Mean among	44.8	41.4	38.8	47.5	40.3
Mean within	32.0	31.4	25.9	40.4	29.6

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
Home ranges in ha.

Table 2-12. Results of t-test comparing home range overlap between *Viverra tangalunga* in an unlogged versus a logged forest in Sabah, East Malaysia

Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	0.500	0.1414	1.372	30	0.176
	Logged	0.377	0.0961			
95% MCP	Unlogged	0.533	0.1870	2.125	30	0.038
	Logged	0.316	0.1253			
95% HM	Unlogged	0.448	0.1414	1.314	30	0.194
	Logged	0.319	0.1505			
95% JTE	Unlogged	0.553	0.1150	1.047	30	0.300
	Logged	0.453	0.1540			
95% FK	Unlogged	0.463	0.1230	1.582	30	0.119
	Logged	0.316	0.1340			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All percent data arc-sine transformed

Table 2-13. Results of t-test comparing home range overlap between male versus female *Viverra tangalunga* in an unlogged forest in Sabah, East Malaysia

Home range estimator	Gender	Mean	Variance	t	df	p
100% MCP	Male	0.443	0.2162	0.217	12	0.832
	Female	0.369	0.0004			
95% MCP	Male	0.508	0.2905	0.504	12	0.624
	Female	0.309	0.0001			
95% HM	Male	0.403	0.1823	0.510	12	0.619
	Female	0.243	0.0001			
95% JTE	Male	0.413	0.0590	0.038	12	0.971
	Female	0.407	0.0004			
95% FK	Male	0.425	0.1600	0.600	12	0.559
	Female	0.249	0.0014			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All percent data arc-sine transformed

Table 2-14. Results of t-test comparing home range overlap between male versus female *Viverra tangalunga* in a logged forest in Sabah, East Malaysia

Home range estimator	Gender	Mean	Variance	t	df	p
100% MCP	Male	0.310	0.0493	0.447	10	0.664
	Female	0.248	0.0676			
95% MCP	Male	0.167	0.0350	0.811	10	0.440
	Female	0.284	0.0890			
95% HM	Male	0.180	0.0357	0.577	10	0.581
	Female	0.274	0.1218			
95% JTE	Male	0.399	0.0702	0.169	10	0.869
	Female	0.369	0.1149			
95% FK	Male	0.221	0.0445	0.213	10	0.836
	Female	0.256	0.1211			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All percent data arc-sine transformed

Table 2-15. Results of t-test comparing home range overlap of *Viverra tangalunga* between males versus females in Sabah, East Malaysia

Home range estimator	Gender	Mean	Variance	t	df	p
100% MCP	Male	0.399	0.158	0.795	24	0.434
	Female	0.278	0.052			
95% MCP	Male	0.394	0.226	0.587	24	0.437
	Female	0.289	0.064			
95% HM	Male	0.328	0.140	0.416	24	0.681
	Female	0.266	0.087			
95% JTE	Male	0.476	0.130	0.629	24	0.536
	Female	0.385	0.083			
95% FK	Male	0.357	0.126	0.714	24	0.482
	Female	0.254	0.086			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All percent data arc-sine transformed

Table 2-16. Results of t-test comparing intra-gender home range overlap between *Viverra tangalunga* in an unlogged versus a logged forest in Sabah, East Malaysia

Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	0.433	0.184	1.106	24	0.280
	Logged	0.279	0.054			
95% MCP	Unlogged	0.480	0.251	1.598	24	0.123
	Logged	0.225	0.060			
95% HM	Unlogged	0.380	0.158	1.126	24	0.271
	Logged	0.227	0.074			
95% JTE	Unlogged	0.503	0.141	0.892	24	0.381
	Logged	0.384	0.085			
95% FK	Unlogged	0.400	0.139	1.236	24	0.228
	Logged	0.238	0.076			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All percent data arc-sine transformed

Table 2-17. Results of t-test comparing inter-gender home range overlap among *Viverra tangalunga* in an unlogged versus a logged forest in Sabah, East Malaysia

Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	0.558	0.106	1.000	32	0.325
	Logged	0.443	0.117			
95% MCP	Unlogged	0.579	0.141	1.510	32	0.141
	Logged	0.376	0.166			
95% HM	Unlogged	0.508	0.129	0.757	32	0.455
	Logged	0.404	0.190			
95% JTE	Unlogged	0.596	0.096	0.718	32	0.478
	Logged	0.500	0.203			
95% FK	Unlogged	0.518	0.110	1.151	32	0.258
	Logged	0.369	0.173			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All percent data arc-sine transformed

Table 2-18. Home ranges in wet and dry months for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Study animal	# Data Points		100% Min. Convex Polygon			95% Min. Convex Polygon			95% Harmonic Mean			95% Jennrich Turner Ellipse			95% Fixed Kernel		
	Dry month	Wet month	Dry month	Wet month	Percent overlap	Dry month	Wet month	Percent overlap	Dry month	Wet month	Percent overlap	Dry month	Wet month	Percent overlap	Dry month	Wet month	Percent overlap
UNLOGGED FOREST																	
MP 1	40*	40*	86	103	80	83	92	79	76	108	87	199	248	92	110	125	86
MP 2	35*	30*	66	71	69	60	66	70	53	47	61	118	153	80	73	74	69
FP 3	45*	39*	70	84	89	57	63	78	71	79	83	132	132	80	71	105	89
MP 5	20*	19*	43	42	66	35	37	75	32	23	53	105	114	75	61	83	85
FP 6	11	31	33	76	88	19	70	94	17	68	99	96	149	87	74	92	86
MP 7	62*	11	120	25	77	108	15	99	133	3	100	197	83	86	157	25	100
Mean			77.0	75.0	76.0	68.6	64.5	75.5	73.0	64.3	71.0	150.2	161.8	81.8	94.4	96.8	82.3
Mean males			78.8	72.0	71.7	71.5	65.0	74.7	73.5	59.3	67.0	154.8	171.7	82.3	100.3	94.0	80.0
Female			70	84	89	57	63	78	71	79	83	132	132	80	71	105	89
LOGGED FOREST																	
FL 9	28*	29*	57	86	94	56	82	93	52	75	80	129	214	83	97	106	75
ML 10	20	22	100	143	69	95	95	72	50	77	54	289	365	90	148	182	81
ML 13	49*	7	327	28	100	284	28	98	391	9	100	446	129	75	412	54	100
FL 14	64*	15*	95	135	97	69	102	93	128	15	80	124	397	100	64	163	92
ML 15	20	23	40	110	77	39	58	76	26	82	93	102	229	100	58	116	96
FL 16	29	15	118	44	93	84	30	93	130	32	100	187	124	88	168	69	100
Mean			159.7	110.5	95.5	136.3	92.0	93.0	190.3	45.0	80.0	233.0	305.5	91.5	191.0	134.5	83.5
Male			327.0	-	-	284.0	-	-	391.0	-	-	446.0	-	-	412.0	-	-
Mean females			76.0	110.5	95.5	62.5	92.0	93.0	90.0	45.0	80.0	126.5	305.5	91.5	80.5	134.5	83.5

* = Contain sufficient number of points to reach asymptote.

Used in statistical analyses only if both categories contain sufficient points.

All home ranges in ha.

Table 2-19. Results of t-test comparing home range size for *Viverra tangalunga* in dry and wet months in Sabah, East Malaysia

Home range estimator	Interval	Mean	Variance	df	t	p
100% MCP	Dry	69.50	357.70	10	1.165	0.277
	Wet	86.83	970.17			
95% MCP	Dry	60.00	252.01	10	1.186	0.267
	Wet	73.66	545.06			
95% HM	Dry	68.66	1089.47	10	0.545	0.598
	Wet	57.83	1284.97			
95% JTE	Dry	134.50	1089.90	10	1.675	0.145
	Wet	209.67	10992.66			
95% FK	Dry	79.33	386.67	10	1.960	0.084
	Wet	109.33	1019.46			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All home ranges in ha.

Table 2-20. Results of t-test comparing dry month home range size for *Viverra tangalunga* between an unlogged and a logged forest in Sabah, East Malaysia.

Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	66.25	314.92	0.552	4	0.611
	Logged	76.00	722.00			
95% MCP	Unlogged	58.75	385.57	0.246	4	0.818
	Logged	62.50	84.50			
95% HM	Unlogged	58.00	398.00	1.157	4	0.312
	Logged	90.00	2888.00			
95% JTE	Unlogged	138.50	1748.33	0.382	4	0.722
	Logged	126.50	12.50			
95% FK	Unlogged	78.75	461.58	0.092	4	0.931
	Logged	80.50	544.50			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All home ranges in ha.

Table 2-21. Results of t-test comparing wet month home range size for *Viverra tangalunga* between an unlogged and a logged forest in Sabah, East Malaysia.

Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	75.00	656.67	1.456	4	0.219
	Logged	110.50	1200.50			
95% MCP	Unlogged	64.50	505.67	1.533	4	0.200
	Logged	92.00	200.00			
95% HM	Unlogged	64.25	1376.92	0.577	4	0.595
	Logged	45.00	1800.00			
95% JTE	Unlogged	161.75	3560.25	2.005	4	0.116
	Logged	305.50	304.50			
95% FK	Unlogged	96.75	524.25	1.542	4	0.198
	Logged	134.50	1624.50			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All home ranges in ha.

Table 2-22. Results of t-test comparing home range size between male and female *Viverra tangalunga* in wet months in Sabah, East Malaysia

Home range estimator	Gender	Mean	Variance	t	df	p
100% MCP	Male	72.0	928.7	1.223	4	0.288
	Female	101.7	834.3			
95% MCP	Male	65.0	757.3	0.890	4	0.424
	Female	82.3	380.5			
95% HM	Male	59.3	1920.4	0.092	4	0.931
	Female	56.3	1285.4			
95% JTE	Male	171.7	4750.4	0.865	4	0.436
	Female	247.7	18406.4			
95% FK	Male	94.0	757.7	1.237	4	0.284
	Female	124.7	1077.7			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All home ranges in ha.

Table 2-23. Results of t-test comparing home range size between male and female *Viverra tangalunga* in dry months in Sabah, East Malaysia

Home range estimator	Gender	Mean	Variance	t	df	p
100% MCP	Male	128.4	13121.4	0.791	6	0.459
	Female	74.0	373.0			
95% MCP	Male	113.4	9817.7	0.873	6	0.416
	Female	61.7	44.3			
95% HM	Male	137.0	21583.4	0.598	6	0.572
	Female	83.7	1564.4			
95% JTE	Male	213.0	18857.6	1.034	6	0.341
	Female	128.3	14.5			
95% FK	Male	162.6	20852.0	0.987	6	0.362
	Female	77.3	305.9			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All home ranges in ha.

2-24. Results of t-test comparing overlap of dry and wet month ranges for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Home range estimator	Interval	Mean	Variance	df	t	p
100% MCP	Dry	0.877	0.030	4	3.965	0.008
	Wet	1.274	0.005			
95% MCP	Dry	0.968	0.019	4	3.269	0.023
	Wet	1.194	0.000			
95% HM	Dry	0.812	0.058	4	0.951	0.206
	Wet	0.927	0.000			
95% JTE	Dry	0.857	0.004	4	1.405	0.197
	Wet	1.275	0.175			
95% FK	Dry	0.977	0.022	4	0.173	0.445
	Wet	1.008	0.051			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All percent data arcsine transformed.

Table 2-25. Day and night home ranges for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

	# Independent Points		100% Minimum Convex Polygon			95% Minimum Convex Polygon			95% Harmonic Mean			95% Jennrich Turner Ellipse			95% Fixed Kernel		
UNLOGGED FOREST	Day locations	Night locations	Day range	Night range	Percent overlap	Day range	Night range	Percent overlap	Day range	Night range	Percent overlap	Day range	Night range	Percent overlap	Day range	Night range	Percent overlap
MP 1	57*	24*	134	88	100	110	77	98	126	60	97	245	221	93	168	124	94
MP 2	44*	21*	90	57	94	85	55	94	95	39	100	159	147	88	116	74	98
FP 3	50*	34	61	87	94	53	71	91	62	77	76	106	174	97	66	107	81
MP 5	25*	14*	37	64	98	37	52	84	29	34	55	83	174	98	49	95	97
FP 6	30	12	86	56	96	71	50	90	80	13	96	140	166	96	112	88	93
MP 7	49*	25	107	106	87	98	85	85	115	107	90	202	206	92	150	171	89
Mean			85.8	69.7	97.3	76.6	61.3	92.0	85.4	44.3	84.0	159.0	180.7	93.0	109.8	97.7	96.3
Mean male			92.0	69.7	97.3	82.5	61.3	92.0	91.3	44.3	84.0	172.3	180.7	93.0	120.8	97.7	96.3
Mean female			61.0	-	-	53.0	-	-	62.0	-	-	106.0	-	-	66.0	-	-
LOGGED FOREST																	
FL 9	43*	16	88	59	94	88	57	96	81	36	81	197	60	84	102	63	78
ML 10	27*	15	120	96	63	115	59	89	89	34	11	292	259	65	193	99	65
ML 13	28*	30*	184	294	87	175	263	79	216	376	99	363	352	73	302	457	96
FL 14	57*	25*	89	127	91	67	127	93	90	87	72	145	287	94	72	117	85
ML 15	27	17	105	56	89	57	44	91	103	30	99	177	132	71	129	75	95
FL 16	28	18	117	61	94	91	34	99	115	57	94	183	150	88	141	94	95
Mean			120.3	210.5	89	111.3	195.0	86	119.0	231.5	86	249.3	319.5	84	167.3	287.0	91
Mean male			152.0	294.0	87	145.0	263.0	79	152.5	376.0	99	327.5	352.0	73	247.5	457.0	96
Mean female			88.5	127.0	91	77.5	127.0	93	85.5	87.0	72	171.0	287.0	94	87.0	117.0	85
BOTH SITES																	
Mean			101.1	126.0	94	92.0	114.8	90	100.3	119.2	85	199.1	236.2	89	135.3	173.4	94
Mean male			112.0	125.8	95	103.3	111.8	89	111.7	127.3	88	224.0	223.5	88	163.0	187.5	96
Mean female			79.3	127.0	91	69.3	127.0	93	77.7	87.0	72	149.3	287.0	94	80.0	117.0	85

* = Contain sufficient number of points to reach asymptote.
Used in statistical analyses only if both categories contained sufficient points.
All home ranges in ha.

Table 2-26. Results of t-test comparing day and night ranges for *Viverra tangalunga* in Sabah, East Malaysia

Home range estimator	Interval	Mean	Variance	t	df	p
100% MCP	Day	106.00	3049.25	0.382	8	0.715
	Night	126.00	9556.35			
95% MCP	Day	94.80	2743.51	0.437	8	0.676
	Night	114.80	7788.47			
95% HM	Day	111.20	4685.74	0.112	8	0.915
	Night	119.20	20981.19			
95% JTE	Day	199.00	11714.14	0.607	8	0.562
	Night	236.20	7000.90			
95% FK	Day	141.40	10140.53	0.670	8	0.716
	Night	173.40	25531.82			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel

Table 2-27. Results of t-test comparing day ranges of *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	87.00	2369.12	0.978	3	0.400
	Logged	136.50	4521.05			
95% MCP	Unlogged	77.33	1379.25	0.894	3	0.437
	Logged	121.00	5854.70			
95% HM	Unlogged	83.33	2449.88	1.166	3	0.328
	Logged	153.00	7975.21			
95% JTE	Unlogged	162.33	6521.44	0.905	3	0.432
	Logged	254.00	23783.81			
95% FK	Unlogged	111.00	3552.82	0.787	3	0.489
	Logged	187.00	26535.63			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel

Table 2-28. Results of t-test comparing night ranges of *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	69.67	256.11	2.221	3	0.113
	Logged	210.50	13904.45			
95% MCP	Unlogged	61.33	190.01	2.586	3	0.081
	Logged	195.00	9313.39			
95% HM	Unlogged	44.33	186.09	1.730	3	0.182
	Logged	231.50	41566.23			
95% JTE	Unlogged	108.67	1421.90	3.757	3	0.033
	Logged	319.50	2080.13			
95% FK	Unlogged	97.67	614.04	1.478	3	0.236
	Logged	287.00	57857.81			

MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
All home ranges in ha.

Table 2-29. Results of t-test comparing overlap of day and night ranges for *Viverra tangalung* in Sabah, East Malaysia

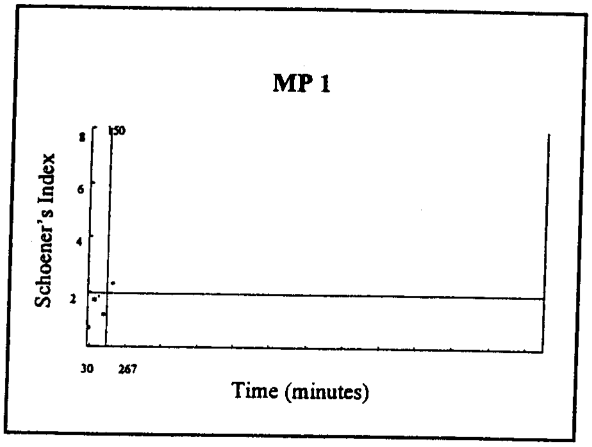
Home range estimator	Site	Mean	Variance	t	df	p
100% MCP	Unlogged	1.388	0.031	0.299	3.000	0.784
	Logged	1.099	0.004			
95% MCP	Unlogged	1.197	0.035	2.150	3.000	0.121
	Logged	1.053	0.040			
95% HM	Unlogged	1.159	0.265	0.096	3.000	0.930
	Logged	1.117	0.195			
95% JTE	Unlogged	1.214	0.022	1.033	3.000	0.377
	Logged	1.020	0.082			
95% FK	Unlogged	1.306	0.006	1.336	3.000	0.274
	Logged	1.151	0.037			

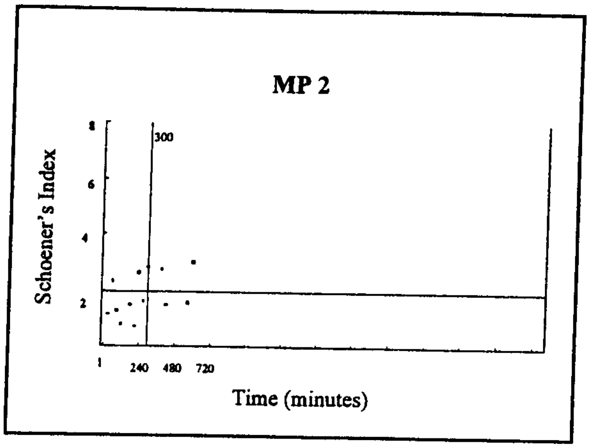
MCP = Minimum Convex Polygon
HM = Harmonic Mean
JTE = Jennrich Turner Ellipse
FK = Fixed Kernel
Percent data arc-sine transformed.

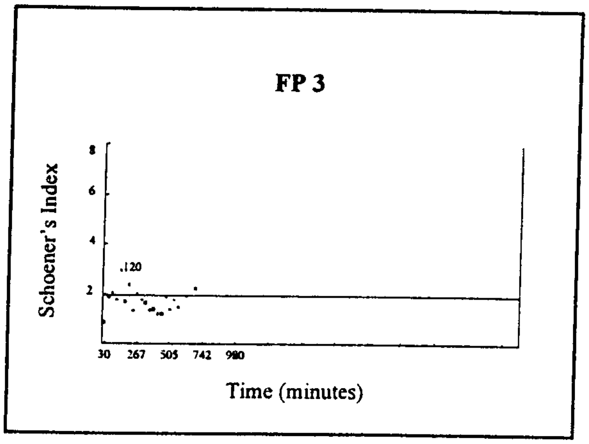
Table 2-30. Cluster analysis for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Study animal	# of clusters	% of total points	Area in cluster	# intersecting trail	# intersecting road	# intersecting other clusters	# males overlapped	# females overlapped
UNLOGGED FOREST								
MP 1	9	80	16.0	4	n/a	11	2	2
MP 2	6	85	17.2	4	n/a	8	2	1
FP 3	6	65	11.6	4	n/a	8	3	0
MP 5	4	80	5.6	1	n/a	8	2	2
FP 6	3	75	11.1	2	n/a	6	3	0
MP 7	8	80	14.0	3	n/a	4	1	1
Mean	**6.0**	**77.5**	**12.6**	**3.0**	n/a	**7.5**	**2.2**	**1.0**
Mean females	**4.5**	**70.0**	**11.4**	**3.0**	n/a	**7.0**	**3.0**	**0.0**
Mean males	**6.8**	**81.3**	**13.2**	**3.0**	n/a	**7.8**	**1.8**	**1.5**
LOGGED FOREST								
FL 9	6	80	12.3	0	5	6	3	1
ML 10	5	95	35.2	2	4	8	1	2
ML 13	4	65	17.9	0	1	0	0	0
FL 14	6	65	4.2	2	3	1	1	0
ML15	3	80	12.2	1	3	6	1	2
FL 16	4	85	16.8	1	4	9	2	1
Mean	**4.7**	**78.3**	**16.4**	**1.0**	**3.3**	**5.0**	**1.3**	**1.0**
Mean females	**5.3**	**76.7**	**11.1**	**1.0**	**4.0**	**5.3**	**2.0**	**0.7**
Mean males	**4.0**	**80.0**	**21.8**	**1.0**	**2.7**	**4.7**	**0.7**	**1.3**

Figure 2-1. Time to reach statistical independence of point locations for *Viverra tangalunga* in an unlogged forest in Sabah, East Malaysia.


MP 1
Schoener's Index
8
6
4
2
150
30
267
Time (minutes)


MP 2
Schoener's Index
8
6
4
2
300
1
240
480
720
Time (minutes)


FP 3
Schoener's Index
8
6
4
2
120
30
267
505
742
980
Time (minutes)

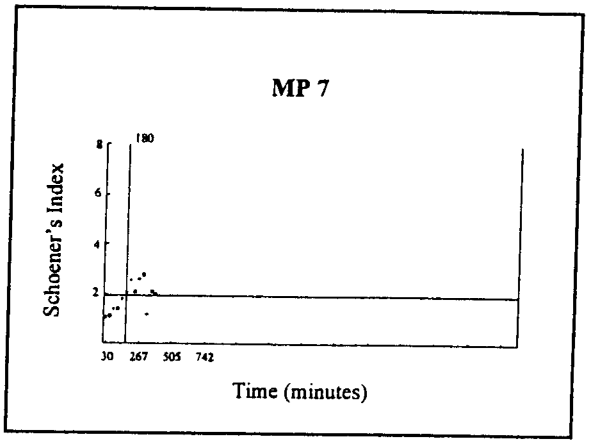
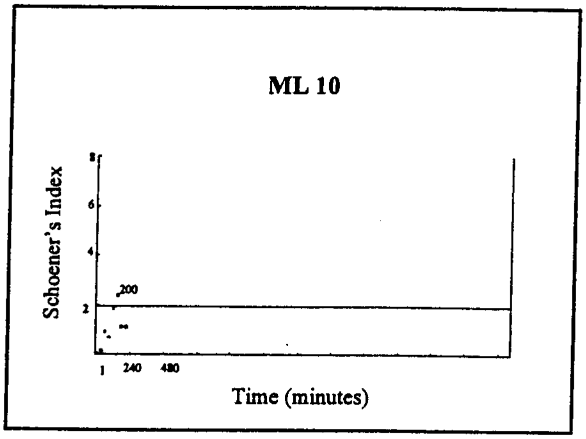
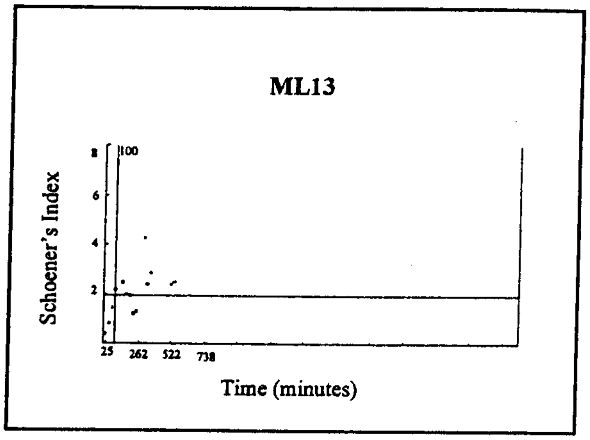
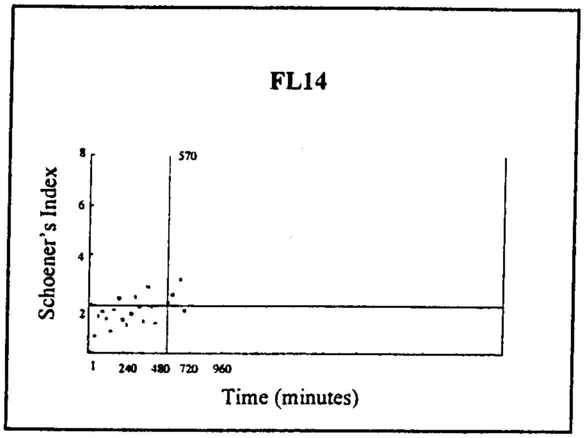
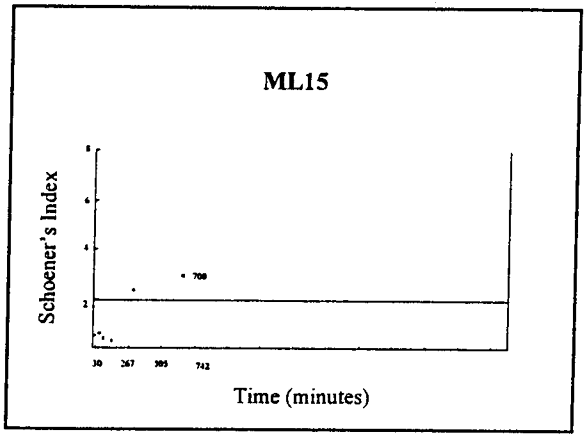

MP 7
Schoener's Index
8
6
4
2
180
30
267
505
742
Time (minutes)

Figure 2-2. Time to reach statistical independence of point locations for *Viverra tangalunga* in a logged forest in Sabah, East Malaysia.


ML 10


ML13


FL14


ML15

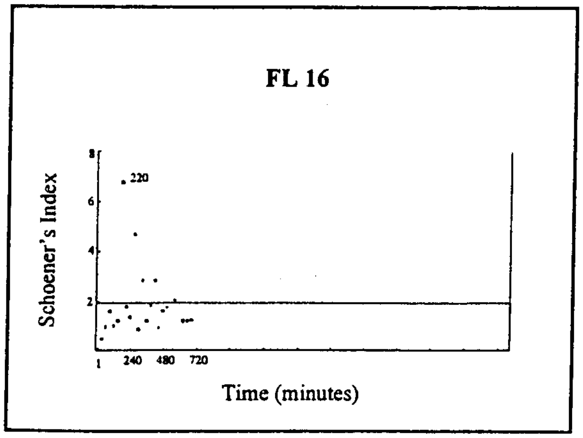
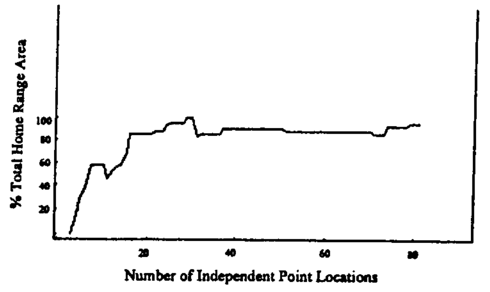
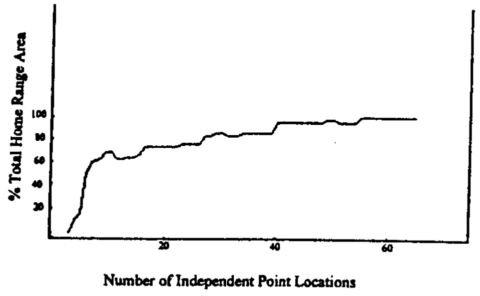

FL 16

Figure 2-3. Home range asymptote for *Viverra tangalunga* in an unlogged forest in Sabah, East Malaysia, using independent data points based on 95% Minimum Convex Polygon estimators. Asymptote is reached when there are sufficient data points to accurately assess home range size. Fluctuations of range size after asymptote result from changes in the distribution of data points as new points are added. This affects which points are selected as part of a 95% polygon.

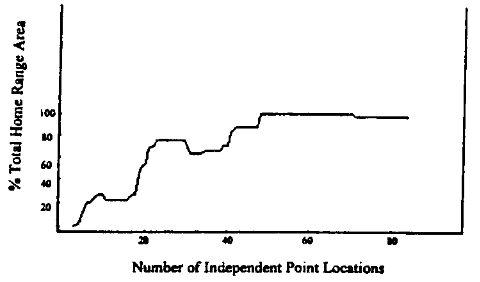
MP 1



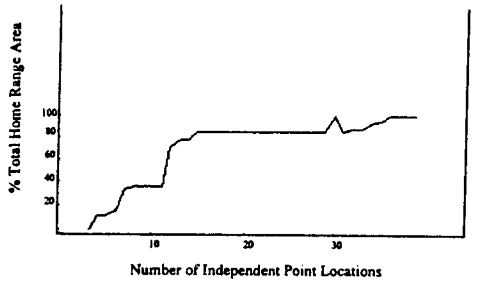
MP 2



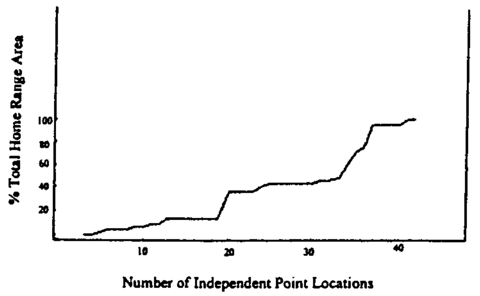
FP 3



MP 5



FP 6



MP 7

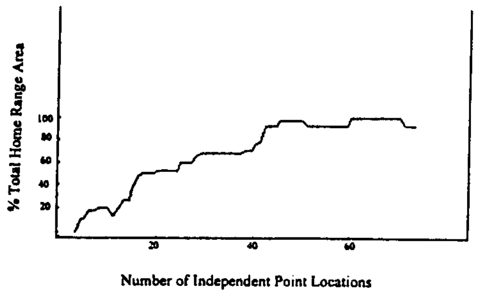
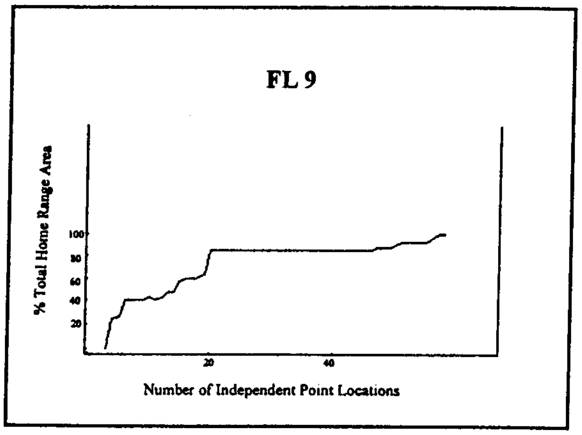
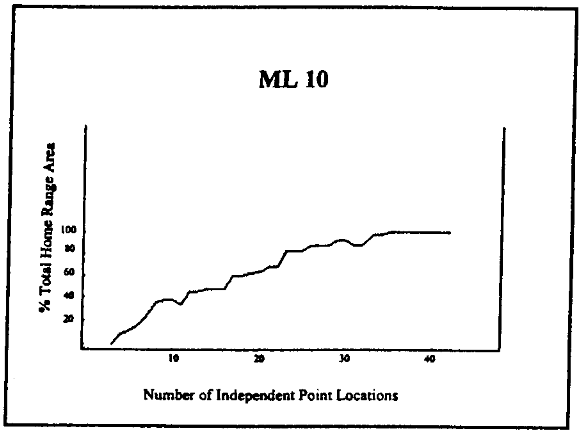
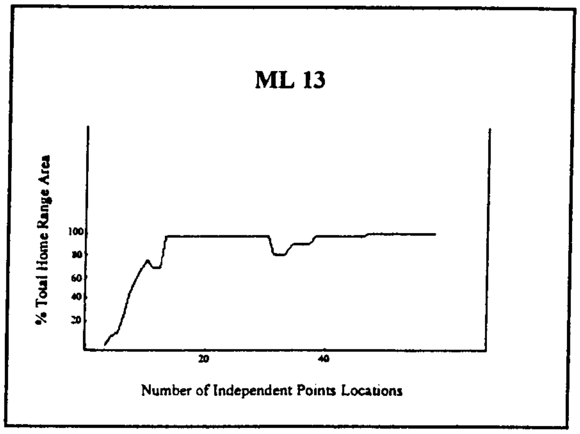
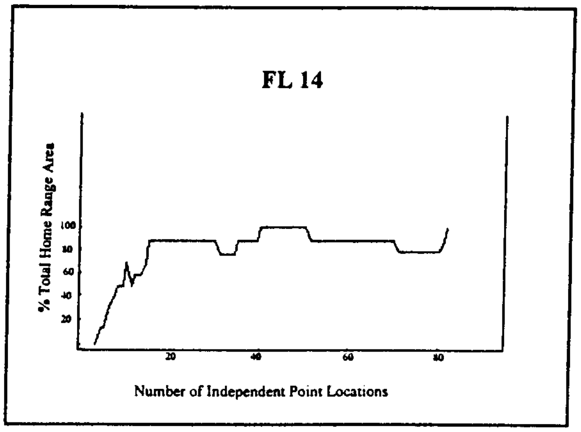


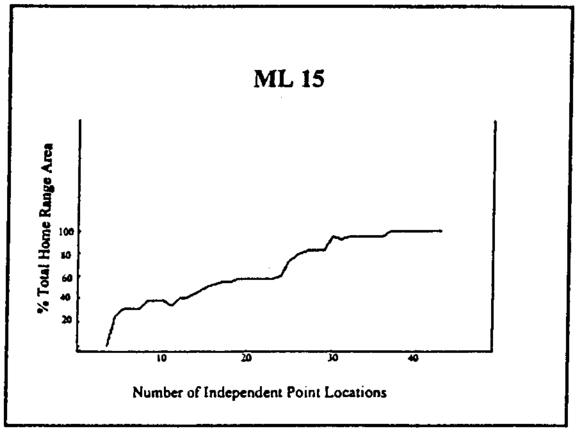
Figure 2-4. Home range asymptote for *Viverra tangalunga* in a logged forest in Sabah, East Malaysia, using independent data points based on 95% Minimum Convex Polygon estimators. Asymptote is reached when there are sufficient data points to accurately assess home range size. Fluctuations of range size after asymptote result from changes in the distribution of data points as new points are added. This affects which points are selected as part of a 95% polygon.


FL 9
% Total Home Range Area
100
80
60
40
20
20
40
Number of Independent Point Locations


ML 10
% Total Home Range Area
100
80
60
40
20
10
20
30
40
Number of Independent Point Locations


ML 13
% Total Home Range Area
100
80
60
40
20
20
40
Number of Independent Points Locations


FL 14
% Total Home Range Area
100
80
60
40
20
20
40
60
80
Number of Independent Point Locations


ML 15
% Total Home Range Area
100
80
60
40
20
10
20
30
40
Number of Independent Point Locations

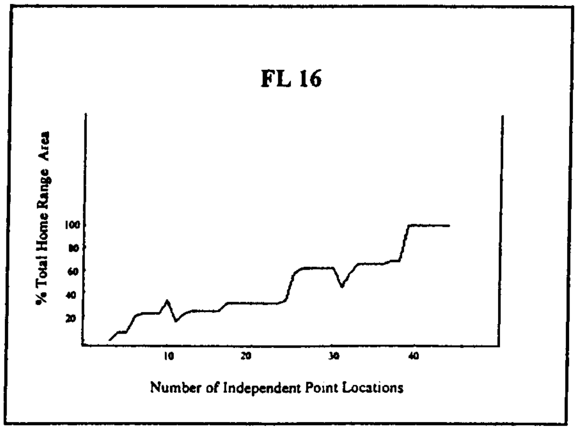
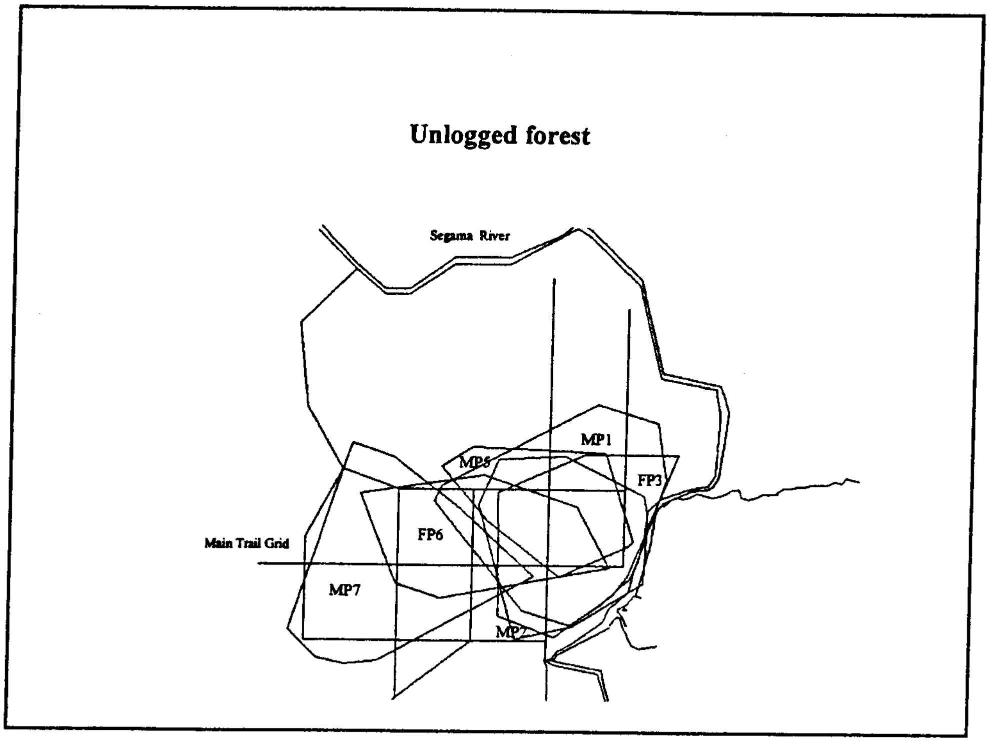
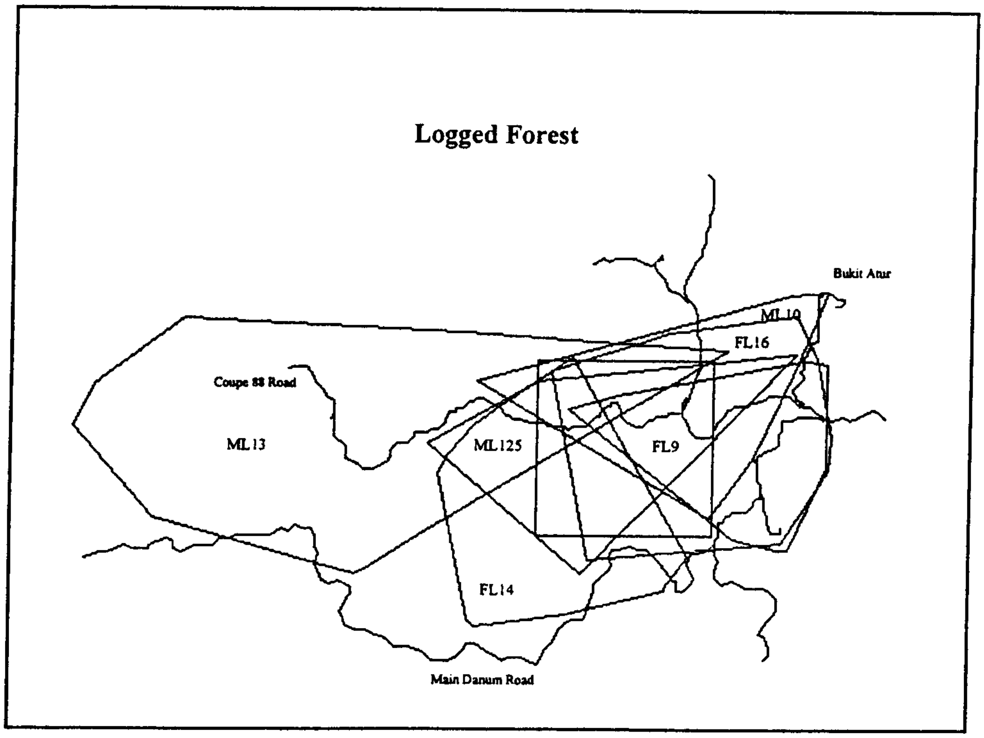

FL 16
% Total Home Range Area
100
80
60
40
20
10
20
30
40
Number of Independent Point Locations

Figure 2-5. Home range areas in an unlogged and a logged forest based on 100% Minimum Convex Polygon for *Viverra tangalunga* in Sabah, East Malaysia.

