CHAPTER III

HOME RANGE, ACTIVITY PATTERNS, AND HABITAT RELATIONS OF MALAYAN SUN BEARS IN THE LOWLAND TROPICAL RAINFOREST OF SABAH, MALAYSIAN BORNEO

ABSTRACT

Six Malayan sun bears (*Helarctos malayanus*) were captured and radio-collared from June 1999 to December 2001 in Ulu Segama Forest Reserve, Sabah, Malaysia to study home-range characteristics, movement patterns, activity patterns, population density, and bedding sites. A total of 343 locations were recorded. Home range sizes, calculated by the 95% adaptive kernel method, averaged 14.8 $\pm$ 6.1 (SD) km^2, and were found in both primary and logged forests. Daily movement distances from these bears averaged 1.45 $\pm$ 0.24 (SD) km, and were affected by food availability, especially availability of figs (*Ficus* spp.). Male Malayan sun bears were primarily diurnal, but a few individuals were active at night for short periods. The first peak of activity occurred early morning, the second started 1300 h, and activity remained high until dusk. A total of 26 sun bear bedding sites were found in the study area. The majority of the bedding sites consisted of fallen hollow logs. Other bedding sites included standing trees with cavities, cavities underneath fallen logs or tree roots, and tree branches high above ground.

INTRODUCTION

The Malayan sun bear (*Helarctos malayanus*) is the smallest of the eight living bear species. Adults are about 120 to 150 cm long and weigh 27 to 65 kg (Stirling

1993). It was originally found in the dense forests of Bangladesh, Myanmar, Thailand, Laos, Kampuchea, Vietnam, Southern China, Peninsular Malaysia, and the islands of Sumatra and Borneo (Stirling 1993). It remains the least known bear species in the world and one of the most neglected large mammal species in Southeast Asia (Servheen 1999). Even basic biological facts such as food habits, home range size, and reproductive biology are unknown. Until recently, little research has been conducted to investigate sun bear ecology, and no organized surveys of the bear's distribution and population densities have been conducted (Meijaard 1997). The lack of biological information on the sun bear is a serious limitation to conservation efforts (Servheen 1999). Therefore, basic research on sun bears is the highest priority need of any bear species worldwide (Servheen 1999).

Davies and Payne (1982) reported that sun bears are found throughout dipterocarp and the lower montane forests of Sabah, Malaysia from 0 to 1350 m in elevation, but are common nowhere. In the past few decades, these forests have been greatly reduced. Malaysia and Indonesia are the world's leading exporters of tropical hardwoods, which originate in sun bear habitat. Although some forests were selectively logged, many forests were being cleared permanently for human developments and agriculture, such as rubber and oil palm plantations. Malaysia has become the world's largest producer and exporter of palm oil (World Rainforest Movement 2001). This large-scale forest conversion into monoculture plantations has led to the reduction of sun bear habitat. Wilson and Wilson (1975), Wilson and Johns (1982), and Johns (1983a) suggested that sun bears exist only in primary forest (they found none in logged forests). With the rapid disappearance of suitable sun bear habitat, the conservation and survival of the Malayan sun bear in Southeast Asia has become both challenging and questionable. Wise conservation planning for Malayan sun bears requires information on the biological needs of this species. We present information on home range size, movement patterns, activity patterns, population densities, and bedding sites of Malayan sun bears in Ulu Segama Forest Reserve, Sabah. These data were collected during a 3-year field study designed to gather biological and ecological information about the Malayan sun bear in the lowland tropical forests of Borneo.

STUDY AREA

This study was conducted between May 1998 and December 2000 at the Ulu Segama Forest Reserve situated on the eastern side of the Malaysian state of Sabah, island of Borneo (Figure 1) ($4^0$57'40"N $117^0$48'00E, 100-1200 m elevation). The reserve encompasses both forests that were selectively logged by the Sabah Foundation on a 100-year timber license, and primary forest including the 43,800 ha Danum Valley Conservation Area (Marsh and Greer 1992). The area has been used as a research site since 1985 to study the ecology of tropical forest flora and fauna and the effects of logging on various ecosystem components (Marsh and Greer 1992). Lowland, evergreen dipterocarp forest comprises about 91% of the conservation area; the remaining area is lower montane forest (Marsh and Greer 1992). Lower montane forest extends from 750 to 1500 m and differs from lowland rainforest in that it has a lower canopy with fewer, smaller emergent trees (Whitmore 1984). Approximately 88% of the total volume of large trees in the conservation area are dipterocarps (Marsh and Greer 1992).

The Danum Valley Conservation Area is surrounded by approximately one million hectares of selectively logged forest. Logging follows the Monocyclic Unit System (Poore 1989) with a 60-year rotation. It involves harvesting all healthy, commercially valuable tree species with a diameter at breast height (dbh) > 60 cm occurring on slope of < 20^o (Marsh 1995). Both conventional tractor logging and overhead cable techniques are used on moderate terrain and steeper slopes. Studies on the impacts of this logging method show that a harvesting of 3-7% of the trees with > 60 cm dbh (translates to 8-18 trees ha^{-1}) destroys over 50% of the trees > 30 cm dbh by logging and road building processes (Wilson and Wilson 1975; Johns 1985, 1988, 1992). Timber extraction rates in the Ulu Segama Forest Reserve are typically high, averaging 118 m^3ha^{-1} over the period 1970-90, with a range of 73-166 m^3ha^{-1} between different logging areas (Marsh and Greer 1992) (this compares to the extraction level of 8.4 and 13.5 m^3ha^{-1} in Neotropical and African rainforests: Yeom 1984). This number represents the removal of about 8 trees ha^{-1} during the logging operation: less than the average extraction rate of 12-15 trees ha^{-1} typical in the rest of Malaysia (Marsh 1995). Compared with other selectively logged forests in Sabah and Malaysia, some parts of the logged forests in the study area can be considered as “good quality” forest, due to relatively lower extraction rates and less human disturbance (such as illegal logging).

When logging is complete in an area, a mosaic of vegetation types remaining, from relatively undisturbed forest, through forested area dominated by pioneer trees, such as *Macaranga, Octomeles, Neolamarkia* and *Duabanga*, to more open area of grasses, ferns, vines, and climbing bamboo (*Dinochloa* spp.), and finally to exposed and compacted mineral soil with little or no vegetation (Willott 2000). These successional forest mosaics have a tendency to increase total biodiversity. In a 1 ha study on floristic composition and forest structure of both primary and logged forest in the study area, Ahmad (2001) found a higher species richness at the family, genus, and species level in a 10-year old logged forest than in primary forest (Table 1). Another similar floristic composition of 4 ha of primary and 10-year old logged forest in the study area revealed higher species richness in primary sites than logged forest sites (291 for primary forest and 274 for logged forest) (Hussin 1994). In general, primary forests are characterized by a taller (45 m compared to 15 m), more well-developed, and less open upper canopy (5.3% compared to 10.7%) than logged forest (Ahmad 2001; Willott 2000). Logged forests, on the other hand, are usually covered by dominant species of certain trees like *Macaranga* and *Mallotus* with abundant vine covers, climbers, and herbs, notably *Melastomata*, *Piper*, and many ginger species (Ahmad 2001). Hussin (1994) reported that the total fruiting frequency of all trees in primary forest was significantly higher than in logged forest. During a mass fruiting in the study area in September 1990, fruit production was clearly higher in the primary forest than in the logged forest (Hussin 1994). Numbers of fig trees, which are an important food source for Malayan sun bear (Wong *et al*. in press.), are higher in primary forest than logged forest in Ulu Segama Forest Reserve (Hussin 1994) and Sungai Tekan Forest Concession, West Malaysia (Johns 1983b). Despite these post-logging changes, many species of large mammals including clouded leopards (*Neofelis nebulosa*), Asian elephants (*Elaphus maximus*), orangutans (*Pongo pymeous*), and Malayan sun bears, were still found in the logged forest during our study.

The climate of Ulu Segama Forest Reserve is weakly influenced by two monsoons (Marsh and Greer 1992). Annual rainfall at Danum Valley Field Center (DVFC) (located within Ulu Segama Forest Reserve and the center of the field effort) is on average of 2700 mm (unpubl. station records 1986-2000), with the wettest period from October to January and the dry period between July and September (Figure 2). Mean daily temperature at the field center during 1999-2000 was 26.7^{o} C. Soils in the reserve include ultisols, inceptisols and alfisols (Newbery *et al*. 1992; Marsh and Greer 1992).

The study area was concentrated in approximately 150 km^2 of both logged (60%) and unlogged forest (40%) adjacent to the DVFC (Figure 3). Primary forest could be found in the 438 km^2 conservation area and the water catchment area of the field center. Logged forest consisted of different logging coupes or cutting units, from which timber was extracted between 1981 and 1991. The elevation in this forest block ranged between 150 m and 600 m.

Three human settlements are found inside this 150 km^2-forest block. DVFC located east of Segama River, was the base station for this study. The development of DVFC began in 1984 and was completed in 1986 to provide facilities for scientific research, education, and conservation. About fifty local staff members and their families were stationed there year-round, with additional seasonal researchers and visiting scholars staying in DVFC at various time of the year. The FACE (Forests Absorbing Carbon-dioxide Emissions) nursery was first set up in 1992 as a base camp and nursery site for an enrichment planting project to rehabilitate 250 km^2 of degraded, logged-over forests with indigenous dipterocarps, fast growing pioneers, and forest fruit trees (Yap et al. 1996). The project is funded mainly by the FACE Foundation of the Netherlands, an organization set up by the Dutch Electricity Generating Board to promote the planting of forests to absorb CO_2 from the atmosphere to offset that produced during power generation. This nursery is located at the center of the study area and houses about eighty permanent staff members and their families year-round. The third human settlement is Takala logging camp, located at the northwest corner of the study area. Takala was the first human settlement in this area with approximately 100 forest workers and family members. Most of them work as contract-workers for the FACE project or logging road maintenance workers. Hunting is strictly prohibited by law in the study forest or adjacent forests. However, poaching activities were still reported during the study period.

METHODS

The study was divided into two phases. Phase I was conducted from June to August 1998, and Phase II went from January 1999 to December 2000. Phase I involved a preliminary survey of sun bear presence in both logged and unlogged forests and a search for baits attractive to bears. The techniques in Phase I were necessary for the completion of Phase II. Phase II involved collecting information on the basic biology of sun bears through the capture and radio-tracking of animals in the forests.

Animal Capture

We used an aluminum culvert trap (Teton Welding and Machine, Choteau, MT, U.S.A.) and three locally made 55-gal. barrel traps to capture sun bears. We also built four wooden log traps to capture bears, but abandoned this method later in the study after two captured bears chewed through the wooden wall of the trap and escaped. Trapping operations started on February 24, 1999 and ended on December 11, 2000. Each trap was equipped with a radio-transmitter that would begin transmitting signals once the trap's door was closed. Signals from the traps' transmitters were monitored several times each day. We checked the traps immediately after receiving these signals to minimize the holding time of captured animals. A variety of baits were used for trapping, but chicken entrails proved to be the most effective. Captured bears were immobilized with Zoletil (tiletamine HCL/ zolazepam HCL) (4 mg/kg of estimated body mass) (Virbac Laboratories, Carros, France), delivered with a jab stick. Each bear was fitted with a non-time delay motion sensitive radio transmitter collar (MOD-400; Telonics Incorporated, Mesa, Arizona, U.S.A.), operating in the 150-151 MHz frequency range. Each collar weighed about 300 g, less than 2% of the bear's body mass, and was designed for 18 months of battery life. Each radio transmitter was equipped with a mercury-tip switch that changed the pulse rate from fast to slow, depending upon the position of the bear's head. The amplitude of radio signals received also changed when the animals traveled in the forest as the signals passed through obstacles like trees and rocks. Animal handling procedures followed the approved University of Montana animal welfare protocol.

Home Range

We located radioed bears using standard methods of ground-based triangulation (White and Garrott 1990) with a TR-4 receivers (Telonics Incorporated, Mesa, AZ, U.S.A.) and a hand held RA-14K rubber-ducky "H" directional antenna (Telonics Incorporated, Mesa, Arizona, U.S.A.). Each location was taken from at least 2 locations at approximately 90-degree angles from the bear's position within 30 minutes, or simultaneously taken by 2 people from different locations in 2-way radio contact. All telemetry locations were taken from 0900 h to 1100 h daily, if possible. Thirty-two bear encounters in the forest within 300 m of the triangulated locations of radioed bears reinforced our confidence in accuracy. The locations of radioed bears was also obtained from recaptures, sightings by field crews, and photographs taken by camera traps. We attempted to locate Bear #122 and Bear #120 twice a month from January 2001 to July 2001. All locations were plotted on 1: 25,000 topographic maps and assigned grid coordinates based on the Universal Transverse Mercator (UTM) system. Home range size was calculated using the Adaptive Kernel method (Worton 1989; Worton 1995), with ArcView GIS 3.2a (Environmental Systems Research Institute, ESRI, Redlands, California, U.S.A.). We calculated the home range core areas of radioed bears using the Adaptive Kernel method with ArcView GIS 3.2a (Environmental Systems Research Institute, ESRI, Redlands, California, U.S.A.). The home range core areas are known as the areas used most intensively by, and most important to, the animals (Burt 1943; Samuel and Green 1988; Powell 2000). The home range core area in this study was defined as the smallest areas enclosing 25% of total use by any given animal (Powell 2000).

Movement Patterns

Location data were used to measure sun bear daily movements and their association to other radioed bears and habitat characteristics. Linear distances between animal locations on consecutive days provided an index of how far animals traveled in a day. We used ArcView GIS 3.2a (Environmental Systems Research Institute, ESRI, Redlands, California, U.S.A.) to calculate average daily travel distance and to plot movement patterns on a map that was digitized manually from a 1:25,000 topographic map.

Activity Patterns

Activity patterns of radioed bears were recorded manually through 24-hour continuous monitoring once a week from a fire observation tower at Bukit Atur (Atur Hill), located at the center of the study area. Using criteria by Beier and McCullough (1988), the signal strength and pulse was scored manually as active (1) or inactive (0) in 10-minute intervals, providing 144 readings per day. Activity rate was calculated by dividing the number of active times by the total number of times for each bear for the time period of interest. Monthly activity was calculated by averaging the percent activity of each 24-hour monitoring period. Only the data from one bear were sufficient to analyze monthly activity from May to November 2000.

Activity of bears was also collected from camera traps. Ten camera traps were used from June 1998 to December 2000. Each camera unit consisted of a fully automatic (auto focus/advance/flash), weather-proof, point-and-shoot 35- mm Pentax 606 camera combined with a passive infrared motion and heat sensor designed specifically for detecting animals in the wild (Wildlife Research Laboratory, Department of Wildlife Conservation, National Pingtung University of Science and Technology, Taiwan R. O. C.). Sites for cameras were carefully chosen near areas of potential wildlife use such as animal trails, water pools, mud wallows, and trap sites. Each camera unit was relocated every 6-10 weeks. A variety of baits such as chicken entrails, meat scraps, fish, fruit, liver-oil, fruit extracts, honey, air refresher, etc. were used in most camera stations to attract animals. Each photograph was printed with the date and time the picture was taken. We assumed that the numbers of photographs taken at various times were correlated to activity periods of bears. In other words, the number of photographs with bears taken in a particular hour represents their relative activity patterns. Time periods were pooled to hours due to small sample size. We compared the activity pattern obtained from the radio signals with the activity data from camera traps by looking at the time period where the animals were active.

Bedding Sites

Bear locations were visited within 2-4 hours after the coordinates were taken to look for any feeding evidence, such as bear scats, feeding sites, or claw marks on trees, and other activities. We also attempted to track radioed bears on foot when possible at a distance so as not to disturb the bear but to visit locations of activity soon after the bear left activity sites. In some cases, bears were observed directly foraging, traveling, and resting. When we found bears resting at bedding sites, we waited close-by quietly until the bears awoke and left the area. After the bears left the area, we recorded details of the microhabitat of the area, took measurements of the bedding sites, and collected scats and hairs.

RESULTS

A total of six bears (5 male, 1 female) were trapped during 2,372 trap nights. Trapping success was extremely low (1 bear/ 396 trap nights), probably due to the low density of sun bears in the study area and their wariness. Physical parameters and other capture information for all captured bears are in Table 2. The results presented below are based on 4 male bears (Bear #125, 124, 122, 120). Data from Bear #123 were not included in the analysis due to the low number of locations and short monitoring period. We failed to collect any data from Bear #121 due to a suspected malfunction of her radio-transmitter within 24 hours after her release.

Home range

Between June 1999 and July 2001, 344 locations of 4 radio-collared male bears were collected. About 80% of these location data came from radio telemetry while the remaining data were collected from trapping, camera traps, and sightings by field crews (Table 3). Bear #125 and Bear #124 were monitored for approximately 4 months and 2 months, respectively, in 1999; Bear #122 and Bear #120 were monitored for approximately 14 months and 10 months, respectively, in 2000 and 2001. The number of locations from which home range was estimated varied from 43 to 176 (mean= 85.7, n=4). From June 22, 1999 to December 31, 2000, the mean interval between locations of individual bears was 1.6 days. Estimation of annual home range was not possible due to the limited monitoring period of radioed bears, except Bear #122, which was monitored for more than 14 months. In this paper, we report the home range sizes of bear tracked, regardless of the duration of monitoring period. Only 1 location per day per bear was used to estimate home range.

The home ranges of 4 male Malayan sun bears in Ulu Segama Forest Reserve ranged between 6.2 km^2 and 20.6 km^2 (Table 3). Average home range size for these bears was 14.8 km^2 (n=4, SD= 6.1 km^2). The home range size of Bear #125 for four months was 16.8 km^2 and incorporated both primary forest (40%) and secondary forest that had been logged in 1988, south of Danum Road (Figure 4). The home range size of

Bear #124 after two months of radio tracking was 6.2 km^2 and was directly north of Bear #125's range. But unlike Bear #125, a logging road located at the center of Bear #124's home range. The home range of Bear #124 only occupied logged forest, which was also selectively logged in 1988. Using a 95% adaptive kernel estimator, the home ranges of Bear #125 and Bear # 124 overlapped by 0.54 km^2.

The number of locations of Bear #122 was the highest among the four bears in our study. His locations were taken almost daily from the time of his capture to December 2000. After that, his locations were taken once every two weeks until June 2001. However, his home range size (20.6 km^2) remained stable after the first four months of locations and did not increase proportionally with the number of locations collected. Bear #122's range originated in logged forest that had been logged in both 1988 and 1989, and incorporated the main logging road and Danum Road (Figure 5). The home range size of Bear #120 was 15.56 km^2 and was found only in logged forest that was logged in 1989. However, Bear #120 probably has a larger home range size because there were several occasions when we failed to locate Bear #120, despite intensive efforts to search for his radio signal. The home range of Bear #120 was located west of Bear #122's range. The home range of Bear #122 and Bear #120 overlapped 3.45 km^2.

Even though the 95% adaptive kernel home range of these bears overlapped, the 25% core areas did not overlap (Figure 6 & 7). Bear #125 and Bear #124 developed one core area within their home ranges, while Bears #122 and #120 developed two core areas within their home ranges. These core areas ranged between 0.32 km^2 and 1.10 km^2 (mean= 0.68 km^2, SD= 0.32 km^2, n= 4) (Table 3).

Movement Patterns

We did not observe radioed Malayan sun bears completing long distance movements or seasonal migrations, probably due to the constant tropical environment where such behaviors are not necessary, or simply perhaps because of the short monitoring period. The daily movement distance for the animals mentioned ranged from 141 m to 5660 m. The mean daily movement distance of the four radioed bears was 1454.5 $\pm$ 240.2 m (Table 4). The use area of Bear #125 was concentrated south of Danum Road (Figure 8). He often traveled back and forth between the primary forest, about one kilometer west of DVFC, where he was captured, and the logged forest at the west end of his range, where his core area was found.

We divided the movement patterns of Bear #122 into two different time periods: May – August 2000, and September – December 2000, because we noticed a shift of area used after the first three months of radio-tracking. During the first period, Bear #122 moved primarily in an east –west direction, north of the main logging road (Figure 9). He developed one core area north of the road, where he found at least four fruiting fig trees and always stayed close to the fig resources until the total depletion of the crop. On 25 July 2000, we tracked Bear #122 on foot in the forest and found him feeding on a fruiting fig tree. Bear #122 remained very close to that fruiting fig tree for the next five days. On 13 October 2000, we recorded him near a garbage dump for the first time since his capture. The dumpsite was located at the most southern tip of his home range and about 3.5 km south from his core area at the northern part of his range. He remained in the vicinity of the garbage dump that became his second core area most of the time until June 2001. He would periodically travel north to his old core area where the fig trees were. Bear #122 crossed the main logging road many times even during daytime.

The home range of Bear #120 located in between Bear #122's range on the east and the Segama River on the west. Bear #120 generally concentrated his movements near his core areas where he was captured and later found a fruiting fig tree (Figure 10). Although the movement patterns of Bear #122 and Bear #120 showed minor overlap, we never found these two bears close to one another. The daily movement distance of Bear #120 were among the longest with a mean of 1810 m. The maximum travel distance of a sun bear in 24 hours was recorded for Bear #120, which was about 5.5 km.

Activity Patterns

24-hours monitoring- a total of 792 h of continuous monitoring for daily activity was obtained in 1999 and 2000 that resulted in 5,687 readings of activity. These included ten days (1,206 readings) of monitoring of Bear #125, nine days (1,104 readings) of Bear #124, three days (238 readings) of Bear #123, and 23 days (3,139 readings) of Bear #122. The analysis was based only on the 24-hour monitoring samples (n=45), and excluded activity data recorded from the brief period of radio monitoring to locate the bears.