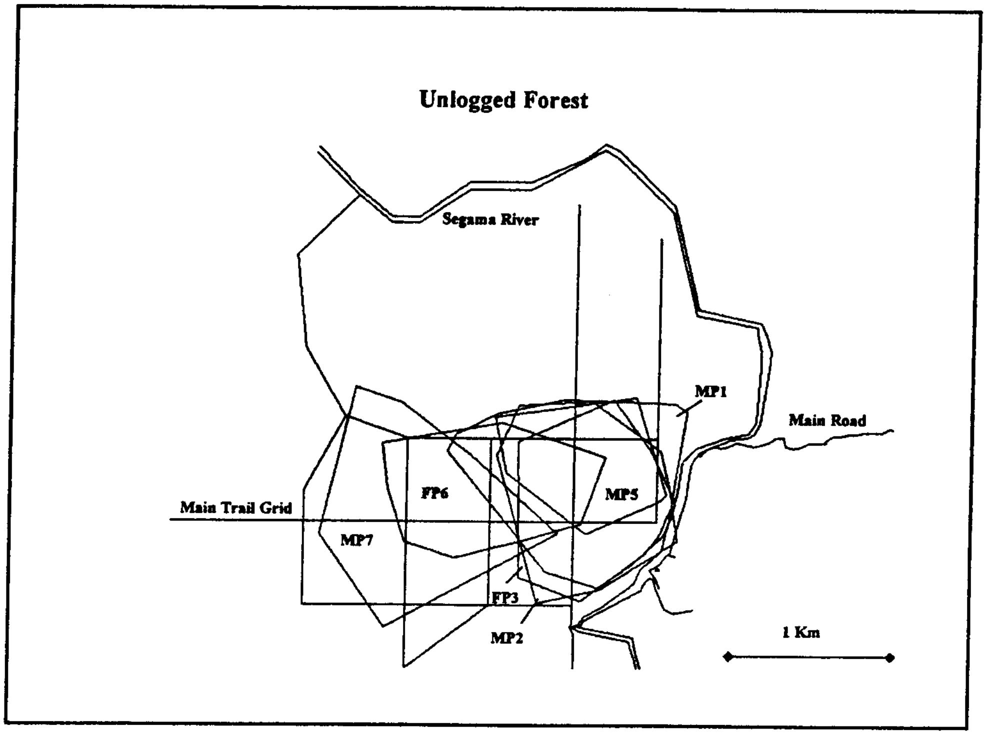


Unlogged forest



Logged Forest

Figure 2-6. Home range areas in an unlogged and a logged forest based on 95% Minimum Convex Polygon for *Viverra tangalunga* in Sabah, East Malaysia.


Unlogged Forest
Segama River
MP1
Main Road
FP6
MP5
Main Trail Grid
MP7
FP3
MP2
1 Km

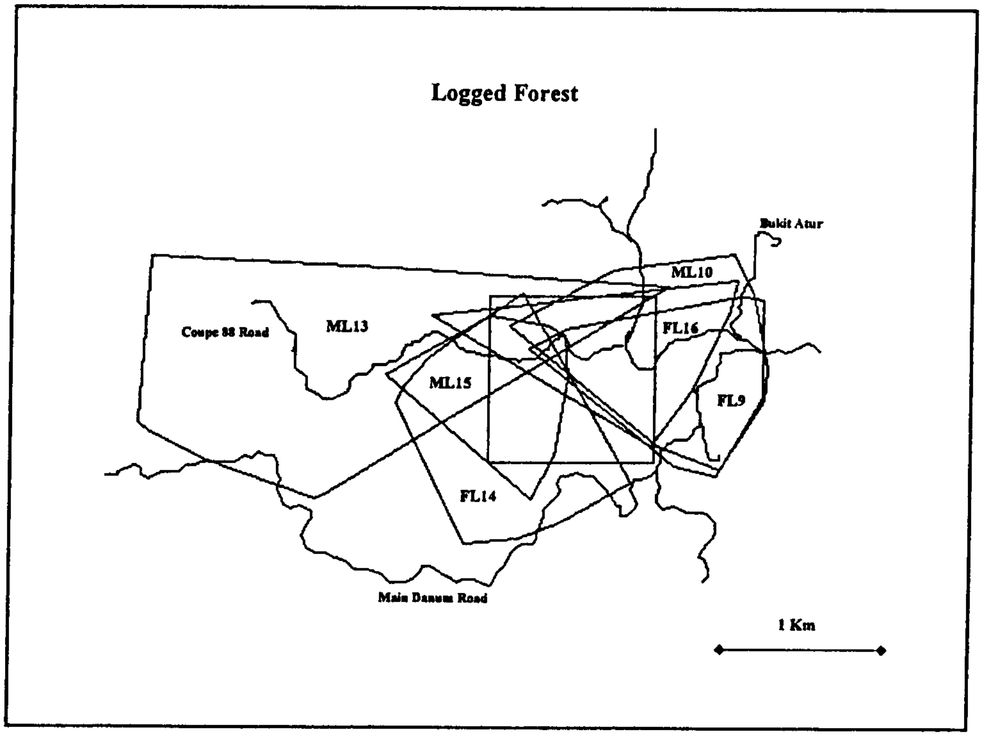
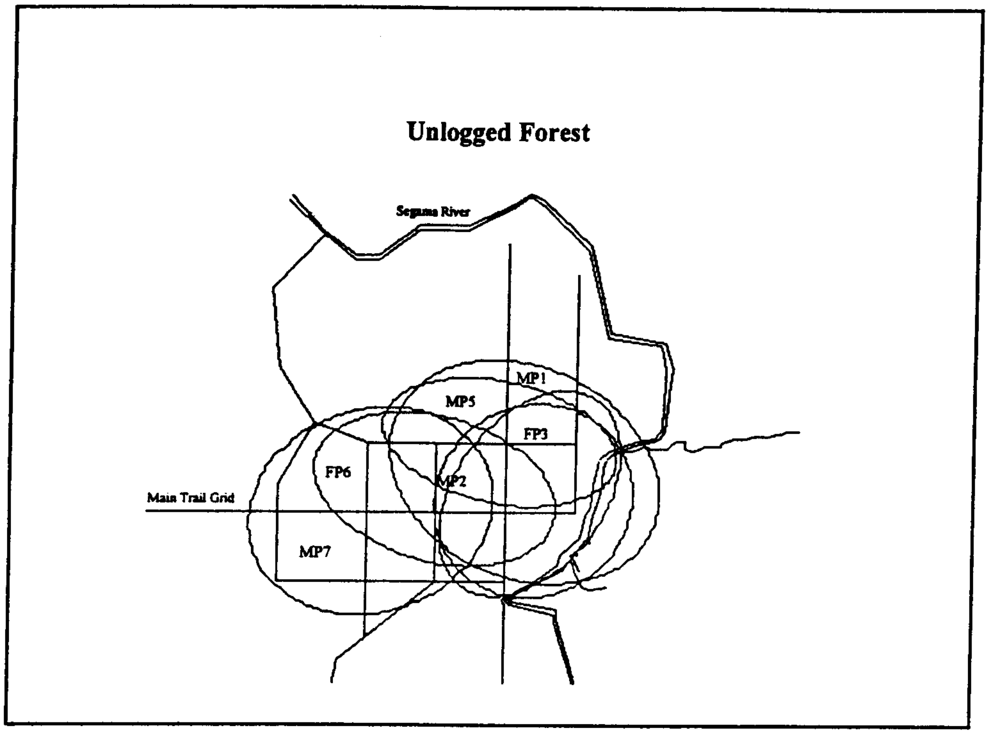

Logged Forest
Bukit Atur
ML10
Coupe 88 Road
ML13
FL16
ML15
FL9
FL14
Main Danum Road
1 Km

Figure 2-7. Home range area in an unlogged and a logged forest based on 95% Jennrich Turner Ellipse for *Viverra tangalunga* in Sabah, East Malaysia.


Unlogged Forest
Segama River
MP1
MP5
FP3
FP6
MP2
Main Trail Grid
MP7

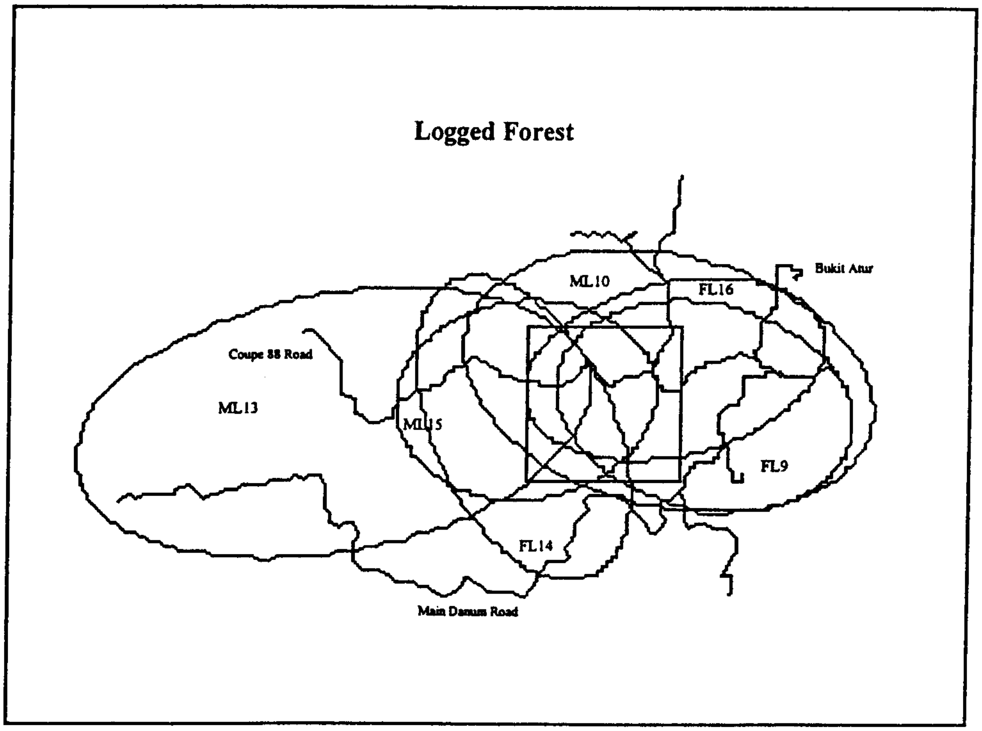
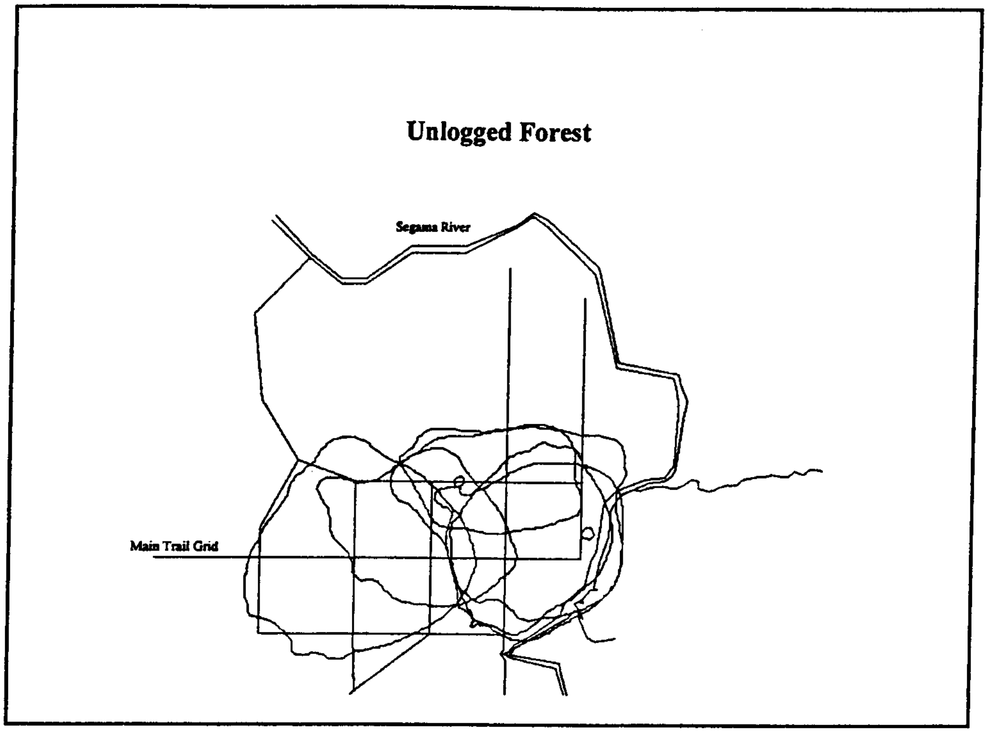

Logged Forest
ML10
FL16
Bukit Atur
Coupe 88 Road
ML13
ML15
FL9
FL14
Main Danum Road

Figure 2-8. Home range areas in an unlogged and a logged forest based on 95% Harmonic Mean for *Viverra tangalunga* in Sabah, East Malaysia.


Unlogged Forest
Segama River
Main Trail Grid

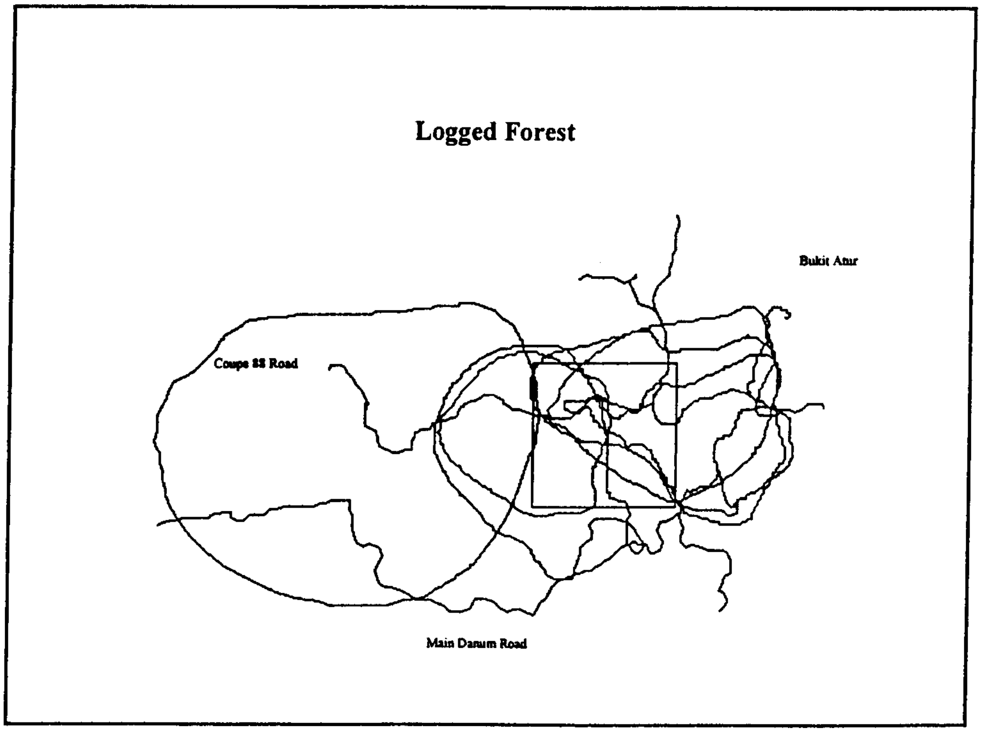
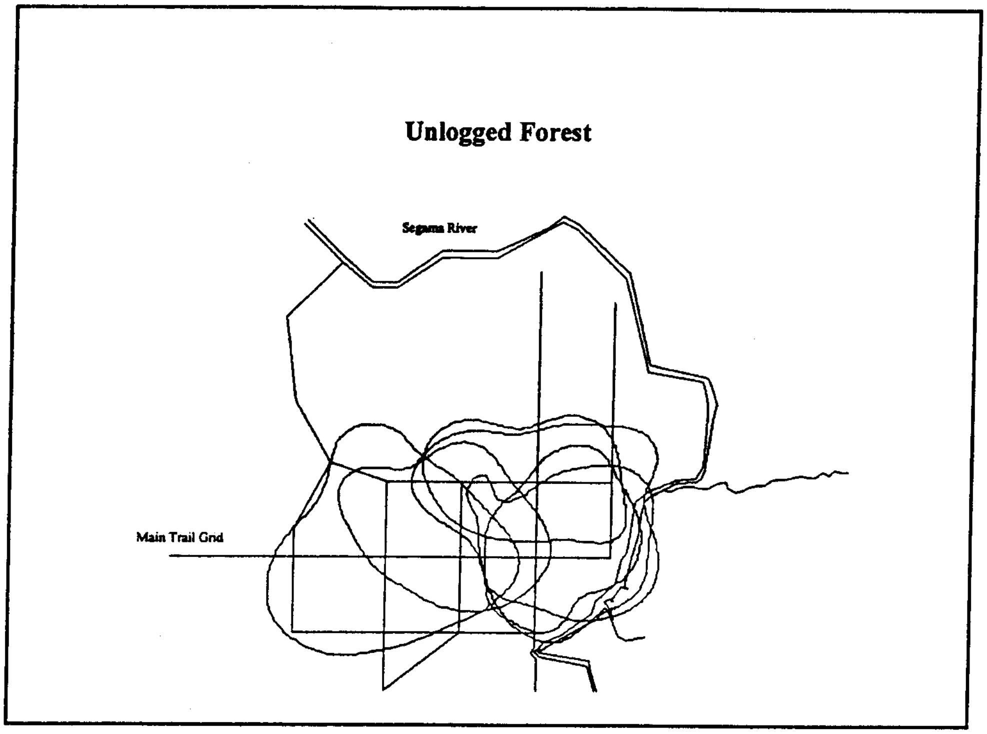
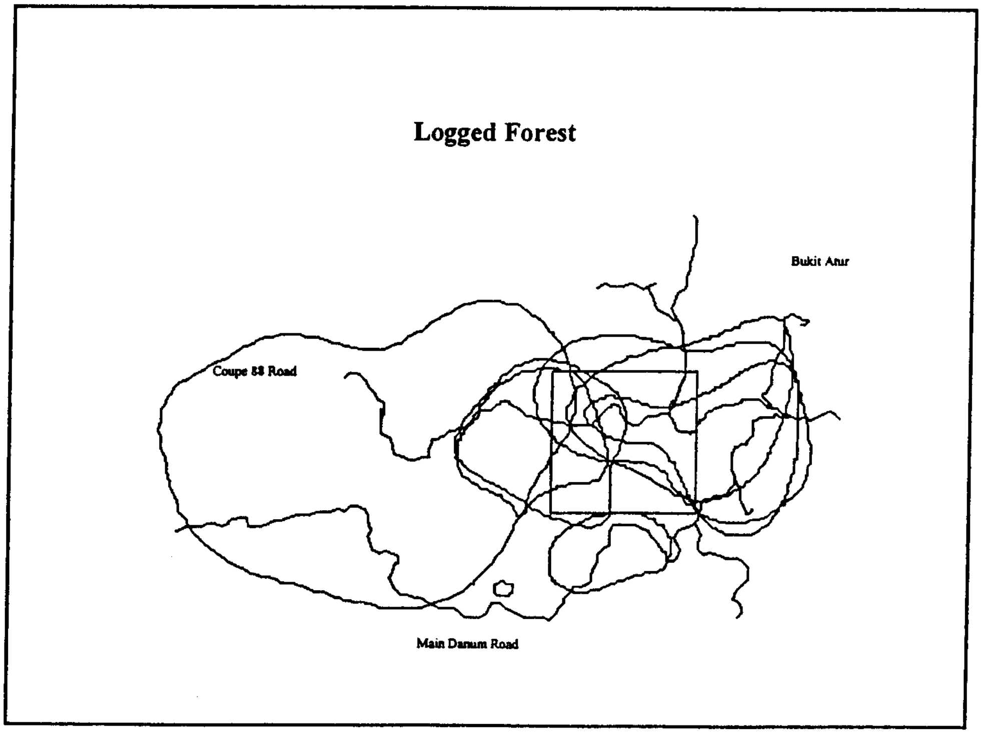

Logged Forest
Bukit Atur
Coupe 88 Road
Main Danum Road

Figure 2-9. Home range areas in an unlogged and a logged forest based on 95% Fixed Kernel for *Viverra tangalunga* in Sabah, East Malaysia.

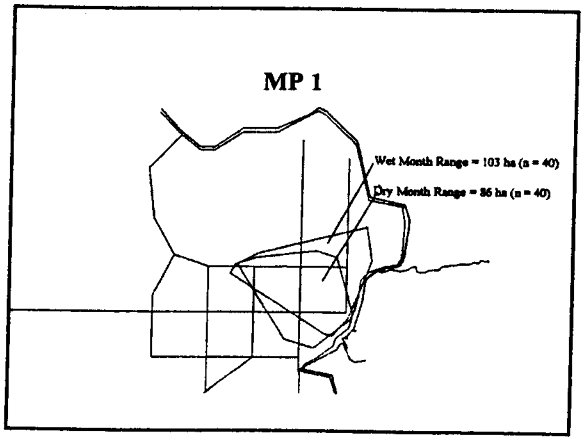


Unlogged Forest

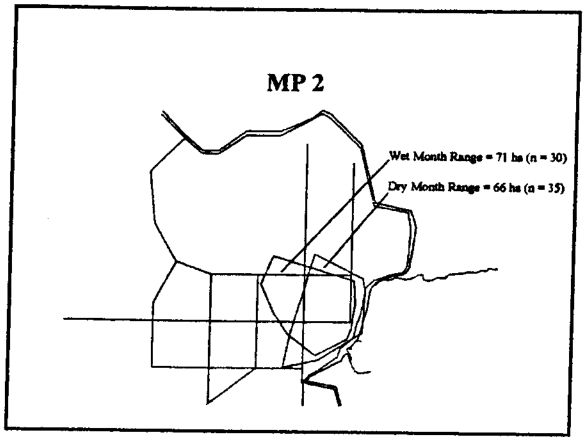


Logged Forest

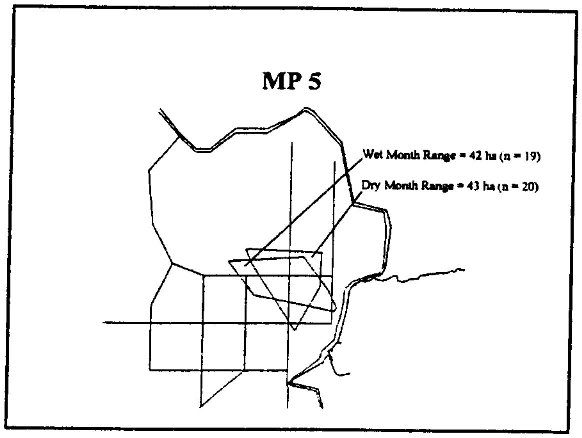
Figure 2-10. Home ranges in dry and wet months in an unlogged forest based on 100% Minimum Convex Polygon for *Viverra tangalunga* in Sabah, East Malaysia.



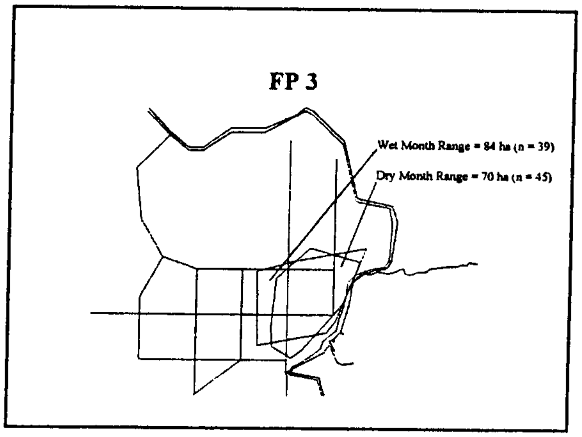
MP 1



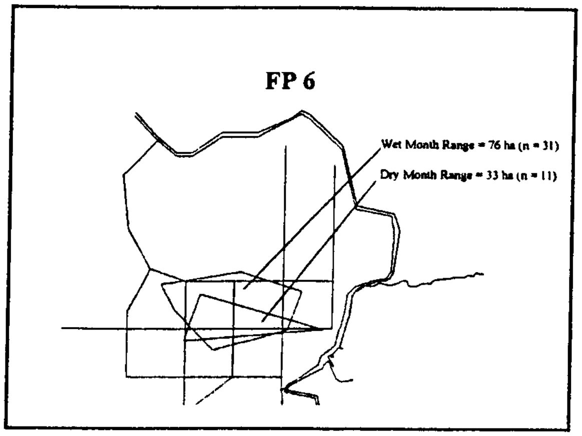
MP 2



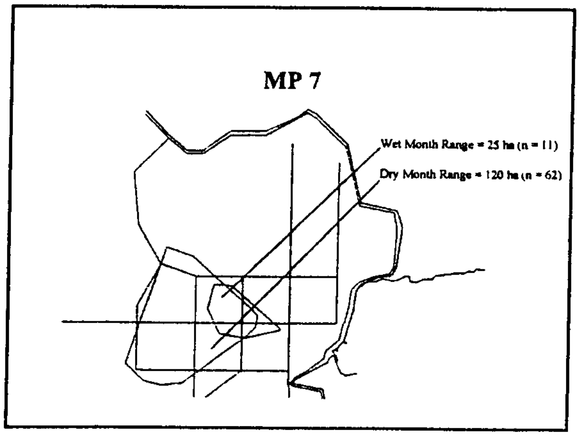
MP 5



FP 3

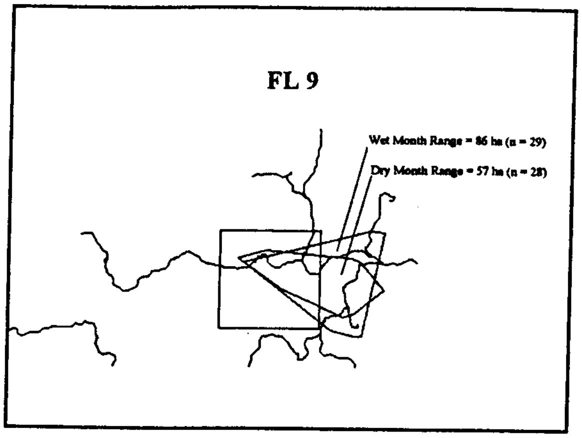


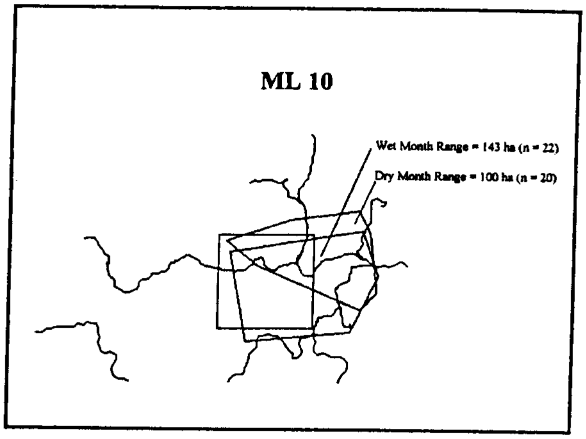
FP 6

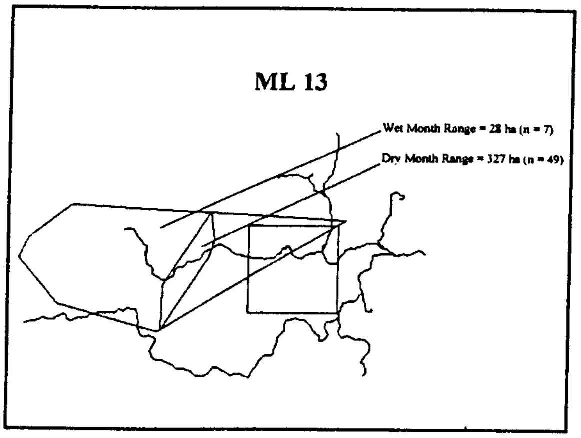


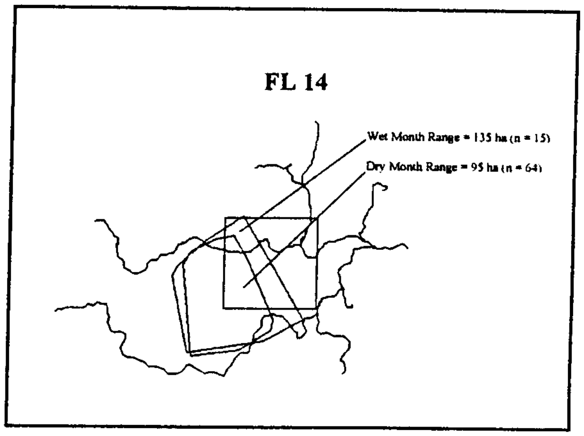
MP 7

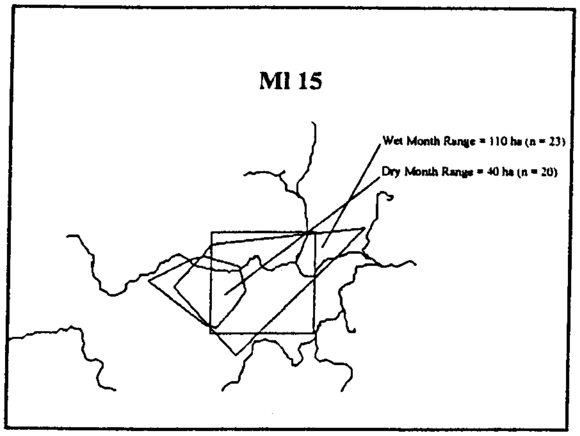
Figure 2-11. Home ranges in dry and wet months in a logged forest based on a 100% Minimum Convex Polygon for *Viverra tangalunga* in Sabah, East Malaysia.


FL 9
Wet Month Range = 86 ha (n = 29)
Dry Month Range = 57 ha (n = 28)


ML 10
Wet Month Range = 143 ha (n = 22)
Dry Month Range = 100 ha (n = 20)


ML 13
Wet Month Range = 28 ha (n = 7)
Dry Month Range = 327 ha (n = 49)


FL 14
Wet Month Range = 135 ha (n = 15)
Dry Month Range = 95 ha (n = 64)


Ml 15
Wet Month Range = 110 ha (n = 23)
Dry Month Range = 40 ha (n = 20)

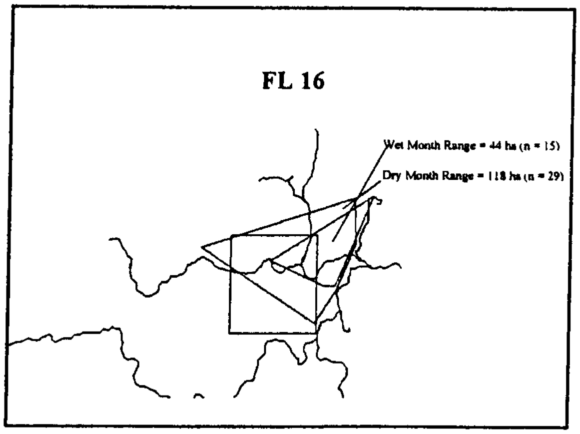
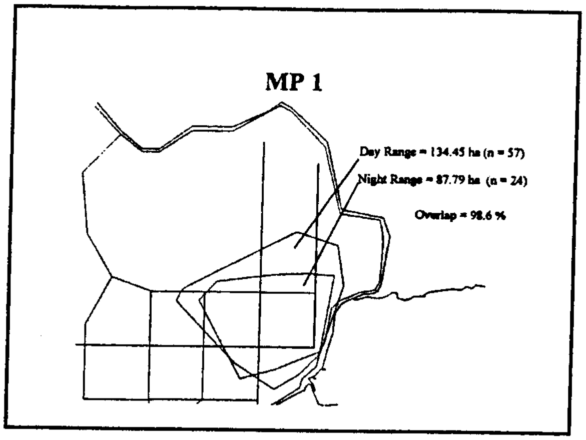
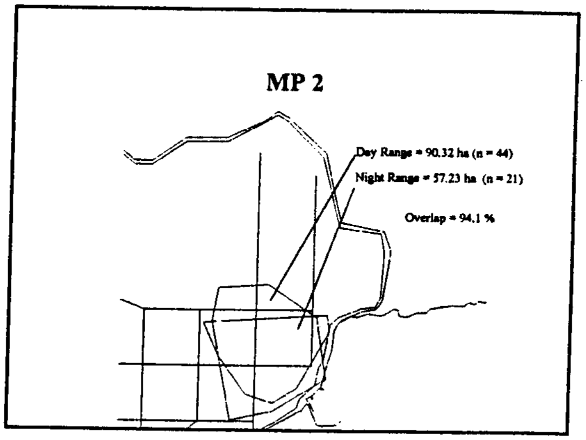

FL 16
Wet Month Range = 44 ha (n = 15)
Dry Month Range = 118 ha (n = 29)

Figure 2-12. Day and night ranges in an unlogged forest based on 100% Minimum Convex Polygon for *Viverra tangalunga* in Sabah, East Malaysia.

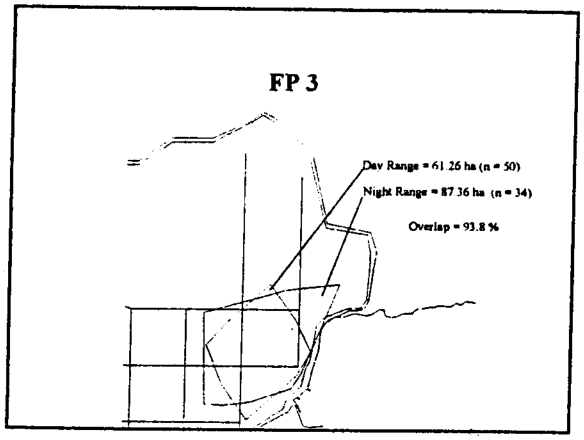
MP 1



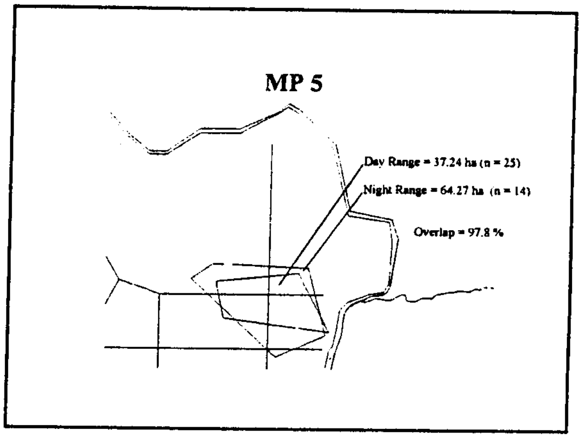
MP 2



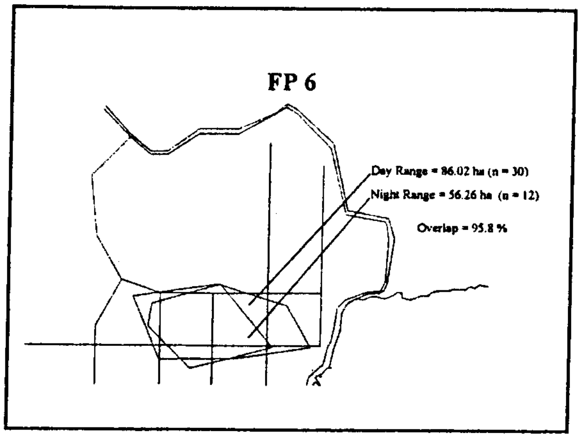
FP 3



MP 5



FP 6



MP 7

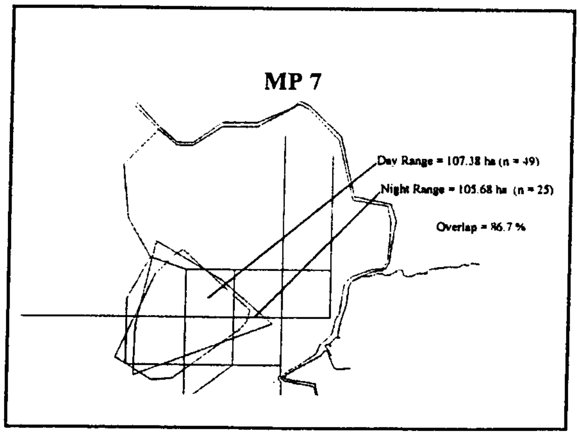
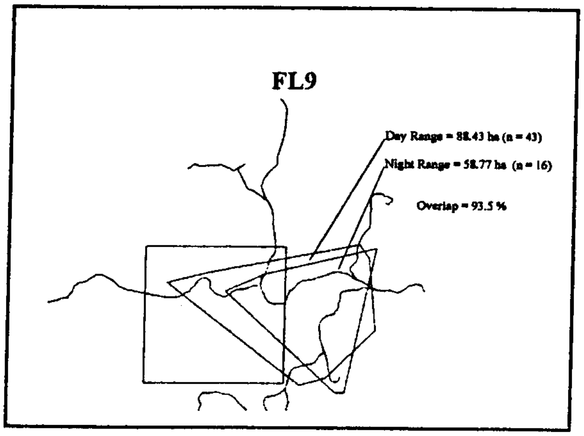
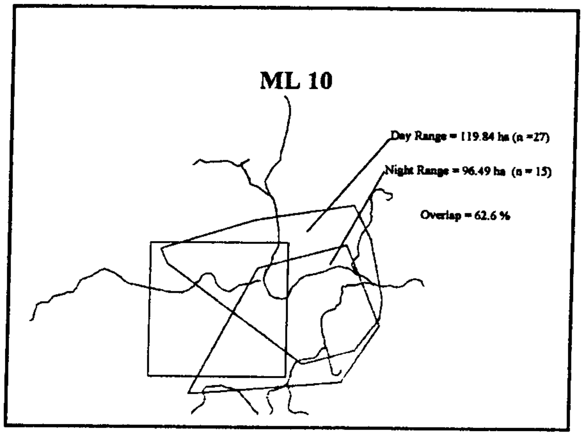
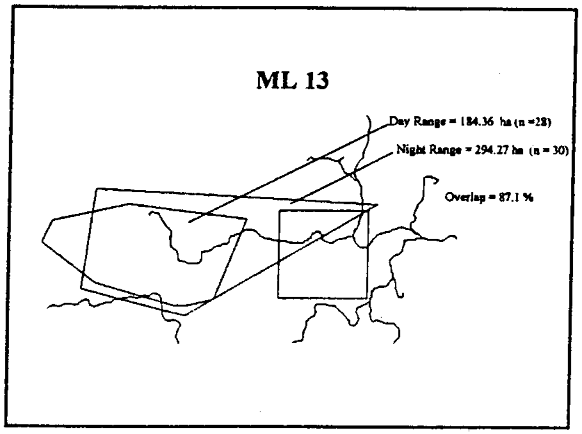
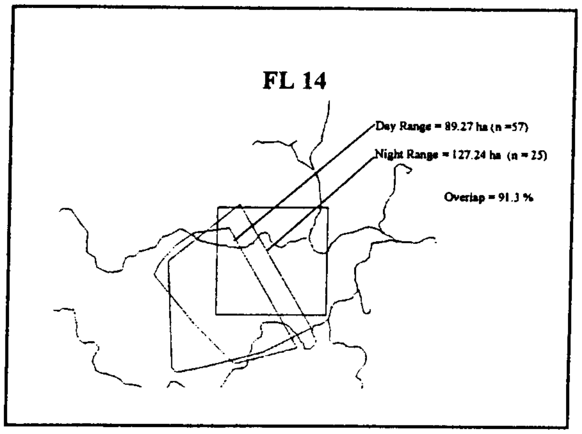


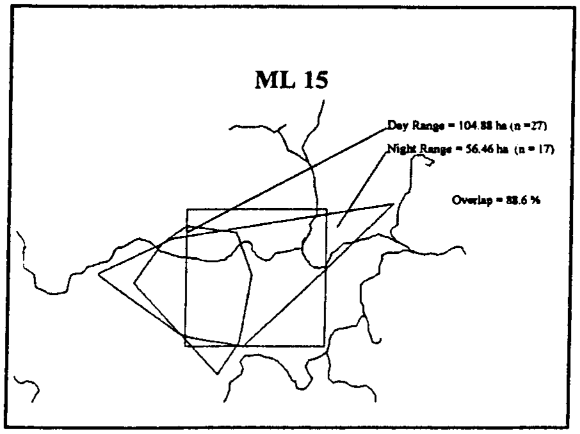
Figure 2-13. Day and night ranges in a logged forest based on 100% Minimum Convex Polygon for *Viverra tangalunga* in Sabah, East Malaysia.


FL9


ML 10


ML 13


FL 14


ML 15

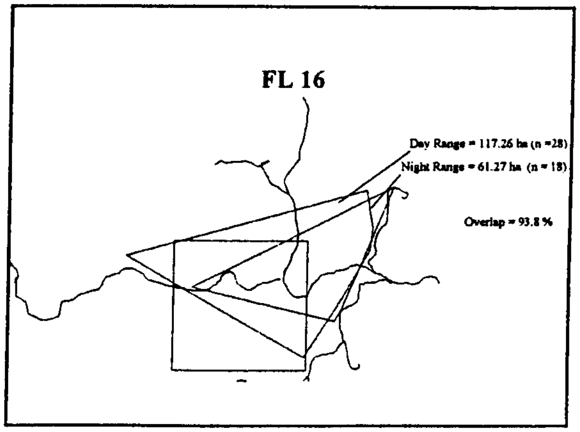
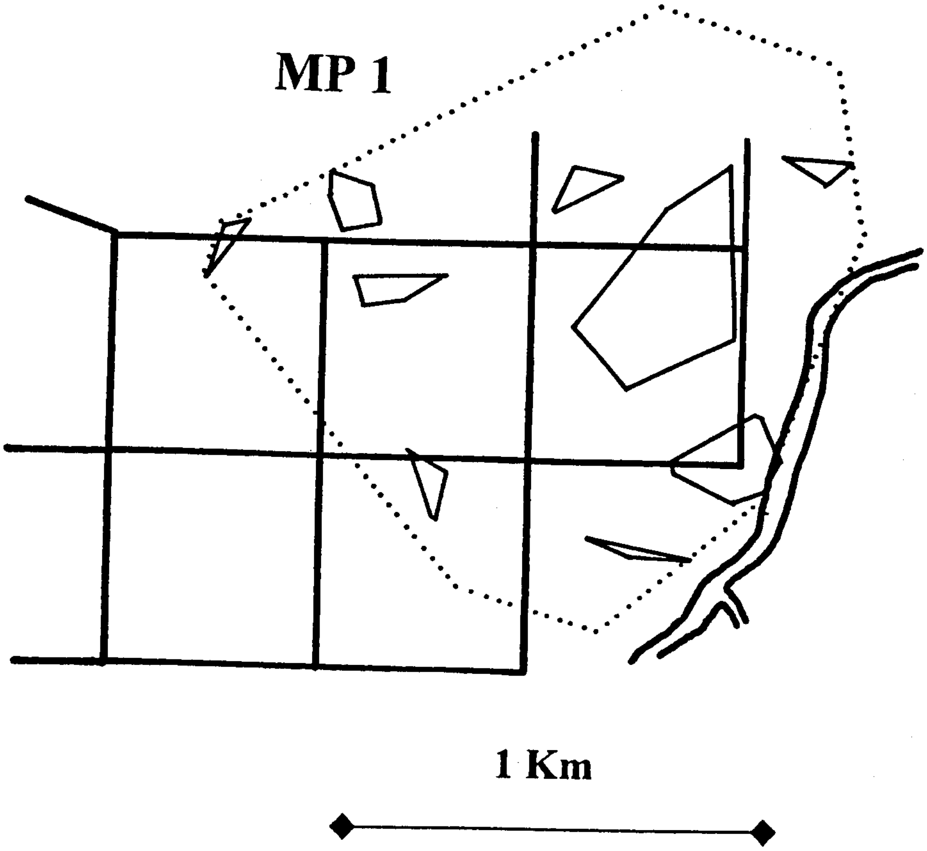
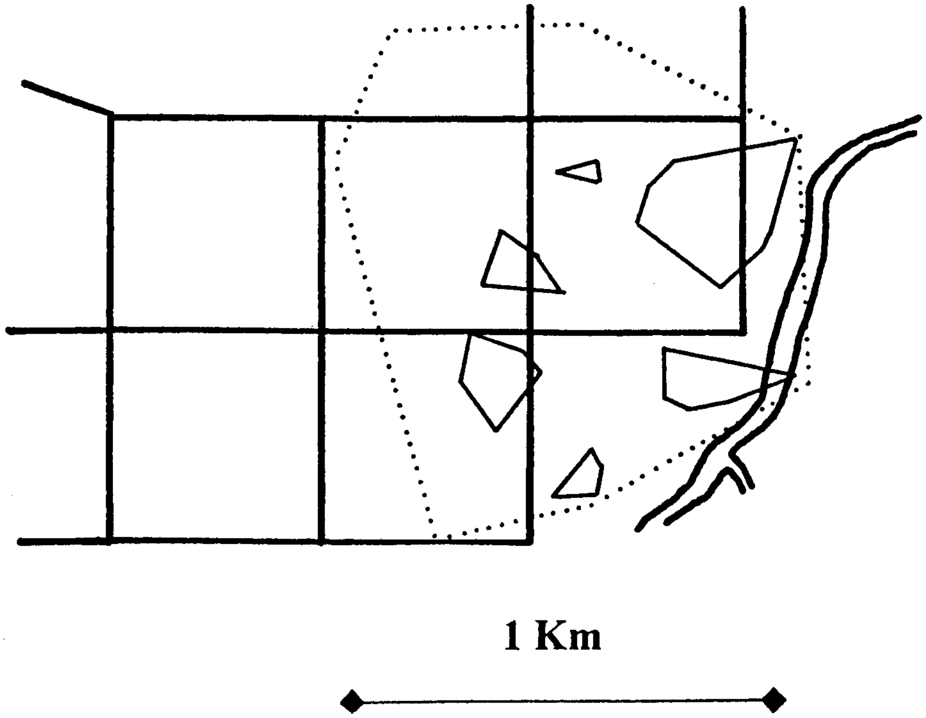

FL 16

Figure 2-14. Home range clusters for *Viverra tangalunga* in an unlogged forest in Sabah, East Malaysia.

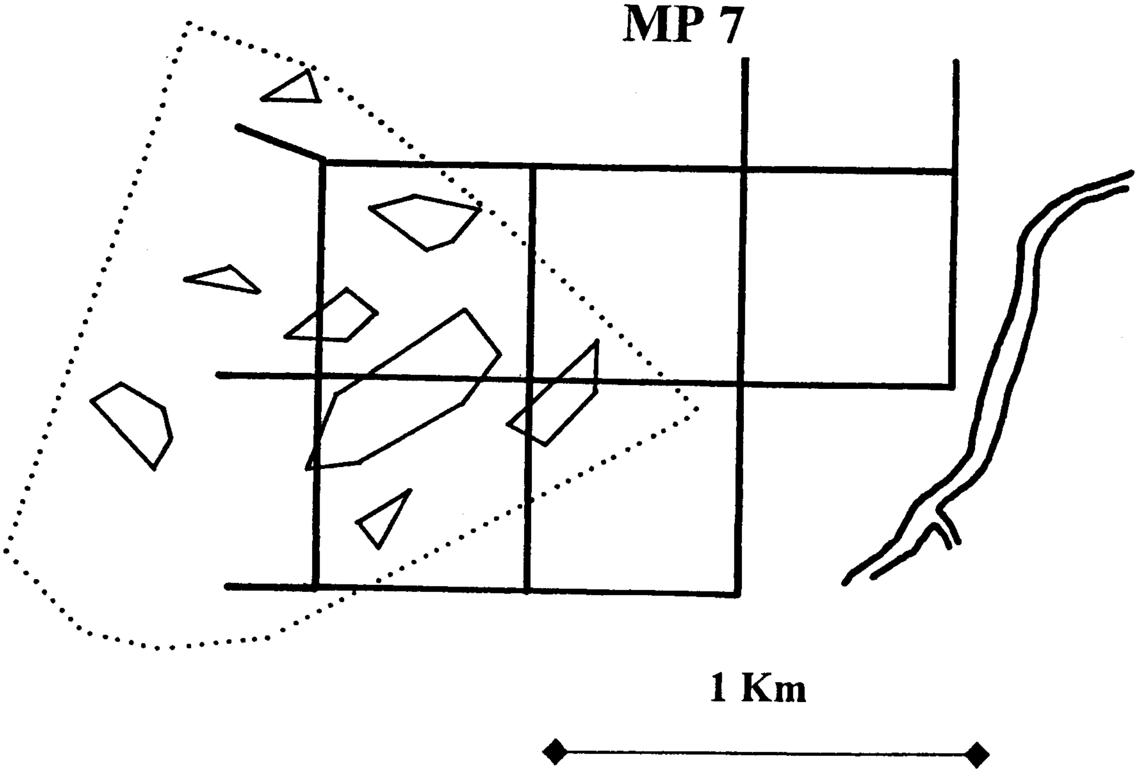
MP 1



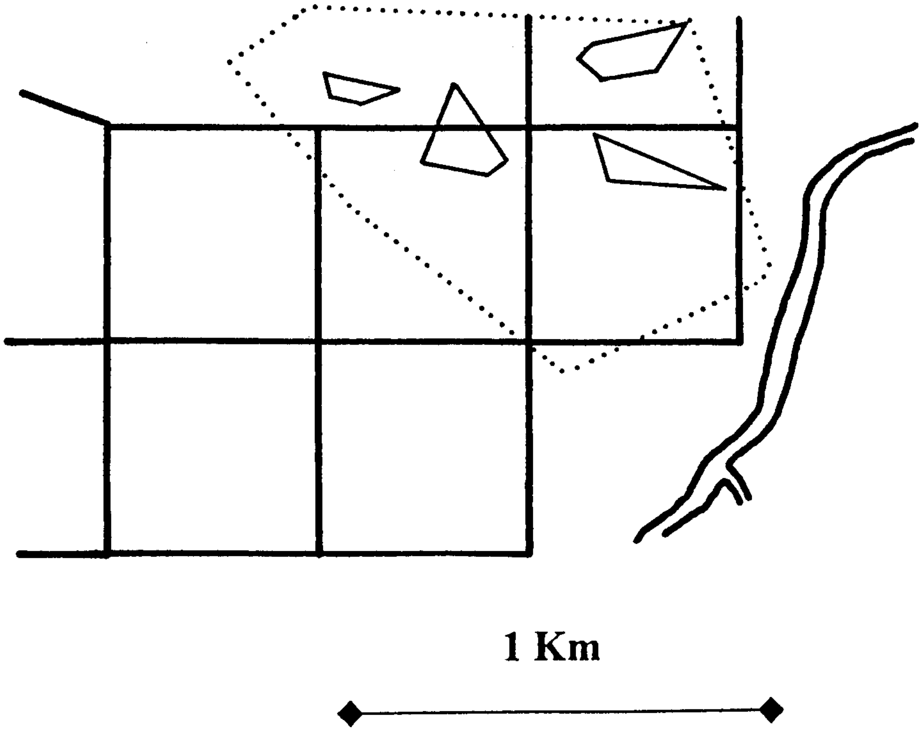
MP 2



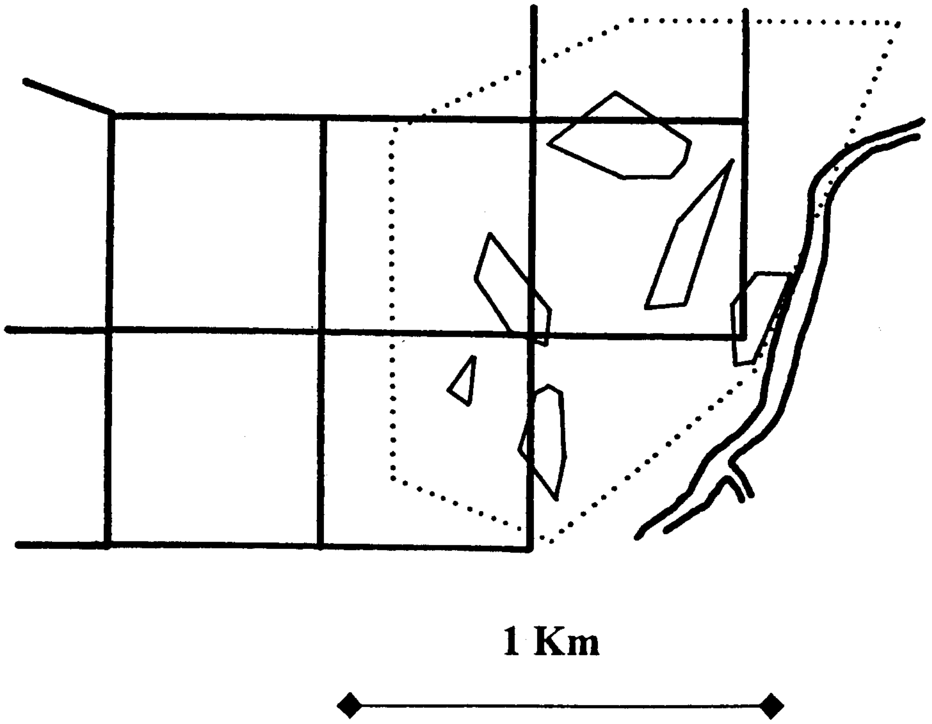
MP 7



MP 5



FP 3



FP 6

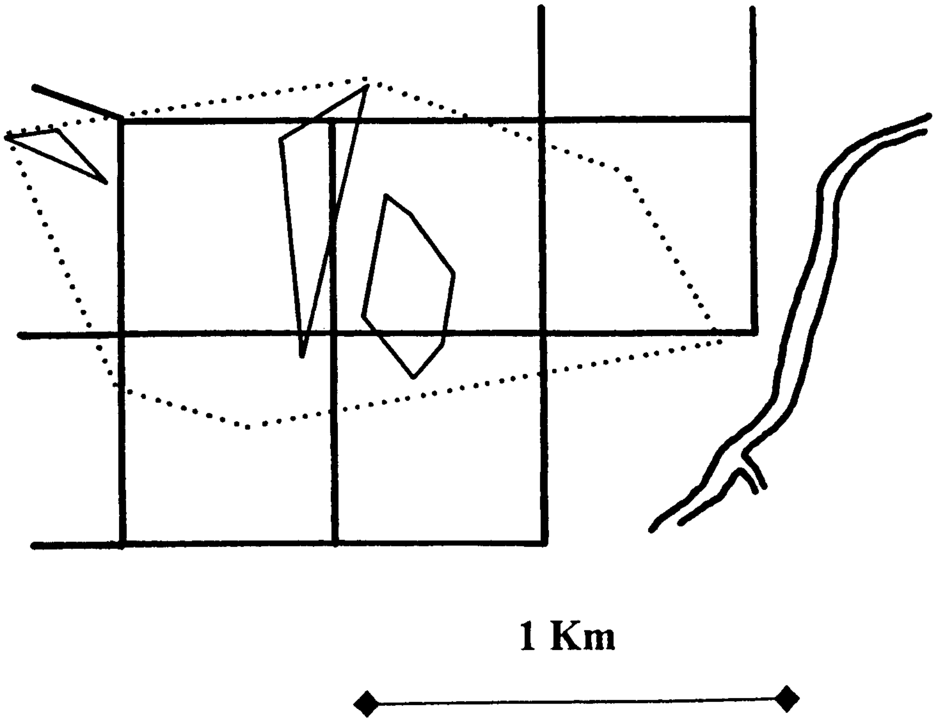
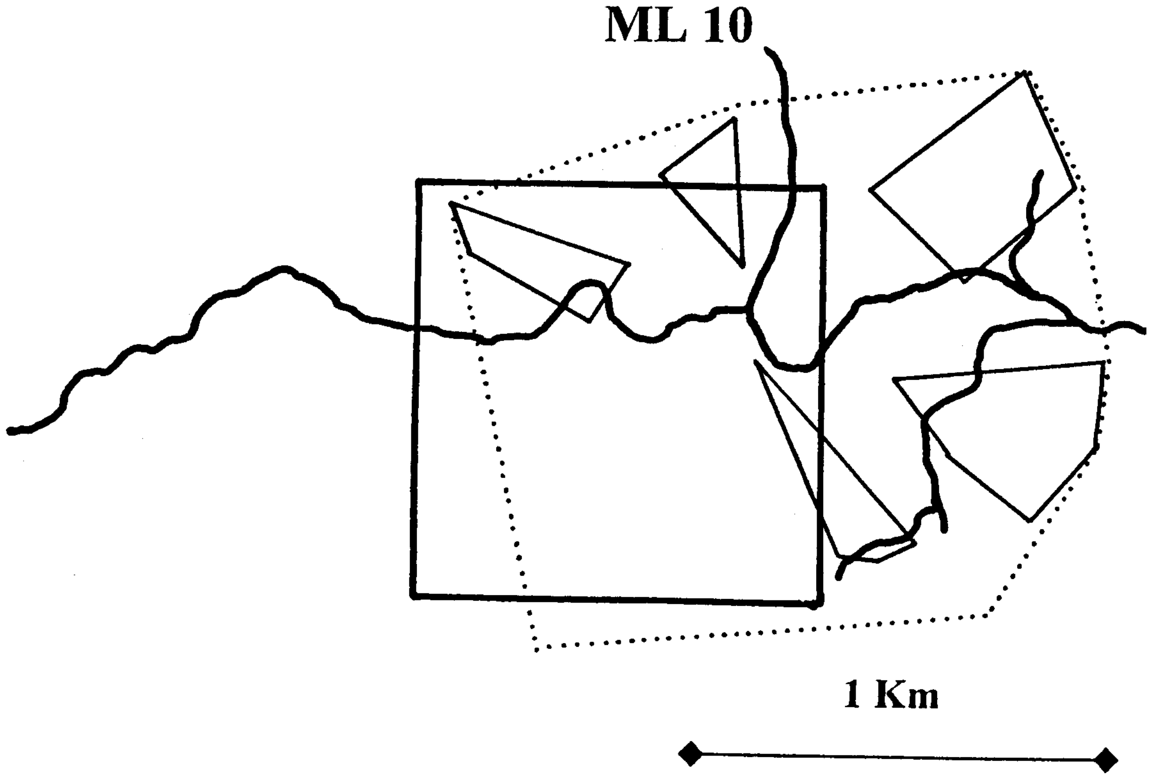
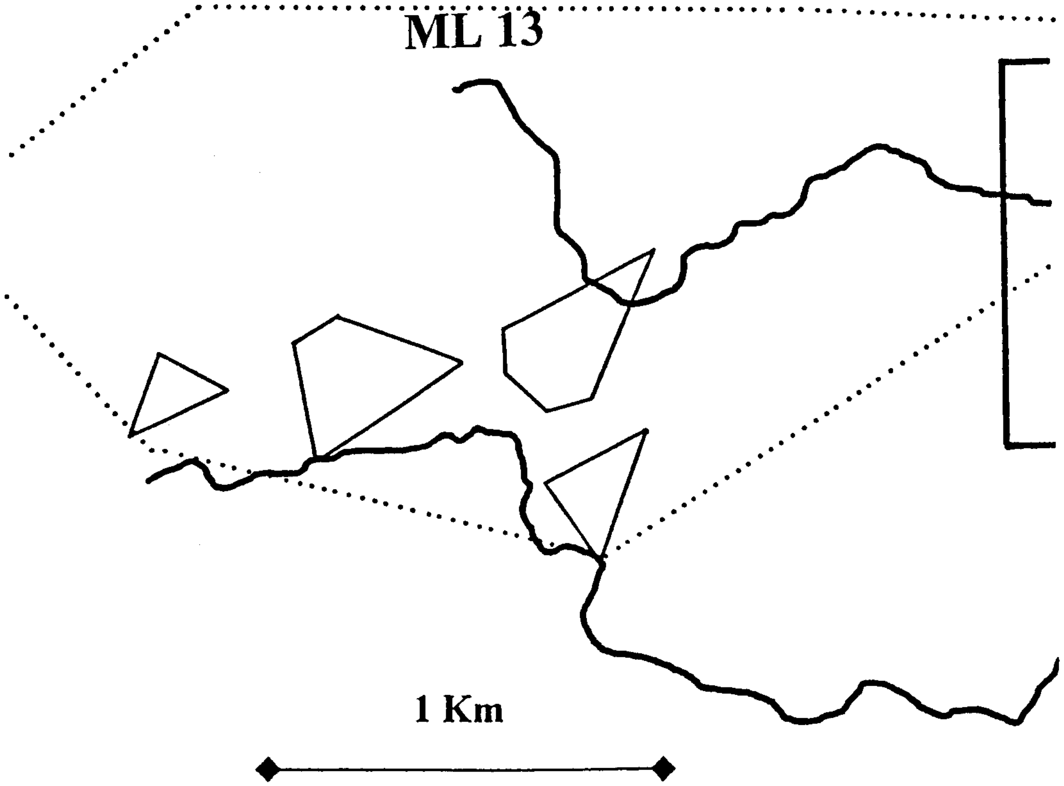
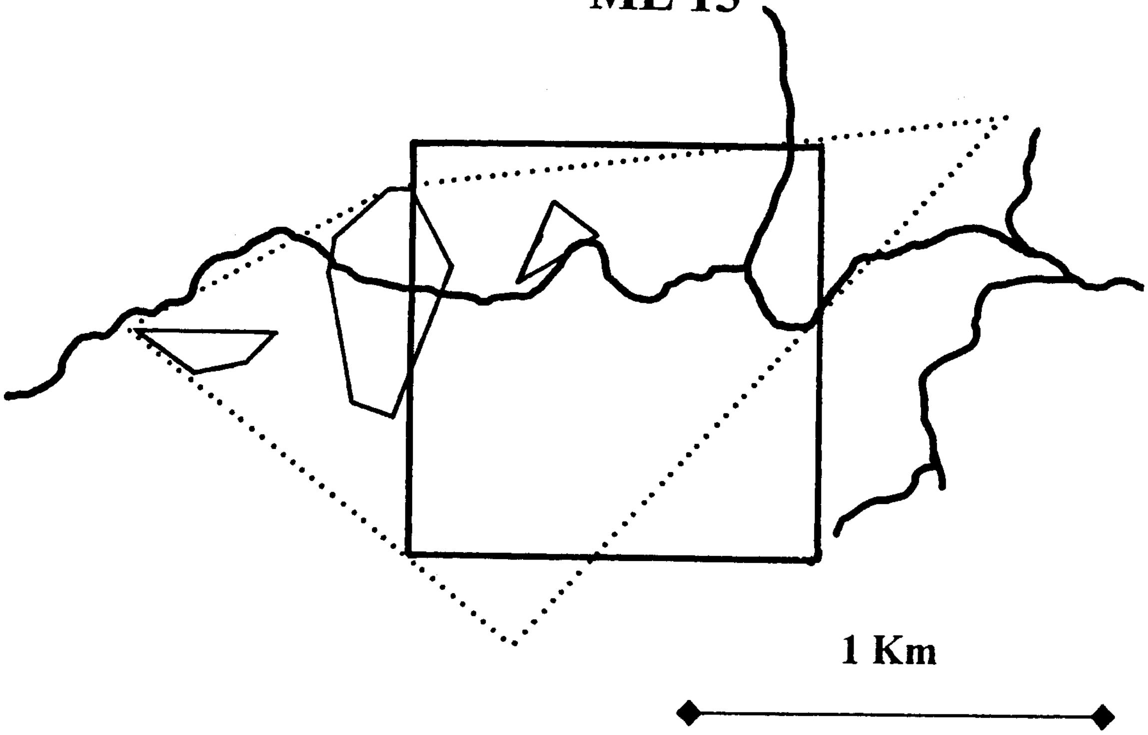


Figure 2-15. Home range clusters for *Viverra tangalunga* in a logged forest in Sabah, East Malaysia.

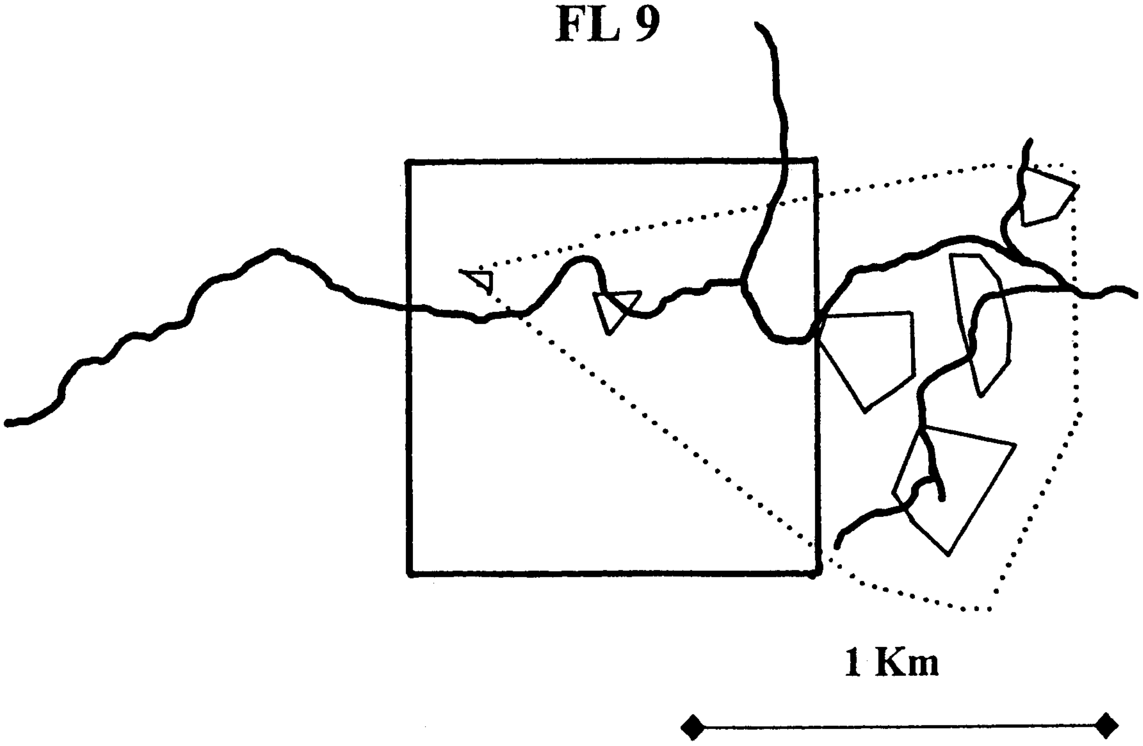

ML 10
1 Km


ML 13
1 Km

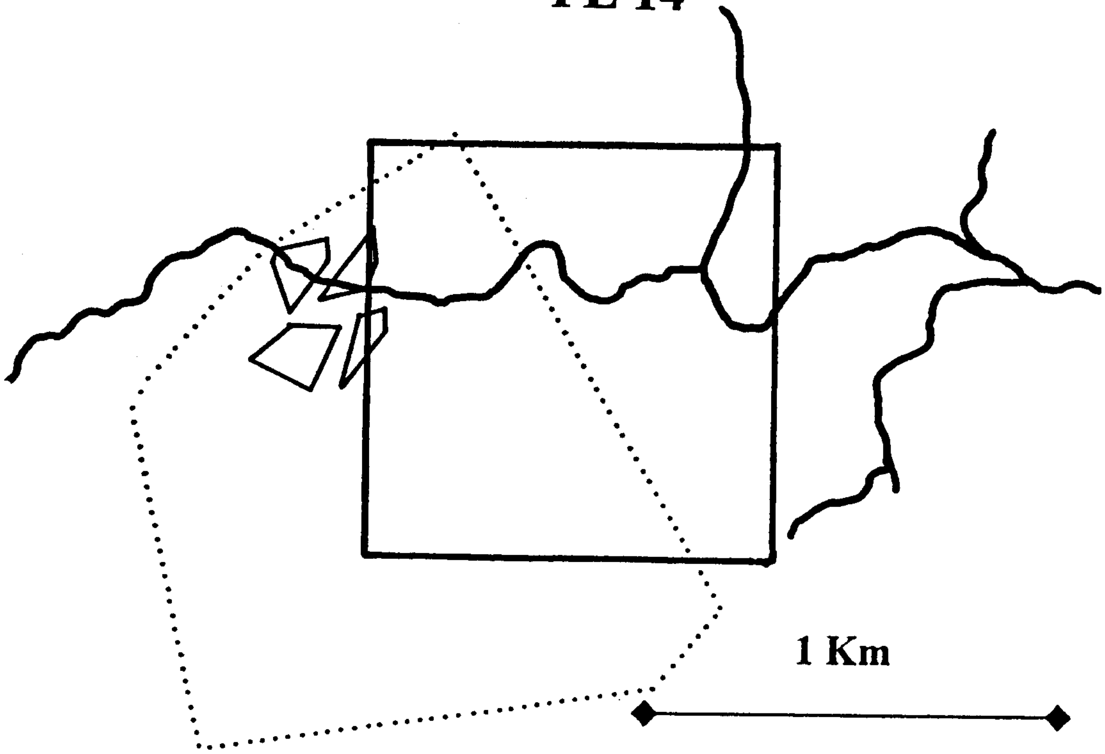
ML 15



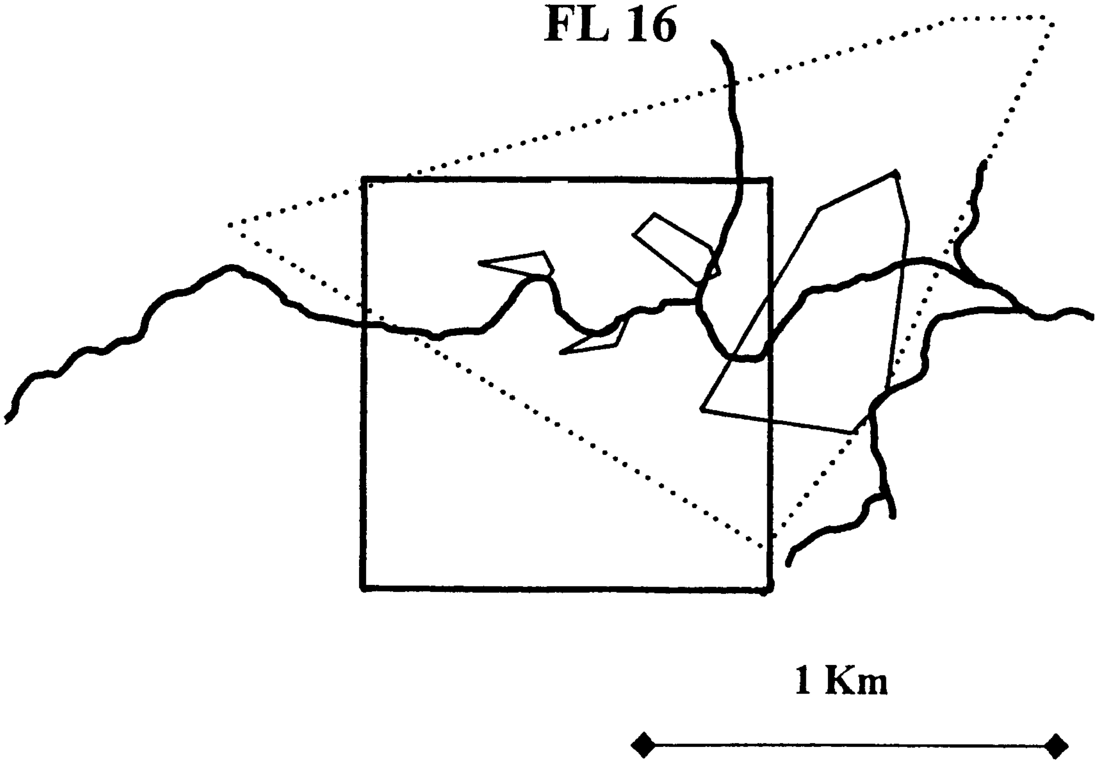
FL 9



FL 14



FL 16



3.

ACTIVITY AND MOVEMENT

INTRODUCTION

Important aspects of the study of a species' ecology include data on activity, behavior, diet, resource availability, and associated parasites. Data on these parameters were generated here for the Malay civet. In order to determine whether these parameters are affected by selective logging, data were collected in an area that had been selectively logged, and an area where no logging activity or other known form of human disturbance had occurred. Although it was not possible to determine the exact cause of any observed differences in activity or movement between site and gender, establishing whether differences exist is an important first step for further studies which investigate the potential sources of these difference.

Among mammals, changes in movement patterns and activity levels are often a response to changes in food abundance, distribution and/or quality (Chapman, 1988). Van Schaik and Griffiths (1996) suggest additional factors that may contribute to an animal expanding or shifting its daily activity interval, including avoidance of predators, evading ectoparasites, excluding competitors, in addition to compensating for a decline in food abundance. Because selective logging significantly alters the forest structure and composition (Howlett, in prep.), it was assumed that any observed differences in the behavior and ecology of *V. tangalunga* between sites were attributable to the effects of selective logging.

Activity

Animals seek to maximize their energy budgets and tend to avoid unnecessary energy output (Morrison *et al.*, 1990). Differences in activity levels for *V. tangalunga* between sites is assumed to reflect differences in some aspect of habitat quality that alters the amount of effort required to satisfy minimum energy requirements. It was hypothesized here that if activity levels are higher in one forest site, it is an indication that either resource availability is lower in this area, or that the density of parasites, predators or competitors is higher.

Activity data also allowed for a characterization of the circadian patterns of *V. tangalunga*, which were previously little known. Macdonald and Wise (1979) provide the only published account of the specific daily activity of a single male *V. tangalunga* based on short term observations insufficient in length to draw conclusions about the behavior of the species. Their observations revealed that the animal moved only at night and foraged almost continually during this time. In this study, it was assumed that daily activity budgets would follow the same pattern.

Among small carnivores, females are more likely to have higher energy demands during parturition and lactation, whereas males are likely to have higher energy demands during mating (Sandell, 1989). It was thus hypothesized that males and females would exhibit different activity levels due to these gender based differences in energy budgets, although no prediction was made as to which gender would exhibit higher activity level.

Movement

The distance an animal moves in a single 24 hour period can be used as an index of energy expenditure (Kenward, 1987). Because there is an inverse relationship between daily distance traveled and resource availability among carnivores and frugivores (Oates, 1986), it was hypothesized here that daily distance traveled differs between sites and is a reflection of differences in the density and dispersion of resources. Also, due to the inherent differences in resource priorities between genders, it was hypothesized that males and females would exhibit different daily travel distances.

Ray (1997) suggests that difference in the speed of travel between two species of herpestids studied in a Central African rain forest resulted from differences in the size and shape of their home ranges. Individuals that had to travel further in order to patrol the borders of their home range were observed to move more quickly. If *V. tangalunga* in this study undertake similar border patrols, then minimum speed of travel and total distance traveled will be directly correlated with home range size. It is also hypothesized here that these parameters differ between study sites and gender.

Dynamic Interactions

Most carnivores are primarily solitary, except during the mating season (Gittleman, 1989). According to Sandell (1989), factors that contribute to the development of solitary behavior patterns include selection of small prey items, foraging for widely dispersed food and absence of paternal investment. Gittleman (1989) proposes that social behavior among small carnivores can fulfill the need for anti-predator defense, particularly among small carnivores in open terrain. Because *V. tangalunga* inhabits dense forest where anti-predator vigilance is of limited utility, social behavior for predator avoidance would seem to be an unlikely strategy for this species. Gompper (pers. comm.) has observed a correlation between the rate of parasitism and the degree of sociality among coatimundi (*Nasua nasua*). Because parasite levels tend to be high among carnivores inhabiting wet tropical habitats (Scott, 1988), it would appear that sociality would prove a disadvantage in this regard. Thus, in this study, it is hypothesized that *V. tangalunga* exhibits solitary behavior in both forest types.

A useful means to determine the social patterns of *V. tangalunga* is to examine the dynamic interactions between individuals. Although difficult to do using the remote sensing methods employed in this study, some data were available to test whether individuals tended to actively avoid or affiliate with others in the immediate area.

Day-bed Sites

Data on day-bed locations can yield useful information on whether *V. tangalunga* is social or solitary, if it creates and utilizes latrines, if it selects permanent or temporary day-beds, and what sort of anti-predator or anti-parasite behavior it exhibits through selection or creation of resting sites. Insufficient data were available to make comparisons of day-bed sites between gender or site, so data on day-beds were pooled and assumed to represent the normal range of variability for this species.

METHODS

Activity

Radio-collars were equipped with activity sensors consisting of a mercury switch that changed the signal pulse rate from 50 to 80 beats per minute when the unit was rotated more than 45°. This feature allowed for remote monitoring of activities that involve changes in the position of the animal's head. Movement was defined as changes in the animal's location, which was detected by fluctuations in the signal strength, resulting from intermittent blocking of the signal by trees and other obstacles as the animal moved through the forest.

Movement and activity data were classified into four categories: inactive and stationary (I/S), active and stationary (A/S), inactive and moving (I/M), and active and moving (A/M). Although it was not usually feasible to observe individuals to visually identify what behaviors corresponded to these categories, certain assumptions could be made. I/S clearly indicated no movement or activity, so it was concluded that the animal was resting or sleeping. A/S involved only head movement, and likely resulted from grooming, feeding or intermittent disruptions of sleep, the last of which did not indicate true activity. It was difficult to distinguish between the three, but because this category was most often detected during periods of rest, and occurred only briefly, it was assumed to be short interruptions of rest. I/M entailed movement from one location to another, with little or no associated head movement, which clearly resulted from travelling. A/M involved both movement from one location to another and head movement, and was usually more localized, leading to the conclusion that it was associated primarily with foraging activity.

To prevent modification of the animal's behavior resulting from the presence of the observer (Burney, 1980; van Schaik and Griffiths, 1996), no attempts were made to conduct visual observations of radio-collared animals. Direct sightings were exploited opportunistically to observe and record behavior, although dense understory and low visibility in the forest at night made direct observations logistically difficult.

Activity was recorded along with each directional bearing taken, as well as during continual follows. In the case of the latter, data on activity and location were recorded at 15 or 30 minute intervals for up to 24 hours, then later pooled into one-hour blocks. Due to the inherent autocorrelation resulting from this method of data collection, no assumptions regarding independence of data were made.

Solitary behavior of study animals and short signal range of transmitters made it difficult to obtain activity and location data on multiple animals, and usually resulted in loss of the signals. Thus, some follows are incomplete. Successful follows entailed both location and activity data on a single animal. Because continual follows had to be aborted in heavy rain due to signal attenuation and risk of damage to radio-receivers, no attempt was made to divide activity data into seasonal categories.

Activity budgets were based on the cumulative percentage of readings in each of the activity categories described above. A histogram of activity in each forest type was generated for both diurnal and nocturnal intervals. Overall activity budgets were based on the mean percentage of time in 24 hours each animal was moving (including both I/M and A/M) versus stationary (I/S and A/S). A two-sample t-test was used to compare activity levels between sites and genders. All statistics were done at $\propto = 0.05$, using Systat 7.0 for Windows (SPSS Inc., Chicago, IL).

Movement

Eight continual follows of four animals were carried out in the unlogged forest. In the selectively logged forest, 11 follows of five individuals were carried out. From these it was possible to estimate minimum daily distance traveled and minimum speed of travel (Laundre, *et al.* 1987), as well as total area used in a single night and the percentage of total home range that area represented. Composite maps of the animal's location at 30 minute intervals provided a visual display of home range use.

Dynamic Interactions

The presence of affiliative or avoidance behavior was determined by generating a cohesion index using Ranges V to test whether individuals with overlapping home ranges were closer than expected by chance. Only location data taken concurrently or almost concurrently could be used for this analysis. Because moving animals were generally not tracked at the same time, most data on dynamic interactions were generated from stationary animals that were probably resting. Cohesion analysis was carried out using a Jacobs Index (1974) to examine dynamic interaction based on the probability of two animals being closer together than predicted by chance alone. For information on methodology, see Kenward, et al. (1993).

Day-Bed Locations

Day-beds were located by triangulating on a resting animal. Dense vegetation and undergrowth made locating resting sites difficult and attempts often resulted in flushing out the animal before locating the actual resting site. Because frequent disturbance of study animals can significantly alter behavior (Mech *et al.*, 1966; Burney, 1980), no more than two walk-ins were attempted per animal. This resulted in the characterization of six day-bed sites site; two in the logged forest and four in the unlogged forest. Collars shed prematurely were located using the same method.

RESULTS

Activity

A total of 2,188 activity readings were taken. Figure 3-1 shows mean activity levels over 24 hours for each study animal except FP 6, for which reliable estimates were not obtained. *V. tangalunga* exhibited an overall activity level of 52.0% (range = 40 – 59%). In the unlogged forest, mean activity was 51.4% (range = 40 – 59%) compared to 52.7% (range = 46 – 58%) in the selectively logged forest. A two sample t-test revealed no difference in overall activity between sites ($t = 0.329$, $p = 0.75$).

Among males in the unlogged forest, mean overall activity was 50.0% (range = 40 – 57%), for the female it was 59%. In the logged forest, mean overall activity among males was 53.0% (range = 48 -55%) and 58% among the females (range = 46 - 57%). When data from both sites were pooled by gender, a t-test revealed no difference in overall activity between males and females ($t = 0.767$, $p = 0.465$).