Male Malayan sun bears exhibited unimodal activity, where activity occurred mostly in the daytime (Figure 11). Activity started at dawn, before sunrise, at 0530 and increased abruptly 30 minutes later. The activity reached a peak (>80% probability of activity) between 0640 and 0800 and decreased slightly between 0910 and 0940 (53% probability of activity), probably due to the morning resting period. Activity then slowly increased and reached the highest peak at 1230 and remained high until a sharp drop of activity at 1640 and immediately rose to a third peak an hour later. Decreasing activity in general occurred after 1800 in the evening and slowly decreased as dusk approached, with sunset at 1830. Due to a dense canopy layer of the forest, the forest floor becomes dark in the forest immediately after sunset at 1830. After 2100, the activity of the sun bears reached its lowest level with < 20% probability of activity and remained at this level until the next morning at dawn. However, we did find variation among bears. For instance, Bear #125 was a strictly diurnal animal. On the other hand, Bear #124 had two major resting periods at 0800 and 1400 shortly after two activity peaks. Bear #124 also had two activity peaks, which reached about 60% probability of activity at 2000 and 0030. Despite these variations in general, male Malayan sun bears at Ulu Segama Forest Reserve were basically diurnal animals.

The monthly percentage of activity for Bear #122 fluctuated between 40% and 70% from May to November 2000; with 52% mean monthly activity level. The bear was most active in September (70%) and least active in July 2000 (Figure 12).

Camera traps- a total of 49 camera trap stations were set up in the forest that accumulated 858 camera/nights (19,418 working hours). These cameras took 2,667 photographs, of which 1,957 were effective photographs that contained at least one animal (73.45% success rate). A total of 198 photographs of Malayan sun bears were taken. However, many of these photographs were of same bear taken continuously by the camera when the bear wandered around the camera station. To make the analysis meaningful, we analyzed the data only from the initial picture, if a series of continuous photographs were taken of the same bear within a 10 minute period. Only 63 photographs fulfilled this criterion and were used for the analysis of activity.

If photographs are used as a measure of activity of Malayan sun bears, the results from camera traps show different activity patterns than the radio monitoring. Photographs of Malayan sun bears were taken predominantly during nighttime, especially at dawn and dusk (Figure 13). Up to 20 photographs (32%) and 9 photographs (14%) were taken at dusk and dawn respectively, in contrast to only 4 photos between 0700 and 1700. Numbers of photographs taken at night ranged from 2 – 4 photos every hour. The Malayan sun bears were more active during the crepuscular period.

Bedding Sites

We found 26 bedding sites for Malayan sun bears. Bedding sites consisted of twelve cavities of hollowed-fallen logs (46%), six on tree branches (23%), five cavities in standing trees (19%), two cavities underneath tree roots (8%), and one cavity underneath a fallen log (4%) (Tables 5 and 6). We sighted radioed bears using seventeen of these bedding sites: either they were resting in/on the bedding sites or coming out/down from them. Other bedding sites were determined from tracking radioed bears on foot and from radio signals transmitted from a hollowed log or cavity. Due to dense undergrowth, we sometimes failed to observe bears when they left bedding sites, but did know the bear left the area from fading radio signals.

We categorized bedding sites of Malayan sun bears into five types: a) cavities in hollowed fallen logs, b) tree branches, c) cavities at the base of standing trees, d) cavities underneath tree root systems, and e) cavities underneath fallen logs. The first type of bedding site was the most common and was frequently found in the study area. These were cavities in large hollowed tree trunks that may measure up to 49 m long, or large hollowed tree branches. They were in trees that either naturally fell, or in trees purposely felled during logging operations, but apparently discarded due to their hollow trunk (Figure 14). They usually have two entrances, one bigger entrance at the base of the tree and one smaller at the far end of the log. These logs were from large sized trees with diameter > 100 cm. (Table 6). The family and species of these tree logs were usually unidentifiable due to the highly decayed condition. However, based on their large size and being purposely felled, we suspected that many of the logs were also members of family Dipterocarpaceae. Like in the standing tree cavities, the floor of hollowed-fallen logs was dry, soft, and sometimes a depression with 80 cm in diameter.

On May 1999, a forest worker sighted two Malayan sun bear cubs, probably at the age of two to three months, emerge from a 40 m hollowed-fallen log (RC 18) and vanish into the dense vegetation. We revisited RC 18 many times and set up a camera trap in front of the cavity entrance to monitor bear activity but failed to detect any bear presence. Instead, the 20-m-deep cavity was occupied by two thick-spined porcupines (*Thecurus crassispinis*) for up to eight months. These types of bedding sites may serve as important dens for females to raise cubs.

The third type of bedding site was a standing tree with a cavity inside the main trunk. We sighted radioed bears using all of the six standing tree cavities (Table 5) as bedding sites for > 2 hours, except RC 1. RC 1 was a tree cavity where we found the remaining skeleton and radio-collar of Bear #123. Bear #123 was suspected of dying from old age and malnutrition (see Chapter 4) and apparently was seeking safe cover. Some entrances of these cavities were cracks on the main tree trunk with relatively narrow width. Others, like RC 02, was actually a tunnel-shaped 170 cm deep cavity from the tree's buttress, where Bear #125 was found deep inside the tunnel. The floor space of these bedding sites was roomy for a bear (Table 5), but the bear usually rested in a corner of the cavity. The floor of these cavities was matted with a thick layer of woody debris from the wall the tree trunk and was surprisingly dry and soft. We found no evidence of bears carrying bedding materials into these bedding sites. The majority tree species of this type of bedding site were from the family Dipterocarpaceae, the main timber species in Sabah.

In general, the forth type of bed was a dirt hole under a tree where parts of the root system were exposed either on flat ground or steep slopes. We sighted Bear #122 on two occasions where he rested inside cavities underneath a standing tree root. One of these sightings occurred on 6 August 2000 where Bear #122 was feeding on a Burmese giant tortoise (*Geochelone emys*).

Bedding sites of Malayan sun bears were not only confined to tree cavities, they also rested in tree branches, high above the ground and exposed. We sighted Bear #122 five times when he rested in a tree, and one sighting from a non-marked bear clinging to the branches of a tree. On June 10, 2000, STW sighted Bear #122 resting in a huge mengaris tree (*Koompassia excelsa)*, the tallest tree species in Borneo, about 50 m above the ground. Bear #122 was lying with his belly on the tree branch, and his four legs hanging down on the tree branch. The mengaris tree was a host tree for a fruiting strangling fig tree (*Ficus* sp.). Bear #122 was observed resting for 40 minutes, with some minor position changes once in a while. He later climbed down to another smaller branch opposite the previous branch to harvest figs. Another similar sighting was made on July 19, 2000 of Bear #122 resting and feeding in another tall mengaris tree, which was hosting a fruiting strangling fig tree. Other sightings included Bear #122 sitting straight up on a tree branch and clinging to the main trunk of a fruiting *Euginia sp*. (Fam. Myrtaceae), and lying on the first branch of a huge *Shorea johorensis* (Fam. Dipterocarpaceae), about 20 m above the ground.

DISCUSSION

This study is one of the first ecological studies ever conducted on wild Malayan sun bears, and there are no scientific reports available to make comparisons. As a result, we used ecological data from American black bears (*Ursus americanus*), Asiatic black bears (*U. thebetanus*), and, to a lesser extent, sloth bears (*Melursus ursinus*) to compare ecological parameters to those of Malayan sun bears. We are aware that the average body weights of these bears used for comparison (100 –115 kg) were more than twice the average body weight of sun bears (45 kg) (Brown 1993).

Home Range and Movement Patterns

Ursids other than Malayan sun bears usually live where there are distinct seasonal changes in food. These bears usually have seasonal home ranges. As mobile and opportunistic mammals, bears show changing home range use in accordance with changes in resource abundance (Hazumi and Maruyama 1987; Powell 1987; Nagy and Haroldson 1990; Smith and Pelton 1990; Reid et al. 1991; Mano 1994; Joshi et al. 1995). Malayan sun bears in the study area were active year round and lived in a relatively constant environment without clearly evident seasons other than in respect to rainfall and fruiting seasons. Analysis of limited scat samples in the study area showed no evidence of shifts in diet (Wong et al. in press). It may be that shifting seasonal home ranges by Malayan sun bears is unnecessary.

Compared to adult male Asiatic black bears and sloth bears that have an average annual home range of 12.5 km^2 and 14.4 km^2, respectively (Hazumi and Maruyama 1987; Joshi et al. 1995), the home range of male Malayan sun bears in this study was slightly larger than that size (mean= 14.8 km^2). However, home ranges of male sun bears were much smaller than the home ranges of male American black bears that range from 79 km^2 to 1,721 km^2 in various states in North America (Amstrup and Beechum 1976; Hugie 1982; Wooding and Hardisky 1994; Warburton and Powell 1985; Smith and Pelton 1990; except for a few studies reporting a smaller annual home range size for male black bears- Garshelis and Pelton 1981; Hellgren and Vaughan 1986; Lindzey and Meslow 1977).

Harestad and Bunnell (1979) evaluated the relationship between North America mammal home ranges and body weights, and postulated that the home range (in ha) (H) of omnivores can be related empirically to body weight (in grams) (W) by the formula $H = 0.059W^{0.92}$. Using this formula, Malayan sun bears with body weights of 40 kg would have home range of approximately 10.1 km^2. If home range size is a reflection of the quality, abundance and distribution of food (Harestad and Bunell 1979; Gittleman and Harvey 1982; Hixon 1987; Gompper and Gittleman 1991), then the large home range size of sun bears in this study may imply low quality, abundance and distribution of food in the study area.

Tropical rainforests usually give an impression of high food abundance throughout the year due to high biodiversity, constant environment, and optimum growing conditions. However, our phenology data (Chapter 4) documented prolonged low fruit production in the forest during the entire study period. This is a typical "non-fruiting period" observed in tropical dipterocarp forest in Borneo and western Malesia. These forests have a striking feature known as "mass flowering" followed by "mass fruiting" (episodic synchronous reproduction interspersed with periods of little or no seed production) (Janzen 1974; Chan and Appanah 1980; Appanah 1985; Ashton et al. 1988; Curran and Leighton 2000). The low fruit production observed during study was most extreme between August 1999 and September 2000 when we observed various stages of starvation among all six radioed bears and bearded pigs (*Sus barbatus*) (Chapter 4). We suspect that two of the monitored bears and several bearded pigs died from starvation during this time (Chapter 4).

We documented two core areas for Bear #122, and both of these core areas were important feeding sites. We saw Bear #122 feeding at a fruiting fig tree in one of the core areas, where he remained close to the fruiting fig tree for weeks until the fig resource was depleted (usually in about two weeks). Bear #122 still came back to check these areas frequently after the fruiting period had ceased. In mid-October 2000, Bear #122 moved southward to a garbage dump that was actively used by the Danum Valley Field Center and FACE nursery. This dumpsite later became the most important core use area after fig sites. We speculated that because of the lack of natural food in the forest, Bear #122 learned to exploit human food at this dump. His physical condition was extremely poor by August and September 2000, and we anticipated he would soon die from starvation. His condition improved significantly after he found the dumpsite. We speculated that the lack of natural foods would have resulted in his death by starvation if not for the dumpsite.