From 18:00 to 8:00, mean nocturnal activity was 80.9% for both sites (range = 71.4 – 88.4%), and from 08:00 to 18:00, activity equaled 21.2% (range = 12.6 – 32%). In the unlogged forest, mean nocturnal activity was 79.3% (range = 71.4 – 87.3%); and mean diurnal activity was 21.6% (range = 15.3 – 32%). In the logged forest, mean nocturnal activity was 82.3% (range = 75.3 – 88.4%), and mean diurnal activity was 20.9% (range = 12.6 – 26.1%).

Mean nocturnal activity level for females was 83.5% (range = 77 – 88%), compared to 77.7% (63 – 84%) for males. Mean diurnal activity level for females was 19.5% (range = 9 – 24%) compared to 19.5% (range = 13 – 30%) for males. These data indicate that *V. tangalunga* is primarily nocturnal ($t = 19.343$, $p < 0.0001$). Although females in this study appeared to be active longer than males, there was no indication that activity budgets differed between gender or forest type (see Table 3-2).

There were two periods of peak activity for animals in the unlogged forest; one from 19:00 to 02:00 and another from 04:00 to 07:30. Among animals in the logged forest, there was an initial peak in activity from 19:30 to 22:00 and a second from 02:00 to 06:30. Thus, nightly activity was not continuous, but interrupted by intervals of lower activity, such as rest.

When activity was divided into different categories [resting (I/S), intermittently active and resting (A/S), traveling or patrolling (I/M), and foraging (A/M)] activity budgets could be developed. Table 3-1 shows percent activity levels in each category for each study animal. Figure 3-2 show mean values for each of these categories in both forest types. During the day, 74.% activity fell into I/S, when the animals were clearly resting. The next highest level of activity was I/M which included 10% of all readings. This indicates that animals were prone to occasionally change location of day-bed site. A/S included 8% of all readings which may have included either routine interruptions of rest, or grooming, while A/M contained only 7% of all readings.

At night, 51% of all readings fell into A/M, while another 30% were in I/M. Thus, over 80% of nocturnal activity entailed moving, in the form of either foraging or travelling. Of the remaining time, 14 % of the readings were categorized as I/S, indicating that some time was spent resting. Only 5% were classified as A/S, thus little time at night was spent in stationary activities such as grooming.

There were no significant differences in activity categories when comparisons were made between study sites and between gender (see Table 3-3 and Table 3-4 respectively for results of two-sample t-tests). Due to a low sample size for females in the unlogged forest, comparisons of activity levels between males and females were based on pooled values from both study sites.

Movement

Table 3-5 shows minimum distance traveled, area used, percent of total home range used (based on a 100% minimum convex polygon) and mean minimum travel speed of *V. tangalunga* in a single night. Minimum daily distance traveled ranged from 1.0 km in 13 hours by male MP 7 in the unlogged forest to 9.7 km in only six hours by male ML 13 in the selectively logged forest. Among females, it ranged from 2.1 km in 12 hours in the unlogged forest, to 8.6 km in 24 hours in the logged site. There was no significant difference in the daily distance traveled between gender ($t = 1.637$, $p = 0.130$) or sites ($t = 0.164$, $p = 0.873$).

Mean minimum area used among males in 24 hours in the unlogged forest was 72.6 ha (range =34.2 - 92.3), for the female, it was 9.6 ha. In the logged site, mean minimum area used among males in 24 hours was 54.4 ha (range = 5.7 - 140.1 ha), among females it was 25.9 ha (range = 11.8 - 43.9 ha). A t-test of total area used for males versus females revealed that males traverse a significantly larger area in a single night than females (t = 2.795, p = 0.016).

The mean minimum percentage of total home range used during continual follows among males in the unlogged forest was 59.1% (range = 25.7 - 69.4%), for the female it was 9.8%. Among males in the selectively logged forest, the mean minimum percent of total home range used in 24 hours was 32.9% (range = 4.6 - 88.5%), for females it was 19.8% (range = 8.3 - 35.7%). A t-test of percent home range used showed that males use a significantly larger percentage of their home range in a single night than females (t = 2.795, p = 0.022).

The mean minimum speed among males in the unlogged forest was 149.5 m/30 min (range = 38.0 - 261.1 m/30 min), and for a single female, the mean minimum speed was 147.7 m/30 min (range = 84.5 - 211.0 m/30 min). In the selectively logged forest, the mean minimum speed of males was 149.8 m/30 min (range = 77.3 - 335.1 m/30 min) and among females it was 167.8 m/30 min (range = 88.2 - 276.9 m/30 min). A paired t-test showed no significant difference in the mean minimum speed between site (t = 0.247, p = 0.81) or gender (t = 1.654, p = 0.12). However, a linear regression of minimum speed with home range size (95% minimum convex polygon) approached significance (R = 0.446, p = 0.055), and a linear regression of minimum daily distance traveled and home range size was significant (R = 0.759, p = 0.0176) for males although not for females (R = 0.058, p = 0.942).

The composite minimum route each animal took during the continual follow are plotted in Figures 3-3 through 3-6. Note that some points are located beyond the boundaries of the animal's calculated home range. In these cases, the outlying point was not used in home range estimates because it either lacked independence, or resulted from bearings below 45° (See Methods, Chapter 2).

Initial nightly activity usually involved directional movement, perhaps to a foraging site, followed by non-directional movement indicative of feeding or foraging. Subsequent movement included directional movement and intervals of rest, then additional directional movement immediately prior to dawn. In almost every case, there was at least one foray to and/or beyond the calculated home range boundaries. These usually occurred in the pre-dawn time interval, and lasted approximately one to two hours. Immediately before dawn, individuals would move to a resting site and remain stationary throughout most of the day. Although the same resting site was not selected, the new site was sometimes in relatively close proximity to the previous site. Occasional relocations during daylight hours were often associated with the onset of heavy rain.

Dynamic Interactions

Examination of dynamic interaction indicate that among radio-collared animals, there were 11 incidents of affiliative behavior and 19 incidents of avoidance. This difference was statistically significant ($\chi^2 = 8.11$,.p = 0.004), indicating that radio-collared individuals in this study were more dispersed than expected by chance alone. Thus, *V. tangalunga* appears to actively avoid direct interactions and exhibited no social behavior.

In the unlogged forest, both radio-collared females were always more dispersed than expected by chance, indicating that active avoidance was taking place. Interactions between radio-collared males entailed three cases of avoidance and three cases of attraction. Between genders, there were three incidents of male-female attraction and five of avoidance. In the logged forest, all three females appeared to actively avoid one another. Among the males, there were two incidents of avoidance and one of attraction. Between genders, there were four incidents of attraction and five of avoidance.

Because there may have been other animals residing in the study areas that were not radio-collared, the results of such a test of dispersion must be viewed with caution, and pertain only to distribution of study animals.

Day-Bed Sites

Six day-bed sites were located; for two females and two males in the unlogged forest, and for two females in the logged forest. These are characterized in Table 3-6.

All six day-bed sites were located at ground level, and were associated with some form of cover from either a fallen log or a dense clump of live or dead vegetation. All day-beds were located on well-drained terrain. All sites appeared accessible via several means of entrance or egress. Day-beds did not appear to be communal and no associated latrines were located.

In the logged forest, the day-bed for female FL 14 was located in a clump of herbaceous vines (*Merremia* sp.), 12 m from the edge of the main road, and consisted of a 12 x 20 cm oval area of matted-down vegetation. The day-bed for FL 16 was adjacent a smaller side road, and was located on a small dry hillock, one m above ground in a stand of Macaranga trees (*Macaranga gigantea*). The site was concealed by climbing vines and dried leaves.

In the unlogged forest, the resting site for female FP 3 was situated on a well drained east-facing slope below a large tree fall. The substrate was thick humus and decomposing wood. The resulting canopy gap created a dense tangle of vegetation surrounding the day-bed site which also provided shelter from above.

The day-bed site for female FP 6 consisted of a clump of strangler fig vines (*Ficus* sp.) at the base of a medium-sized canopy tree that had become dislodged from above and created a vine tangle at the base of the tree. This site was well sheltered and inaccessible to larger animal.

In the unlogged forest, male MP 2 had a day-bed site situated less than 100 m from the edge of the forest and approximately 50 m from the west bank of the Segama River. The site was located on the ground in a stand of wild ginger (*Alpinia* sp.), ferns (*Diplazium* sp.) and herbaceous vines (*Merremia* sp.). The site was on an east-facing slope of about 10° and consisted of a circle of matted down vegetation similar to that of FL 14.

The day-bed for male MP 7 was on a NE-facing slope, at the base of an old tree fall, below two large sections of trunk. It was approximately 50 m from the nearest trail in a relatively open area that was surrounded by dipterocarp saplings and poles. The area was dry, with good drainage and no streams in the immediate vicinity. The bed was located on a layer of humus and sheltered above by the fallen tree.

DISCUSSION

Activity

In this study, *V. tangalunga* was predominantly nocturnal and crepusular, which is considered the ancestral condition among mammals (Martin, 1990). Although most rain forest carnivores are considered cathemeral, van Schaik and Griffith (1996) concluded via camera trapping in northern Sumatra and West Java, that most viverrids in these forests are actually nocturnal. The activity pattern of *V. tangalunga* in this study supported their conclusions although evidence for crepuscular behavior was also observed. Nocturnal and crepuscular behavior may serve to reduce interference competition for fruit resources with diurnal frugivores such as birds and primates. That many prey species of *V. tangalunga* are nocturnal and crepuscular (e.g. scorpions, chilopods, blattodea and rodents) may provide additional explanation for the nocturnal and crepuscular behavior observed.

Mean activity budgets did not differ significantly between sites or gender. Activity increased dramatically with the onset of nightfall and declined shortly after dawn. Nocturnal activity levels peaked in the intervals after dark and before dawn, and showed one or more declines in the interim, indicating periods of rest that varied between animals in timing and duration. These variations may have been influenced by extrinsic factors such as weather and resource availability, and/or intrinsic factors such as health, reproductive status or previous activity levels.

Because activity is often associated with foraging, the timing and duration of which are usually a function of resource availability (Gittleman, 1989), these similarities in activity budgets between sites indicate that resource availability did not differ in the logged and the unlogged forests. The similarity in activity between gender may result from an overall similarity of energy output although males and females may have very different energy demands during breeding, parturition and lactation.

Activity budgets in this study were in concordance with observations of a single male *V. tangalunga* in Sarawak who was observed to be active only at night (Macdonald and Wise, 1979). Results were also similar to those observed among other civet species: five *P. hermaphroditus* in Nepal's Royal Chitwan National Park were active from 18:00 until 04:00 (Joshi, *et al.*, 1995), a single female in the same area was totally inactive during daylight hours (Dhungel and Edge, 1985) and a small Indian civet (*Viverricula malaccensis*), two *P. hermaphroditus* and large Indian civet (*Viverra zibetha*) in Thailand were generally active between 16:30 and 04:30, with peaks in activity between 19:30 and 01:30 (Rabinowitz, 1991a).

Mean overall activity levels in this study also compared favorably to those reported by Rabinowitz (1991a) for civets in Thailand (50 to 55%). Values were also similar to those reported for the large spotted genet (*Genetta maculata*, Gray 1830), near Elmenteita, Kenya, which had an activity budget of 47% and was 75 - 88% active between sunset and sunrise, while only 20% active during daylight (Fuller *et al.*, 1990).

Movement

Upon becoming active, animals moved directly from their day-bed to what was assumed to be a foraging site. Here, there was non-directional movement often criss-crossing over itself within a small area, which was assumed to involve foraging. Movement during continuous follows usually occurred within a portion of the animal's home range rather than around the perimeter, indicating that *V. tangalunga* were not regularly patrolling their home range borders and thus were probably not territorial. However, both genders made short forays beyond their home range boundaries, which may have involved scent marking or communication with other animals in adjacent or overlapping ranges.

Females were more localized in their daily movement, using a smaller total area and a smaller proportion of their total home range than males, although there was no difference in the minimum distance traveled in a 24 hour period between genders. One female in the logged forest (FL 14) was believed to be caring for at least one juvenile which may have influenced her movement patterns. During this time, her movement was restricted to a small portion of her home range and was characterized by very localized movement. This restricted movement may have resulted from limited mobility of her young.

The comparatively larger area covered by males may be explained in part by the lack of limitations associated with rearing young. Because solitary male carnivores invest more energy into procuring females (Sandell, 1989), the larger area covered by males and the correlation between distance traveled and home range size may be a function of investment in reproductive success. The peak in travel times just after dusk and just before dawn exhibited by both genders may have resulted from the spatial separation between foraging and resting sites.

Minimum daily distance traveled and speed of travel among *V. tangalunga* were similar to estimates from two long-nosed mongooses (*Herpestes naso*) in Central African Republic, another forest-dwelling, terrestrial viverrid with mixed diet. These animals traveled a mean distance of 2.3 km in 24 hours at a speed of 92 m in 30 minutes (Ray, 1997).

If a correlation between travel speed and home range size does indicate territorial behavior as suggested by Ray(1997), then the fact that a linear regression did not reach significance in this study, implies that no territorial behavior occurred. The extensive home range overlap observed in both sites supports this conclusion.

The observed tendency for *V. tangalunga* to be hyperdispersed could represent one means of avoidance in the absence of true territoriality. Scat collected along roads in the logged forest may have served as a means of communication to facilitate avoidance. One location on the central road in the logged forest site yielded an unusually high abundance of scat, with several deposits often separated by less than a meter. This area corresponded with home range boundaries (95% MCP) of two males (ML 13, ML 15) and may have been a site where communication between these males occurred.

The higher incidence of road traffic mortality among male civets could have resulted from a tendency for males to use roads more than females. Because males would travel further over a larger area than females in a single night, they may be more prone to utilize roads in the course of their regular movement. The high incidence of sub-adult road kills could have resulted from high mortality within this age category due to lack of experience, or a high frequency of road use by sub-adults. It is possible that some animals killed on roads were scavenging road kill themselves. The presence of animal fat and muscle tissue, but no bones, in the stomach of an old male *P. hermaphroditus* would suggest this (see Table 4-1).

Roads are used by big cats for travel, hunting (Schaller, 1967; Sunquist, 1981) and communication (Rabinowitz, 1986) and may serve similar functions for *V. tangalunga.* The presence of roads and similar linear clearings can have detrimental effects on populations of wildlife, such as fragmentation of populations, reduced genetic interaction, and increased mortality resulting from vehicle traffic (Goosem, 1997). For *V. tangalunga*, there was no observed fragmentation of populations as roads were readily crossed, and in many cases used with considerable frequency. However, the corollary of this is that there was evidence of increased mortality from vehicular traffic. Whereas roads may be an attractive habitat feature to this species, high traffic volume could result in a disproportionately high rate of mortality for species that are attracted to and use roads with high frequency. Although Goosem (1997) suggests means to reduce road mortality such as to provide alternate means of crossing, when the attraction to the road involves using it for range marking, inter species communication, travel and foraging, these recommendations do not apply. Thus, in logged areas that contain intact assemblages of fauna attracted to roads, the best means to reduce road mortality is reduce vehicular traffic and impose speed restrictions.

In the unlogged forest, where there were considerably fewer roads, there was no evidence of road traffic mortality for either gender. Vehicular accidents were the only source of mortality observed among civets during the course of the study, and accounted for eight known civet deaths. Sub-adults represented half of all known road kills. Thus, roads are an important source of mortality for animals inhabiting logged forests and may contribute to the slightly lower observed population density among *V. tangalunga* in these areas. Because fatality from vehicles appeared higher among males, it may also account in part for the observed female bias in trap success in the logged forest (3:8). Ecologically, a gender bias in favor of females should not significantly reduce the reproductive potential of the populations.

Dynamic Interactions

Radio-collared *V. tangalunga* were more widely dispersed than would be expected by chance alone, indicating that they actively avoided one another when selecting day-bed sites. Females were consistent in this pattern, whereas males exhibited both hyperdispersion and clumping of resting sites. Although inter-gender spacing of resting locations tended towards avoidance in this study, it was not possible to determine which gender was more prone towards avoidance. The overall trend of avoidance was similar to inter-gender behavior of the African palm civet (*N. binotata*) wherein animals showed home range overlap but were intolerant of potential competitors, particularly among females (Charles-Dominique 1978).

Day-Bed Sites

V. tangalunga selected day-beds located exclusively on the ground in well drained sites. Day-bed sites were either below a fallen tree, inside a dense vine tangle or within dense ground vegetation near the forest edge. Day-beds consisted of small temporary resting sites occupied by a single animal and did not appear permanent or communal. Day-beds were not observed to be used on consecutive nights. Observations in this study were consistent with those of Macdonald and Wise (1979) who found that a male *V. tangalunga* used at least six day-beds, all of which were located on the ground, in either dense undergrowth, or within the shelter of a limestone cave. Rabinowitz (1991a) also noted that civets in Huai Kha Khaeng did not return to day-bed sites on a regular basis. All day-beds located for two male *V. zibetha* shared two characteristics of day-beds of *V. tangalunga;* both were located on the ground and usually in dense vegetation. Because neither species is an agile climber, selection of high cover may compensate for a lack of access to cover and protection afforded by trees. The observed lack of fidelity to a single or few day-bed sites in this and other studies could be attributed to parasite avoidance as was suggested by Ray (1997), to explain similar behavior among *H. naso*. The numerous Strongyloid parasites such as *Ancylostoma* found in association with *V. tangalunga* (see section on Internal Parasites) are transmitted through infected soil and could play a role in reduced fidelity to terrestrial day beds. Similarly, the various species of tick parasites detected in both sites can be transmitted by frequent use of common areas, so reduced fidelity to day-beds could reduce Ascarid infestation.

No latrines were found in association with day-bed sites, although Macdonald and Wise (1979) reported finding 15 feces in the resting places for a single male *V. tangalunga* and captive individuals were observed to use latrines (pers. obs.). Again the presence of Strongyloid-type parasites may lead to an increased tendency to avoid defecation near rest sites.

Table 3-1. Activity levels of *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

			DAY					NIGHT		
Study animal	n	I/S	A/S	I/M	A/M	n	I/S	A/S	I/M	A/M
UNLOGGED FOREST										
MP 1	322	70%	14%	9%	7%	193	16%	6%	43%	36%
MP 2	239	77%	11%	6%	6%	127	13%	11%	35%	42%
FP 3	277	68%	11%	13%	9%	180	9%	5%	31%	56%
MP 5	117	79%	10%	6%	5%	86	14%	15%	9%	62%
MP 7	189	69%	2%	24%	5%	111	19%	0%	28%	53%
Mean		73%	10%	11%	6%		14%	7%	29%	50%
LOGGED FOREST										
FL 9	193	86%	7%	3%	5%	102	14%	7%	25%	54%
ML 10	107	75%	6%	10%	9%	68	15%	2%	37%	47%
ML 13	210	71%	7%	12%	11%	140	12%	3%	32%	53%
FL 14	214	69%	14%	10%	7%	160	14%	4%	23%	59%
ML 15	203	84%	3%	10%	3%	179	22%	2%	36%	40%
FL 16	117	73%	9%	6%	13%	104	10%	2%	29%	60%
Mean		76%	7%	9%	8%		14%	3%	30%	52%
Mean male		75%	8%	11%	7%		16%	6%	31%	47%
Mean female		74%	10%	8%	9%		12%	5%	27%	57%
Overall mean		74%	8%	10%	7%		14%	5%	30%	51%

I/S = Inactive/Stationary
A/S = Intermittently Active/Stationary
I/M = Inactive/Moving
A/M = Active/Moving

Table 3-2. Results of t-tests of diurnal and nocturnal activity levels among *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Time	Site	Mean	Variance	df	t	p
Day	Unlogged	0.202	0.00624	9	0.213	0.836
	Logged	0.193	0.00336			
Night	Unlogged	0.908	0.02045	9	0.629	0.545
	Logged	0.95	0.00593			
	Gender					
Day	Male	1.362	0.00396	8	0.272	0.792
	Female	1.374	0.00547			
Night	Male	0.896	0.01124	8	1.524	0.162
	Female	0.993	0.00828			

Day = 08:00 - 18:00
Night = 18:00 - 08:00

Table 3-3. Results of t-tests of activity levels between male and female *Viverra tangalunga* in Sabah, East Malaysia

Activity	Gender	Mean	Variance	df	t	p
Day						
I/S	Male	0.850	0.0069	9	0.256	0.804
	Female	0.834	0.0172			
A/S	Male	0.076	0.0020	9	0.956	0.364
	Female	0.100	0.0010			
I/M	Male	0.110	0.0038	9	0.883	0.400
	Female	0.079	0.0020			
A/M	Male	0.066	0.0006	9	1.111	0.295
	Female	0.085	0.0011			
Night						
I/S	Male	0.159	0.0014	9	2.051	0.070
	Female	0.115	0.0007			
A/S	Male	0.055	0.0031	9	0.320	0.757
	Female	0.046	0.0004			
I/M	Male	0.320	0.0123	9	0.809	0.440
	Female	0.273	0.0012			
A/M	Male	0.497	0.0108	9	2.011	0.075
	Female	0.606	0.0011			

I/S = Inactive/Stationary
A/S = Active Intermittently/Stationary
I/M = Inactive/Moving
A/M = Active/ Moving

Table 3-4. Results of t-tests of activity levels between *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Activity	Site	Mean	Variance	df	t	p
Day						
I/S	Unlogged	0.814	0.0057	9	0.965	0.363
	Logged	0.870	0.0124			
A/S	Unlogged	0.097	0.0021	9	0.915	0.384
	Logged	0.074	0.0014			
I/M	Unlogged	0.115	0.0056	9	0.884	0.400
	Logged	0.085	0.0012			
A/M	Unlogged	0.064	0.0002	9	0.986	0.350
	Logged	0.081	0.0012			
Night						
I/S	Unlogged	0.142	0.0014	9	0.110	0.915
	Logged	0.144	0.0019			
A/S	Unlogged	0.074	0.0014	9	1.608	0.142
	Logged	0.033	0.0034			
I/M	Unlogged	0.296	0.0163	9	0.215	0.835
	Logged	0.308	0.0034			
A/M	Unlogged	0.522	0.0147	9	0.424	0.682
	Logged	0.549	0.0076			

I/S = Inactive/Stationary
A/S = Active Intermittently/Stationary
I/M = Inactive/Moving
A/M = Active/Moving

Table 3-5. Results of continuous follows of *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Study animal	Date	Time interval	Duration of follow	Total distance [1]	Mean speed[2]	Area covered[3] (MCP)	% total home range[3]
UNLOGGED FOREST							
MP1	11/1/96	12:00-10:30	10.5	4.1	194.9	33.3	24.0%
MP 2	11/1/96	10:30-10:00	24.0	9.1	261.1	73.7	73.5%
FP 3	11/1/96	19:30-03:30	12.0	2.1	211.0	5.5	5.6%
FP 3	11/20/96	09:30-09:30	24.0	3.2	84.5	9.6	9.8%
MP 7	3/24/97	12:00-01:00	13.0	1.0	38.0	1.7	1.3%
MP 7	4/8/97	13:30-13:30	24.0	5.9	134.4	92.3	69.4%
MP 7	4/27/97	17:35-17:30	24.0	6.3	144.1	90.3	67.9%
MP 7	5/16/97	13:30-13:30	24.0	4.4	124.7	34.2	25.7%
Mean				**4.5**	**149.1**	**60.0**	**49.3%**
Mean Male				**5.1**	**149.5**	**72.6**	**59.1%**
Mean Female				**2.7**	**147.7**	**9.6**	**9.8%**
LOGGED FOREST							
ML 10	12/9/96	10:00-14:00	6.0	2.0	119.6	10.9	6.1%
ML 13	4/1/97	17:00-11:00	6.0	9.7	335.1	140.1	42.6%
ML 13	6/20/97	09:00-09:00	24.0	5.9	138.1	87.4	26.6%
ML 15	11/7/96	13:00-08:30	19.5	3.4	77.3	14.9	12.0%
ML 15	11/8/96	10:30-10:30	24.0	4.8	102.0	5.7	4.6%
ML 15	12/9/96	12:00-09:00	21.0	4.7	126.8	109.5	88.5%
FL 14	3/11/97	09:00-09:00	24.0	2.4	128.6	11.8	8.3%
FL 14	3/31/97	10:30-10:30	24.0	2.5	206.0	16.1	11.3%
FL 14	4/22/97	17:00-17:00	24.0	8.6	276.9	27.2	19.1%
FL 16	11/11/96	11:00-11:00	24.0	4.0	88.2	30.4	24.7%
FL 16	5/5/97	17:30-17:30	24.0	6.5	139.2	43.9	35.7%
Mean				**5.0**	**158.0**	**48.7**	**25.6%**
Mean male				**5.1**	**149.8**	**54.4**	**32.9%**
Mean female				**4.8**	**167.8**	**25.9**	**19.8%**

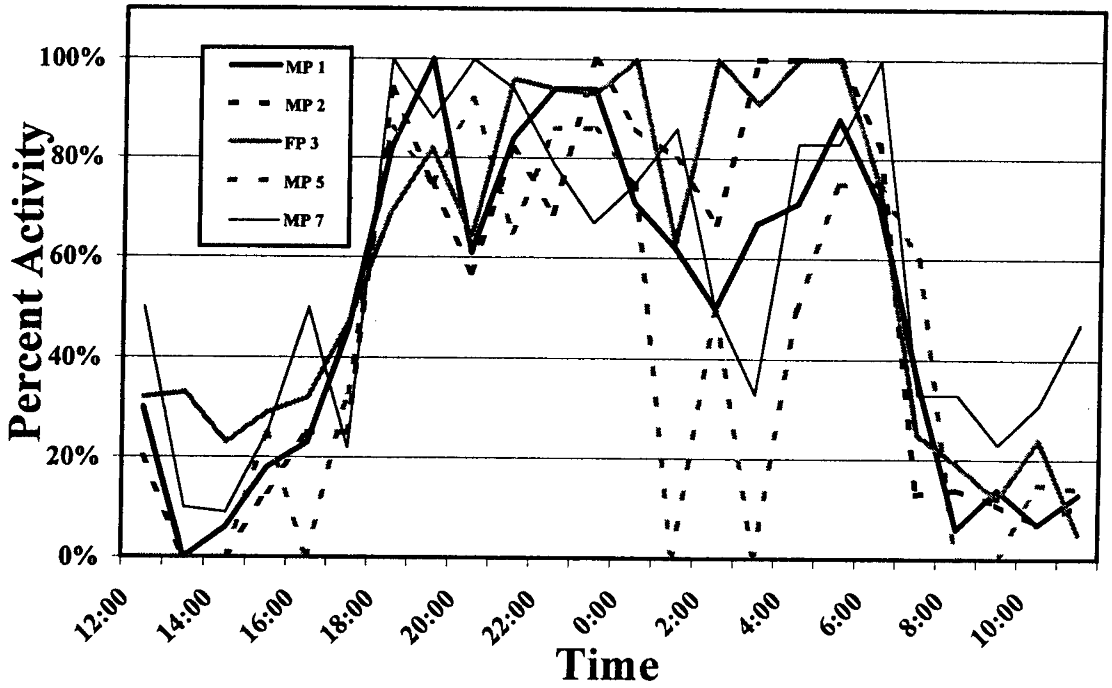
1 = km.
2 = m/30 min.
3 = ha.

Table 3-6. Characteristics of day-bed sites for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia

Study animal	Date	Location	Dist. from trail	Elevation	Cover	Vegetation type	Bed characteristics	Slope	Hydrology	Canopy	Proximity to forest
UNLOGGED FOREST											
MP 2	10/30/96	1	100 m	ground level	moderate	Below stand of wild ginger in thicket of	Temporary, solitary, flattened vegetation	E 20°	50 m from Segama river	open	100 m beyond forest edge
MP 7	1/30/97	2	50 m	ground level	low	In forest ridge/slope among stand of poles	Floor level spot below old large fallen tree	W 15°	dry	closed	within
FP 6	11/6/96	4	10 m	ground level	high	Inside dense clump of fallen strangler fig vines	Could not see inside den without destroying	S 10°	dry	closed	within
FP 3	12/19/96	5	100 m	ground level	high	In large open area; trees all broken/dead, no canopy, dense ground vegetation, vine tangles, rotan and creepers	Probably near large fallen tree with signs of pigs, dry and well shelterd	E 10°	stream within 50 m	open	within
Radio-Collar FP 6		6	40 m	ground level	high	In dense vegetation in stand of mature dipterocarp trees	Laying on ground above carpet of dead leaves	SW 20°	30 m from stream	closed	within
LOGGED FOREST											
FL 16	9/26/96	7	6 m	1 meter hillock	high	In climbing vine tangle	Dry area covered with leaves and twigs	0°	dry	none	20 m beyond forest edge
FL 14	10/18/96	8	2 m	ground level	open	Small clump of roadside vegetation		0°	dry	none	25 m beyond forest edge
Radio-collar FL 11		9	19 m	500cm above ground	moderate	In stand of macaranga trees	Inside hole in fallen log	0°	dry	closed	20 m inside

Figure 3-1. Hourly activity levels for *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia.

Unlogged Forest



Logged Forest

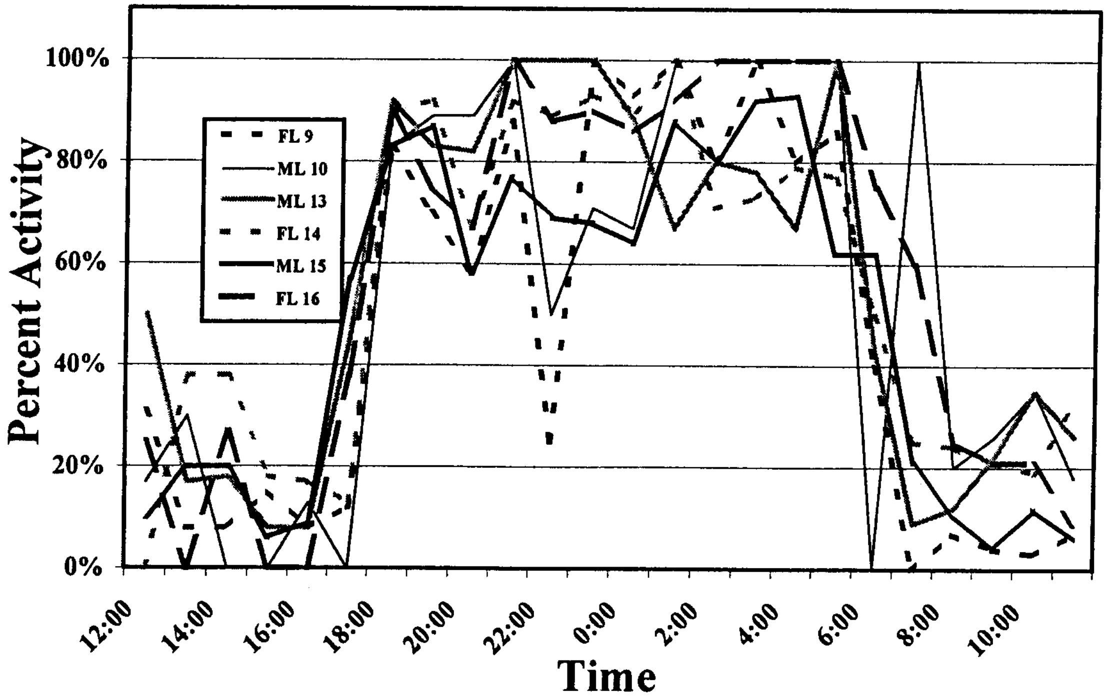
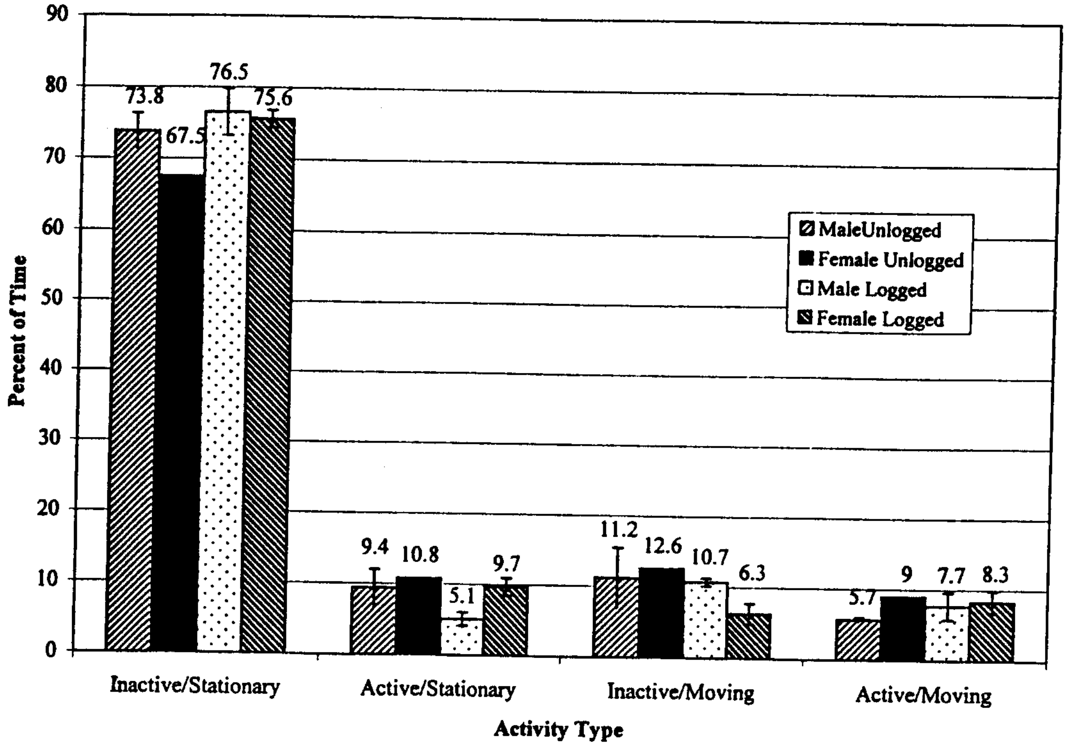


Figure 3-2. Mean diurnal and nocturnal activity levels for *Viverra tangalunga* in both forest types in Sabah, East Malaysia.

Diurnal activity categories



Nocturnal activity categories

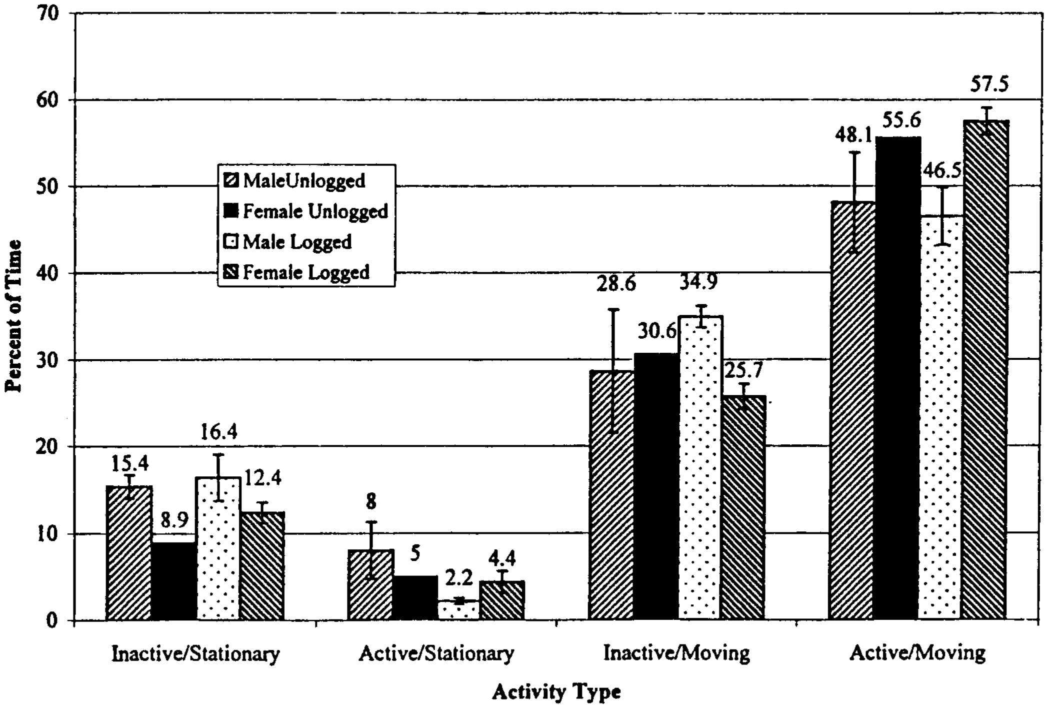
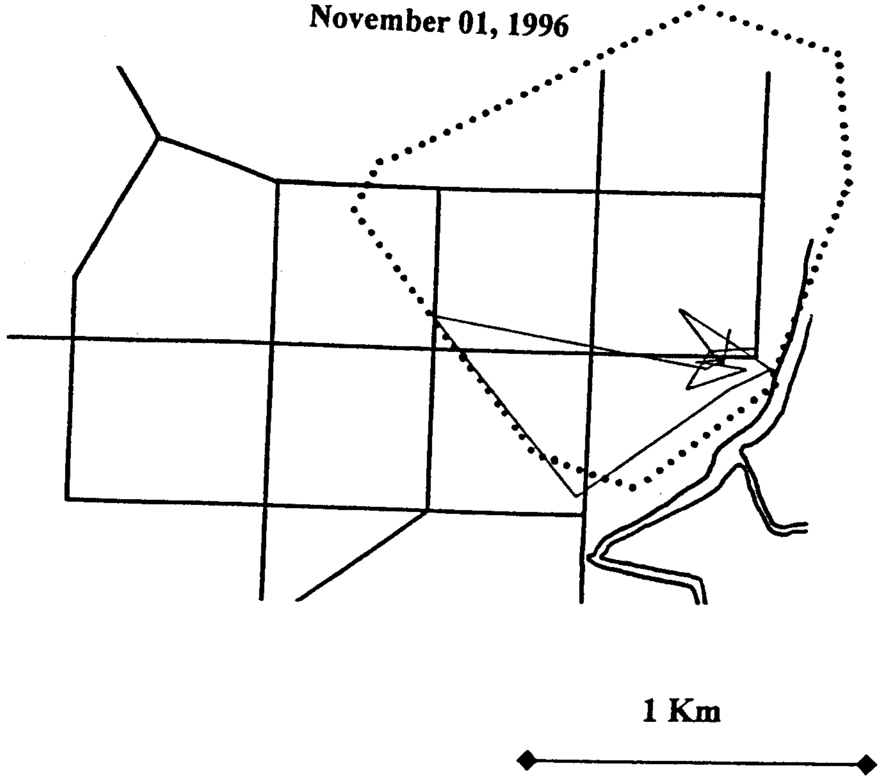
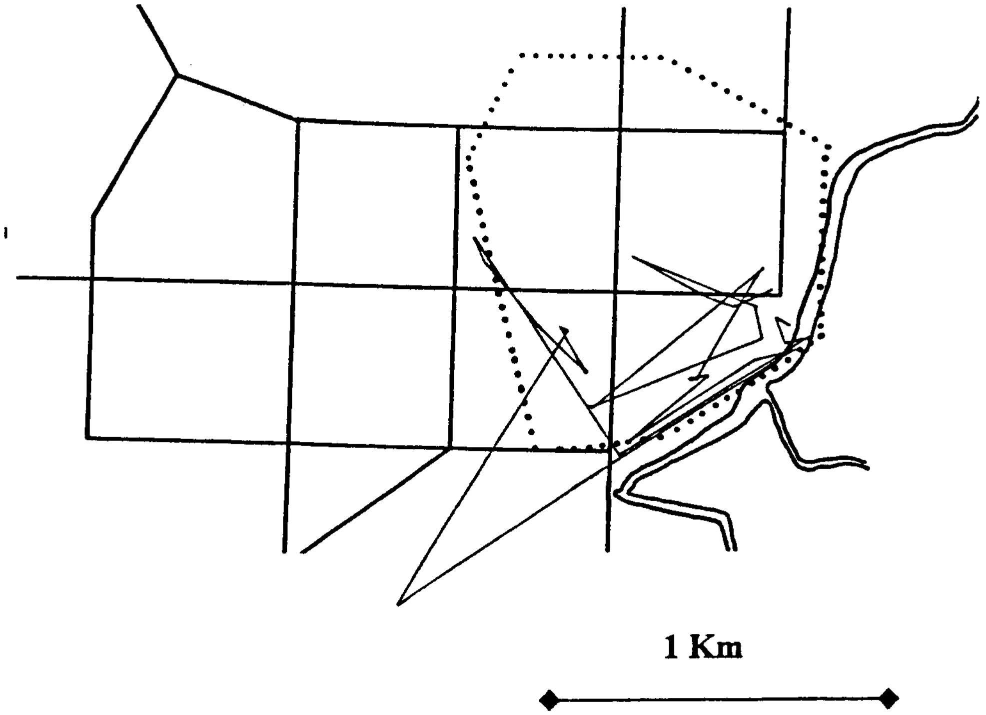


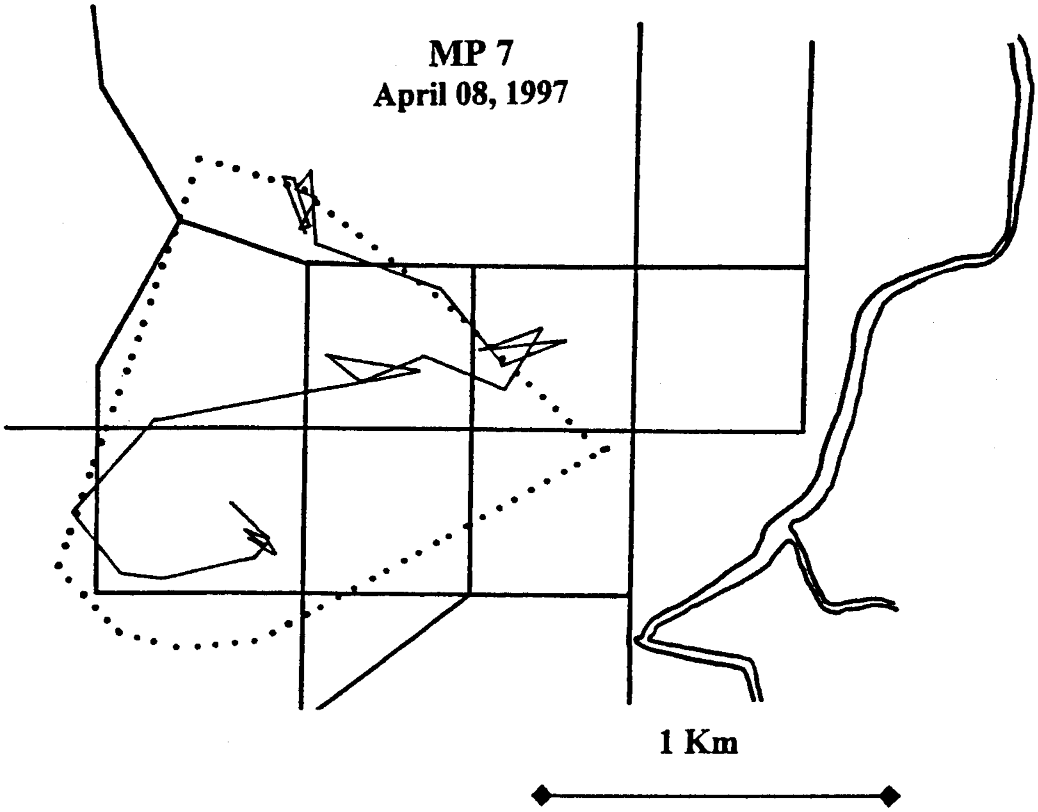
Figure 3-3. Route traveled by male *Viverra tangalunga* during continuous follows in an unlogged forest in Sabah, East Malaysia.

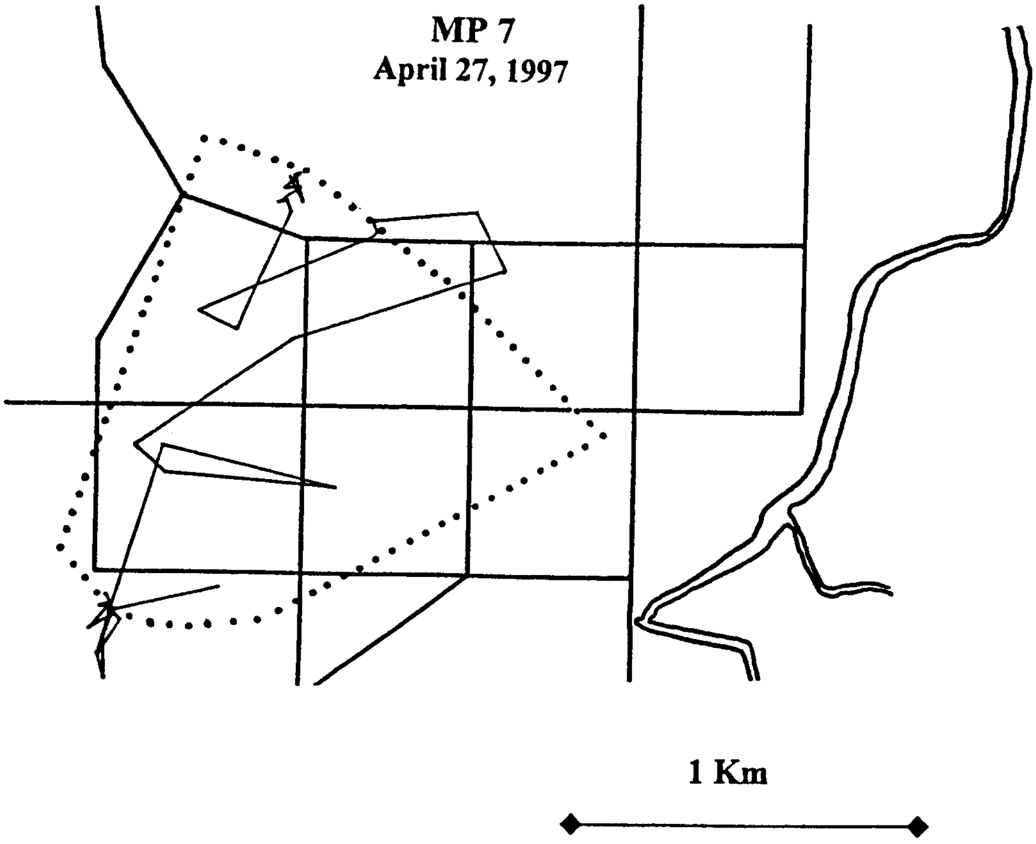
MP 1
November 01, 1996

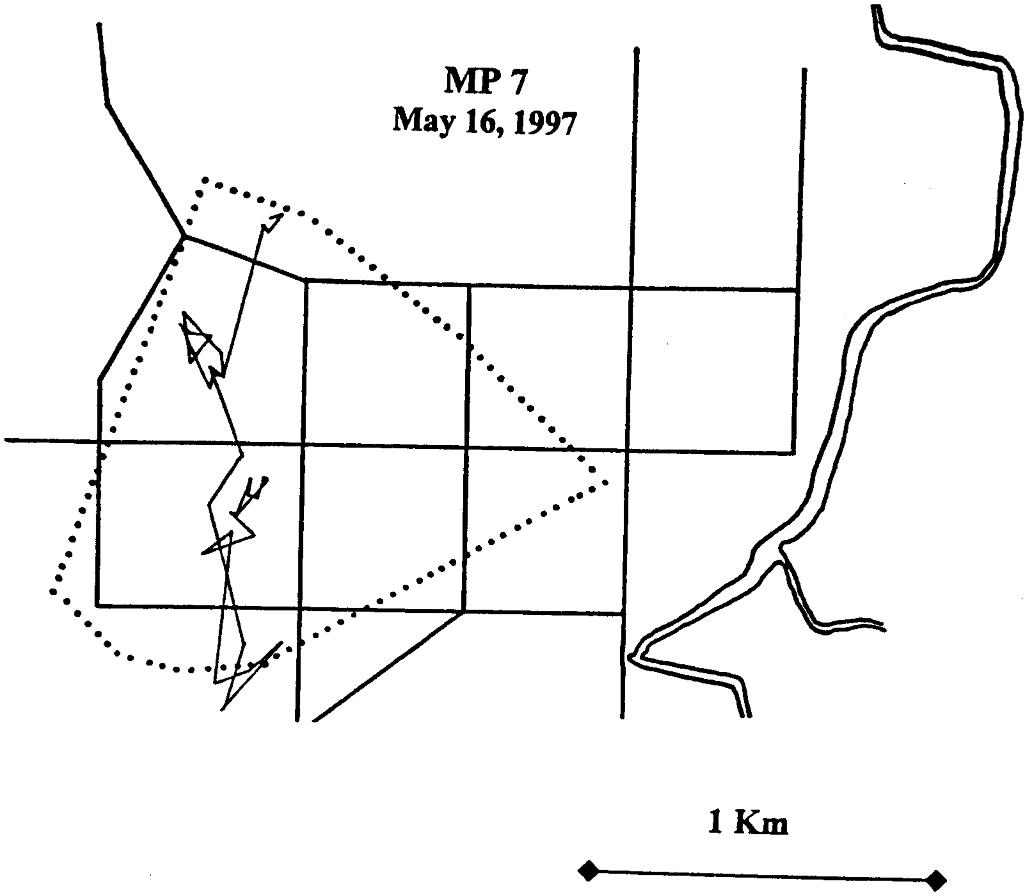


MP 2
November 01, 1996




MP 7
April 08, 1997


MP 7
April 27, 1997



MP 7
May 16, 1997

Figure 3-4. Route traveled by female *Viverra tangalunga* during continuous follows in an unlogged forest in Sabah, East Malaysia.

FP 3

November 20, 1996

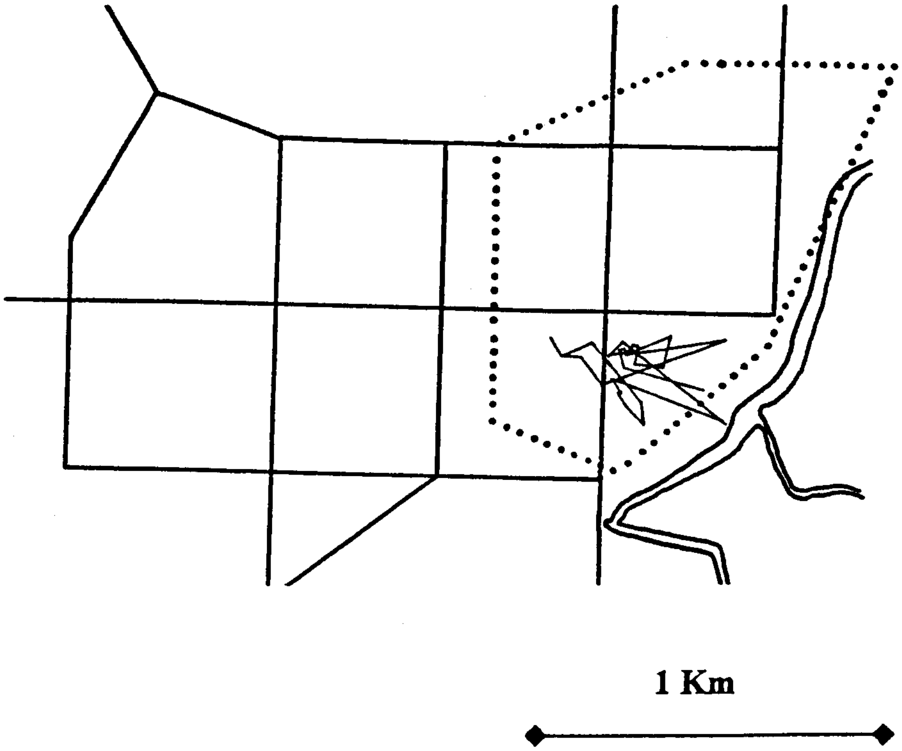
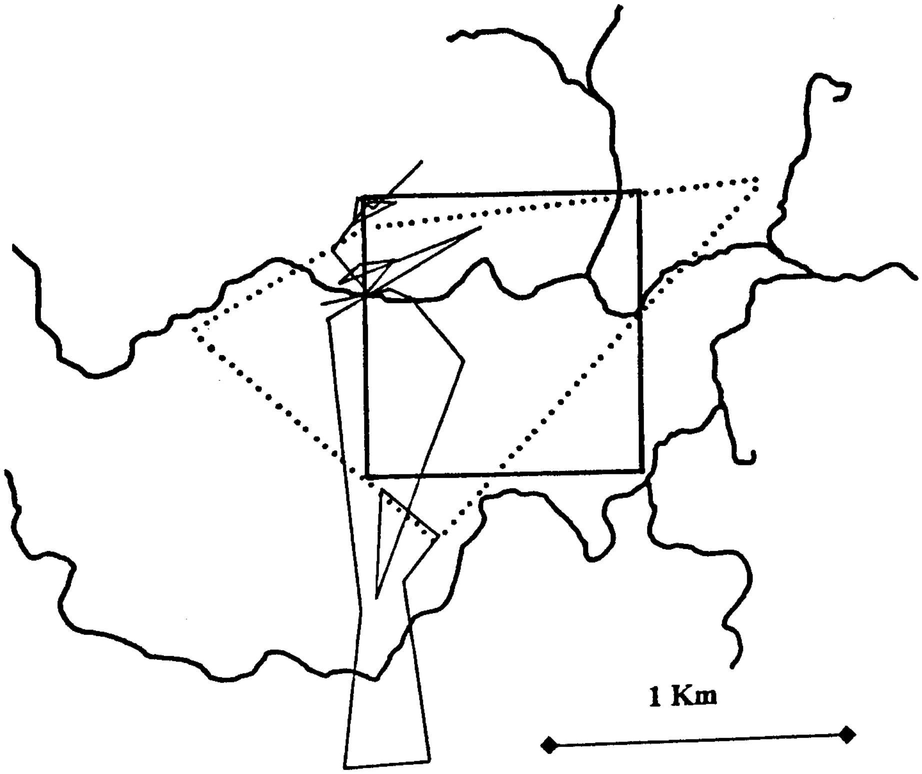
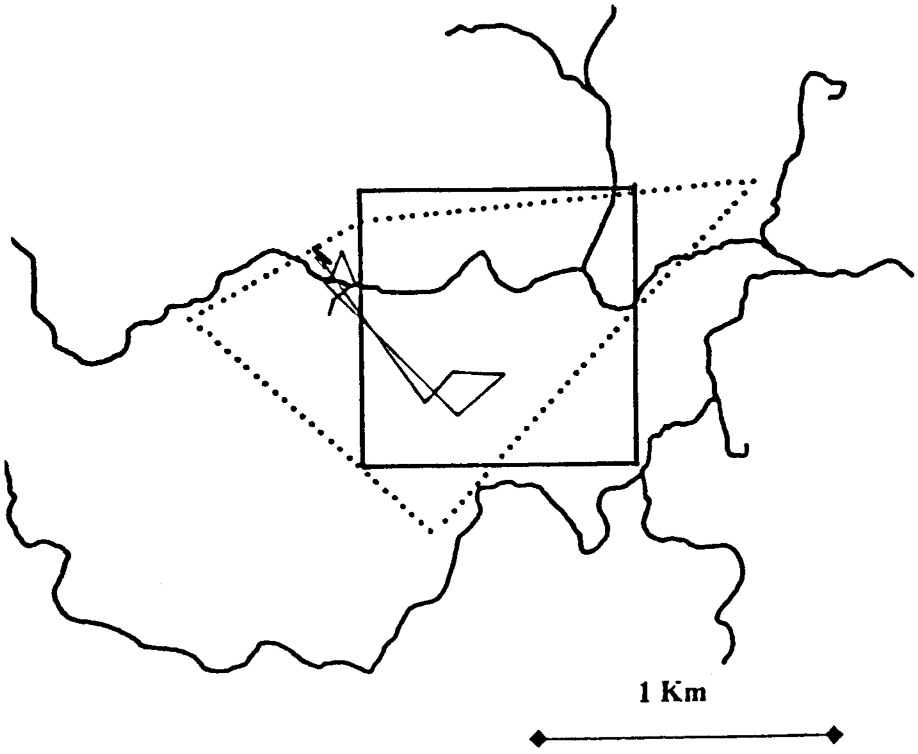


Figure 3-5. Route traveled by male *Viverra tangalunga* during continuous follows in a logged forest in Sabah, East Malaysia.

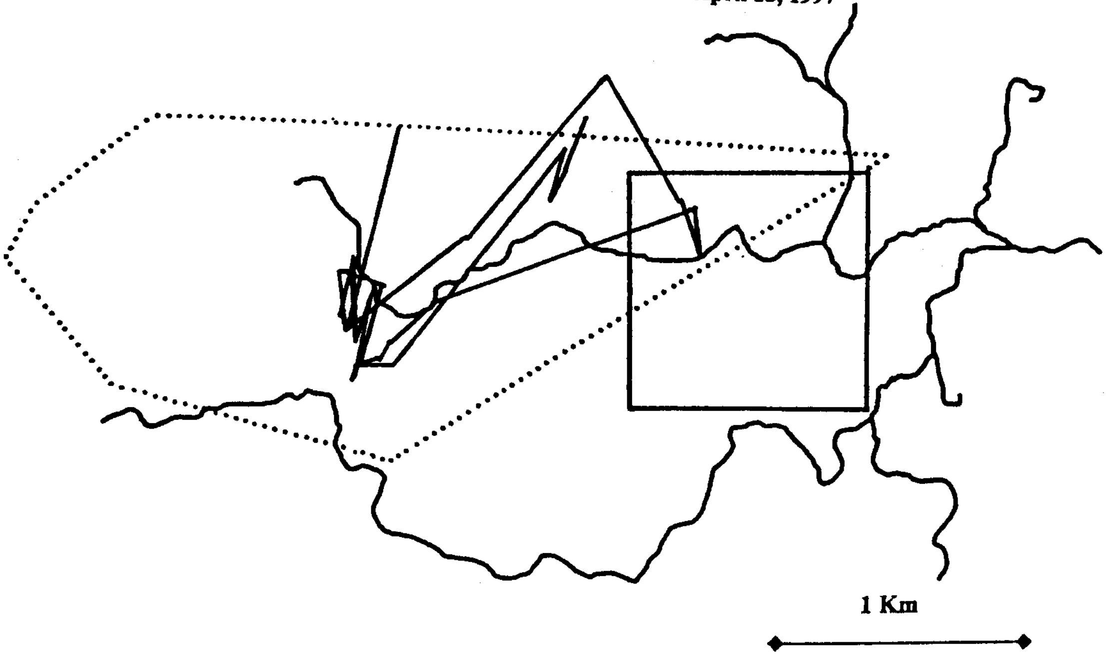
ML 10
December 09, 1996



ML 15
November 07, 1996



ML 13
April 15, 1997



ML 13
June 20, 1997

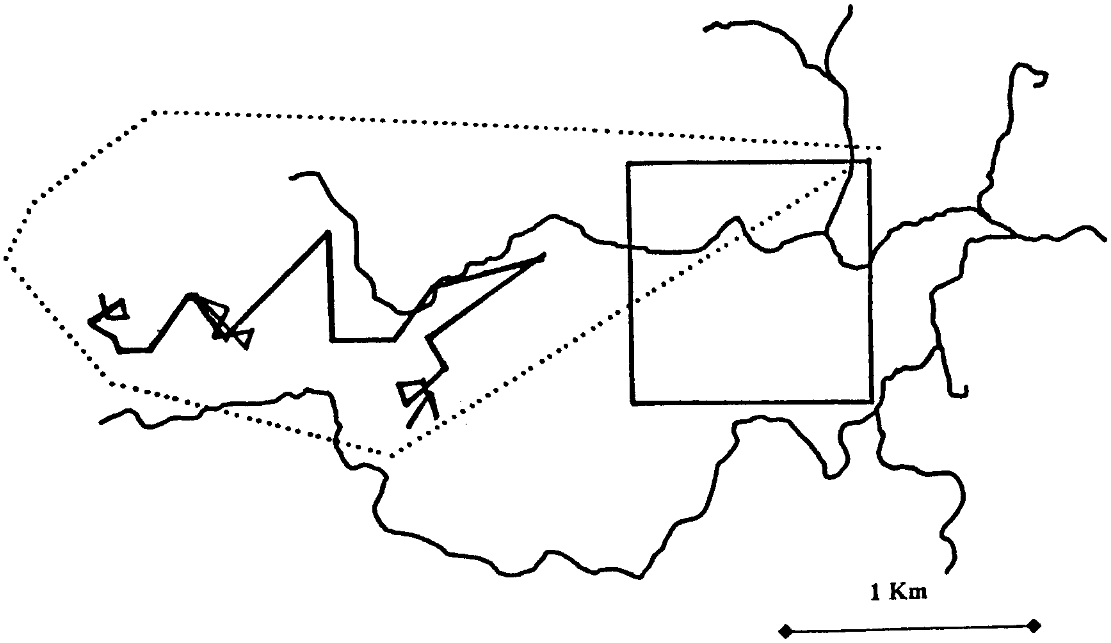
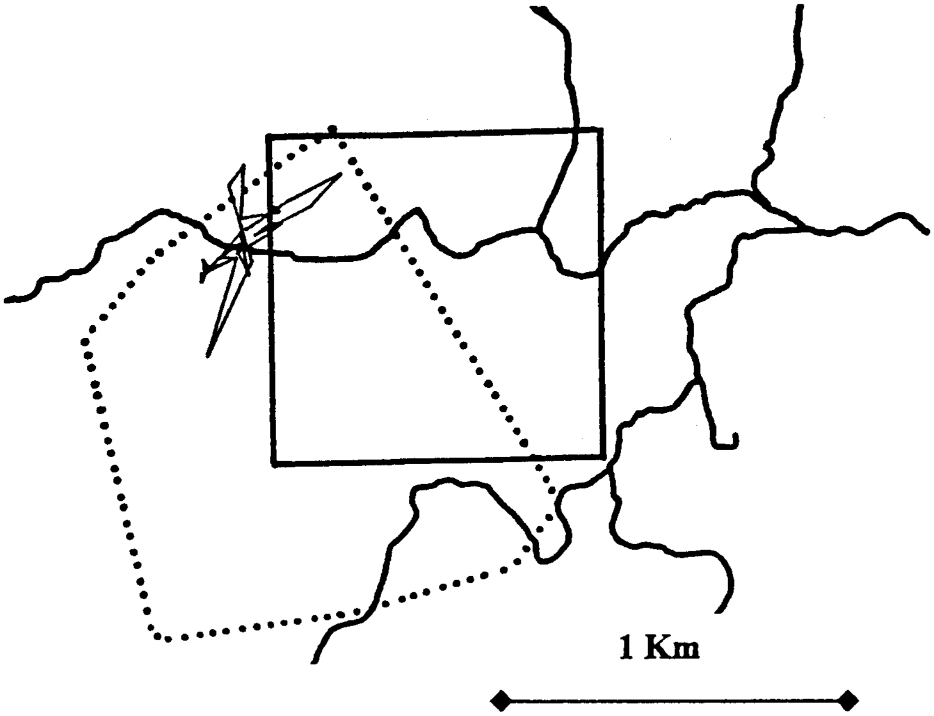
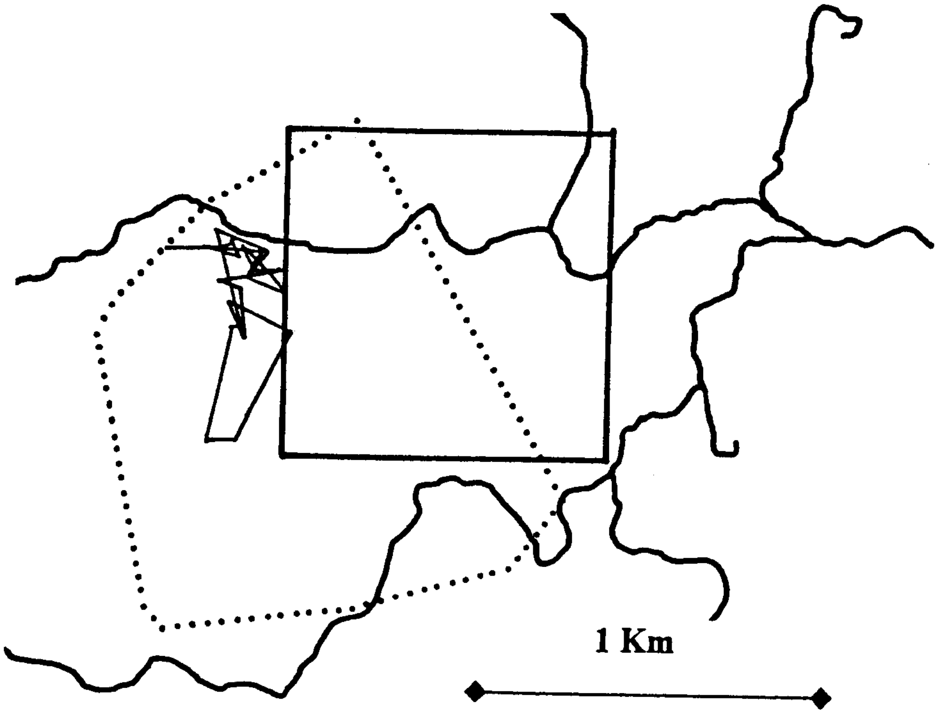


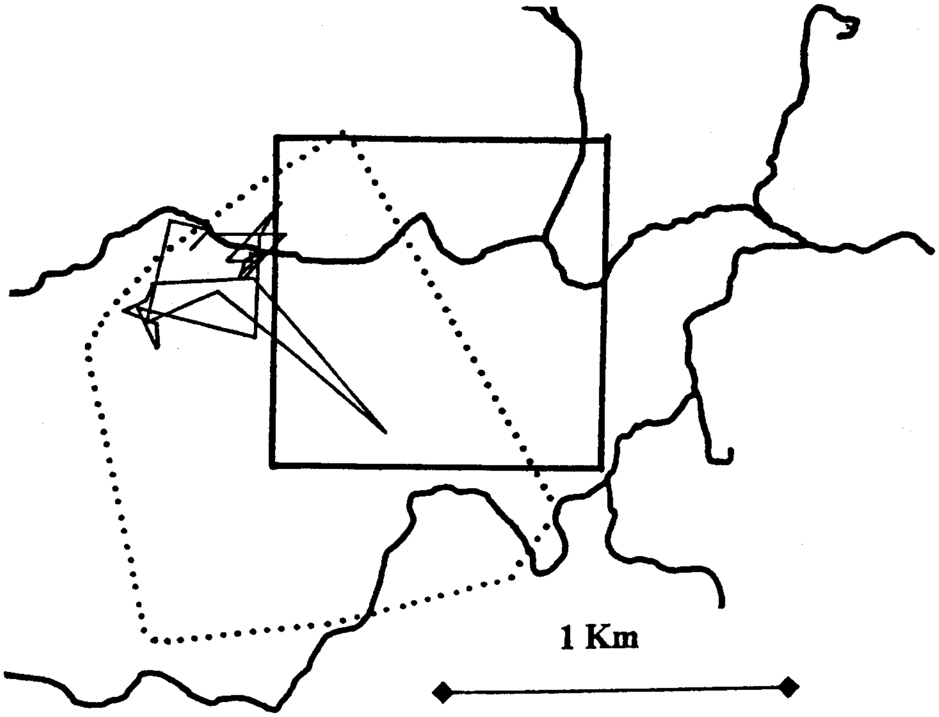
Figure 3-6. Route traveled by female *Viverra tangalunga* during continuous follows in a logged forest in Sabah, East Malaysia.

FL 14
March 11, 1997



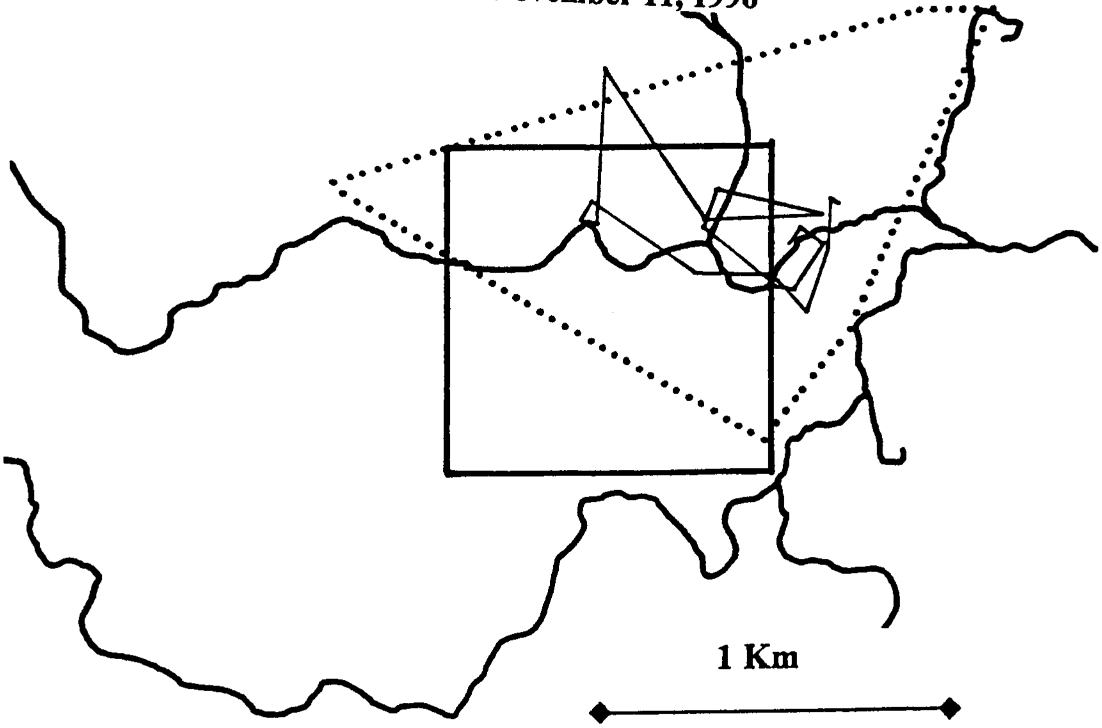
FL 14
March 31, 1997



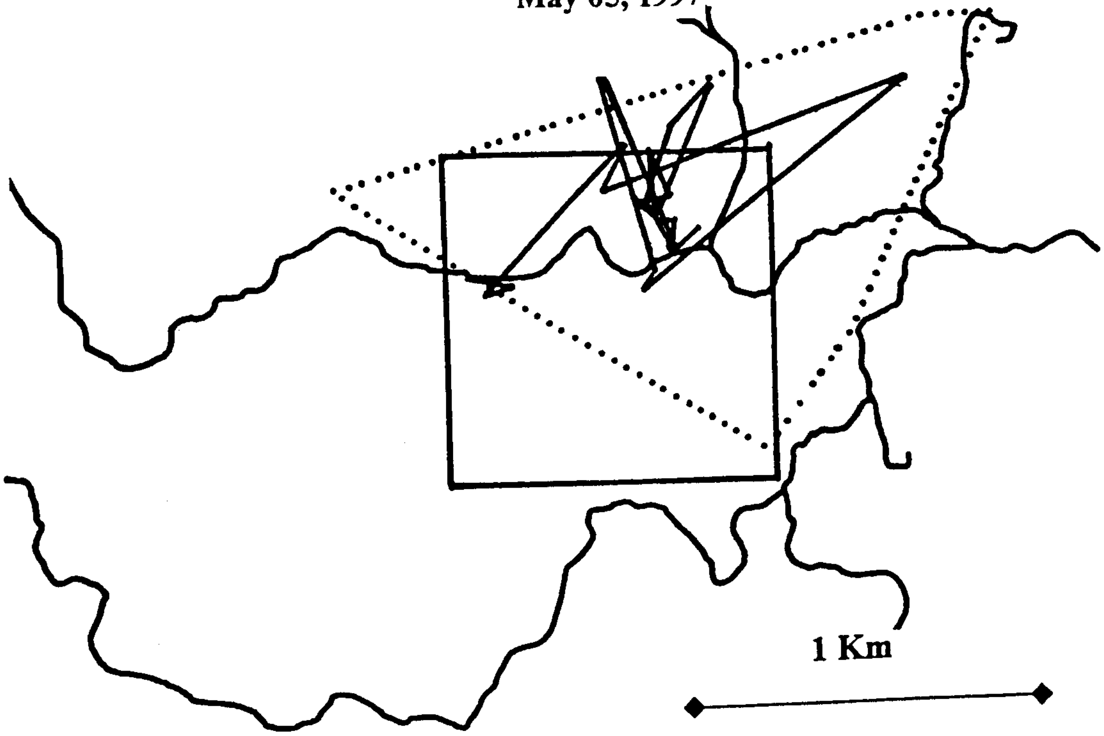


FL 14
April 22, 1997

FL 16
November 11, 1996



FL 16
May 05, 1997



4.

DIET AND PARASITES

INTRODUCTION

Information on a species' diet is essential not only for an understanding of its basic ecology, but because diet is often tied to resource availability, which is in turn directly impacted by habitat modifications. Thus, a species' ability to adapt to environmental changes is largely dependent upon its dietary plasticity.

In this study, scat analysis and stomach contents from road kills were used to quantify the diet of civets in logged and unlogged areas. Pit trapping provided an index of relative prey availability in both sites. Although no quantification of fruit availability was carried out, the presence of seeds in civet scat provided information on the extent of frugivory and the species consumed. This information is particularly important in terms of seed dispersal and forest regeneration. Fruit availability in dipterocarp forests declines after selective logging (Johns, 1985), and seed dispersal by vertebrates is an important component of forest recovery (Corlett, 1995). Studies of the role civets play in this process are lacking, yet among Asian carnivores, civets are the most consistently frugivorous (Corlett, 1998). Further, dispersal of large-seeded fruits is dependent on very few vertebrate species, many of which are vulnerable to the effects of human disturbance. *V. tangalunga* has demonstrated some ability to persist, in disturbed habitat, thus data on the extent of frugivory and the species of fruit consumed are important in order to gain a better understanding of their role in forest regeneration.

Parasites often play an important role in regulating host populations and become particularly important when habitat is altered and host species become stressed. Among carnivores, parasites are often a function of diet; therefore, data on both internal and external parasites are included here.

Diet

Omnivory is thought to be a rare strategy among terrestrial vertebrates. In studies of food webs, the presence of organisms that feed on more than one trophic level is believed to have a destabilizing effect on the system (Pimm, 1982), while dietary specialists are often assumed to be more efficient at procuring food. Studies to test this theory have been unsuccessful in detecting any increase in efficiency or survival rates for specialists (Dean and Ricklefs, 1980), but evidence to the contrary has been reported. Hamilton *et al.* (1978) found that during periods of low food availability, oryx (*Oryx gazella*), which are more restricted in their dietary intake, died of starvation, while the more omnivorous chacma baboons (*Papio ursinus*) were able to survive by accessing alternate food sources unavailable to the oryx. Berenstain (1986) showed that among long-tailed macaques (*Macaca fascicularis*) in eastern Borneo, both dietary breadth and flexibility in ranging patterns were important factors that allowed them to survive under highly variable environmental conditions. Similarly, Johns (1985) concluded that animal species adapted to search for a variety of food resources unevenly distributed in space and time survive logging better than species that rely on a highly predictable diet.

Thus, dietary generalists may be more adaptable and more likely to survive under conditions of continually changing resource availability and high competition for food. Despite the relative rarity of terrestrial omnivores, the few species that fill this niche are usually quite abundant in their habitat (e.g., raccoon and opossum) indicating that they can be highly successful.

Many species of civets are reported to be at least partially omnivorous (Eisenberg, 1989). Although the Malay civet is considered primarily carnivorous and insectivorous (Payne *et al.*, 1985), it has been reported to feed on leaves, fruit and even camp scraps (Macdonald and Wise, 1979) and could therefore be considered a dietary generalist.

The limited information on the wild diets of many civet species is primarily obtained from incidental finds or road kills. These often yield conflicting reports, which could be an indication of the highly omnivorous and opportunistic feeding behavior of civets, or could reflect seasonal shifts in dietary intake. Rabinowitz (1991b) has suggested that sympatric civet species are able to coexist by partitioning resources on a spatial as well as dietary level. However, it is also possible that such high species packing is facilitated in part by high dietary plasticity which may serve to reduce interspecific competition. Data on the diet of civets from road kills and scat were collected here to examine dietary breadth and overlap between species and between study sites.

Parasites

Parasites play a major role in the ecology, behavior and survival of many species of mammal, particularly after an environmental disturbance (see Dobson and Hudson, 1986 for a review). Despite previous assumptions that disease is rare among wild animal populations (Scott, 1988), data on natural die-offs among mammals indicate that disease is often the cause, particularly among carnivore species (Young, 1993). Carnivores are often exposed to a wide variety of parasites by virtue of ingesting other animals, both living and dead (Young, 1993), thus parasites should be considered in any discussion of carnivore ecology (e. g. May, 1988; Scott, 1988; Thorne and Williams, 1988). Although infection is fairly common among wild carnivores, particularly in the wet humid tropics, the effects are often varied, and can influence an individual's behavior, movement, home range size and even an individual's ability to hold an exclusive territory. Factors such as stress, diet, population density and frequency of encounter with other individuals all influence the rate and extent of infection and the incidence of disease and/or death (Scott, 1988).

Because so little is known about the diseases of small carnivores (Williams and Thorne, 1996) there are currently no data by which to determine what species of parasite or levels of infection represent 'normal' levels. This study represents the first effort to the author's knowledge to generate such baseline data for *V. tangalunga* and other sympatric civets. Further, human activities often have a profound effect on the incidence of infection and disease in populations of wild animals, and due to the high rate of habitat modification in this geographic region, such changes are likely to occur among the area's wildlife. Therefore, data on parasite assemblages in relatively undisturbed areas are essential for comparison with those in disturbed or degraded areas.

Most species of macroparasites tend to be unevenly dispersed in their host population (e. g McNeill, 1983; Watkins and Harvey, 1942) so in a given area, only a few individuals are heavily infected, and a small sample will frequently overlook the presence of a disease or infection. Because the observation of a parasite in a preserved scat sample is affected by the age of the sample at collection and the amount of time that passes before it is examined, no quantitative analysis of parasite load was possible in this study. Comparisons of parasite assemblages between sites could be made only on the basis of percent similarity, diversity and richness.

In addition, different factors that influence the incidence and extent of infection often have opposing effects. For example, high density and high home range overlap is expected where resources are more abundant, but can also contribute to a higher incidence of infection (Anderson, 1982). Conversely, poor habitat quality or scarce resources, can also lead to an increase in the rate of parasite infection, due to poor health and high stress. Therefore both a healthy as well as a stressed civet population could be expected to carry relatively high parasite loads.

METHODS

Diet

Data on the feeding ecology of *V. tangalunga* and other sympatric civets were obtained through scat analysis and examination of stomach contents. Scats were collected opportunistically from December, 1995 through May, 1997. Scat collection was more successful along roads. Due to the lack of roads in the unlogged forest, some samples were collected from a nearby ecotourism facility, Borneo Rain Forest Lodge, a straight-line distance of approximately six km from the field center.

Scats were identified on the basis of size, location, morphology and banding patterns of grooming hairs. When grooming hairs were not located in the scats, or could not be identified with certainty, they were considered collectively as from civets and not attributed to any single species.

Scats were bagged, labeled and dried at 50 °C for 24 hours. They were later soaked in 30% ethanol for 12 hours and examined under a dissecting microscope for content analysis. Diet items were identified using a reference collection of prey items from the study area. Seeds were identified by botanists at the Forest Research Center in Sandakan, East Malaysia.

Stomachs were retrieved from six civet road kills collected in the logging concession [two each of *V. tangalunga,* common palm civet (*Paradoxus hermaphroditus),* banded palm civets (*Hemigalus derbyanus*)]. Contents were preserved in 10% formalin and identified under a dissecting microscope. Data were recorded on a presence absence basis. A sub-sample was examined at 100x magnification for earthworm chaetae.

Comparisons of diet between sites were made for *V. tangalunga* as well as for other civets as a group. Frequency of encounter of each diet category was compared between sites using a χ^2 test of observed versus expected frequency based on the assumption of no difference between sites. The Renkonen index of percentage similarity (Krebs, 1989) was used to quantify the extent that assemblages overlapped between sites. Diversity of the diets between sites was determined using Simpson's index of diversity (Ricklefs, 1997) and species richness was compared between sites. Differences between sites were evaluated with a χ^2 test as above. In order to test for opportunistic feeding, diet composition was compared to prey availability.

Prey Availability

Prey availability was determined through pit trapping, from 8 October, 1996 to 7 November, 1996 in both forest types. In each study site pit traps consisted of 10 smooth-sided plastic buckets 22.6 cm deep and 25.2 cm in diameter, with four, one m long, 10 cm high sheets of perpendicular metal radiating out at 90 degrees along Cartesian coordinates increasing the total trap area to four m^2. Traps were buried so that the lip was flush with the ground, and placed at 10 m intervals along an east-west transect. One inch of untreated water was placed in each trap to drown captured animals. Traps were checked on alternate days for 30 days. Both transect sites were located 100 m in from the edge of the trail grids. The transect in the selectively logged forest was selected to traverse both undisturbed and heavily disturbed forest patches. Species richness, diversity and similarity of prey availability between sites were estimated as above. Comparisons between sites were made using a χ^2 test.

Internal Parasites

A subsample of fresh scat collected was preserved in 10% formalin for gut parasite analysis. Samples were sent to the Department of Comparative Medicine at the University of Tennessee, Knoxville and were analyzed using both sucrose and zinc sulfate flotation. Internal parasites were identified primarily to family and genus, although two were identified to species. All quantification and comparisons of internal parasites were carried out with the same methodology used for diet and prey availability data.