For decades, bears throughout the world have been known for exploiting human food at garbage dumps. Many of these bears became nuisance animals (Howard and Marsh 1972; Herrero 1983; Rogers 1989; Eberhardt and Knight 1996; Thomas 1999). On October 2001, a nuisance Malayan sun bear was captured in DVFC and detained by Sabah Wildlife Department. This adult male bear appeared in the vicinity of the field center in early August to feed on garbage. It also broke into the staff kitchens to steal human food (Senthilvel K.K.S. Nathan, veterinarian, Sabah Wildlife Department, Sepilok Orangutan Rehabilitation Center, Sabah, Malaysia, personal communication, 2001). Due to strict prohibitions on poaching in the vicinity of the field center, this bear was very lucky to be alive. In other areas, nuisance sun bears that ruin oil palm plantations and agriculture are usually killed by angry stockmen and farmers (Servheen 1993a; Santiapillai and Santiapillai 1996; Meijaard 1999b). Fredriksson (1998) reported three out of five ex-captive sun bears that were radio-collared and released into the wild were eaten, shot, and/or killed for the sale of their body parts, as they wandered close to human settlements. Servheen (1993b) noted that one of the primary bear conservation needs is for people who live in bear habitat to properly dispose of their garbage.

Movement Patterns

Many studies on the movement patterns of American black bears (Amstrup and Beechum 1976; Garshelis and Pelton 1981; Kasbohm et al. 1998) and brown bears or grizzly bears (Clevenger et al. 1990; McLoughlin et al. 1998) conclude that food availability was the most important factor that influenced bear movements. No distinct fruiting period where bear food became abundant occurred during the entire study period. Thus, it was not possible to compare daily movement distances between fruiting season and non-fruiting season. Amstrup and Beecham (1976) reported that the daily movements of American black bears were greater (mean = 1.5 km) in 1973 when food was sparse, than in 1974 (mean = 1.1 km), when food was diverse and abundant. Similarly, Pelton (1989) reported American black bears in Tennessee moved 2-4 times farther in poor acorn years than in good ones, and Rogers (1977) documented increased numbers of bears moving during scarce food years (in Kasbohm et al. 1998).

Malayan sun bears during our study fed mainly on invertebrates, such as termites (Isoptera), beetles (Coleoptera) and beetle larvae (Coleoptera), and figs, if available (Wong et al. in press). Our observations of sun bears in the study area indicated that bears were constantly searching for food while walking with their head pointing down the ground and nose sniffing debris on forest floor. The low fruit production between June 1999 and December 2000 has caused the bears to be constantly in search of food.

In our study, figs were the most important fruit eaten by Malayan sun bears especially because figs were available in large quantities at certain sites (Wong et al. in press). Figs are a keystone resource for tropical frugivorous species, especially birds, primates and bats (Janzen 1979; Leighton and Leighton 1983; Terborgh 1983; Kalko et al. 1996; Kinnaird et al. 1999). The attractiveness of figs for wildlife has been attributed to their asynchronous fruiting patterns, the tendency to produce large crops of 10,000 – 60,000 fruits that ripen synchronously per tree, and low interannual variation in fruit production (Janzen 1979; Leighton 1990). In 1999, we failed to find any fruiting fig trees in the home ranges of Bear #125 and Bear #124 and thus have limited information on the use of figs by these bears. However in 2000, we found five fruiting fig trees inside the home ranges of Bear #122 and Bear #120, and three other fruiting fig trees outside their range with fresh sun bear claw marks on the tree trunks. On two occasions, we either sighted or photographed (from camera traps) up to three different bears, both marked and unmarked, visiting the same fruiting fig trees. Similar sightings also were reported in Barito Ulu Research Area, Central Kalimantan, where at least three sun bears were present in the 430-ha forest during a fruiting peak in May 1997 (McConkey and Galetti 1999). We strongly believe that food availability, especially figs, has a strong influence on movement patterns of sun bears.

Activity Patterns

Activity patterns of animals are considered an adaptation to seasonal and diurnal variation of environmental factors (Cloudsley-Thompson 1961; Nielsen 1983). Aschoff (1964) stated that the daily activity pattern of an animal results from a complex compromise between optimal foraging time, social activities, and environmental constraints. In our study, male Malayan sun bears exhibited a definite diurnal pattern of activity based on 24-hour monitoring. Diurnal behavior of Malayan sun bears was also reported by Lim (1999) and MacKinnon et al. (1996). Based on camera traps and some direct observations, Yasuma (1994) stated that the sun bear is nocturnal. Other reports that support the latter included Lekagul and McNeely (1977), Tweedie (1978), Medway (1978), Domico (1988), Nowak (1991), and Sheng et al. (1998). Other references, however, considered sun bears as active mainly at nighttime, but also sometimes during the day (Davies and Payne 1982; Kanchanasakha et al. 1998), and periodically active during day and night (Payne et al. 1995; Yasuma and Andau 2000). A behavioral study of captive Malayan sun bears at zoos showed a naptime between 1000 h and 1100 h, and a highest peak of social activity between 1430 h and 1500 h (Hewish and Zainal-Zahari 1995). Another study of captive sun bears reported activity concentrated during morning and evening, and resting occurring during most of the daytime (Feng and Wang 1991). However, this behavior was related to the feeding time in captivity and this artificial setting has likely resulted in the diurnal behavior of the captive sun bears. J. Holden's (researcher FFI, Sungai Penuh, Indonesia) reported photographs of sun bears taken by camera traps in Sumatra, Indonesia, were often made between 1200 and 1500 hrs (in Meijaard 1999b), suggesting bears in that area move about considerably at midday. van Schaik and Griffiths (1996) showed that the Malayan sun bears were active both day and night.

The majority of sun bear photographs taken by camera traps in our study were made during the crepuscular period (dusk and dawn) and nighttime, with very few photographs taken during the daytime (Figure 13). The results were contradictory to our 24-h monitoring data, if the relative number of photographs taken at different time periods implies bear activities. This phenomenon can be explained by the disproportional sampling efforts and strata when setting up camera traps. Usually these camera-traps were set up 1.3 m above the ground and were targeted more on terrestrial animals then arboreal animals. Malayan sun bears are known for their arboreal activities like foraging, resting, and nest building in trees (Fetherstonhaugh 1940; Medway 1978; Payne et al. 1985; Domico 1988; Kanchanasakha et al. 1998; Lim 1998; Meijaard 1999b; Wong et al. in press). Of 32 sightings of sun bears in the study, we sighted sun bears in trees on seven of these occasions. Nevertheless, this number may be misleading because sun bears are difficult to sight in the wild due to thick undergrowth. It would be even harder to sight them in trees simply because of the thicker and multi-layer canopy in tropical rainforest (S.T. Wong, personal observation).

The contradictory results between activity data collected from different methods were also reported by Pei (1998). He compared the activity pattern data of Formosan macaques (*Macaca cyclopsis*) gathered from field observation and camera traps. These differences in activity pattern may stem from the fact that these data were collected from different strata. Data from Wu and Lin (1993) were mainly collected from observing Formosan macaques from the forest canopy, whereas the data from Pei (1998) was mainly collected from camera trapping that was set up on the forest floor. Knowing the specific niche occupied by the study animals and setting up the camera traps at appropriate forest strata to reduce bias can overcome this problem.

Another possibility for this contradictory results may simply caused by the wariness of sun bears to human scents found at the camera stations. These bears may avoid these camera sites during the daytime and would only approach during the nighttime.

In North America, behavior of bears is apparently associated with human-induced modifications to the environment (Ayres et al. 1986). This may explain the nocturnal behavior of American bear species, such as grizzly bears and American black bears feeding in orchards, garbage dumps, and campgrounds (Waddell and Brown 1984; Ayres et al. 1986). Diurnal activity in bears and other wildlife is usually considered as a result of low human activity (Roth and Huber 1986; Griffiths and van Schaik 1993a). A similar idea was also suggested by I. Singleton (Leuser Development Project, Medan, Indonesia): in heavily disturbed areas sun bears may have undergone a change from predominantly diurnal to nocturnal activity to avoid confrontation with humans (in Meijaard 1999b).

Griffiths and van Schaik (1993b) provided support for the variability of sun bear daily activity patterns in relation to human disturbance. By using camera trapping, they compared sun bear activity and density in two study areas in northern Sumatra, i.e., a heavily human-traveled area (Ketambe, 0.728 human passes/camera week) and a pristine site (Bengkung, 0.003 human passes/camera week), with similar vegetation and topography. Their data indicated 100% of nocturnal activity in Ketambe, while only 18%

of nocturnal activity in Bengkung (Griffiths and van Schaik 1993b). These observations indicate that human traffic in a tropical rainforest can, in itself, alter the activity period of Malayan sun bears, even if unaccompanied by any disturbing activities such as logging, hunting and fire making (Meijaard 1999b). The low level of human activities in the home range of Bear #125 and Bear #123 may have resulted their diurnal activity patterns, if this was true. In contrast, the home range of Bear #124 and Bear #122 included a 20-m wide logging road with intense human use (quantitative measures not available). The home range of these two bears also occur in a large-scale enrichment-planting project to rehabilitate logged forests, where forest workers visited these forests several time a year to maintain planting strips and to survey the survival rates of seedlings planted (Yap et al. 1996; Yap and Simmons 2000). These human activities may have caused Bear #124 and Bear #122 to have more nocturnal activities. In fact, the majority photographs taken by camera traps were from Bear #124 and Bear #122 (71% nocturnal activity), while none were taken of Bear #125 and Bear #123.

Nocturnal behavior of sun bears to avoid human confrontation may pose another threat to their survival. We found several wounds from shotgun pellets on Bear #124's back when he was first captured. After two months of radio-tracking and intensive monitoring, his signals disappeared and he was never seen or photographed in the study area again, despite intensive search efforts. We suspect that this bear was shot along roads from a vehicle with spotlights at night. This method is widely used in Sabah and Sarawak, Malaysia, where opportunistic poachers shoot almost all animals encountered, including ungulates, primates, clouded leopards, and Malayan sun bears (Caldecott 1986; Bennett and Dahaban 1995; Bennett et al. 2000). Conversely, we had never heard of poaching from vehicles during daytime anywhere in Sabah, at least. If poaching pressure were high on bears whose home range incorporated roads that allowed access to the forest interior, this nocturnal behavior would have adverse impacts to the survival of these animals. Eight months after the disappearance of Bear #124, we radio-collared Bear #122, which took over the home range of Bear #124 until the end of the study. Bear #122 used forests adjacent to the busy logging road and frequently crossed it, even during daytime. On June 14, 2000, at 1000 h, STW observed Bear #122 resting on the lowest branch of a huge *Shorea johorensis*, about 50 m north of the logging road, for 20 minutes. Bear#122 was on a big tree branch, about 20 m above the ground. His front legs were placed on the branch with his chin on top of his paws. He raised his head every time a vehicle passed by, but the vehicles did not seem to disturb him. Further investigations on the effect of human activities to daily activity patterns and the negative impacts of logging roads would promote understanding the trade-off between diurnal and nocturnal behavior.