External Parasites

External tick parasites (Acaridae) were collected opportunistically from immobilized *V. tangalunga*. Ticks were preserved in 95% ethanol and sent to the

Department of Parasitology at the University of Queensland for identification. All ticks were identified to genus or species level.

RESULTS

Diet

Table 4-1 contains a list of all items identified in the stomachs of six road kills examined. The stomach of one juvenile male *V. tangalunga* contained Lumbricidae chaetae, grass, and the remains of some Hymenoptera and Orthoptera. A sub-adult female *V. tangalunga* contained small berries and seeds of the same unidentified plant species, as well as Lumbricidae chaetae, Formicidae, Coleoptera, Orthoptera and leaf matter. The stomach of one old male *P. hermaphroditus* contained all the items listed above as well as vertebrate fat and muscle tissue, and a flower of the family Asteraceae. The other *P. hermaphroditus* was a sub-adult male, whose stomach contained only seeds of the genus *Connarus*. The stomach contents of an adult male *H. derbyanus* was comprised primarily of a single brown spiny rat (*Maxomys rajah*), as well as some plant matter, a claw from a species of Brachyura and various other arthropod legs, probably from insects. The other *H. derbyanus* was a sub-adult male, whose stomach contained remains of an Araneae, Lumbricidae chaetae, a Coleopteran and legs from a Chilopoda. The carcass of another adult *H. derbyanus* was collected, but its stomach contents were not intact. The fact that six of the seven road kills encountered were males and four were sub-adult or juvenile is noteworthy (see section on Trap Success).

A total of 180 scats were examined. Mean diameter was 1.76 cm (range = 1.3 - 2.6 cm) (n = 95). This was similar to the mean diameter of scats from captive *V. tangalunga* of 1.8 cm. (range = 1.4 - 2.3 cm.) (n = 10). Many scats containing seeds lacked sufficient morphology to be measured. These were usually deposited on the Segama Bridge where both a *P. hermaphroditus* and a small-toothed palm civet (*Arctogalidia trivirgata)* were frequently observed. Bartels (1964) reported that palm civets deposit feces in a long, gelatinous mass on bridges. Thus, it is possible that many of the samples comprised primarily of fruit and seed remains are from palm civets.

Scat from the selectively logged forest was collected along logging roads both within and around the logged forest study site. Scat identified as being from unlogged forests was often collected in close proximity to the field station, or a small ecotourism facility similar in size, which makes the validity of their classification as being from unlogged forest somewhat tenuous. The low encounter rate of scats along trails in the unlogged forest may have been a function of the extremely high decay rate (pers. obs.).

Grooming hairs present in scats (n = 78), were dominated by those which bore coloration and banding patterns that matched those of *V. tangalunga* (n = 62). The only other small carnivore species in the area with similar hair banding patterns are the banded linsang (*Prionodon linsang)* and leopard cat (*Felis bengalensis*), both of which are considerably smaller than *V. tangalunga* and generally have shorter fur. Scat diameter of captive *F. bengalensis* in the Dusit Zoo, Bangkok, and of individuals captured in Huai Kha Khaeng was one cm (Rabinowitz, 1990a). Because *P. linsang* is smaller than *F. bengalensis* it is unlikely that its feces would be larger than one cm. Therefore, only scats with a range of diameter within that from known *V. tangalunga*, and that contained grooming hairs of appropriate size and coloration, were attributed to *V. tangalunga*. Seventeen of these were collected in areas of unlogged forest and 41 were collected in the selectively logged forest. Table 4-2 lists items identified from these scats and the frequency of occurrence for each category. All other scats with diameters that fell within the range of those from captive *V. tangalunga* but that lacked identifiable grooming hairs were considered collectively as having originated from civets, as it was not possible to attribute them to species. The content and frequency of occurrence from these samples are listed in Table 4-3.

Invertebrates were the most commonly observed diet items for *V. tangalunga*. Most frequently encountered were beetles (Coleoptera), crabs (Brachyura), scorpions (*Palamneus sulpides*), and millipedes (*Sphaeropieus* sp.). The next most commonly encountered diet category was fruit. Vertebrates consumed include rodents, insectivores, small birds, snakes and lizards. A Renkonen index of percent similarity between diets of *V. tangalunga* in both forest sites revealed 72.82% similarity. Fruit comprised a larger component of diet for *V. tangalunga* in the unlogged forest. Conversely, invertebrates represented a proportionally larger segment of the diet of *V. tangalunga* in the selectively logged forest. However, the only diet item that differed significantly between sites was snails (Stylommatophora) which were more prevalent in the diet of animals from the unlogged forest ($\chi^2 = 13.12$, $p < 0.001$).

The most commonly encountered diet category for civets as a group was fruit. The next most commonly observed diet item were centipedes (*Scolopendra* sp.) followed by beetles (Coleoptera), crabs (Brachyura), millipedes (*Sphaeropieus* sp.) and scorpions (*Palamneus sulpides*). A Renkonen index of percentage similarity revealed 59.91% similarity in the diets of civets between forest types. A main source of difference was that fruit represented a proportionally larger component of the diet of civets in the unlogged forest ($\chi^2 = 11.89$, $p < 0.001$). One vertebrate and many invertebrate taxa occurred with a higher than expected frequency in the logged forest [Lacertilia ($\chi^2 = 5.96$, $p = 0.0134$), Blattodea ($\chi^2 = 15.09$, $p < 0.001$), Coleoptera ($\chi^2 = 18.00$, $p < 0.001$), Formicidae ($\chi^2 = 4.15$, $p = 0.008$), Scorpione ($\chi^2 = 8.77$, $p = 0.003$), Chilopoda ($\chi^2 = 11.28$, $p < 0.001$) and Myriapoda ($\chi^2 = 4.36$, $p = 0.0367$)]. Because invertebrate densities did not differ between sites (see next section), it is possible that the higher frequency of these invertebrate taxa in the diet resulted from a decline in the availability of fruit between sites. Diet taxon richness for civets as a group did not differ from expected values between sites ($\chi^2 = 0.40$, $p = 0.525$) nor did diversity ($\chi^2 = 3.43$, $p = 0.064$).

At least 20 species of fruit trees from 18 genera were consumed by members of the civet community (Table 4-4). *Ficus* sp., *Connarus* sp. and *Annona* sp. were the most commonly identified seeds in scats attributed to civets. Most scat samples containing fruit were collected in or near areas of unlogged forest. Although the density and diversity of fruit trees may have been artificially high around Danum Valley Field Center and Borneo Rain Forest Lodge, at least six of the genera identified from scats were present in a 40 x 40 m vegetation plot in the unlogged forest (Newbery, *et al.* 1992). In addition, all taxa represented were common in the unlogged forest, and only two species (*Dimocarpus longan* and *Psidium* sp.) have been commonly domesticated (J. Sugau, pers. comm.).

A Renkonen index of similarity (Krebs, 1989) between the diet of *V. tangalunga* and the diet of all other civets revealed 59.2% similarity in the unlogged forest and 69.4% in the selectively logged forest. Whereas many of the same taxa were eaten by both groups, *V. tangalunga* utilized significantly more invertebrates than other civet species [Blattodea ($\chi^2 = 23.53$, $p = 0.015$), Brachyura ($\chi^2 = 10.74$, $p = 0.001$), Chilopoda ($\chi^2 = 16.79$, $p < 0.000$), Coleoptera ($\chi^2 = 11.61$, $p = 0.001$), Isoptera ($\chi^2 = 8.16$, $p = 0.004$) and Scorpiones ($\chi^2 = 6.33$, $p = 0.012$)]. These differences could serve as a means of reducing dietary competition between closely related viverrids that tend to be generalized feeders.

Prey Availability

A total of 256 vertebrates and invertebrates were captured in pit traps in the unlogged forest, and 234 were captured in the selectively logged forest (See Table 4-5). The most numerous invertebrate captured in pit traps were ants (Formicidae), roaches (Blattodea) and beetles (Coleoptera). Other commonly observed groups were millipedes (*Platyrachus* sp.), spiders (Araneae), and centipedes (*Scutigera* sp.). The most numerous vertebrates captured were shrews (*Suncus* sp.) and the rough skink (*Mabuya rudis*). The number of organisms in each taxon retrieved from pit traps in both sites were remarkably similar. A Renkonen index of percentage similarity (Krebs, 1989) revealed 99.64% similarity between sites in trap results.

Internal Parasites

Table 4-6 lists all internal parasites identified from scat collected during the course of the study. Whereas some parasites could be identified to genus and two to species, the majority were tentatively identified only to order. A total of 88 scat samples were sent to the University of Tennessee, Knoxville, for analysis: 59 from unlogged forests and 29 from logged forests. Of these, 68% tested positive for parasites: 66% from the unlogged site and 76% from the logged site. Among samples from the unlogged forest, 39 contained a total of 261 parasites or eggs from 26 separate groups. Of these, 18 were identified at least to order and eight to genus. Among the samples collected in the selectively logged forest, 21 contained parasites, in which there were a total of 116 individual parasites or eggs identified from 22 groups. Of these, 12 were identified to order and nine to genus.

A total of 216 scat samples were initially sent to the Tawau Veterinary Clinic in Sabah, East Malaysia, for parasite identification. Of these, 166 were returned negative (76.9%). Due to the unusually high percentage of negative results it was decided that the remaining samples would be sent to the University of Tennessee. By far the two most common parasites detected in the data from Tawau were *Ancylostoma* and *Capillaria.* Whereas *Capillaria* was also commonly detected in the samples from the University of Tennessee, only one sample was found to contain *Ancylostoma brauni.* Similarly, *Toxicara* was commonly seen in the data from Tawau but not detected at the University of Tennessee.

The most common endoparasite identified in the batch sent to the University of Tennessee were the Strongylate-type, which made up 66 eggs from 21 samples from the unlogged forest and 12 eggs from six samples in the logged forest. Also common was *Capillaria,* which accounted for 22 parasites from nine of the unlogged forest samples and 22 parasites from 10 of the logged forest samples. A frequently encountered family was Coccidia which accounted for 15 parasites from five samples in the unlogged forest and 12 parasites from seven in the selectively logged sites. A Renkonen Index of similarity of parasites showed 61.6%. similarity between sites. A χ^2 test revealed no significant difference in the frequency of occurrence of any parasite type between sites. A Simpson's diversity index (Ricklefs, 1997) was 3.0 in the unlogged forest and 2.38 in the logged site; however, these values did not differ significantly between sites ($\chi^2 = 2.25$, $p = 0.58$). Species richness did not differ between sites ($\chi^2 = 1.17$, $p = 0.254$). A χ^2 test of observed versus expected percent frequency of internal parasite groups shows that only three parasite types differed significantly from expected; there were more Coccidia and lungworm type parasites in the logged forest ($\chi^2 = 3.52$, $p = 0.0614$, $\chi^2 = 3.08$, $p = 0.0790$ respectively), and more strongyloid type parasites in the unlogged site ($\chi^2 = 3.25$, $p = 0.0713$).

Scat from a single female *V. tangalunga* captured by a film crew in a patch of unlogged forest immediately adjacent to the field center, contained *Capillaria* sp., *Trichuris* sp., *Mamomoganomus* sp., and nematode larvae. Scat attributed to *V. tangalunga* contained the following parasites: *Capillaria* sp., *Toxicara* spp., *Ancylostoma* spp., *Isospora* spp., strongylate-type, Coccidia, *Paragonomus* spp., *Monocystis*, *Gnathostoma* spp., Trematoda, pinworm-type eggs, other nematodes, *Eimeria* spp., Monocystis, *Sacrocystis*-type, dermanysid and mesostigmatid mites.

Gut parasites from two *H. derbyanus* examined as road kill included *Capillaria* sp., other trematode eggs, *Demodex*-type eggs, *Ascaridia*-type eggs and pinworm-type eggs. Gut contents from a single *P. hermaphroditus* road kill contained *Eimeria* oocysts, monocystis and possibly *Ascaridia* eggs.

External Parasites

Table 4-7 lists all external acarid parasites collected during this study. Ticks were collected from four males and one female in the unlogged forest and two male and three females in the selectively logged forest. A total of 76 ticks were collected and identified, of these, 57 were identified to genus, 42 were identified to species and 14 were not identified. A total of 29 ticks were found on *V. tangalunga* captured in the unlogged forest and 47 on *V. tangalunga* in the unlogged forest.

A total of five species of tick were identified, the most common being *Haemaphysalis asiaticus*. This species was present on all five *V. tangalunga* in the unlogged site and four out of the six in the selectively logged site. A total of 22 *H. asiaticus* were identified, which accounted for 31% of all ticks. The next most common species identified was *Haemaphysalis koningsbergeri*, which was present on two individuals in the unlogged forest and two in the logged forest. Eight of these were identified, and accounted for 11% of all ticks. The other species identified were *Haemaphysalis vidua,* which accounted for four identified individuals; on two study animals in the unlogged forest and one in the logged forest. A single specimen of *Haemaphysalis cornigera,* was seen only once, in the logged forest. A χ^2 test of observed versus expected tick density between sites revealed no difference ($\chi^2 = 1.74$, $p = 0.211$).

DISCUSSION

Diet

Invertebrates and fruit were the principal components of the diet for *V. tangalunga* and other civet species in the area. A wide variety of vertebrate taxa were also represented in civet diets, including: rodent, lizard, snake, bird, fish, insectivore, and bat. The presence of leaf and grass fragments have been reported in the diet of other civets (Gao, *et al.* 1987; cited in Chuang and Lee, 1997) but were discounted as an important dietary items due to their low nutritional value. In this study, most plant matter encountered other than seeds were small fragments likely to have been ingested incidentally. Among scats attributed to *V. tangalunga,* all the above taxa were represented with the exception of bats. However, bats were reported in the diet of a single *V. tangalunga* in Sarawak (Macdonald and Wise, 1979) that frequented a large roost within its home range. The low occurrence of bats in the diet of civets in this study may be due to the low density of known bat roosts in the area (pers. obs.).

Scat containing fruit seeds were collected throughout the study period and showed no monthly change in availability. The high occurrence of fruit in the diet of *V. tangalunga* and other civet species reflects the importance of this food resource to these species, and indicates that civets may be important seed dispersers. A single *V. tangalunga* in Borneo was observed consuming seeds defecated by gibbons and showed a preference for seeds over figs and other whole fruits (K. McConkey, pers.

comm.). Thus, *V. tangalunga* may also be a seed predator in some cases. Efforts to germinate seeds collected from fresh scats would be necessary to determine the viability of seeds defecated intact by this species. No effort was made to do so in this study. Previous efforts to germinate seeds from civet scat met with little success (M. Heydon, pers. comm.) but the sample represented a small fraction of seed taxa observed in this study.

The higher occurrence of seeds in scat from *V. tangalunga* and other civet species from the unlogged forest may be a function of higher fruit availability in this site. If *V. tangalunga* is an agent of seed dispersal, it could play a role in re-establishing fruit trees in the logged forest provided there was access from one area to the other and movement between them, and provided that seeds germinate. Whereas animals may repopulate the logged forest in a relatively short period of time, there would be a considerably longer lag time for recolonization of trees that may account for the observed disparity in fruit consumption in the logged forest.

Among Asian Carnivora, civets are the most consistently frugivorous (Corlett, 1998) and even some members of the subfamily Viverrinae are predominately frugivorous during certain times of the year (Dudgeon and Corlett, 1994). Corlett (1998) suggests that civets may be the major agents of seed dispersal for some genera of Asian trees, particularly those that have large-size seeds, since these are more limited in the number of species capable of dispersing them. Further, under conditions of disturbance, species which might otherwise play a minor role in seed dispersal may become vital if the primary disperser becomes rare or locally extinct. Whereas many viverrids are highly vulnerable to habitat disturbance (Schreiber *et al.* 1990), *V. tangalunga* appears to thrive under these conditions, and may thus become increasingly important as an agent of seed dispersal in the event of local extinction or decline of other species. For this reason, investigation of the viability of seeds ingested by civets is an important area for further study.

The presence of toxic invertebrates in the diet of *V. tangalunga* and other civets, including giant centipedes (*Scutigera* sp.) and scorpions (*Palamneus sulpides*), indicates that some civet species may be resistant to these toxins. This phenomenon has been observed among some herpestids (Hiscock and Perrin, 1990). Some species, such as the banded mongoose (*Mungo mungo*) are known to roll or paw toxic prey items before ingesting them, which may serve to remove any stingers or noxious secretions (Rood, 1975). Yet both *V. tangalunga* and other civets consumed at least some toxins in their diet, as six scats were found to contain poison sacs from scorpions. Such an immunity to the potential harmful effects of ingesting toxic prey could be of adaptive significance by allowing these species to take advantage of a dietary resource that may not be available to other species.

The occurrence of earthworm chaetae in the stomach contents of two *V. tangalunga,* one *P. hermaphroditus* and one *H. derbyanus* indicates that Lumbricidae may be an important component of the diet of civets. Chuang and Lee (1997) found that earthworms were present in 66.9% of scats of the lesser oriental civet (*Viverricula indica)* in Fushan Forest, northern Taiwan, and the content of two stomachs from Owston's palm civet (*Chrotogale owstoni*) were found to contain earthworms (Walker, 1975). Because oligochaetes are soft bodied and leave no visible macroscopic remains, it is difficult to detect their presence in the diet, despite their potential significance in the diet of some civets.

The low occurrence of rodent or other vertebrate remains in scat indicate that civets as a group did not rely heavily on this diet category. However, a dietary study of the closely related *V. indica* found that the occurrence of rodents in the diet was positively correlated with rodent abundance in the habitat (Chuang and Lee, 1997). It is possible that the low occurrence of rodents in the diet of *V. tangalunga* in Danum is also a function of their relative unavailability as a diet item, either due to actual low numbers, increased availability of alternative diet items, or strong competition from more specialized rodent predators such as leopard cats and marbled cats. Population densities of some rodent species can increase dramatically after selective logging (Isabirye-Basuta and Kasenene, 1987; Harrison, 1969) or other forms of human disturbance (Delany, 1971). As an adaptable species and a dietary generalist, *V. tangalunga* would be likely to exhibit dietary switching similar to that observed for *V. indica*. Thus, *V. tangalunga* may play an important role in regulating rodent densities in areas that are severely disturbed and where other control agents have become rare.

The moderate degree of dietary overlap between *V. tangalunga* and other sympatric civet species indicates that there is some level of niche separation on a dietary level. Whereas many of the same taxa are eaten by both groups, *V. tangalunga* utilize more invertebrates than other civet species in the study area. This difference may serve to reduce direct competition between *V. tangalunga* and other species of sympatric civet.

Prey Availability

There was 99.6 % similarity in the density and diversity of terrestrial small vertebrates and invertebrates captured in pit traps in the two sites. This indicates that prey levels did not change significantly after selective logging. This conclusion was in agreement with findings in a study of leaf litter invertebrates from the same area (Burghouts, *et al.* 1992). The authors found no seasonal variation for all invertebrates between a logged and unlogged site, and found no significant difference between sites for most invertebrates identified in civet diets, with the exception of Scorpionidae and Isoptera, which were reported to be higher in the unlogged forest. The proximity of the selectively logged site to areas of unlogged forest may also be an important factor in the lack of discrepancy between sites through recolonization.

A Renkonen index of percent similarity between pit trap results and the diet of *V. tangalunga* showed 55.02% overlap of taxa, indicating a considerable difference between potential resources and diet. Further, although scorpions and chilopods were present in pit traps, the species identified from diet (*Palamneus sulpides* and *Scutigera* sp. respectively) rarely appeared in pit traps. Among myriapods, the species most commonly observed in scats (*Sphaeropoeus* sp.) was never encountered in pit traps, whereas *Platyrachus* sp. was by far the most commonly encountered myriapod in pit traps but never identified in scats. Brachyura and Stylommatophora appeared frequently in the diet but were never encountered in pit traps.

Other prey items appeared with greater frequency in pit traps than in the diet of *V. tangalunga*, including Insectivora, Orthoptera, and Araneae. Many species within these orders are fast moving and may therefore be more difficult for *V. tangalunga* to capture. Macdonald and Wise (1979) watched a single male *V. tangalunga* consume some Orthoptera and Amphibia that it captured by either running and lunging, or leaping. However, if less agile prey items are equally available and they require less energy to procure, optimal foraging theory predicts that that they will be preferred (Morrison, *et al.* 1992), and may explain the underutilization of these groups in this site.

If the contents of pit traps accurately represent the encounter frequency of small terrestrial organisms, then it appears that *V. tangalunga* is not simply an opportunistic feeder but shows a degree of prey preference. A similar pattern was observed among an assemblage of neotropical carnivores in Venezuela, where seven species of sympatric small carnivores exhibited considerable overlap in trophic niche while maintaining a degree of prey preference (Bisbale, 1986). Such generalization of diet among potential competitors may serve to reduce interspecific competition (Hamilton, *et al.* 1978) by increasing the resource base for all carnivores. For *V. tangalunga*, omnivory paired with some prey preference may have an adaptive origin, although further studies would be needed to explore this possibility.

Internal Parasites

There was a high degree of similarity of the internal parasite assemblages from civet feces collected in unlogged and selectively logged forests. Given the proximity of these sites, such overlap is not unexpected. The only internal parasites identified to species were *Capillaria hepatica* and *Ancylostoma brauni*. *Capillaria* is a genus of nematode lungworms belonging to the superfamily Metastrongyloidea. *C. hepatica* is a generalized trichinelloid helminth, occurring in many different vertebrate hosts in a wide variety of habitats (Cameron, 1956). The eggs of *C. hepatica* inhabit the liver of rodents and then become infective upon death and decay or ingestion of the host. Because some civets feed on rodents, infection through ingestion of the host is probably a significant means of transmission.

Ancylostoma is a genus of nematode hookworms in the order Strongyloides, and is common in small carnivores. Infection from *Ancylostoma* and other strongyloid parasites often occurs through the skin from contact with infected soil, and is particularly high in areas where feces mixes with soil. If the deposition of scat plays a role in inter-gender communication, it may contribute to the high rate of infection observed.

There were several protozoan parasites in the suborder Eimeriorina that appear to be common in fecal samples from both forest sites. The genus *Sacrocystis* was common in both sites and is known to have a predator-prey life cycle (Dubey *et al.*, 1989). Also common was *Coccidia*, a common genus of gut parasite found in reptiles, birds and mammals, (Cameron, 1956). Because both birds and reptiles appear as prey items among civets in this study, a primary means of infection may be through predation of an infected animal.

Isospora is another common protozoan parasite of mammalian carnivores, and generally has low host specificity. The high diversity of civets in the study area maks it likely that many such generalist parasites infect several or all species present.

The *Gnathostoma* encountered may have been *G. spinigerum*, since it occurs in the stomach of many carnivores, is highly pathogenic, and occurs in warm countries (Cameron, 1934). This genus is exclusive to carnivores and is transmitted to the final host via a crustacean intermediate host (Cameron, 1956). Brachyurans were one of the most commonly encountered prey items for civets, and may serve as an intermediate host.

The *Paragonimus* encountered may have been the Oriental lung fluke (*Paragonimus westermanii)* since this is a species endemic to Southeast Asia and has been found in carnivores from this region (Davis and Anderson, 1971). Snails, crabs and crayfish are the intermediate host (Cox, 1982), and predation may be one means of infection since both are consumed with high frequency by civets in both study areas. Liat and Betterton (1977) found that in feeding trials, viverrids ate both species of host crab found in Malaysia (*Potamiscus johorensis* and *Parathelphusa maculata*).

Many genera of internal parasite identified in this study were reported for small carnivores both within this region and elsewhere. *Capillaria*, *Toxicara,* *Aelurostrongylus* and *Sarcocystis* were present among felids in a dry forest mosaic in Thailand (Patton and Rabinowitz, 1994). Overall, 11 of 21 parasite taxa they listed were also identified from the civets in Danum Valley. There was also overlap of internal parasite genera found in a neotropical felid community (Patton, *et al.* 1986), wherein nine of the 14 parasite genera present were also identified in this study.

Because many parasite groups encountered have intermediate hosts which are often prey species, the presence of these parasite oocysts does not necessarily indicate infection of the predator (Patton and Rabinowitz, 1994). However, many members of the parasite taxa represented here are usually transmitted to the host through predation of intermediate vertebrate and invertebrate hosts, or transport hosts.

Although the greater dependence upon invertebrate prey in the logged forest may relate to the higher incidence of Coccidia and lungworm parasites observed in the logged forest, no cause and effect could be inferred. Overall, whereas civets are able to adapt to changing conditions by modification of their diet, they do not appear to be subject to an increased risk of infection by a wider variety of parasites.

Because habitat disturbance can result in disease outbreak by creating conditions that favor an abnormally high abundance of relatively few species (Dobson and May, 1986), and *V. tangalunga* often thrives in disturbed habitat, close monitoring of this species in disturbed areas is particularly important for management purposes. Whereas the segregation of populations often serves to prevent the spread of infection, free movement of organisms between disturbed and undisturbed areas may facilitate the transmission of disease (Dobson and May, 1986), and may explain the similarity of civet parasite assemblages between sites. Data on normal densities and normal parasite assemblages provided here will serve as a baseline for comparison with future studies.

External Parasites

The density and diversity of external acarid parasites on *V. tangalunga* were similar between sites. Thus, the number of ticks and the number of tick species infecting *V. tangalunga* does not appear to be affected by selective logging. As above, this may result from transmission across forest type due to their proximity. The most commonly recorded species of tick identified in this study was *Haemaphysalis asiaticus*, which has been reported from an Asian golden cat (*Catupuma temminickii*) in the Lao People's Democratic Republic (Robbins *et al.*, 1997). It is an easily identified, morphologically distinctive species, whose primary hosts are viverrids and felids that range over most of the Southeast Asian region (Hoogstral and Trapido, 1966). The next most commonly encountered ascarid species was *Haemaphysalis koningsbergeri,* which has been identified previously on many species of carnivores from Borneo and peninsular Malaysia (Kohls, 1957). It is not exclusive to the Carnivora, but appears to be predominantly host specific to this order. A classified host list shows that most families of carnivore have members which serve as hosts to this parasite. Among Viverridae, *H. koningsbergeri* was identified on *P. hermaphroditus*, masked palm civet (*Paguma larvata*), *Arctogalidia* *trivirgata,* and *H. derbyanus* (Kohls, 1957). However, *V. tangalunga* was not previously identified as a host. The low host specificity for this tick species indicates that other civet species in the area have a high likelihood of being parasitized by this species. Because direct contact between individuals and repeated use of resting sites may increase the risk of tick parasite infection, avoidance between individuals and low day-bed site fidelity (see sections on Dynamic Interactions and Day-Bed Use) may help control outbreaks of infection.

Table 4-1. Stomach contents of three species of civet in a logged forest in Sabah, East Malaysia.

Viverra tangalunga #1 Sub-adult female	fruit Annelida Formicidae Coleoptera Orthoptera
Viverra tangalunga #2 Juvenile male	leaves Annelida Hymenoptera Orthoptera
Paradoxurus hermaphroditus #1 Adult male	Composite flower (Asteraceae) fruit seeds leaves Annelida Chilopoda Araneae Brachyura animal muscle tissue and fat
Paradoxurus hermaphroditus #2 Sub-adult male	fruit (*Connarus* sp.)
Hemigalus derbyanus #1 Adult male	*Maxomys rajah* seeds Brachyura Composite flower (Asteraceae)
Hemigalus derbyanus #2 Sub-adult male	Chilopoda Annelida Coleoptera Araneae

Table 4-2. Diet items from scat of civets[1] in an unlogged (n=66) and a logged forest (n=54) in Sabah, East Malaysia, 10/95 to 5/97

DIET ITEM	UNLOGGED FOREST	LOGGED FOREST
Acarina	0	1
Araneae	2	4
Aves	1	5
Blattodea	2	17
Brachyura	12	18
Chilopoda	11	28
Chiroptera	0	1
Coleoptera	6	27
Formicidae	1	8
Fruit	60	21
Insectivora	1	0
Isoptera	2	0
Lacertilia	0	5
Leaf	9	8
Myrapoda	9	17
Ophidia	1	3
Orthoptera	3	4
Osteichthyes	1	3
Rodentia	3	8
Scorpiones	6	18
Stylommatophora	3	8
Unidentified bone	1	2
Unidentified larva	3	2

1 = Not including samples identified as from *V. tangalunga.*

Table 4-3. Diet items from scat of *Viverra tangalunga* in an un logged (n=17) and a logged forest (n=41) in Sabah, East Malaysia from 10/95 to 5/97

DIET CATEGORY	UNLOGGED FOREST	LOGGED FOREST
Araneae	2	2
Aves	0	1
Blattodea	3	17
Brachyura	11	22
Chilopoda	0	1
Coleoptera	8	28
Formicidae	0	3
Fruit	13	18
Insectivora	0	1
Isoptera	2	5
Lacertilia	0	2
Leaf	5	7
Myriapoda	7	11
Ophidia	2	1
Rodentia	0	2
Scorpiones	5	19
Stylommatophora	7	1
Unidentified bone	3	7
Unidentified larva	3	11

Table 4.4. Seeds identified from scat of civets (n =48) in an unlogged and a logged forest in Sabah, East Malaysia, 10/95 to 5/97

FRUIT TAXA	UNLOGGED FOREST	LOGGED FOREST
Adenia sp. (Passifloraceae)		1
Alangium sp. (Alangiaceae)	2	1
Annona sp. (Annonaceae)	4	
Apocynaceae	3	
Connarus sp. (Connaraceae)	5	
Dialium indium (Leguminosae)	1	
Dimocarpus longan (Sapindaceae)		1
Ficus sp. (Moraceae)	15	1
Garcinia sp. (Guttiferae)	1	
Glochidion sp. (Euphorbiaceae)	1	
Leguminosae	2	1
Menispermaceaea	1	
Microcos sp. (Tiliaceae)		1
Palaquium sp. (Sapotaceae)	2	
Polyalthia sp. (Annonaceae)	1	
Pometia pinnata (Sapindaceae)	1	
Psidium sp. (Myrtaceae)	2	
Vitaceae	1	

All seed identifications by Mr. John Sugau,
Botanist, Forest Research Center, Sandakan, East Malaysia

Table 4.5. Contents of pit traps in an unlogged and a logged forest in Sabah, East Malaysia, 10/8/96 to 11/7/96

PREY CATEGORY	UNLOGGED FOREST	LOGGED FOREST
Annelida	4	3
Arania	17	19
Blattodea	20	23
Camponotus sp.	38	31
Chaperina fusca	1	0
Coleoptera	30	21
Diptera	1	2
Formicidae	88	81
Hemiptera	2	5
Hymenoptera	2	1
Isoptera	3	1
Kalophrynus pleurostigma	1	1
Lepidoptera	1	0
Mabuya rudis	13	5
Orthoptera	21	17
Platyrachus sp.(Diplopoda)	19	22
Rattus sp.	1	1
Scorpionidae	4	2
Scutigera (Chilopoda)	0	1
Scutigera sp. (Chilopoda)	6	5
Suncus sp.	12	12

Table 4-6. Internal parasites in scat samples from civets in an unlogged (n = 59) and a logged (n = 29) forest in Sabah, East Malaysia

INTERNAL PARASITE	UNLOGGED FOREST	LOGGED FOREST
Acanthocephala type	1	0
Aelurostrongylus sp.	2	1
Ancylostoma sp.	2	0
Ascaridia sp.	2	0
Bi-flagellate protozoan	1	0
Capillaria	9	10
ciliated protoszoan	1	0
Coccidia	5	7
Demodex sp.	1	0
Dermanysid mite	3	2
Eimeria	3	1
Giardia sp.-possible	1	0
Gnathostoma sp.	7	1
Hymenolysis sp. type	1	0
Isospora sp.(?)	4	1
lungworm type	2	4
Mamomoganomus sp.	1	0
Mesostigmatid mites	1	0
mites	13	9
Monocystis	9	5
Monostygmatid mite	1	0
mosquito larvae	1	0
nematode larva	8	2
Opisthorchidae	1	0
Paragonimus sp.	0	2
pinworm type	8	2
Raillietium sp.	1	0
Sacrocystis sp. like	6	4
Sarcoptic mites	1	0
Spiruridea	0	1
Strongylate-type	21	4
Taeniidae	0	1
Trematoda	7	5
Trichuris sp.	0	1
yeast fungi	0	1

Parasite identifications by Dr. Sharon Patton
Department of Parasitology, University of Knoxville, TN

Table 4-7. **External tick parasites identified from *Viverra tangalunga* in an unlogged and a logged forest in Sabah, East Malaysia.**

EXTERNAL PARASITE	UNLOGGED FOREST	LOGGED FOREST
Ambylomma sp.	7	3
Haemaphysalis asiaticus	10	11
Haemaphysalis cornigera	0	1
Haemaphysalis koningsbergeri	3	3
Haemaphysalis sp.	6	1
Haemaphysalis vidua	2	0
Unknown		

All identifications by Matthew Shaw,
Department of Parasitology, University of Queensland, Queensland Australia

5.

CONSERVATION IMPLICATIONS

Malay civets inhabiting both an unlogged and a selectively logged dipterocarp forest in Danum Valley occupied overlapping home ranges of approximately one km^2. Home range size was considerably larger than previously reported (Macdonald and Wise, 1979). Home ranges did not differ significantly between sites, although mean values were larger in the logged forest. Males and females exhibit no significant differences in home range size although mean range size was larger for males.

Home range use was highly uniform, with no discernible difference between day and night ranges. There was also no apparent seasonal shift in home range size or location, which may be due in part to the highly irregular onset of both monsoon effects in this relatively aseasonal region.

Eight years after logging, the population of *V. tangalunga* in a selectively logged forest is lower than that in an unlogged forest. It is possible that the population is in an intermediate stage of recovery; however, it is also possible that the logged forest does not sustain as high a density as the unlogged forest. Density estimates between sites differ less than previously estimated (Heydon and Bulloh, 1996) and reveal a less dramatic decline subsequent to logging. This may be a function of the more recently logged forests examined in the first study. The fact that the density of *V. tangalunga* did not undergo a dramatic increase in response to selective logging demonstrates that this species poses no threat to the survival of other less adaptable conspecifics.

V. tangalunga is nocturnal/crepuscular and terrestrial. It exhibits no territoriality yet is solitary and avoids other individuals. Activity levels averaged 55% and were strongly correlated with the onset of dark. Activity levels peaked immediately after dark and shortly before dawn, indicating this species is in part crepuscular. Most activity entailed foraging and traveling, with males utilizing a significantly larger area and larger percentage of their home range in a single night than females.

Roads and trails were centrally located within the home ranges of all study animals, and may be considered an important resource. Roads are used by big cats for travel, hunting (Schaller, 1967; Sunquist, 1981) and communication (Rabinowitz, 1986) and may serve similar functions for *V. tangalunga.* Although roads can have detrimental effects on populations through fragmentation of habitat (Goosem, 1998), this was not the case for *V. tangalunga.* However, in the logged forest, there was evidence of mortality from vehicular accidents. Males experienced higher road-traffic mortality, suggesting that they use roads with higher frequency than females. Vehicular accidents were the only source of mortality observed and accounted for eight known deaths. Sub-adults represented half of all known road kills. Thus, roads are an important source of mortality in the logged forests and may contribute to the lower observed density in these areas. Because fatality from vehicles appeared higher among males, it may also account for the female trap bias in the logged forest. A gender bias in favor of females should not significantly reduce the reproductive potential of the population in this area.

Malay civets are omnivores, who show some prey selection and high dietary flexibility. Diet was comprised primarily of invertebrates, including beetles, crabs, scorpions, pill millipedes, centipedes and earthworms. Fruit made up a significant portion of diet, particularly in the unlogged forest, whereas vertebrates, including rodents, insectivores, birds, snakes, lizards and amphibians comprised a larger portion of diets in the selectively logged forest. These differences in feeding ecology may reflect a difference in vertebrates and fruit resource availability; however, quantification of terrestrial invertebrates indicated no difference between sites. Dietary differences may be a behavioral adaptation that facilitates survival under changing conditions. Among taxa quantified through pit trapping, presence in diet did not correspond directly with availability, indicating that civets may not be strictly opportunistic in their feeding ecology.

Species richness and diversity of gut parasites from *V. tangalunga* and other civets were similar between sites. Selective logging has not led to any apparent increase in the diversity of parasite species infecting civets. External tick parasites were also similar between sites.

The proximity of the logged forest site to large areas of unlogged forest may be a significant factor affecting the results of this study. The relatively high density of Malay civets in the logged forest may have resulted in part from the proximity of the unlogged area, which may serve as a reservoir of biological diversity to the selectively logged forest. Therefore, the results of this study do not apply to situations where logged forest is isolated from areas of undisturbed habitat.

Population density in the selectively logged forest was stable. There was no emigration out of the logged forest or use of accessible areas of unlogged forest, indicating that this area provides suitable resources to sustain a permanent population of Malay civets. Parasite assemblages were similar between sites in terms of diversity and richness. Again, the unlogged forest may serve as a reservoir of prey and other resources so these observations pertain only to these conditions.

Johns (1985) found that the biomass of generalist-oriented species of many taxa increased in a logged forest in West Malaysia. *V. tangalunga*'s generalist ecology demonstrated in this study is clearly an important factor in its ability to persist in a logged forest. However, the fact that a single species demonstrates an ability to survive long term disturbances should not be used as a justification for further disturbance of other areas (Johns, 1985). Although *V. tangalunga* is able to survive some forms of selective logging, it is of considerable conservation interest to generate data on the other less noticeable or abundant civet species which may exhibit a very different response to selective logging. This is particularly important for species which are less common such as the banded linsang (*Prionodon linsang*), or those which are probably endangered, such as the otter civet (*Cynogale bennettii*) (Schreiber, *et al* 1990).

A study of the forest diversity in a selectively logged dipterocarp forest in Indonesian Borneo indicates that the remaining forest retained a high degree of tree diversity and density (Cannon, 1994). Although encouraging, it should not be assumed that these forests are capable of supporting the same diversity of native fauna. However, it can be concluded that these forests continue to be suitable habitat for at least some of the original flora and fauna. In fact, a large area of logged forest may support species that would not persist in small isolated patches of unlogged forest (Johns, 1985). Thus, logged forests in conjunction with connected areas of unlogged forest should be managed as part of a long term conservation strategy, and be actively protected from further degradation or encroachment.

Once logging is completed, the Danum Valley Conservation Area and the surrounding concession will no longer be afforded their current level of protection. The area's status as a Class One Forest Reserve does not itself guarantee the continued protection of the native flora and fauna within the conservation area. Given Asia's current economic turmoil, a change in economic priorities or an increased demand for timber and other natural resources could rapidly alter the fate of this area. Climatic factors such as the recent drought and rampant forest fires in Borneo pose additional threats to these areas. The recent discovery of mineral resources in the nearby Maliau Basin Conservation Area raises the possibility that Danum Valley Conservation Area could be targeted for similar resource exploitation. Even if current policy stands, as logging continues in the surrounding area, and as the buffer zone of unlogged forest decreases, there can be expected a slow but significant encroachment of human influence into the conservation area.

Due to its location, Sabah is subject to a high rate of illegal immigration from the Philippines and Indonesia. This has led to an increasing, and increasingly impoverished, population determined to satisfy their basic needs often at the expense of the native flora and fauna. Wilkie *et al.* (1992) conducted a study of the impact of logging on wildlife populations in Congo, where market-hunting pressure is high; they found that after logging, wildlife populations declined more as a result of increased access into the forest by poachers, than actual removal of trees. Although this aspect of logging was not addressed in this study, it should be kept in mind for future studies, particularly since civet meat is known to be commercially valuable among Chinese Malays, and could easily become a common game species for immigrants into the area. Thus, hunting pressure may become a viable threat to *V. tangalunga* as well as other species of wildlife in the area.

Perhaps the best use of selectively logged forests is to serve as a wide buffer zone surrounding unlogged or primary forest reserves, or as corridors connecting such areas. The logged forest provides a degree of isolation from the direct (hunting, and settlement) and indirect (pollution and erosion) effects of human disturbance. The unlogged areas would also provide a natural reservoir of biological diversity to recolonize the logged forests. Because some animals survive well in undisturbed habitat and others survive better in large patches of disturbed forest, the optimal conservation scenario would incorporates both forest types.

In order to reduce the effects of encroachment of illegal settlement, shifting agriculture and hunting pressure, portions of the logged forests can be designated as a park and be used for nature tourism, recreation and education. Patches of undisturbed forest could be selected for trails, while facilities can be constructed in conjunction with heavily damaged areas such as log landing yards. Such areas can provide natural experiences and abundant wildlife viewing to capitalize upon Sabah's healthy ecotourism industry. These facilities could be geared not only towards the international tourist, but to an increasing local population of middle-class Malaysians, as well as visitors from nearby countries such as Singapore and Hong Kong. Well maintained park facilities can generate sufficient revenue to merit rangers and vehicles that not only serve to maintain facilities and interface with visitors, but also discourage illegal activities such as poaching and settlement. Natural areas can thereby serve to promote conservation through fostering national pride in the native flora and fauna.

A final important aspect of this study is that it provides baseline data on the behavior and ecology of the Malay civet under relatively undisturbed conditions and under conditions of moderate human disturbance. This allows for comparisons with future studies of Malay civets under different conditions. This study also demonstrates the relative ease of studying this species in comparison to many other less abundant and more elusive carnivores and provides a protocol for future research projects. From this, it is possible to make future management decisions and policies based on a greater understanding of the complex interactions between human disturbance and the response of one species of wildlife.

6.

SUMMARY

1. A study of the Malay civet was carried out from December, 1995, through June, 1997, in the Ulu Segama Forest Reserve in Sabah, East Malaysia. To investigate this species ecology, and examine the impact of selective logging, data were collected in a forest logged eight years ago, and an unlogged forest. Data on density, ranging behavior, activity, diet and parasites were collected via live trapping, radio-telemetry and scat analysis.

2. Trap success in the unlogged forest was 1/42.1 trap nights (n = 10), and 1/52.4 trap nights in the logged forest (n = 14), and did not differ between sites (χ^2 test, $\propto = 0.05$). Sex ratio in the logged site (3:8) differed from that in the unlogged (8:2), and may have been affected by higher road traffic mortality among males in the logged area (6:1).

3. Sexual dimorphism was observed only in hind foot length, head circumference and neck circumference (t-test, $\propto = 0.05$), which were all larger among males.

4. Density was 1/0.46 km^2 in the unlogged forest, 1/1.07 km^2 in the logged, and showed no significant difference between sites (χ^2 test, $\propto = 0.05$). This indicates that *V. tangalunga* is not negatively impacted by selective logging, although proximity to an unlogged forest may have facilitated recovery by serving as a source for recolonization.

5. Mean home range size (95% minimum convex polygon) in the unlogged forest was 79.1 ha for females, 93 ha for males (4:2). In the logged forest, it was 105 ha for females, 159.6 ha for males (3:3). Home range size did not differ significantly between site or gender (Two-way ANOVA, $\propto = 0.05$), but was larger than previously reported.

6. Home range size was not affected by rainfall. Unpredictable seasonality in this area may contribute to the lack of observed seasonal shifts in home range size or location.

7. Home range overlap in the unlogged forest averaged 41% for males and 30.5% for females. Overlaps in the logged forest were 16.3% and 26.8%, respectively. Degree of overlap showed no significant difference between site or gender (t-test, $\propto = 0.05$).

8. Patterns of dispersion between individuals revealed a tendency towards avoidance; females consistently avoided other females while males exhibited both patterns of clumped spacing and hyperdispersion. No social behavior was observed, other than that between parent and offspring.

9. Activity levels averaged 55%, and were similar among forest types and gender. Peak activity occurred after dark and before dawn. From 18:00 to 08:00 hours, mean activity levels were 81%. Day and night ranges overlapped extensively.

10. Males traveled further and used a larger portion of their home range per day than females. Roads and trails were centrally located in all home ranges and may be considered an important resource. Scat deposited on roads may aid in

communication.

11. Day beds were terrestrial, located on well-drained sites with high cover such as fallen trees and vine tangles. Beds were solitary, and not used on consecutive days.

12. Diet was comprised primarily of invertebrates and fruit, as well as rodents, insectivores, birds, snakes and lizards. Dietary flexibility may facilitate survival under changing conditions. As a non-obligate frugivore, *V. tangalunga* may play a significant role in forest regeneration. Because it thrives in logged forests and consumes large-seeded fruits, it may replace less adaptable seed dispersal agents in highly disturbed areas.

13. Six species of tick from *V. tangalunga* and at least 22 taxa of internal parasite from the civet community were identified. Parasite diversity did not differ between sites.

14. *V. tangalunga* thrives in both unlogged and selectively logged forests and is thus not an appropriate indicator species to assess the impact of logging on wildlife. Selectively logged forests appear to provide suitable habitat for the Malay civet.

REFERENCES

Anderson, R. M. (1982) Epidemiology. In: Cox, F. E. G. (ed.) *Modern Parasitology*. Blackwell Scientific Publications. London. pp. 204-251.

Appanah, S. (1993) Mass flowering of dipterocarp forests in the aseasonal tropics. *Journal of Bioscience* 18: 457-474.

Arthur, S. M., Krohn, W. B., Gilbert, J. R. (1989) Home range characteristics of adult fishers *Journal of Wildlife Management* 53(3): 674-679.

Bartels, E. (1964) On *Paradoxurus hermaphroditus javanicus*, the palm civet or toddy cat in western Java. *Beaufortia*, 124: 193-201.

Baskin, Y. (1994) Ecologists dare to ask: how much does diversity matter? *Science* 264: 202-203.

Berenstain, L. (1986) Responses of long-tailed macaques to drought and fire in eastern Borneo: A preliminary report. *Biotropica* 18(3):257-262.

Bisbale, E. ,F. J. (1986) Food habits of some neotropical carnivores in Venezuela (Mammalia, Carnivora) *Mammalia* 50(3): 329-337.

Blockhus, J. M., Dillenbeck, M., Sayer, J. A., Wegee, P., (eds.) (1991) *Conserving Biological Diversity in Managed Tropical Forests*. The IUCN Forest Conservation Programme. IUCN, Glans, Switzerland. pp. 49-53.

Brady, C. A. (1979) Observations on the behavior and ecology of the crab-eating fox, *Cerdocyon thous*. In: J. F. Eisenberg, (ed.) *Studies of Vertebrate Ecology in the Northern Neotropics*. pp. 161-172. Washington, DC: Smithsonian Institution Press.

Burgess, P. F. (1971) The effect of logging on hill dipterocarp forests *Malayan Nature Journal* 24: 231-237.

Burghouts, T., Ernsting, G., Korthals, G., DeVries, T. (1992) Litterfall, leaf litter decomposition and litter invertebrates in primary and selectively logged dipterocarp forest in Sabah, Malaysia. *Philosophical Transactions of the Royal Society of London.* B 335: 407-416.

Burney, D. A. (1980) *The Effects of Human Activities on Cheetahs (Acinonyx jubatus Schr.) in the Mara Region of Kenya.* M.Sc. thesis, Univ. of Nairobi.

Buskirk, S. W., Lindstedt, S. L (1989) Sex biases in trapped samples of Mustelidae. *Journal of Mammalogy* 70: 88-97.

Buskirk, S. W., McDonald, L. L. (1989) Analysis of variability in home-range size of the American marten. *Journal of Wildlife Management* 54(4): 997-1004.

Butler, S. (1987) Battle to save Sabah's forests. *Financial Times* (UK) April 16th.

Cameron, T. W. M. (1934) *The Internal Parasites of Domestic Animals: A Manual for Veterinary Surgeons*. A. and C. Black, LTD London.

Cameron, T. W. (1956) *Parasites and Parasitism*. Methuen and Co. London.

Cannon, C. H., Peart, D. R., Leighton, M., Kartawinata, K. (1994) The structure of lowland rainforest after selective logging in West Kalimantan, Indonesia. *Forest Ecology and Management* 67: 49-68.

Carpenter, F. L., MacMillen, R. E. (1976) Threshold model of feeding territoriality and test with a Hawaiian Honeycreeper. *Science* 194: 639-642.

Chapman, C. (1988) Patterns of foraging and range use by three species of neotropical primates. *Primates* 29(2): 177-194.

Charles-Dominique, P. (1978) Ecologie et vie sociale de *Nandinia binotata*: comparison avec les prosimiens sympatriques du Gabon., *Revue d'Ecologie (Tierre et Vie)*, 32: 477-528.

Chivers, D. J. (1974) The siamang in Malaya: a field study of a primate in tropical rain forest. *Contributions to Primatology*, 4: 1-335.

Chuang, S. A., Lee, L. L. (1997) Food habits of three carnivore species (*Viverricula indica, Herpestes urva,* and *Melogale moschata*) in Fushan Forest, northern Taiwan. *Journal of Zoology, London* 243: 71-79.

Clutton-Brock, T. H., Harvey, P. H. (1975) Ranging behavior of red colobus (*Colobus badus tephrosceles*) in the Gombe National Park. *Animal Behavior* 23:607-722.

Cochran, W.W. (1980) Wildlife telemetry. In: Schemnitz, S.D. (ed.) *Wildlife Management Techniques Manual.* Fourth Edition. The Wildlife Society, Washington, D.C. 516 p.

Cochran, W.W., Lord, R D. (1963) A Radio-tracking system for wild animals. *Journal of Wildlife Management* 27(1): 9-23.

Collins, N. M., Sayer, J. A., Whitmore, T. C. (1991) *The Conservation Atlas of Tropical Forests: Asia and the Pacific.* Simon and Schuster, New York. pp. 201-210.

Conforti, K. (1996) *The status and distribution of small carnivores in Huai Kha Khaeng/Thung Yai Naresuan Wildlife Sanctuaries, West-Central Thailand.* M. S. Thesis. University of Minnesota.

Constable, (1989) News from the field: new white leaf monkey observed in Southeast Sabah. *Primate Conservation 10: 30-31.*

Corlett, R. T. (1995) Tropical secondary forests. *Progress in Physical Geography.* 19: 159-172.

Corlett, R. T. (1998) Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) Region. *Biological Review* 73: 413-448.

Corlett, R. T., LaFrankie, J. V. (1998) Potential impacts of climate change on tropical Asian forests through an influence on phenology. *Climate Change* 39: 439-453.

Cox, F. E. G. (ed.) (1982) *Modern Parasitology: A Textbook of Parasitology.* Blackwell Scientific Publications. Oxford, England.

Davis, J. W., Anderson, R. C. (1971) *Parasitic Diseases of Wild Animals.* The Iowa State University Press. Ames, Iowa.

Dean, J. M., Ricklefs, R. E. (1980) Population size variability and aggregation among forest lepidoptera in southern Ontario. *Canadian Journal of Zoology* 58:394-399.

Delany, M. J. (1971) The biology of small rodents in Mayanja Forest, Uganda. *Journal of Zoology* 165: 85-129.

DeVries, T. H. (1989) A comparison between the litter dwelling arthropod fauna in a primary and secondary rain forest in northeast Borneo. Unpublished report: Amsterdam Free University.

Dhungel, S. K., Edge, W. D. (1985) Notes on the natural history of *Paradoxurus hermaphroditus*. *Mammalia* 49(2): 302-303.

Dioli, M. (1997) Notes on the morphology of the horns of a new artiodactyl mammal from Cambodia: *Pseudonovibos spiralis*. *Journal of Zoology, London* 241: 527-531.

Dixon, K. R., Chapman, J. A. (1980) Harmonic mean measures of animal activity areas. *Ecology* 61: 1040-1044.

Dobson, A. P., Hudson, P. J. (1986) Parasites, disease and the structure of ecological communities. *TREE* 1(1): 11-14.

Dobson, A. P., May, R. M. (1986) Disease and conservation. In: Soulé, M. (ed.) *Conservation Biology: the Science of Scarcity and Diversity* Sinauer Associates, Sunderland, MA. pp. 345-365.

Dubey, J. P., Speer, C., A., Fayer, R. (1989) *Sarcocystosis of Animals and Man.* CRC Press, Boca Raton, Florida.

Dudgeon, D., Corlett, R. T. (1994) *Hills and Streams: An Ecology of Hong Kong.* Hong Kong University Press, Hong Kong.

Dung, V. V., Giao, P. M., Ghinh, N. N., Tuoc, D., Arctander, P., MacKinnon, J. (1993) A new species of living bovid from Vietnam *Nature* 363: 443-445.

Eisenberg, J. F. (1989) An introduction to the Carnivora. In Gittleman, J. L. (ed.) *Carnivore Behavior, Ecology, and Evolution.* Cornell University Press, Ithica, New York.

Fimbel, C. (1994) Ecological correlates of species success in modified habitats may be disturbance and site-specific: The primates of Tiwai Island. *Conservation Biology* 8(1): 106-113.

Fowler, M. E. (1986) *Zoo and Wild Animal Medicine. 2nd Edition.* W. B. Saunders Co., Philadelphia, PA.

Fuller, T. K., Bikenvicius, A. R., Kat, P. W. (1990) Movement and behavior of large spotted genets (*Genetta maculata*) near Elmenteita, Kenya (Mammalia Viverridae) *Tropical Zoology* 3: 13-19.

Gao, Y. T., Wang, S., Zhang, M. L., Ye, S.Y., Shou, J. D. (Eds.) (1987) [*Fauna Sinica, Mammalia: Carnivora.*] Beijing: Academia Sinica, Science Press. [In Chinese].

Gittleman, J. L. (1989) Carnivore group living: comparative trends. In: Gittleman, J. L. (ed.) *Carnivore Behavior, Ecology, and Evolution.* Cornell University Press, Ithaca, N. Y. pp. 183-207.

Gittleman, J. L., Harvey, P. H. (1982) Carnivore home-range size, metabolic needs and ecology. *Behavioral Ecology and Sociobiology* 10: 57-63.

Goldman, C. A. (1982) *Regional Proceedings of the American Association of Zoological Parks and Aquaria.* pp. 14-34.

Gompper, M. E., Gittleman, J. L. (1991) Home-range scaling: intraspecific and comparative trends. *Oecologia* 87: 343-348.

Goosem, M. (1997) Internal Fragmentation: the effects of roads, highways and powerline clearings on movements and mortality of rainforest vertebrates. In: Laurance, W. F., Bierregarard, R. O. (eds.)*Tropical Forest Remnants, Ecology, Management, and Conservation of Fragmented Communities.*

Gorman, M. L., Trowbridge, B. J. (1989) The role of odor in the social lives of Carnivores. In: Gittleman, J. L. (ed.) *Carnivore Behavior, Ecology and Evolution.* Cornnell University Press, Ithica, New York. pp. 57-88.

Grzimek, B. (1991) *Encyclopedia of Mammals*: Volume III McGraw Hill, New York.

Hamilton, W.J., Buskirk, R.E., Buskirk, W.H. (1978) Omnivory and utilization of food resources by chacma baboons, *Papio ursinus*. American Naturalist 112 (987): 911-924.

Harrison, J. (1964) *An Introduction to the Mammals of Sabah.* The Sabah Society, Kota Kinabalu.

Harrison, J. (1969) The abundance and population density of mammals in Malayan lowland forests. *Malayan Nature Journal* 22: 174-178.

Hayssen, V., van Tienhoven A., van Tienhoven, A. (1993) *Asdell's Patterns of Mammalian Reproduction.* Cornell University Press, Ithica. pp. 285-288.

Heydon, M. J. (1994) *The ecology and management of rain forest ungulates in Sabah, Malaysia: implications of forest disturbance*. Unpublished report. Institute of Tropical Biodiversity. University of Aberdeen.

Heydon, M. J., Bulloh, P. (1996) The impact of selective logging upon sympatric civet species (*Viverridae*) in Borneo. *Oryx* 30(1): 31-36.

Hiscock, K., Perrin, M. R. (1990) A dietary comparison between two sympatric viverrids *Helogale parvula* (Sundevall, 1846) and *Mungo mungo* (Gmelin, 1788). *Journal of African Zoology* 307-312.

Hoogstraal, H., Trapido, H. (1966) Studies on Southeast Asian *Haemaphysalis* ticks (Ixodoidea, Ixodidae). Species described by Supinoin 1897 from Burma, with special reference to *H. (Rhipistoma) asiaticus (H. dentipalis* Warburton and Nuttall) *Journal of Parasitology* 52: 1172-1187.

Howlett, B. (in prep.) Pioneer tree distribution and forest recovery in a logged forest of Sabah, Malaysia.

Ikeda, H., Ono, Y., Baba, M., Doi, T., Iwamoto, T. (1982) Ranging and activity patterns of three nocturnal viverrids in Omo National Park, Ethiopia. *African Journal of Ecology* 20: 179-186.

Isabirye-Basuta, G., Kasenene, J. M. (1987) Small rodent populations in selectively felled and mature tracts of Kibale Forest, Uganda *Biotropica* 19(3): 260-266.

Jacobs, J. (1974) Quantitative measurements of food selection. *Oecologia* 14: 413-417.

Jefferies, D. J. (1974) Earthworms in the diet of the red fox (*Vulpes vulpes*) *Journal of Zoology, London* 173: 251-252.

Jennrich, R. I., Turner, F. B. (1969) Measurement of non-circular home range. *Journal of Theoretical Biology* 22: 227-237.

Johns, A. D. (1983) *Ecological Effects of Selective Logging in a West Malaysian Rain-forest.* Ph.D. thesis, University of Cambridge.

Johns, A. D. (1985) Selective logging and wildlife conservation in tropical rain-forests: problems and recommendations. *Biological Conservation* 31: 355-375.

Johns, A. D. (1986) Effects of selective logging on the behavioral ecology of west Malaysian primates. *Ecology* 67(3): 684-694.

Johns, A. D. (1992) Vertebrate response to selective logging: implications for the design of a logging system. *Philosophical Transactions of the Royal Society of London. B* 335: 437-442.

Johnsingh, A. J. T. (1986) *Diversity and conservation of carnivorous mammals in India.* Proceedings of the Indian Academy of Science Supplement. pp. 73-89.

Joshi, A. R., David Smith, J. L., Cuthbert, F. J. (1995) Influence of food distribution and predation pressure on spacing behavior in palm civets. *Journal of Mammalogy* 76(4): 1205-1212.

Kasenene, J. M. (1987) *The Influence of Mechanized Logging, Felling Intensity and Gap Size on the Regeneration of a Tropical Moist Forest in the Kibale Forest*

Reserve, Uganda. Ph.D. dissertation, Michigan State University, E. Lansing, USA.

Kaufmann, J. H. (1983) On the definitions and functions of dominance and territoriality. *Biological Review* 58: 1-20.

Kennedy, D. N., Swaine, M. D. (1992) Germination and growth of colonizing species in artificial gaps of different size in dipterocarp rain forest. *Philosophical Transactions of the Royal Society of London. B.* 335: 357-366.

Kenward, R. E. (1987) *Wildlife Radio Tagging: Equipment, Field techniques and Data Analysis.* London: Academic Press.

Kenward, R. E., Hoddard, K. H. (1996) *Ranges V Manual: An Analysis System for Biological Location Data.* Institute of Terrestrial Ecology

Kenward, R. E., Marcstrom, V., Karlbom, M. (1993) Post-nesting behavior in goshawks, *Accipiter gentilis*. Sex differences in sociality and nest switching. *Animal Behavior* 46: 371-378.

King, C. M. (1975) The sex ratio of trapped weasels (*Mustela nivalis*). *Mammal Review* 5(1): 1-8.

Kitchings, J. T., Storey, J. D. (1984) Movement and dispersal of bobcats in East Tennessee. *Journal of Wildlife Management* 48(3): 957-961.

Kitchner, A. (1993) *The Natural History of the Wild Cats.* Comstock Publishing, Ithica, New York. pp. 187-188.

Knick, S. T. (1990) Ecology of bobcats relative to exploitation and a prey decline in Southeastern Idaho. *Wildlife Monographs* No. 108: 1-42.

Kohls, G. M., (1957) Malaysian parasites-XVIII ticks (Ixodoidea) of Borneo and Malaysia. *Malaya* 28: 65-94.

Korthals, G. W. A description of the litter dwelling arthropod fauna in a primary and a secondary rain forest in Northeast Borneo. Unpublished report. (1990) Amsterdam Free University.

Krebs, C. J. (1989) *Ecological Methodology*. Harper-Collins Publishers, New York, N. Y.

Lambert, F. R. (1991) Conservation of fig eating birds in Malaysia. *Biological Conservation* 58: 31-40.

Lambert, F. R., Marshal, A. G, (1991) Keystone characteristics of bird-dispersed *Ficus* in Malaysian lowland rain forest. *Journal of Ecology.* 79: 739-809.

Larson, J. S., Taber, R. D. (1980) Criteria of Sex and Age. In: Schemnitz, S. D. (ed.) *Wildlife Management Techniques Manual.* The Wildlife Society, Washington, D. C.

Laundre, J. W., Reynolds, T. D., Knick, S. T. (1987) Accuracy of daily point relocations in assessing real movement of radio-marked animals. *Journal of Wildlife Management* 51: 937-940.

Leighton, M., Leighton, D. R. (1983) Vertebrate responses to fruiting seasonality within a Bornean rain forest. In: Sutton, S. L. Whitmore, T. C., Chadwick, A. C. (eds.) *Tropical rain forests: ecology and management.* Blackwell Scientific Publications, Oxford. pp. 181-196.

Lekagul, M. D. , McNeely, B. A. (1977) *Mammals of Thailand.* Ladprao Press, Bangkok.

Lenth, R. V. (1981) On finding the source of a signal. *Technometrics* 23(2): 149-154.

Liat, L. B., Betterton, C. (1977) *Paragonimus westermani* in Malaysian Felidae and Viverridae; probable modes of transmission in relation to host feeding habits. *Journal of Helminthology* 51: 295-299.

Liew, T. C. (1978) Forest manipulation and regeneration in Sabah. *Malay Forester* 31: 155-165.

Litvaitis J. A., Sherburne, J. A., Bissonette, J. A. (1986) Bobcat habitat use and home range size in relation to prey density. *Journal of Wildlife Management* 50(10): 110-117.

Louwman, J. W. W. (1970) Breeding the banded palm civet and the banded linsang, *Hemigalus derbyanus* and *Prionodon linsang. Int. Zoo Yb.* 10: 81-82.

Macdonald, D. W. (1980) The red fox (*Vulpes vulpes*) as a predator upon earthworms, *Lumbricus terrestris Z. Tierpsychol* 52: 171-200.

Macdonald, D. W. (ed.)(1984) *All the World's Animals: Carnivores.* Torstar Books, Inc., New York., NY.

Macdonald, D. W., Wise, M. J. (1979) Notes on the behavior of the Malay civet *Viverra tangalunga* Gray. *Sarawak Museum Journal* 48: 295-299.

Mace, G. M., Harvey, P. M. Clutton-Brock, T. H. (1983) Vertebrate home range size and energetic requirements. In: Swingland, I. R., Greenwood, P.J. (eds.) *The Ecology of Animal Movement.* Clarendon Press, Oxford. pp. 32-53.

Maddock, A. H. (1993) Small carnivores trapped at Vernon Crookes Nature Reserve *Lammergeyer* 42, July 1993 pp. 35-42.

Malaysian Timber Council (1998) Malaysian Forestry as an Industry. www.mtc.com.my/aboutmtc/aboutmtc.htm.

Marsh, C. W. (1995) *Danum Valley Conservation Area management plan: 1995-2000.* Yayasan Sabah/Innoprise Corporation Sdn. Bhd.

Marsh, C. W., Greer, A. G. (1992) Forest land-use in Sabah, Malaysia: an introduction to Danum Valley. *Philosophical Transactions of the Royal Society of London. B* 335: 331-339.

Marshall, A. G. (1992) The Royal Society's South-east Asian rain forest research Programme: an introduction. *Philosophical Transactions of the Royal.Society of London B* 335: 327-330.

Martin, R. D. (1990) *Primate Origins and Evolution.* Chapman and Hall, London.

May, R. M. (1988) Conservation and disease. *Conservation Biology* 2(1): 28-30.

McNab, B. K. (1995) Energy expenditure and conservation in frugivorous and mixed-diet carnivorans. *Journal of Mammalogy* 76(1): 206-222.

McNeill, M. (1983) Echinococcus granulosus (Cestoda: Taeniidae) infections in moose (Alces alces) from soutwestern Quebec. MSc. Thesis, Institute of Parasitology, McGill University, Quebec, Canada.

Medway, L. (1969) *The Wild Mammals of Malaya.* Oxford University Press, London, UK.

Mergen, F., Vincent, J. R., (eds.) (1987) *Natural Management of Tropical Moist Forests: Silvicultural and Management Prospects of Sustained Utilization.* Yale University Press, New Haven, Connecticut, USA.

Milton, K., May, M. L. (1976) Body weight, diet and home range area in primates. *Nature* 259: 459-62.

Mohr, C. O. (1947) Table of equivalent populations of North American small mammals. *American Midland Naturalist* 37: 223-249.

Morrison, M. L., Marcot, B. G., Mannan, W. (1992) Foraging Behavior. In: *Wildlife-Habitat Relationships; Concepts and Applications*. The University of Wisconsin Press. pp. 179-220.

Mykytka, J. M., Pelton, M. R. (1988) Evaluation of four standard home range methods based on movements of Florida black bear. *Biotelemetry* 159-166.

Nel, J. A. J, Mills, M. G. L., van Aared, R. J. (1984) Fluctuating group size in bat-eared foxes (*Otocyon megalotis*) in the south-western Kalahari. *Journal of Zoology, London* 203: 294-298.

Newbery, D. McC., Campbell, E. J. F., Lee, Y. F., Risdale, C. E., Still, M. J. (1992) Primary lowland dipterocarp forest at Danum Valley, Sabah, Malaysia: structure, relative abundance and family composition. *Philosophical Transactions of the Royal Society of London. B.* 335: 341-356.

Niemitz, C., Nietsch, A., Warter, S., Rumpler, Y., (1994) *Tarsius dianae*: A new primate species from Central Sualwesi (Indonesia) *Folia Primatologica* 1991: 56: 105-116.

Oates, J. F. (1986) Food distribution and foraging behavior. In: Smuts, B. B., Cheney, D. L., Seyfarth, R. M., Wrangham, R. W., Struhsaker, T. T. (eds.) *Primate Societies.* The University of Chicago Press, Chicago. pp. 197-206.

O'Connell, M. (1989) Population dynamics of Neotropical small mammals in seasonal habitats. *Journal of Mammalogy* 70(3): 532-548.

Packer, C., Pusey, A. E. (1987) Intrasexual cooperation and the sex ratio in African lions. *American Naturalist* 130: 636-642.

Palomares, F. (1994) Site fidelity and effects of body mass on home-range size of Egyptian mongooses. *Canadian Journal of Zoology* 72: 465-469.

Patton, S., Rabinowitz, A. (1994) Parasites of wild felidae in Thailand: a coprological survey. *Journal of Wildlife Diseases* 30(3): 472-475.

Patton, S., Rabinowitz, A., Randolph, S., Strawbridge Johnson, S. (1986) A coprological survey of parasites of wild neotropical felidae. *Journal of Parasitology* 72(4): 517-520.

Payne, J. (1992) *Why are rhinoceros rare in Borneo forests?* In; Proceedings of the International Conference Of Forest Biology and Conservation in Borneo Ghasally, Murtedza and Siraj (eds.) Center for Borneo Studies Publication No. 2, Yayasan Sabah, Kota Kinabalu.

Payne, J., Francis, C. M., Phillipps, K. (1985) *A Field Guide to the Mammals of Borneo.* The Sabah Society/ World Wildlife Fund, Malaysia. Kuala Lumpur, Malaysia.

Peter, P., Feiler, A. (1994) Horner von einer unbekannten Bovidenart aus Vietnam (Mammalian: Runinantia). *Faun. Abh. (Dres.)* 19: 169-176 [In German].

Pianka, E. R. (1978) *Evolutionary Ecology*. Harper and Row, New York.

Pimm, S.L. (1982) *Food Webs*. Chapman and Hall, London.

Rabinowitz, A. R. (1986) Ecology and behavior of the Jaguar (*Panthera onca*) in Belize, Central America *Journal of Zoology, London* (A) 210: 149-159.

Rabinowitz, A. (1990 a) Notes on the behavior and movements of leopard cats, *Felis bengalensis*, in a dry tropical forest mosaic in Thailand. *Biotropica* 22 (4): 379-403.

Rabinowitz, A. R. (1990 b) Fire, dry dipterocarp forest, and the carnivore community in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Natural History Bulletin of the Siam Society* 38: 99-115.

Rabinowitz, A. R. (1991a) Behavior and movement of sympatric civet species in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Journal of Zoology, London* 223: 281-298.

Rabinowitz, A. R. (1991b) Chasing shadows called civets. *Int. Wildl.* November/December, 1991. pp. 38-45.

Rabinowitz, A. R. (1997) *Wildlife Field Research and Conservation Training Manual.* Paul-Art Press, Inc. New York.

Rabinowitz, A. R., Myint, T., Khaing, S. T., Rabinowitz, R. (in press) Description of the leaf deer (*Muntiacus putaoensis*) a new muntjac from Myanmar. *Journal of Zoology, London.*

Rabinowitz, A. R., Walker, S. R. (1991) The carnivore community in a dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Journal of Tropical. Ecology* 7: 37-47.

Rabinowitz, A., Amato, G., Khaing, U. S. T. (1998) Discovery of the black muntjac, Muntiacus crinifrons (Artiodactyla, Cervidae), in north Myanmar. *Mammalia* 62(1): 105-108.

Ray, J. C. (1997) Comparative ecology of two African forest mongooses, *Herpestes naso* and *Atilax paludinosus. African Journal of Ecology* 35: 237-253.

Rice, C. (1986) Observations on predators and prey at Eravikulam National Park, Kerala. *J. Bombay Nat. Hist. Soc.* 83(2): 283-305.

Ricklefs, R. E. (1997) *The Economy of Nature.* Fourth Edition W. H. Freeman and Co. New York.

Robbins, R. G., Karesh, W. B., Rosenberg, S., Schonwalter, N., Inthavong, C. (1997) Two noteworthy collections of ticks (Acari: Ixodida: Ixodidae) from endangered carnivores in the Lao People's Democratic Republic *Entomological News* 108(1): 60-62.

Rood, J. P. (1975) Population dynamics and food habits of the banded mongoose. *East. African Wildlife Journal* 13: 89-111.

Rowe-Rowe, D. T., Green, B. (1981) Steel-jawed traps for live capture of black-backed jackals. *South African Journal of Wildlife Research* 11: 63-65.

Salsbury, C. M., Armitage, K. M. (1994) Home-range size and exploratory excursions of adult, male yellow-bellied marmots. *Journal of Mammalogy* 75(3): 648-656.

Sandell, M. (1989) The mating tactics and spacing of solitary carnivores. In: Gittleman, J. L. (ed.) *Carnivore Behavior, Ecology and Evolution.* Cornell University Press, Ithica, New York.

Schaller, G. (1967) *The Deer and the Tiger*. Universith of Chicago Press.

Schaller, G. B., Rabinowitz, A. (1995) The saola or spindlehorn bovid *Pseudoryx nghetinhensis* in Laos. *Oryx* 29(2) 107-114.

Schaller, G. B., Vrba, Elizabeth S. (1996) Description of the giant muntjac (*Megamuntiacus vuquangensis*) in Laos *Journal of Mammalogy* 77(3): 675-683.

Schreiber, A. (1989) Mysterious mustelids, very mysterious viverrids. *BBC Wildlife* Dec. 816-823.

Schreiber, A., Wirth, R., Riffel, M. (1990) Weasels, civets, mongooses and their relatives: An action plan for conservation. IUCN/SSC Mustelid and Viverrid Specialist Group. Glans, Switzerland.

Scott, M. (1986) Southeast Asia's forests; lost for the trees. *Far Eastern Economic Review* (*Hong Kong*) April 10th.

Scott, M. E. (1988) The impact of infection and disease on animal populations: implications for conservation biology. *Conservation Biology* 2(1):40-56.

Skorupa, J. P. (1987) Do line-transect surveys systematically underestimate primate densities in logged forests? *American Journal of Primatology* 13: 1-9.

Skorupa, J. (1990) Responses of rain forest primates to selective logging in Kibale Forest, Uganda: A summary report. In: Benirschke, K. (ed.) *Primates: The Road to Self-Sustaining Populations.* Springer-Verlag, New York.

Skorupa, J. P., Kasenene, J. M., (1984) Tropical forest management: can rates of natural treefall help guide us? *Oryx* 18(2): 96-101.

Smuts, G. L. (1978) Interrelations between predators, prey, and their environment. *BioScience* 28(5): 316-320.

Sokal, R. R., Rohlf, F. J. (1987) *Introduction to Biostatistics 2nd Edition.* W. H. Freeman and Co., New York.

Springer, J. T. (1979) Some sources of bias and sampling error in radio triangulation. *Journal of Wildlife Management* 43(4): 926-935.

Struhsaker, T. T (1973) A re-census of vervet monkeys in the Masai-Amboseli Game Reserve, Kenya. *Ecology* 54: 930-932.

Sunquist, M. E. (1981) The social organization of tigers (*Panthera tigris*) in Royal Chitwan National Park, Nepal. *Smithsonian. Contributions to Zoology* No. 336: 1-98.

Sunquist, M. E., Sunquist, F., Daneke, D. E. (1989) Ecological separation in a Venezuelan Llanos carnivore community. *Advances in Neotropical Mammalogy* (1989) 197-232.

Swihart, R. K., Slade, N. A. (1985) Testing for independence of observations in animal movements. *Ecology* 66: 1176-1184.

Taylor, M. E. (1969) Notes on the breeding of two genera of viverrids, *Genetta* ssp. And *Herpestes sanguieus*, in Kenya. *East African Wildlife Journal* 7: 168-169.

Thiollay, J. M. (1992) Influence of selective logging on bird species diversity in a Guianan rain forest. *Conservation Biology* 6(1): 47-63.

Thorne, E. T., Williams, E. S. (1988) Disease and endangered species: the black-footed ferret as a recent example. *Conservation Biology* 2(1): 66-74.

Toy, R. J., Marshall, A. G., Pong, T. Y. (1992) Fruiting pehenology and the survival of insect fruit predators: a case study from the South-east Asian Dipterocarpaceae *Philosophical Transactions of the Royal Society of London.* B (335): 417-423.

Tuoc, D., Dung, V. V., Dawson, S., Arctander, P., MacKinnon, J. (1994) Introduction of a new large mammal species in Vietnam. *Science and Technology News, Forest Inventory and Planning Institute (Hanoi)* March 4-13 [In Vietnamese].

Uhl, C. (1989) Ecological impacts of selective logging in the Brazilian Amazon: A case study from the Paragonimus Region of the State of Para. *Biotropica* 21(2): 98-106.

van Schaik, C. P., Griffiths, M. (1996) Activity periods of Indonesian rain forest mammals. *Biotropica* 28: 105-112.

Verts, B. J. (1963) Equipment and techniques for radio-tracking striped skunks. *Journal of Wildlife Management* 27(3): 325-339.

Voigt, D. R., Tinline, R. R. (1980) Strategies for analyzing radio-tracking data. In: *A Handbook on Biotelemetry and Radio Tracking.* C. J. Amlaner, Jr. and D. W. MacDonald, (eds.): pp. 387-404.

Walker, E. P. (1975) *Mammals of the World.* 3rd Edition. John Hopkin's University Press, Baltimore.

Walker, S. R., Rabinowitz, A. R. (1992) The small-mammal community of a dry-tropical forest in Central Thailand. *Journal of Tropical. Ecology* 8: 57-71.

Walsh, R. P. D. *Climate data for Danum Valley.* Unpublished Danum Valley Report No. 98 (1990).

Waterman, P. G., Davies, A. G., Bennett, E. L. (1988) Food selection by two Southeast Asian colobine monkeys (*Presbytis rubicunda* and *Presbytis melalophos*) in relation to plant chemistry. *Biological Journal of the Linnean Society* 34: 33-56.

Watkins, C. V., Harvey, L. A. (1942) On the parasites of silver foxes on some farms in the South West. *Parasitology* 34: 155-179.

Weckwerth, R. P., Hawley, V. D. (1962) Marten food habits and population fluctuations in Montana. *Journal of Wildlife Management* 26(1): 55-74.

Wee Lek, C. (1977) *Conservation of habitats.* Part V: Proceedings of IUCN Conference on Southeast Asia.

White, G. C. , Garrott, R. A. (1990) *Analysis of Wildlife Radio-Tracking Data.* Academy Press, New York, NY.

White, L. J. T. (1994) Biomass of rain forest mammals in the Lope Forest Reserve, Gabon. *Journal of Animal Ecology* 63: 499-512.

Whitmore, T. C. (1984) *Tropical Rain Forests of the Far East.* Clarendon Press, Oxford.

Wilkie, D. S., Sidle, J. S., Boundzanga, G. C. (1992) Mechanized logging, market hunting and a bank loan in Congo. *Conservation Biology* 6(4): 570-580.

Williams, E. S., Thorne, E. T. (1996) Infectious and parasitic diseases of captive carnivores, with special emphasis on the black-footed ferret (*Mustela nigripes*). *Review of Scientific Technology* 15(1): 91-114.

Wilson, C. C., Wilson, W. L. (1975) The influence of selective logging on primates and some other animals in East Kalimantan. *Folia Primatologica* 23: 245-274.

Wilson, C. C., Johns, A. D. (1982) Diversity and abundance of animal species in undisturbed forest, selectively logged forest and plantations in east Kalimantan, Indonesia. *Tropical Conservation* 24: 205-218.

Wong, M. (1985) Understory birds as indicators of regeneration in a patch of selectively logged West Malaysian rain forest. In: *Conservation of Tropical Forest Birds* (eds.) A. W. Diamond and T. E. Lovejoy. ICBP Technical Pub. No. 4 Cambridge International Council for Bird Preservation. pp. 249-263.

Worton, B. J. (1987) A review of models of home-range for animal movement. *Ecological Modeling,* 38: 277-298.

Worton, B. J. (1989) Kernel methods for estimating the utilization distribution in home range studies. *Ecology* 70: 164-168.

Wright, P. S. (1975) The soils of Sabah (Vol.3) western parts of Tawau and Lahad Datu districts. Land resource study 10. London: Land Resource Division

Young, T. P. (1993) Natural die-offs of large mammals: implications for conservation. *Conservation Biology* 8(2): 410-418.

Zainoor, S. (1986) Sabah enjoying good spell in sawn timber trade. *Sarawak Tribune (Malaysia)* July, 7th.