The variation in the monthly percentage of activity for Bear#122 could result from food availability, especially with the availability of fruiting fig trees that caused the low monthly activity on July 2000 (40% activity). When sun bears found fruiting fig trees, they tended to stay close to the fruit crop with little activity. On July 18, 2000, we found Bear #122 feeding on a fruiting fig tree (Fig tree #2) and he stayed at the vicinity for the next five continuous days until the fruit resource was almost depleted. Two days later, on July 25, we found Bear #122 feeding on another fruiting fig tree (Fig tree #3) and remained close to the fig tree for another five days. We revisited Fig tree #3 on July 26 to monitor the activities of the fruiting fig tree and found Bear #122 remaining inactive $\leq$ 30 m from the tree. From 0900 h to 1800 h, we recorded three short activity periods of Bear #122 that lasted between 20 – 35 min, and he remained inactive the rest of the time. In contrast to the low percentage of monthly activity resulting from the availability of fruiting trees, the increased monthly percentage of activity in September (70%) (Figure 12) may be explained by the intense stress of hunger (see Chapter 4). In addition to the lack of evidence showing that Bear #122 consumed figs, photographs from camera traps taken on late August revealed an extremely emaciated Bear #122. He has protruding vertebra, ribs, and hipbones, with sparse fur and most of the hair on his face is gone (Figure 15). Additional evidence of the condition of Bear #122 came from the fact that he was recaptured seven times from August 19 to October 3, 2000. Each time he was recaptured, Bear#122 had consumed all available bait and stayed quietly inside the trap until we released him hours later. This “trap-happy” behavior can be explained by food desperation, which had overcome his wariness to capture. Limited information is available on hunger stress directly increasing activity of bears, but this phenomenon has been documented on other mammalian species. Smythe et al. (1982) reported that two large caviomorph rodents, the agouti (*Dasyprocta punctata*), and the paca (*Cuniculus paca*), foraged longer during the season of fruit shortage on Barro Colorado Island, Panama.

Bedding sites

Malayan sun bears used several kinds of day beds or bedding sites. However, during our study, we never found a tree nest. The use of “tree nests”, or small “platforms” by sun bears, has been reported by Fetherstonhaugh (1940), Lekagul and McNeely (1977), Domico (1988), Piether (in Santiapillai and Santiapillai 1996), Kanchanasakha et al. (1998), Lim (1999), and McConkey and Galetti (1999). Domico (1988) and Brown (1993) described that sun bears make their beds in small platforms from broken branches, 2 to 7 m high in a tree, and this bed looks similar to the nests of orangutan, but are usually nearer to the tree trunk and more loosely made. Fetherstonhaugh (1940:17) described the nest building process by a six-month-old captive female sun bear.

> "She would shinny up a tree, climb out upon a limb until she reached a convenient fork where there were small leafy branches handy, and proceed to pull the twigs and leaves underneath her belly, lying upon them with her chin in the fork of the limb, her body along its length and all four legs hanging down. If overtaken by rain the procedure was the same and it was ludicrous to see her literally scuttle up the nearest tree and work against time to get a mat of leaves and twigs under her belly while leaving her back to the mercy of the elements; there she would stay with a look of patient misery on her face and not even hunger would get her down until the shower was over".

Similar nest-building techniques for the sun bears were also reported by hunters from North Sumatra, Indoensia (Meijaard 1999b). I. Singleton (in Meijaard 1999b) photographed a sun bear using an old nest, which was thought to have been constructed by an orangutan. Given the possibility that sun bears may use old orangutan nests, we checked for bear claw marks on > 100 of trees with orangutan nests during the study. We failed to find any trees with both an orangutan nest and bear claw marks. Interestingly, Pieters (in Santiapillai and Santiapillai 1996) observed sun bears in disturbed habitats and states that it is mostly in secondary forest that stick nests are used. This observation was confirmed by G. Fredericksson (in Meijaard 1999b) who observed 14 nests in plantations and gardens and none in the forest area during 3 years of survey work. McConkey and Galetti (1999) found three distinguishable sun bear nests in the tree canopy of a fruiting *Canarium pilosum* in the forest at Barito Ulu Research Area, a 430-ha forest located in Central Kalimantan, Indonesia, where orangutans are absent. Although no information about human disturbance in the forest is provided by McConkey and Galetti, the small forest size implies potential disturbance from the surrounding environment. Nest building might only occur in areas with significant human disturbance, where safe resting places are rare (Meijaard 1999b). In addition, the presence of big cats that share the same habitat with sun bears in Sumatra and the Asia Mainland, such as tigers (*Panthera tigris*) and leopards (*Pantrera pardus*), may cause sun bears to seek safer ground for bedding. Although the interaction between these species has rarely been reported, these big cats pose a significant threat to the life of this small bear. Lim (1998) suggested that the only likely enemies of the sun bear are a hungry tiger or panther (leopard). Van Balen (1914) (in Meijaard 1999b) reported a fight between a Sumatran tiger (*P.t. sumatrae*) and a sun bear in southern Sumatra. This kind of interaction may explain why reports of nest building behavior of sun bears in the forests (except plantation and gardens) were often from Sumatra and Asian Mainland, but not Borneo where these two large cats are absent. Clouded leopards are present in Borneo but this is a smaller cat and may be less of a threat to sun bears. Two other bear species that are reported to construct day-nests in trees are the South American spectacled bear (*Tremarctos ornatus*) (Peyton 1980; Domico 1988; Weinhardt 1993) and Asiatic black bear (Osteen 1966; Matthiessen 1978; Domico 1988; Schaller et al. 1989; Brown 1993). Asiatic black bears also construct day beds on the ground with bamboo and tree saplings (Schaller et al. 1989).

In contrast to the common reports of sun bears using tree nests as day beds, the use of tree cavities by sun bears has never being reported. These cavities in hollowed trees are commonly found in the study area. Other bear species such as Asiatic black bears (Lekagul and McNeely 1977; Wang 1988; Li et al. 1994), American black bears (Hayes and Pelton 1994; Weaver and Pelton 1994; White et al. 2001), and giant panda (Schaller et al. 1989) also utilize similar hollow tree cavities, not as day beds, but as denning sites for female bears giving birth to young. We believe that these tree cavities can also be denning sites for pregnant female sun bears. The sighting on May 1999 of two sun bear cubs coming out of a hollow log (RC18) helps further prove the potential function of such logs as dens for both female sun bears and cubs.

Johnson and Pelton (1983) reported that bear scats (mean = 2.5, range = 1-4) were found in all 25 summer beds of American black bears in Tennessee, USA. We found only five bedding sites (3 tree cavities, and 2 tree roosts) with scats near the beds, out of a total of 26 bedding sites found. One of these bedding sites, RC20, used by Bear #120, had 17 scats of various age. Radio tracking data indicate that the bear stayed in that area for at least four days, and harvested figs from a fruiting strangling fig tree about 250 m away. All of the scats contained primarily fig seeds, and with very few exoskeletons of termites and beetles.

CONCLUSION

Before the project started on May 1998, the Malayan sun bear was the least known bear in the world and the least studied large mammal in Southeast Asia. The lack of studies stemmed from the fact that sun bears are rare, seldom seen, compete for conservation attention with other species of higher conservation interest (i.e. tigers, orangutans, and rhinos), and live in a relatively harsh environment. This project has taken twenty-seven months of intensive field study to begin to describe the basic ecological aspects of this elusive bear in the Borneo rainforest. We learned that the Malayan sun bear requires a large home range, moves considerably in search of food, and uses old and large trees as bedding and denning sites. Food apparently varies significantly throughout the year, and in some areas bears may starve due to natural fluctuations in abundance of food. These findings also contradict several former studies on the impacts of selective logging on wildlife, which suggested that sun bears exist only in primary forest and that few are found in logged forests (Johns 1983a; Wilson and Wilson 1975; Wilson and Johns 1982). Our study clearly showed that Malayan sun bears do exist in logged forest. The importance of primary forest to the survival of the sun bear is unclear. More study is needed to understand the specific impacts of logging on the disturbance and survival of sun bears. Well designed logging practices, or environmentally friendly logging methods, such as reduced impact logging, should be considered by forest managers to benefit both human and wildlife needs. Other implications for forest managers include maintaining of large trees that lack commercial value (e.g., trees with cavities, hollow trees), prohibitions on damaging fig trees and the creation of buffer zones around fig trees, strict control of poaching activities, closing of logging roads after logging is completed, and education of local communities on the importance of the maintenance of forests and wildlife. Our results can generally be extrapolated to other part of Southeast Asia where the sun bear still exists in similar environments. Today, with the rapid disappearance of suitable sun bear habitat from logging, forest fire, and conversion of tropical rainforests into plantations and human settlements, the future of this little-known bear is far from secure. Well-planned conservation programs for Malayan sun bears should be a top priority for government authorities, non-government organizations (NGOs), and the scientific community. This conservation program should work closely with the various agencies, involve law enforcement agencies, the general public, and local communities who live and work in sun bear habitat. The program will hopefully gain national and international attention and recognition similar to conservation programs for Southeast Asian elephants, Sumatran rhinoceros (*Dicerorhinus sumatrensis*), tigers, and orangutans.

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Table 1. Tree biodiversity inventory of lowland tropical rain forest distributed in 1 ha of sampling area each in primary forest and logged forest sites at Ulu Segama Forest Reserve, Sabah, Malaysia.

PARAMETER	Primary forest	Logged forest	Total
Species richness	106	136	185
Number of families	39	41	46
Number of genera	70	89	111
Most speciose family	Dipterocarpaceae (13 sp.)	Euphorbiaceae (23 sp.)	
No.Dipterocarp species	13	20	
Most common Dipterocarp	*Parashorea tomentella* (n=21)	*Shorea johorensis* (n=19)	*P. tomentella* (n=31)
Tree species with highest number (ha^{-1})	*Diospyros* sp. (n=23)	*Shorea johorensis* (n=19)	*Sygygium* sp. (n=35)
Number of tree species with only one individual in 1 ha	41 species (8.8%)	13 species (2.9%)	70 sp. (7.7%)
Dipterocarp: Non-dipt. Ratio	1 : 5.5	1 : 2.8	

Source: Ahmad (2001)

Table 2. Physical parameters and capture information for radio-collared Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia.

ID #	Sex	Capture Date	Date Last Monitored	Age Class	Body Condition	Wt (kg)	TL (cm)	SL (cm)
125	M	22 June 99	12 Oct 99	Old	Fair	44	121	20
124	M	10 Jul 99	20 Sep 99	Old	Fair	40	124	24
123	M	7 Aug 99	10 Sep 99	Old	Poor	34	124	20
122	M	4 May 00	25 Jul 01	Sub-Ad	Poor	30	117	
121	F	24 Sep 00	25 Sep 00	Adult	Very poor	20	110	20
120	M	11 Oct 00	11 Jun 01	Adult	Fair	40	123	21

Age – Based on tooth wear, tooth color, body size, and overall condition

Body condition – Based on fat level, fur condition, and general appearance. Divided into 5 categories: range from “very poor”, “poor”, “fair”, “good” and “very good”.

Wt – Body weight, during first captured

TL – Total body length.

SL – shank length

Table 3. The number of locations of each bear collected from radio-telemetry, capture, camera trap, and sighting used in home range estimation.

Bear #	Capture Date	Date Last Monitored	Radio-telemetry	Capture	Camera trap	Sighting	Total # of locations	95% adaptive kernel home range	*Core area	Forest type
125	22 June 99	12 Oct 99	60	1	0	5	66	16.8 km^2	1.10 km^2	Primary & Logged
124	10 Jul 99	20 Sep 99	28	2	12	1	43	6.2 km^2	0.32 km^2	Logged
122	4 May 99	25 Jul 01	143	9	9	15	176	20.6 km^2	0.65 km^2	Logged
120	11 Oct 00	11 Jun 01	44	2	10	2	58	15.5 km^2	0.65 km^2	Logged
Total			275	14	31	23	343	Mean= 14.8 km^2	Mean= 0.68km^2	

*The home range core area was defined as the smallest areas enclosing 25% adaptive kernel home range of total use by any given animal.