Appendix I. List of all non-volant mammals recorded in Danum Valley, Sabah, East Malaysia

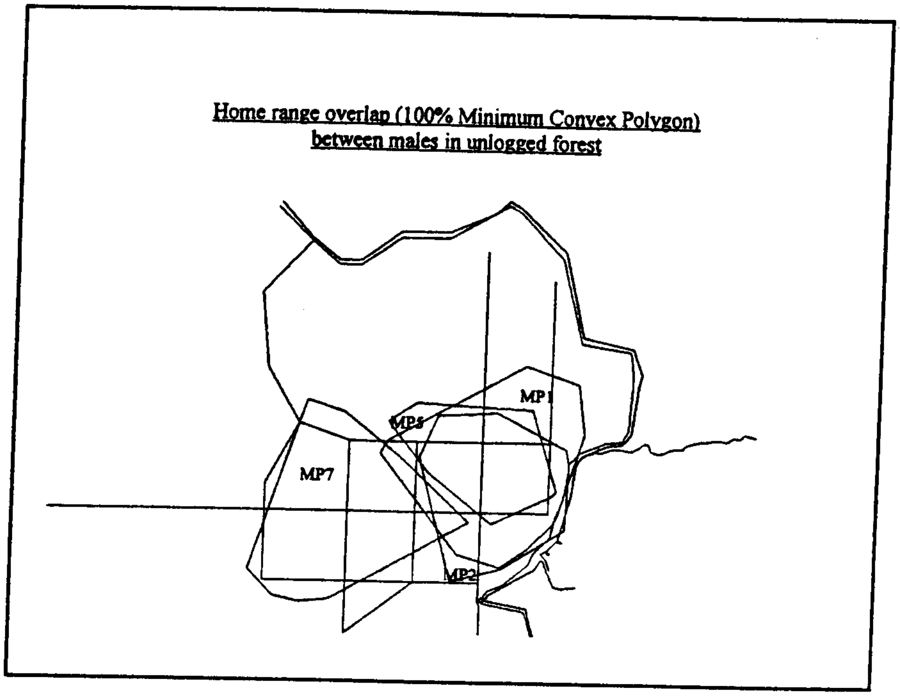
List compiled by Louise H. Emmons

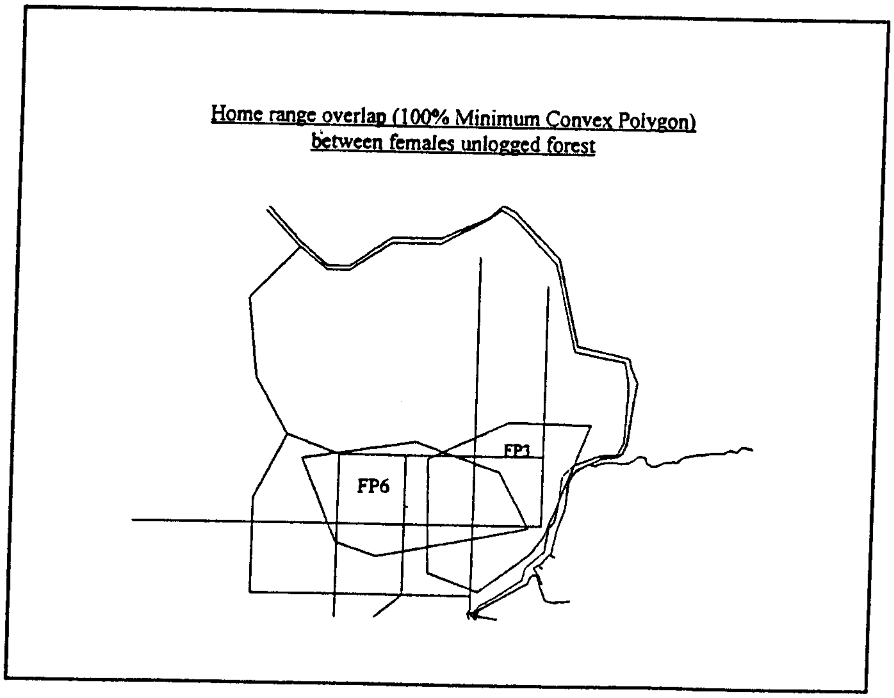
Species	English	Bahasa Malay
Bovidae		
Bos javanicus	Banteng	Tembadau
Cercopithecidae		
Hylobates muelleri	Borneo Gibbon	Wak-wak
Macaca fascicularis	Long-tailed Macaque	Kera
Macaca nemestrina	Pig-tailed Macaque	Berok
Pongo pygmaeus	Orangutan	Orang hutan
Presbytis cristata	Silvered Leaf Langur	Lotong kelabu
Presbytis hosei	Hose's Langur	Lotong kikok
Presbytis rubicunda	Red Leaf Langur	Lotong merah
Cervidae		
Cervus unicolor	Sambar Deer	Rusa/Payau
Muntiacus atherodes	Yellow Muntjak	Kijang
Munitacus muntjak	Red Muntjak	Kijang
Cynocephalidae		
Cynocephalus variegatus	Flying Lemur	Kubong
Elephantidae		
Elephas maximus	Asian Elephant	Gajah
Erinaceidae		
Echinosorex gymnurus	Moon Rat	Ticus bulan
Felidae		
Felis bengalensis	Leopard Cat	Kuching hutan
Felis marmorata	Marbled Cat	Kuching dahan
Felis planiceps	Flat Headed Cat	Kuching hutan
Neofelis nebulosa	Clouded Leopard	Rimau dahan
Hystricidae		
Hystrix brachyura	Common Porcupine	Landak raya
Thecurus crassispinis	Thick-spined Porcupine	Landak Borneo
Trichys fasciculata	Long-Tailed Porcupine	
Lorisidae		
Nycticebus coucang	Slow Loris	Kong kang

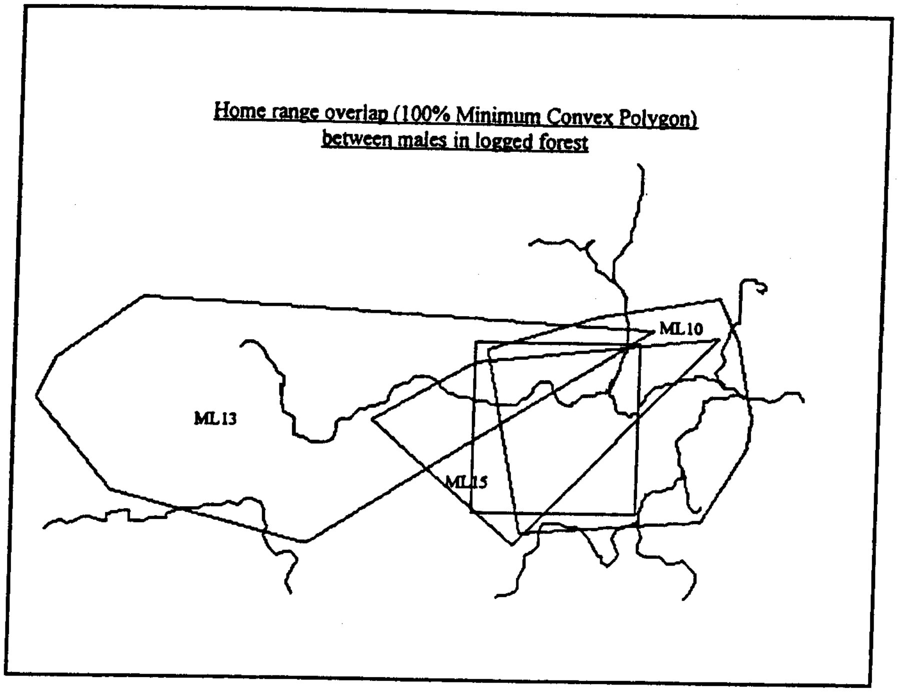
Manidae		
Manis javanica	Pangolin	Tenggiling
Muridae		
Haeromys sp.	Ranee-Mouse	Tikus terkechil
Lenothrix canus	*Grey Tree Rat*	
Leopoldamys sabanus	Long Tailed Giant Rat	
Maxomys cf whiteheadi	Whitehead's Rat	
Maxomys rajah	Brown Spiny Rat	
Maxomys surifer	Red Spiny Rat	
Niviventer cremoriventer	Dark Tailed Tree Rat	
Sundamys muelleri	Muller's Rat	
Mustelidae		
Aonyx cinera	Oriental Small-clawed Otter	Memerang kechil
Lutra perspicillata	European Otter	Memerang
Lutra sumatrana	Hairy-nosed Otter	Memerang kumis
Martes flavigula	Yellow-throated Marten	Pulusan akar
Mustela nudipes	Malaysian Weasel	Pulusan tanah
Mydaus javanensis	Malay Badger	Teledu
Rhinocerotidae		
Dicerorhinus sumatrensis	Sumatran Rhinoceros	Badak
Scuridae		
Aeromys tephromelas	Black Giant Flying–squirrel	Tupai turbang hitam
Aeromys thomasi	Flat-tailed Giant Flying-squirrel	Tupai terbang merah
Callosciurus adamsi	Plain Pygme Squirrel	
Callosciurus notatus	Common Red-bellied Squirrel	Tupai merah
Callosciurus prevosti	Prevost Squirrel	Tupai Gading
Exilisciurus exilis		
Petaurillus sp.	Pygme Flying-squirrel	Tupai terbang kerickek
Petaurista petaurista	Red Giant Flying-squirrel	Tupai terbang merah
Ratufa affinis	Giant Squirrel	Tupai kerawak
Rheithrosciurus macrotis	Giant Tufted Ground Squirrel	Tupai besar jambul
Rhinosciurus laticaudatus	Shrew-faced Ground Squirrel	Tupai naning
Sundasciurus hippurus	Horse-tailed Squirrel	Tupai ecor-kuda
Sundasciurus loweii	Short-tailed Little Squirrel	Tupai ecor pendek
Suiidae		
Sus barbatus	Bearded Pig	Babi janggut
Tarsiidae		
Tarsius bancanus	Tarsir	Kera hantu

Tragulidae		
Tragulus javanicus	Lesser Mouse Deer	Pelandok
Tragulus napu	Greater Mouse Deer	Pelandok
Tupaiidae		
Ptilocercus lowii	Pentail Tree-shrew	Tupai akar malam
Tupaia glis	Common Tree-shrew	Tupai munchong besar
Tupaia gracilis	Slender Tree-shrew	Tupai munchong kurus
Tupaia minor	Lesser Tree-shrew	Tupai munchong kechil
Tupaia tana	Large Tree-shrew	Tupai munchong belang
pendek		
Ursidae		
Helarctos malayanus	Malaysian Sun Bear	Beruang
Viverridae		
Arctictis binturong	Binturong	Binturong
Acrtogalidia trivirgata	Small Toothed Palm Civet	Musang akar
Cynogale bennettii	Otter Civet	Musang memerang
Hemigaus derbyanus	Banded Palm Civet	Musang gengulang
Herpestes brachyurus	Short-tailed Mongoose	Bambun ekor pendek
Herpestes semitorquatus	Collared Mongoose	Bambun ekor panjang
Paradoxurus hermaphroditus	Common Palm Civet	Musang pulut
Paguma larvata	Masked Palm Civet	Musang lamri
Prionodon lisang	Banded Linsang	Musang linsang
Viverra tangalunga	Malay civet	Tangalung

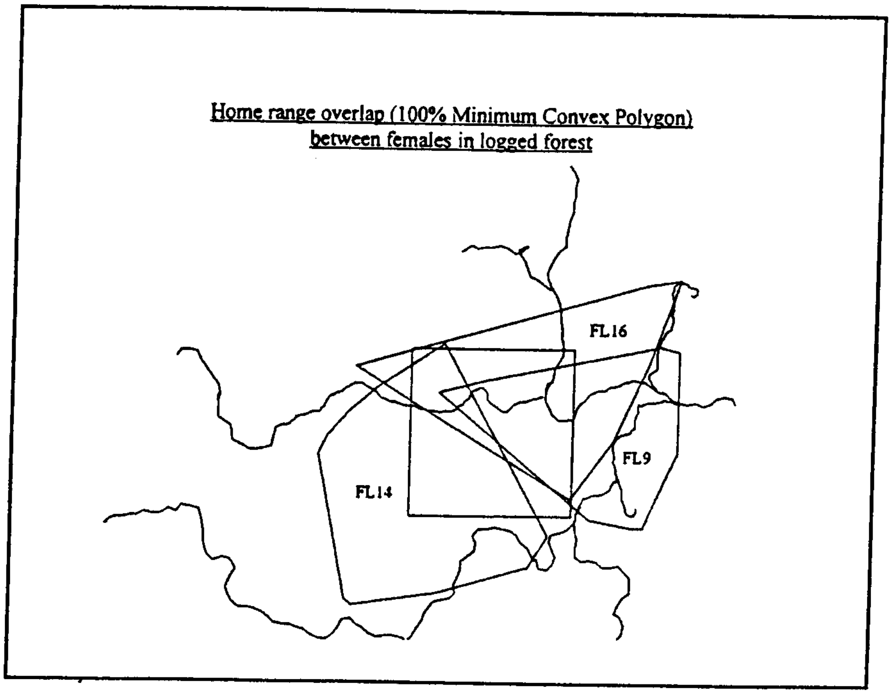
Appendix II. Home range polygons separated by site and gender.



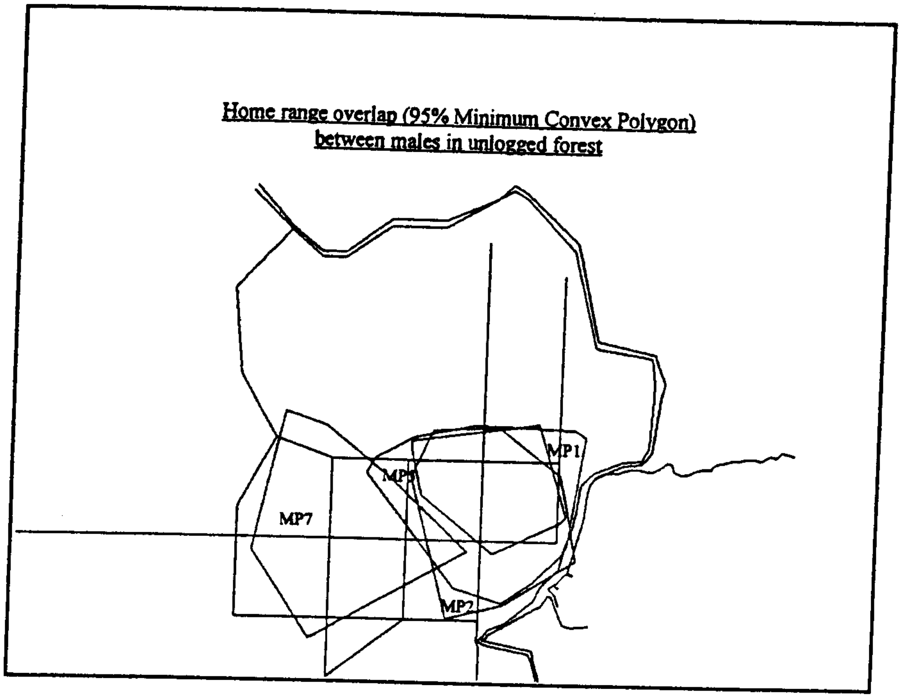




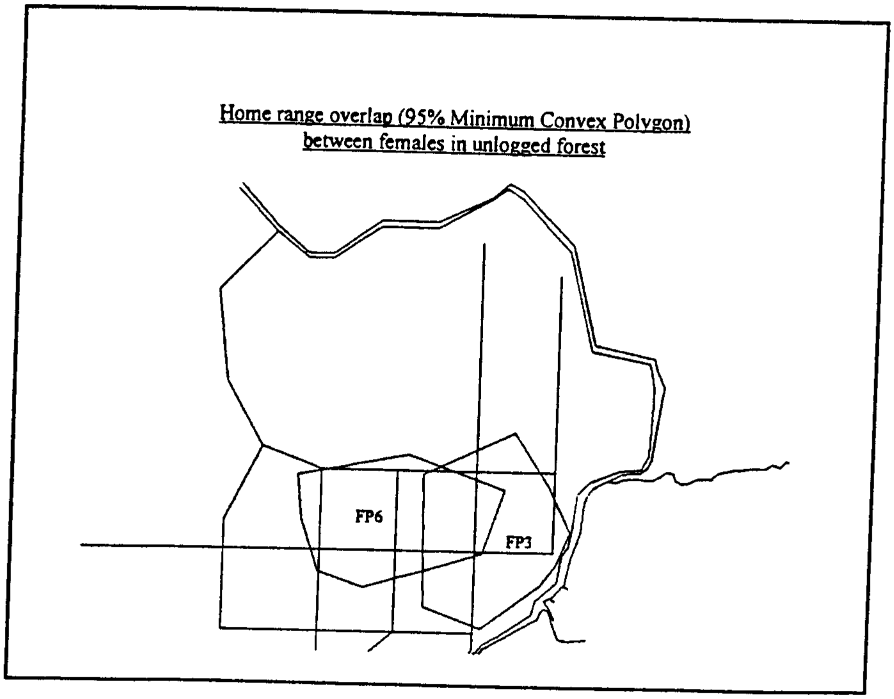
Home range overlap (100% Minimum Convex Polygon) between males in logged forest



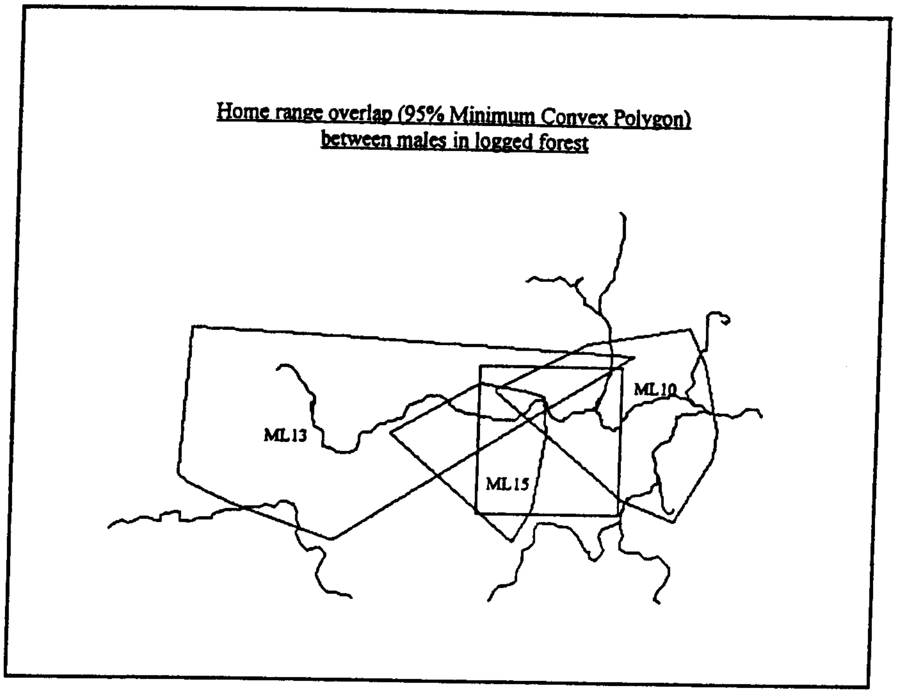
Home range overlap (100% Minimum Convex Polygon) between females in logged forest



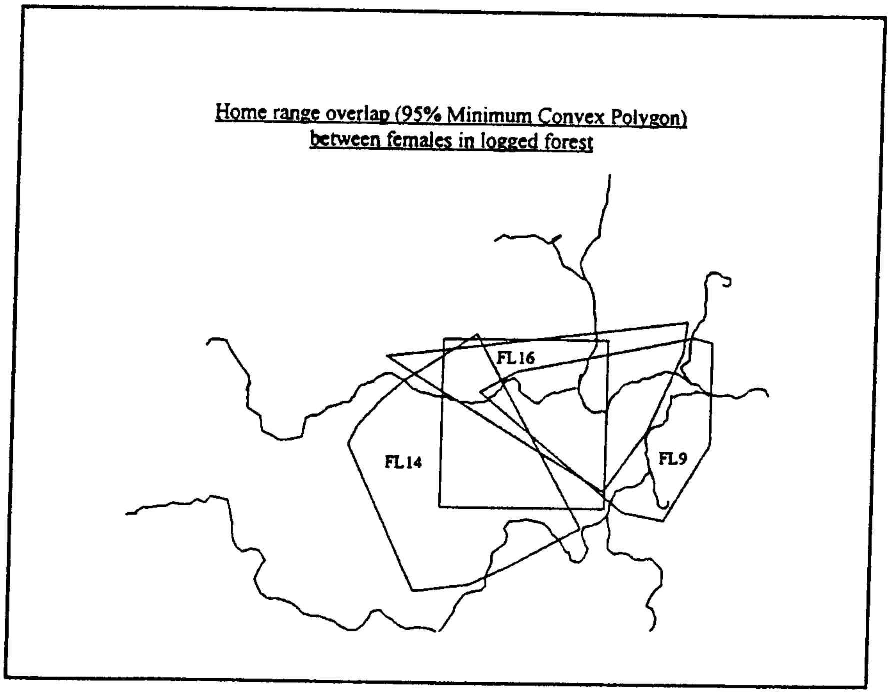
Home range overlap (95% Minimum Convex Polygon)
between males in unlogged forest



Home range overlap (95% Minimum Convex Polygon)
between females in unlogged forest

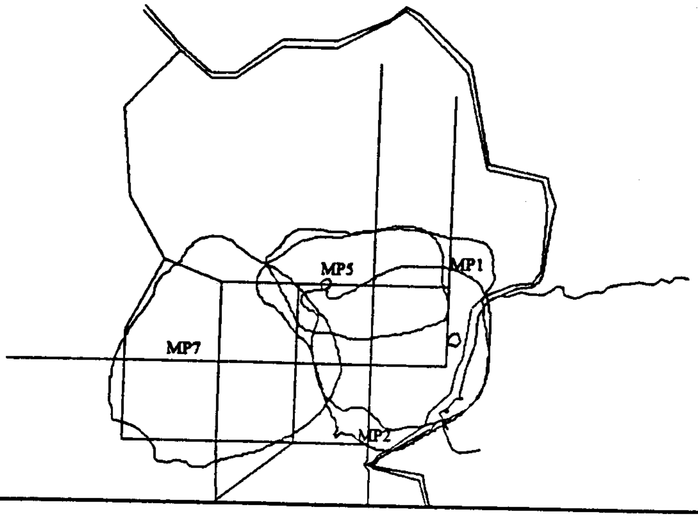


Home range overlap (95% Minimum Convex Polygon) between males in logged forest

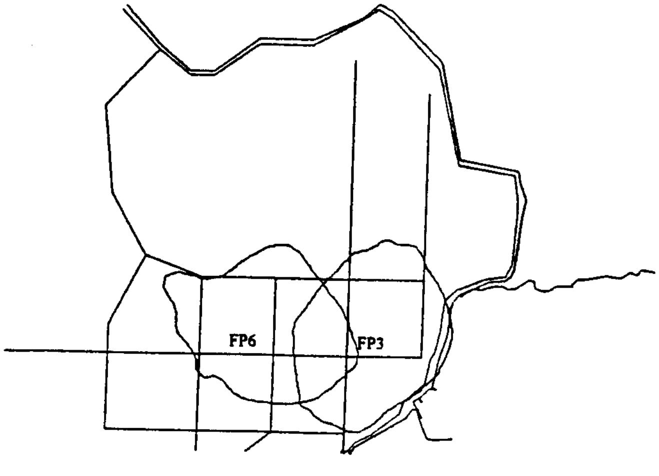


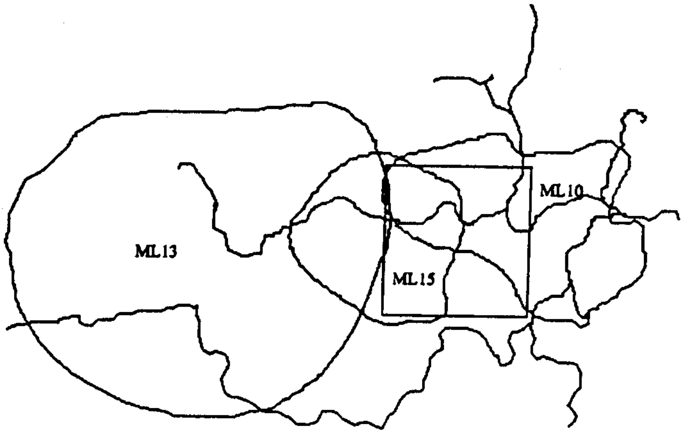
Home range overlap (95% Minimum Convex Polygon) between females in logged forest

Home Range Overlap (95% Harmonic Mean) between Males in unlogged forest

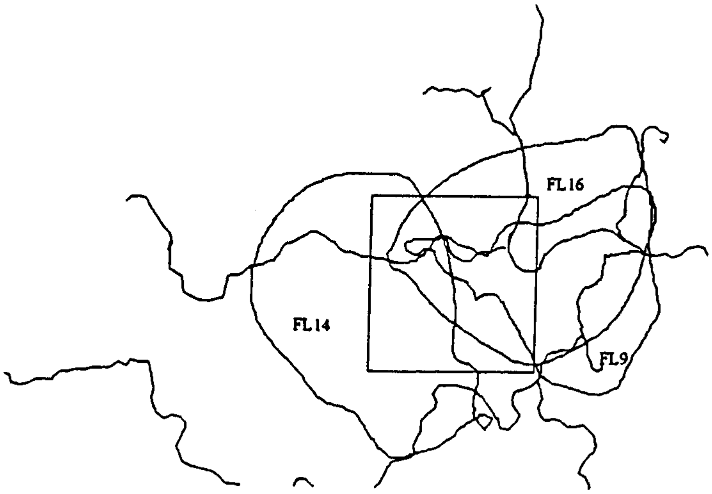


Home range overlap (95% Harmonic Mean) between females in unlogged forest

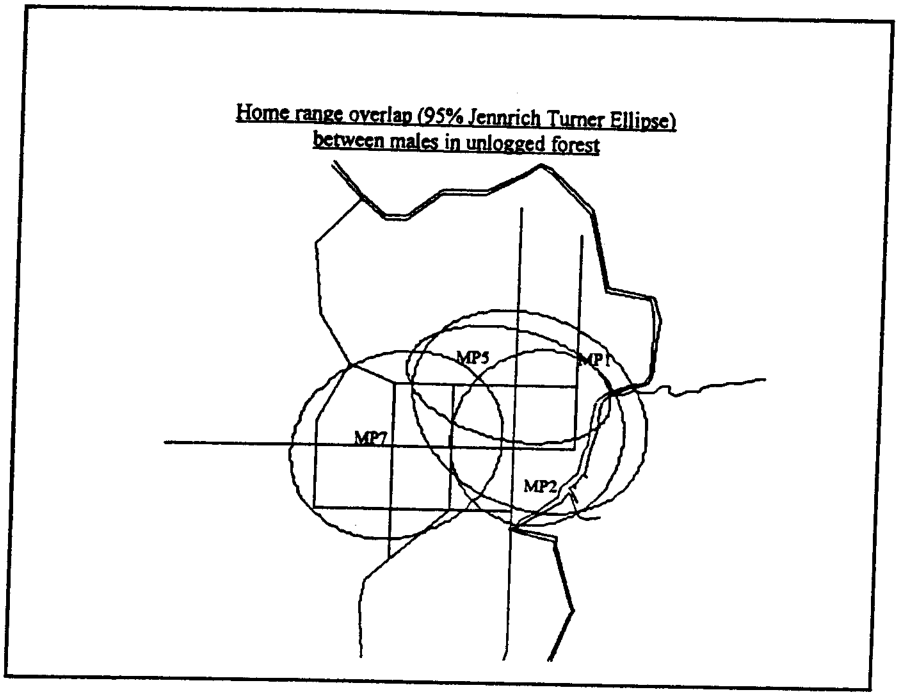


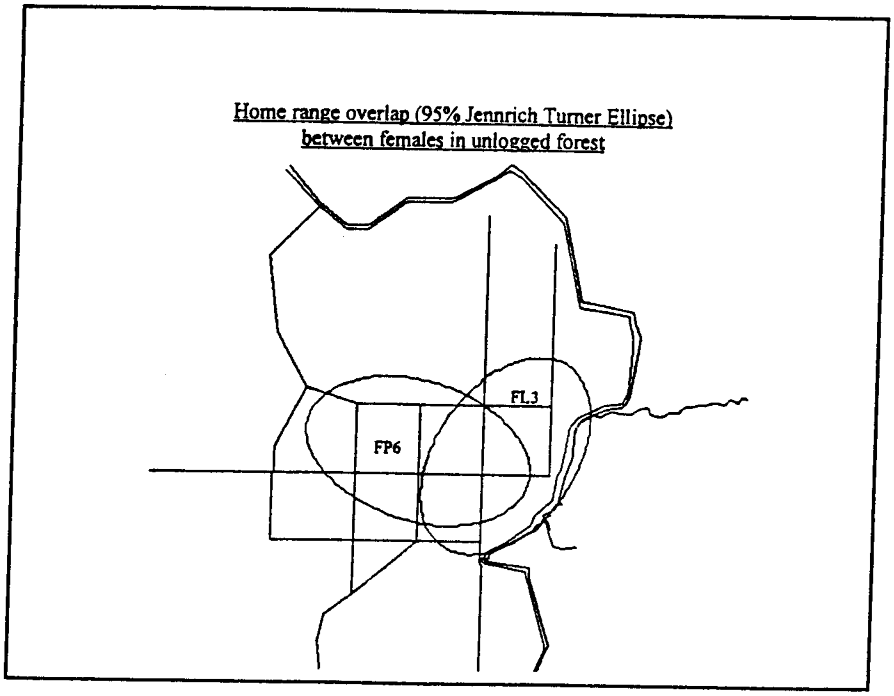


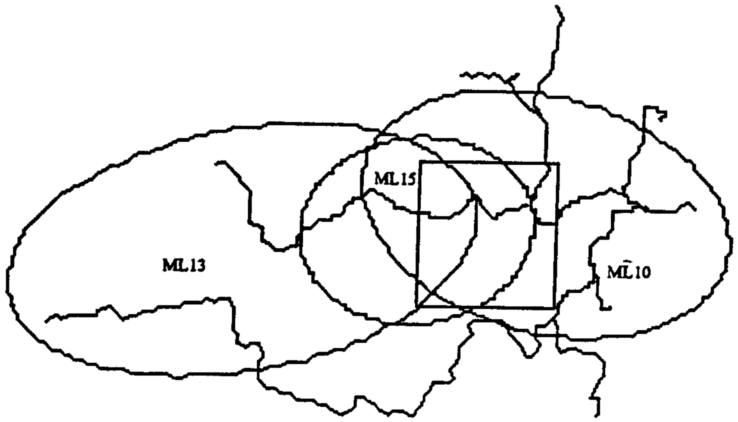
Home range overlap (95% Harmonic Mean) between males in logged forest



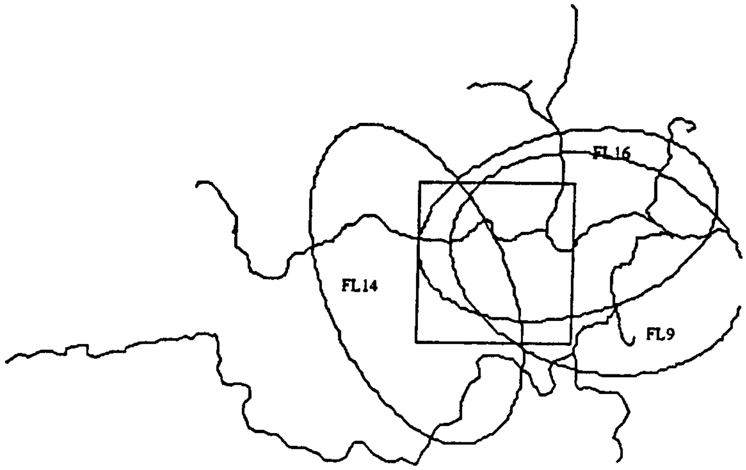
Home range overlap (95% Harmonic Mean) between females in logged forest


Home range overlap (95% Jennrich Turner Ellipse) between males in unlogged forest

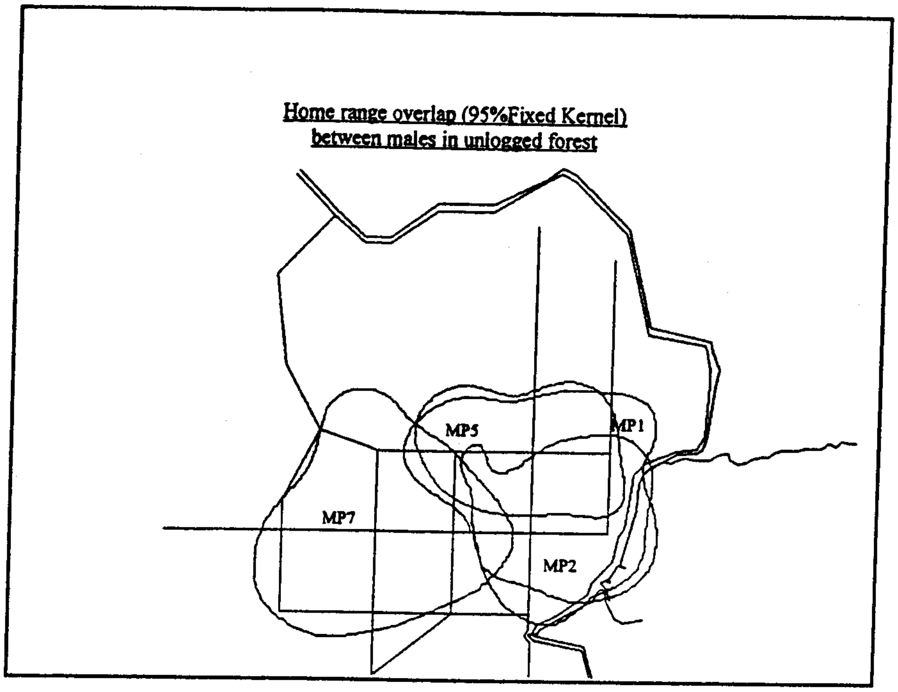

Home range overlap (95% Jennrich Turner Ellipse) between females in unlogged forest



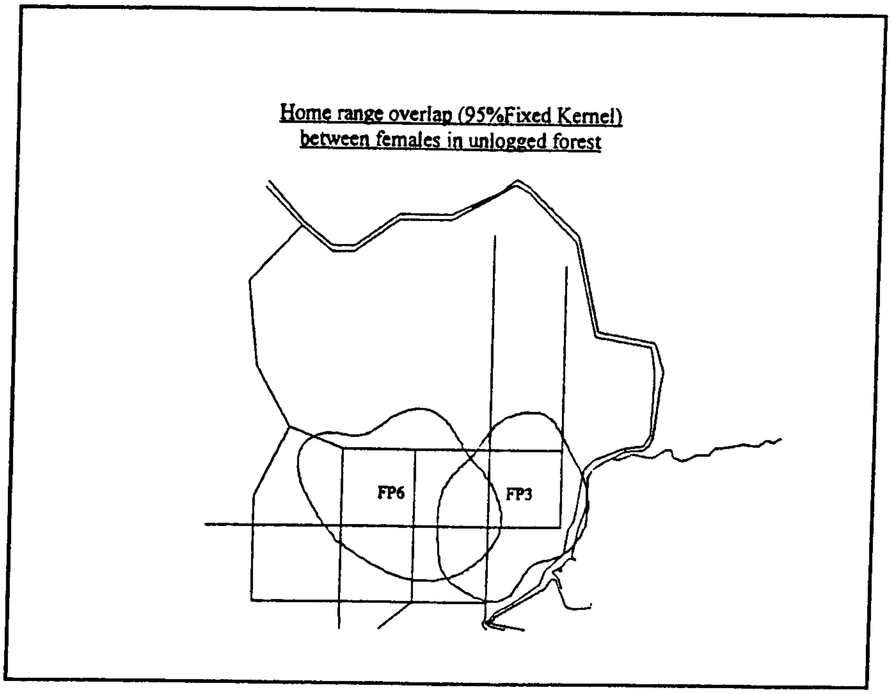
Home range overlap (95% Jennrich Turner Ellipse) between males in logged forest



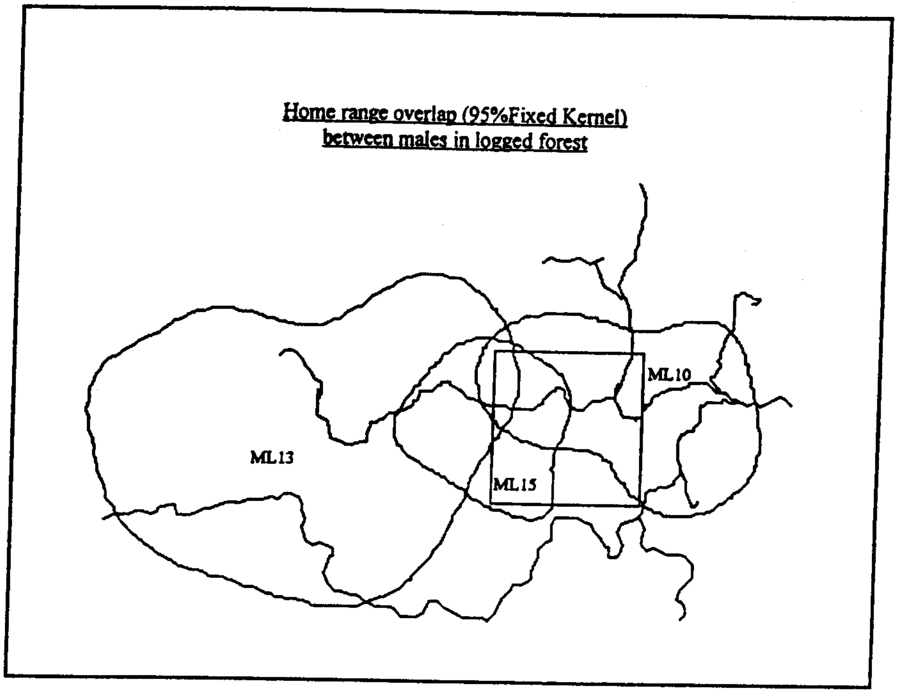
Home range overlap (95% Jennrich Turner Ellipse) between females in logged forest



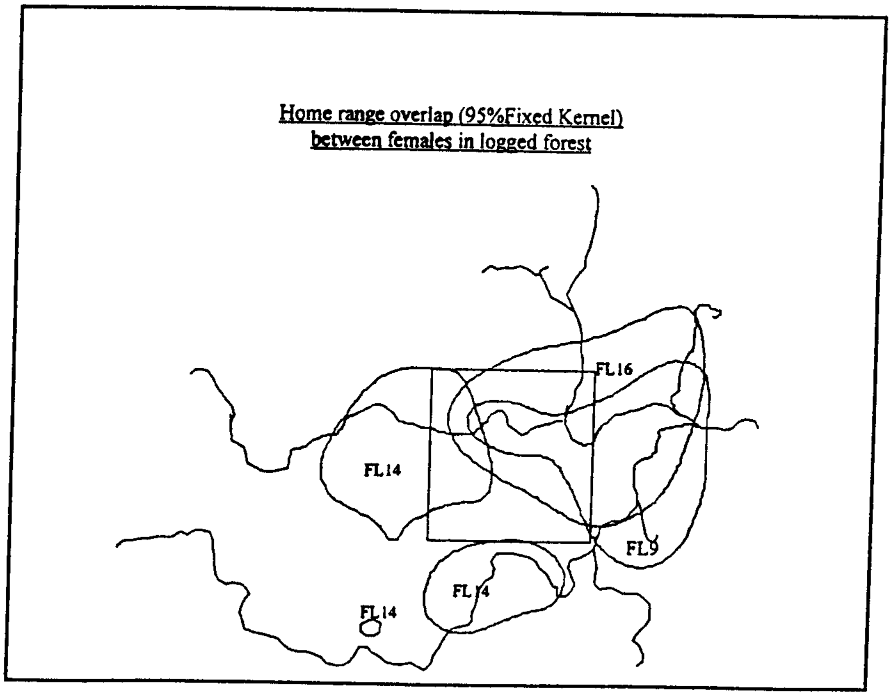
Home range overlap (95%Fixed Kernel) between males in unlogged forest



Home range overlap (95%Fixed Kernel) between females in unlogged forest



Home range overlap (95%Fixed Kernel) between males in logged forest



Home range overlap (95%Fixed Kernel) between females in logged forest

ABSTRACT

Christina Paulette Colón

B.A. Drew University, 1988
M.A. New York University, 1990

Ecology of the Malay Civet (Viverra tangalunga) in a Logged and an Unlogged Forest in Sabah, East Malaysia

Dissertation directed by David A. Burney, Ph. D.

Malay civets in a dipterocarp rain forest were studied from December, 1995, through June, 1997, in the Ulu Segama Forest Reserve in Sabah, East Malaysia. To investigate the basic ecology of this species and explore the potential impact of selective logging, data on home range, activity and diet were collected on study animals in an unlogged and a selectively logged forest, and comparisons made.

Density in the unlogged forest was 1/0.46 km^2, and 1/1.07 km^2 in the logged forest. Mean home range size based on a 95% minimum convex polygon was 110 ha. and did not differ between sites or genders. Mean home range overlap was 30.7% and showed no significant difference between site or gender. In areas of overlap, study animals tended to avoid one another. Females were consistent in their avoidance of other females, whereas males exhibited both avoidance and affiliative tendencies.

Activity levels were similar between forest types and genders, and averaged 55%. Peak activity occurred from 1800 to 0600 hours, during which mean activity levels equaled 81%. Day and night ranges overlapped extensively. In a single day, males traveled further and used more of their home range than females. Roads and trails were

centrally located in all home ranges, but males were more affected by road traffic mortality than females. Day bed sites were located exclusively on the ground on well drained sites with high cover.

Diet was comprised primarily of invertebrates and fruit. Other diet items included insectivores, rodents, birds, snakes and lizards. Six species of tick and 16 species of internal parasite were identified from *V. tangalunga*, however parasite loads did not differ significantly between sites.

Although density was lower than previously reported and home range size was larger, these data indicate that *V. tangalunga* does not appear to be negatively impacted by selective logging. Proximity to unaffected habitat may facilitate recovery of populations in logged forests. Dietary flexibility may also facilitate survival under changing conditions. *V. tangalunga* is not an appropriate indicator species to assess the impact of logging on the wildlife community.

VITA

Christina Paulette Colón was born in New York City on September 4, 1965 to Norma Lois Oland-Colón of Philadelphia, Pennsylvania, and Wilfredo Colón-Lopez of Carolina, Puerto Rico. She and her brother Wilfredo III, were raised in Philadelphia by her mother and grandparents. She attended elementary school at Plymouth Meeting Friends School and graduated high school from Germantown Friends School in May, 1984. She received a scholarship to Drew University in Madison, New Jersey, where she earned a B.A. in Biology with a minor in Anthropology in May, 1988. She earned an M.A. in Environmental Conservation Education from New York University in May, 1990, where she conducted thesis research on environmental education in Belize and worked among the Maya Mopan at the Cockscomb Basin Jaguar Preserve.

Her experience in wildlife conservation include full time employment as a rescue coordinator for Volunteers for Wildlife, volunteer lecturing for The Rainforest Alliance, and extensive experience as an educator at Elmwood Park Zoo, Turtle Back Zoo, Staten Island Zoo, and most recently, Bronx Zoo/Wildlife Conservation Society. While on staff at WCS, she spent three years as Secondary Instructor for Adult and Continuing Education. She entered the Ph.D. program at Fordham University on a Presidential scholarship in the fall of 1992. In 1995 she accepted a Fulbright Scholarship to Malaysia where she conducted research on the Malay civet in northern Borneo until June of 1997. During this time she also received a Research Fellowship from WCS and was elected Research Associate of the Royal Society of London. This dissertation was completed in the spring of 1999.