Table 4. Linear distance (m) between consecutive daily locations (approximately 24 h apart) of Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia.

Bear ID	n	Mean	SD	Minimum	Maximum
125	36	1286	962	250	4890
124	17	1382	930	320	3150
122	88	1340	826	141	3667
120	24	1810	1294	316	5660
Total		1454 ± 240		256 ±83	4341±1142

Table 5. Dimensions of cavities of standing trees that served as bedding sites for Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia

Site No.	**Slope**	**Tree spp.**	**Est. tree height**	**DBH**	**Size of entrance (Greatest width x height)**	**Floor space (Greatest length x width)**	**Remarks**
RC01	20 degree	*Shorea sp.*	40 m (broken top)	160 cm	30 x 30 cm	100 x 100	live tree
RC03	10 degree	*Shorea sp.*	20 m (broken top)	190 cm	40 x 60 cm	120 x 150 cm	Dead tree
RC04	15 degree	*Dryobalanops lanceolata*	25 m	120 cm	19 x 120 cm	120 x 100 cm	Dead tree
RC09	Flat	Unknown	35 m	58 cm	27 x 33 cm	not measured	live tree, underneath tree root cavity
RC11	30 degree	Fam. Dipterocarpaceae	35 m	115 cm	16 x 137 cm	90 x 90 cm	live tree
RC02	Flat	Fam. Dipterocarpaceae	20 m	145 cm	50 x 26 cm	170 x 40 cm	Dead tree, cavity in the buttress
RC13	45 degree	*Macaranga hypoleuca*	10 m	35 cm	80 x 38 cm	2.1 m depth	cavity underneath the root system

Table 6. Dimensions of hollow logs on the forest floor that served as bedding sites for Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia.

Site No.	Slope	Tree spp.	Length of log	Diameter	Size of entrance (Greatest width x height)	Depth of cavity	Remarks
RC05	flat	Fam. Dipterocarpaceae	9.3 m	136 cm	136 x 120 cm	9.3 m	Chain-sawed
RC06	10 degree	*Shorea johorensis*	11.0 m	78 cm	45 x 50 cm	11.0 m	
RC07	flat	unknown	23.3 m	120 cm	90 x 90 cm	23.3 m	
RC08	40 degree	Fam. Dipterocarpaceae	26.0 m	124 cm	50 x 44 cm	9.3 m	
RC10	30 degree	unknown	4.8 m	136 cm	175 x 50 cm	4.8 m	Chain-sawed
RC12	flat	unknown	15.0 m	110 cm	62 x 40 cm	14 m	Chain-sawed
RC14	30 degree	unknown	49.3 m	104 cm	40 x 37 cm	6.0 m	
RC15	flat	unknown	6.3 m	110 cm	40 x 60 cm	4.0 m	
RC16	12 degree	Fam. Dipterocarpaceae	22.0 m	97cm	60 x 37 cm	4.9 m	
RC17	12 degree	Unknown	7.1 m	77 cm	70 x 54 cm	2.3 m	
RC18	15 degree	Unknown	40.0 m	130 cm	100 x 70 cm	20.0 m	
RC20	18 degree	unknown	11.3 m	113 cm	63 x 53 cm	11 m	Chain-sawed
RC19	30 degree	Unknown					Chain-sawed; cavity underneath the log

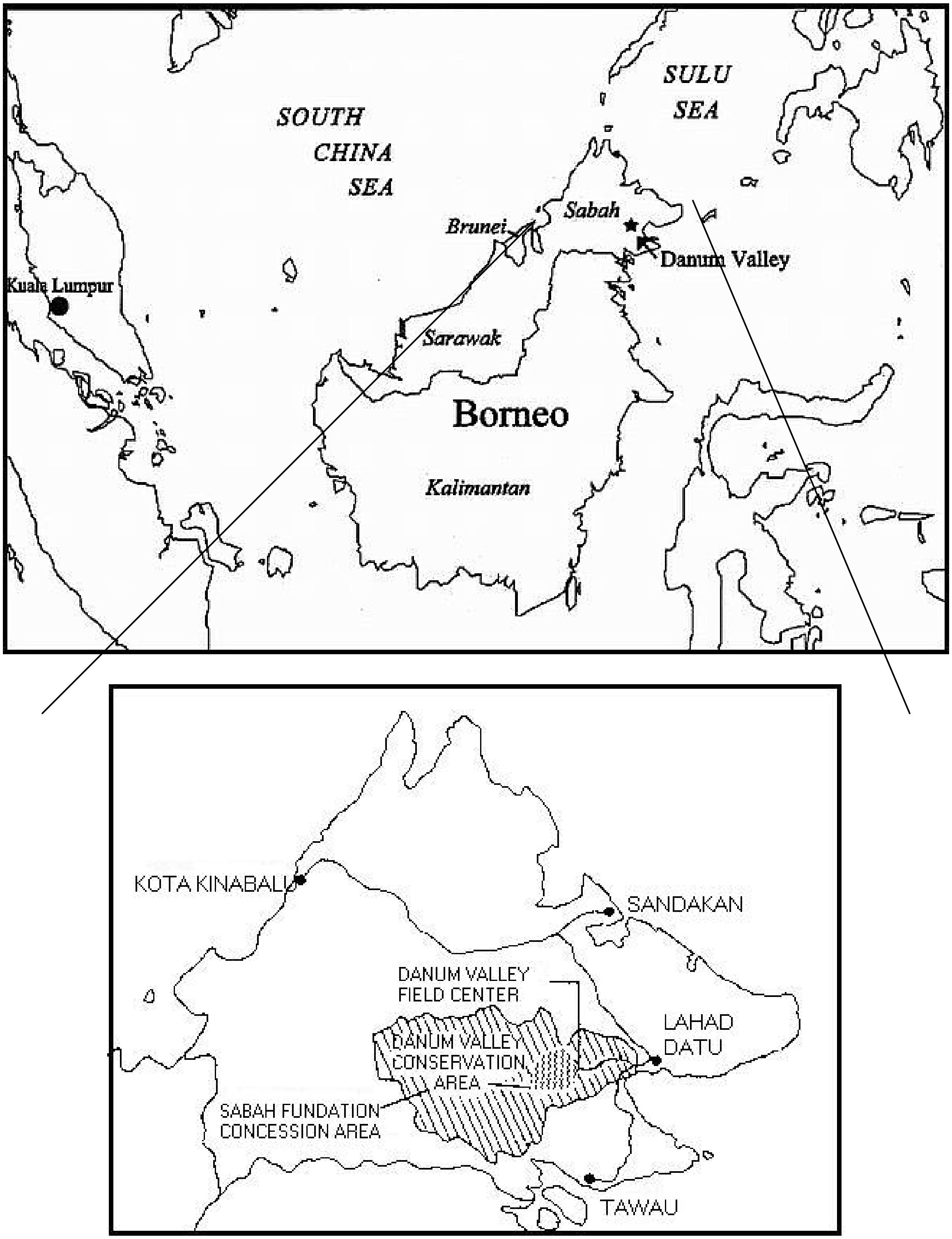

Figure 1. Location of the study area at Danum Valley Field Center at the state of Sabah, Northern Borneo.

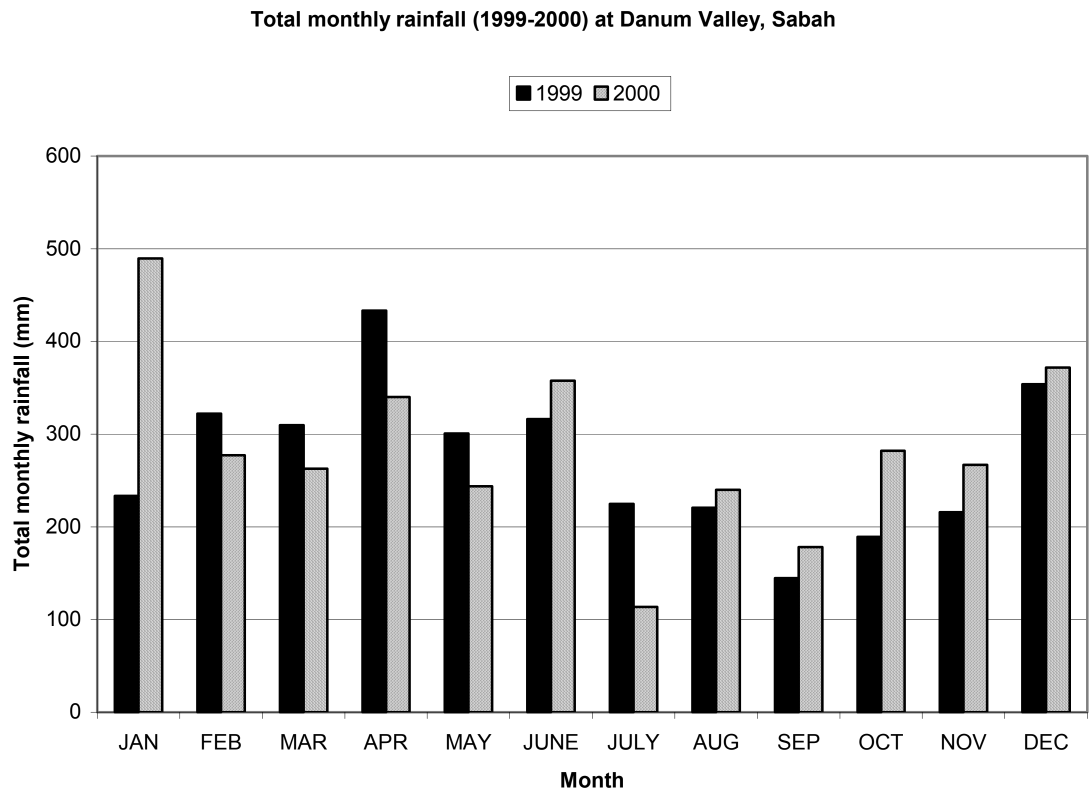

Figure 2. Total monthly rainfall in Danum Valley Field Center, Ulu Segama Forest Reserve, Sabah, Malaysia from 1999-2000.

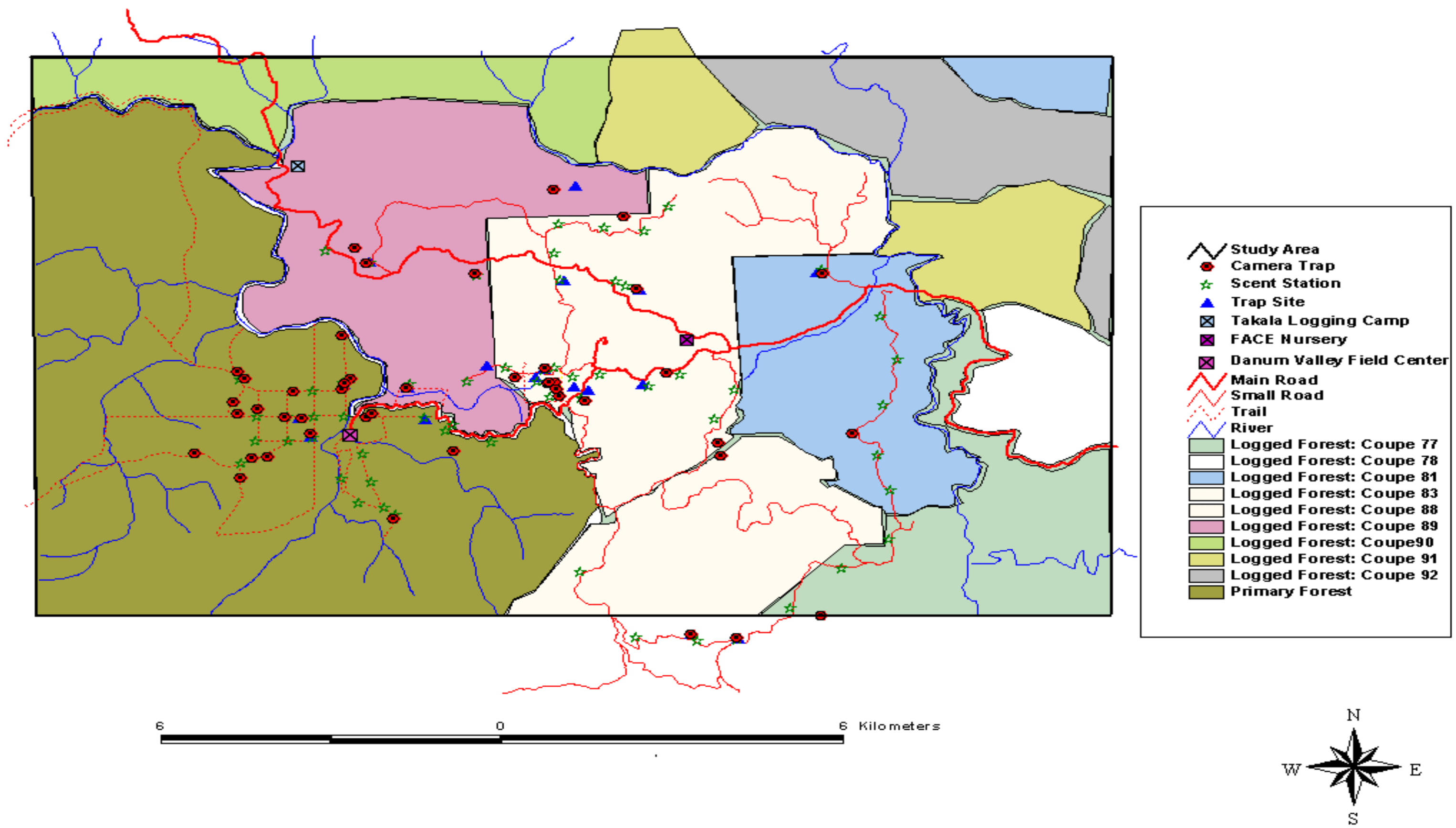

Figure 3. Traps sites, camera locations, scent stations, and logging history in the study area on approximately 150 km^2 within and adjacent to the Danum Valley Field Center

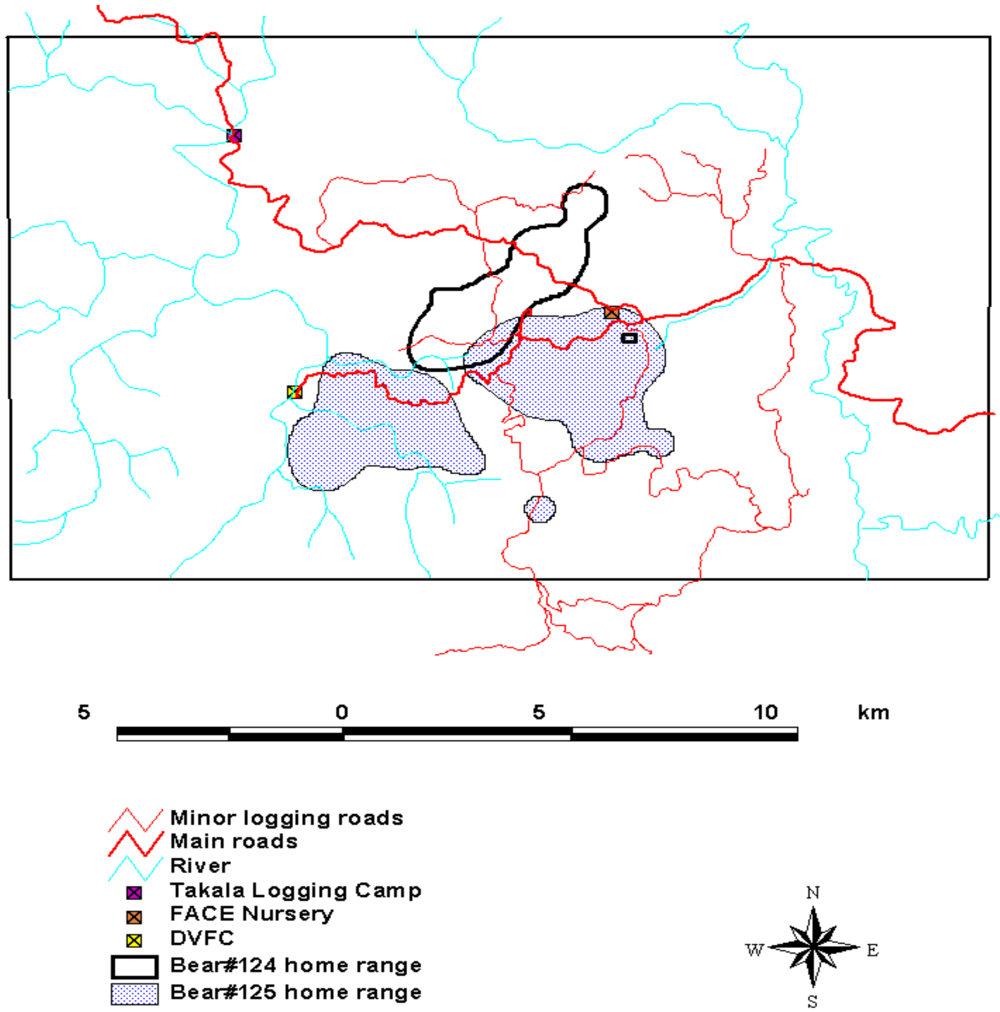

Figure 4. 95% adaptive kernel home range of Bear #125 and Bear #124 in Ulu Segama Forest Reserve, Sabah, Malaysia, from June – October 1999.

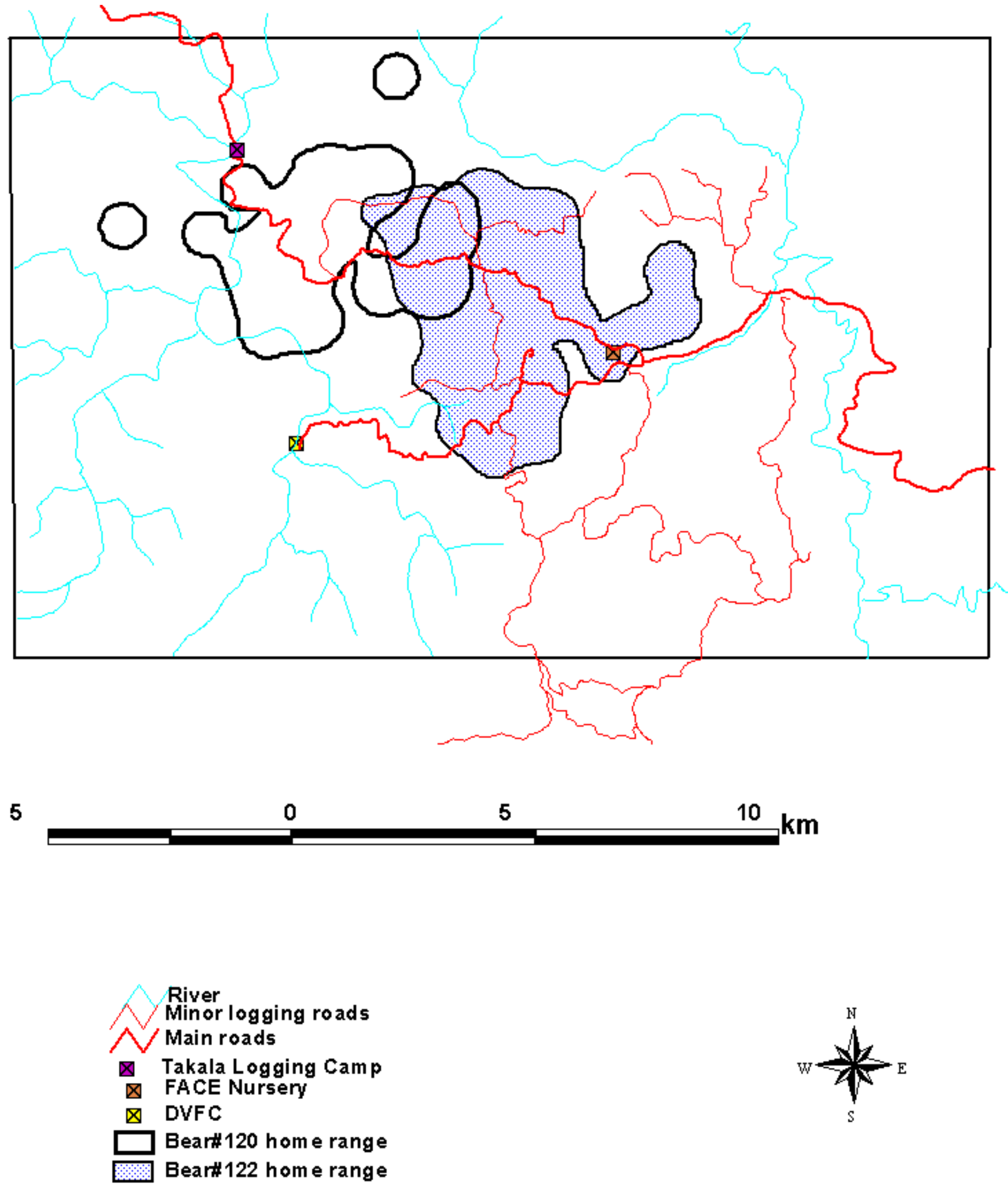

Figure 5. 95% adaptive kernel home range of Bear #122 and Bear #120 in Ulu Segama Forest Reserve, Sabah, Malaysia, from May 2000 – July 2001.

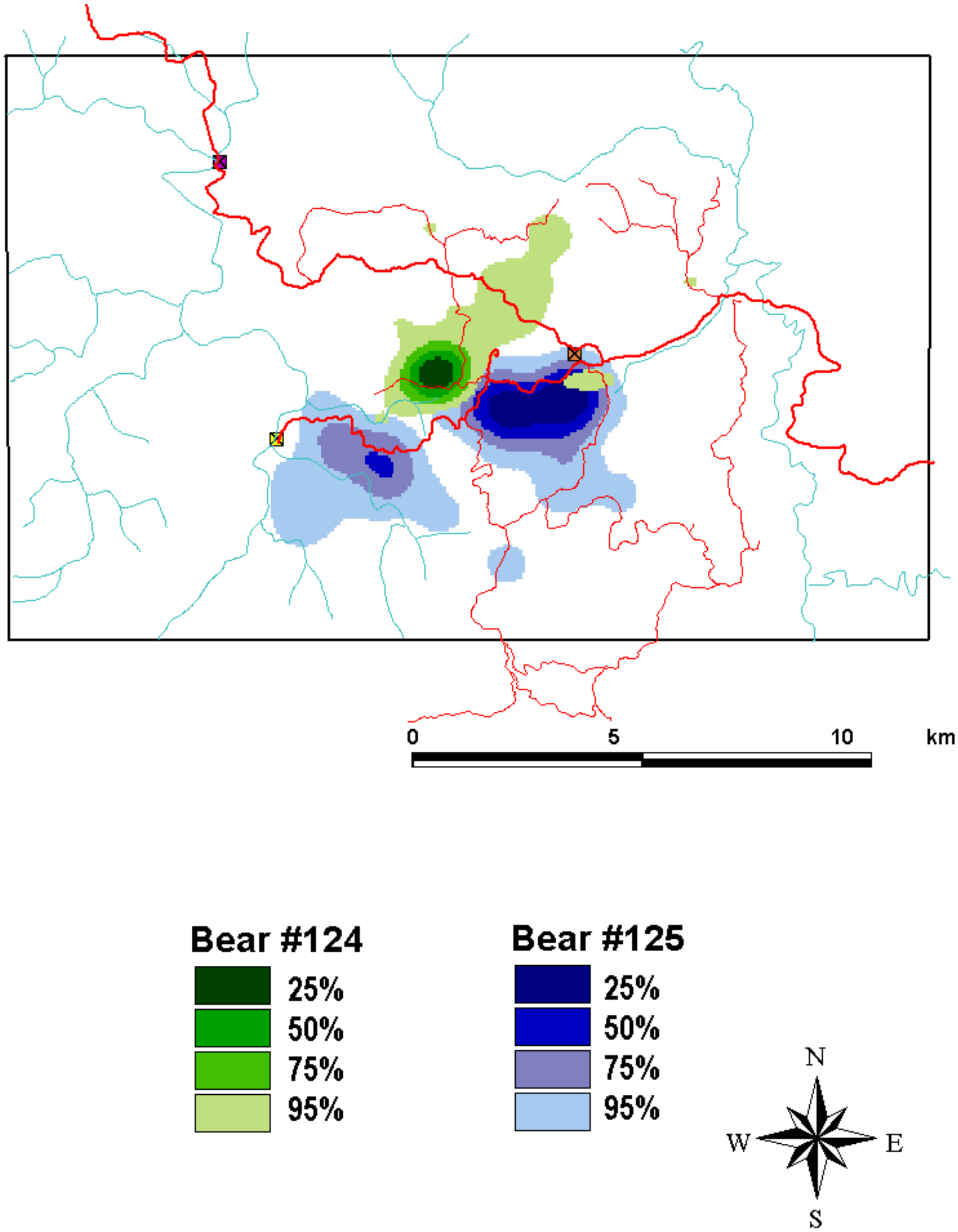

Figure 6. Adaptive kernel home range for Bear #125 and Bear #124 in Ulu Segama Forest Reserve, Sabah, Malaysia, during 1999 showing various utilization isoclines (in percent) and core areas.

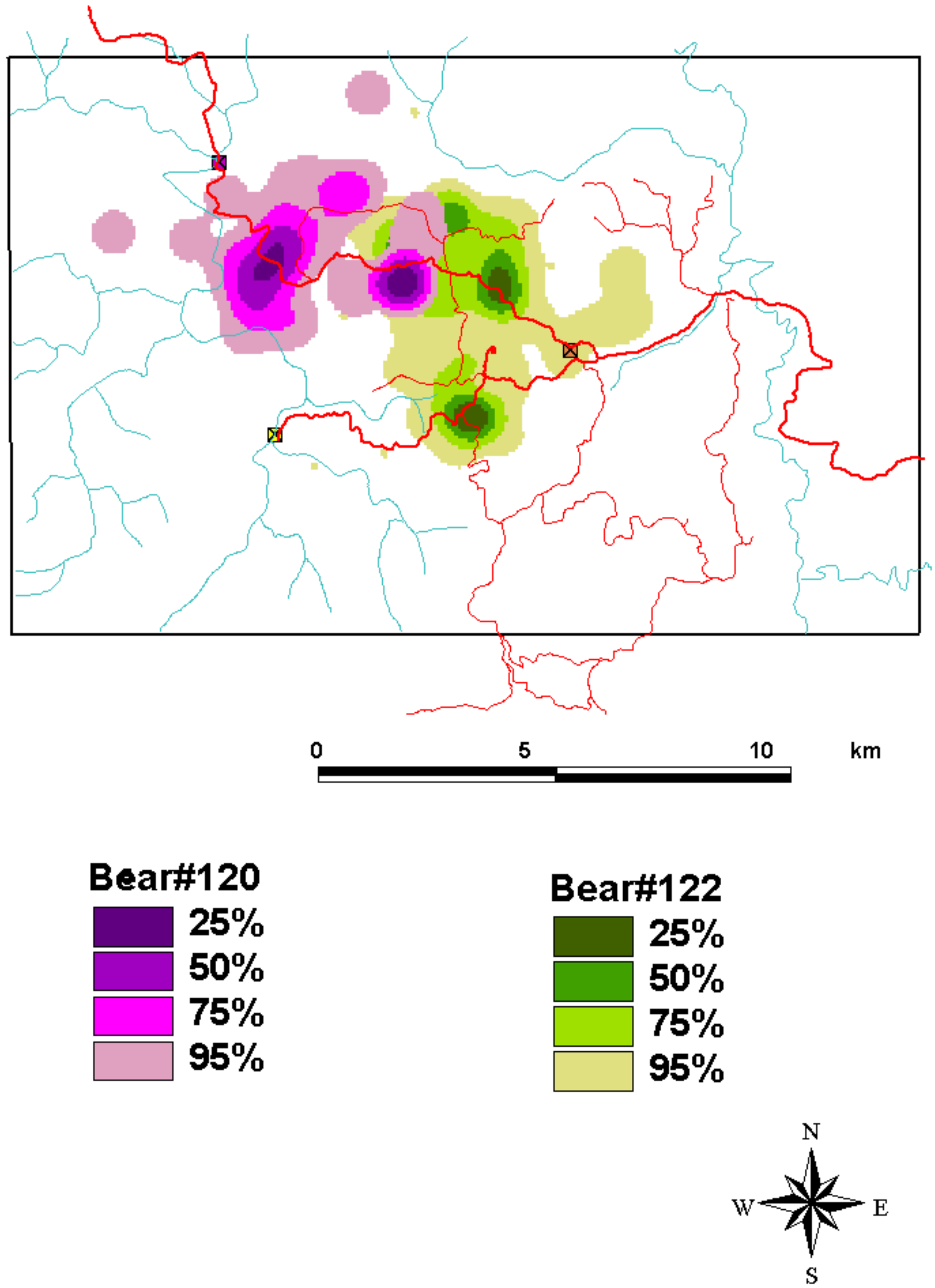

Figure 7. Adaptive kernel home range for Bear #122 and Bear #120 in Ulu Segama Forest Reserve, Sabah, Malaysia, during 2000 showing various utilization isoclines (in percent) and core areas.

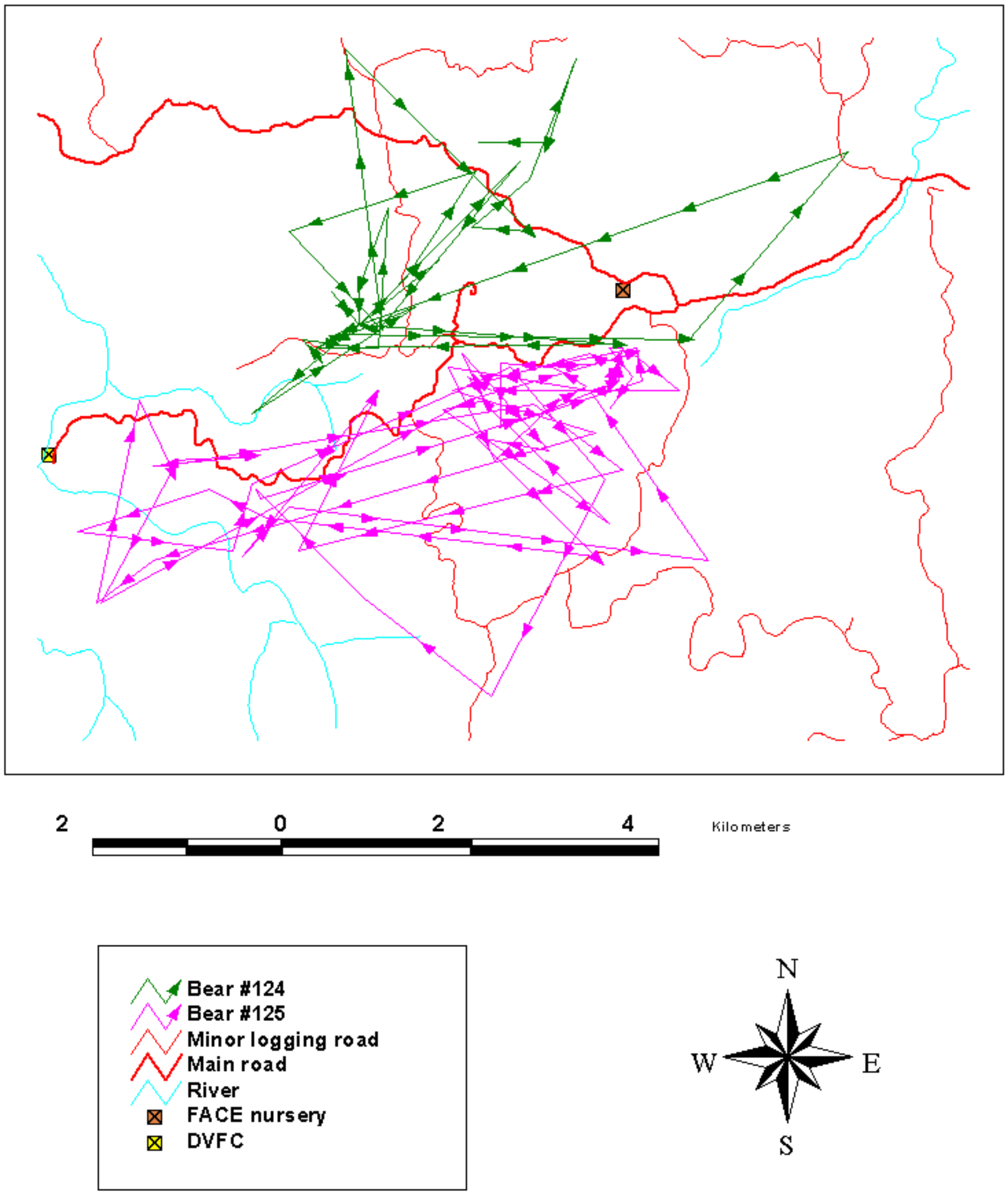

Figure 8. Movement patterns of Bear #125 and Bear #124 in Ulu Segama Forest Reserve, Sabah, Malaysia, from June to October 1999.

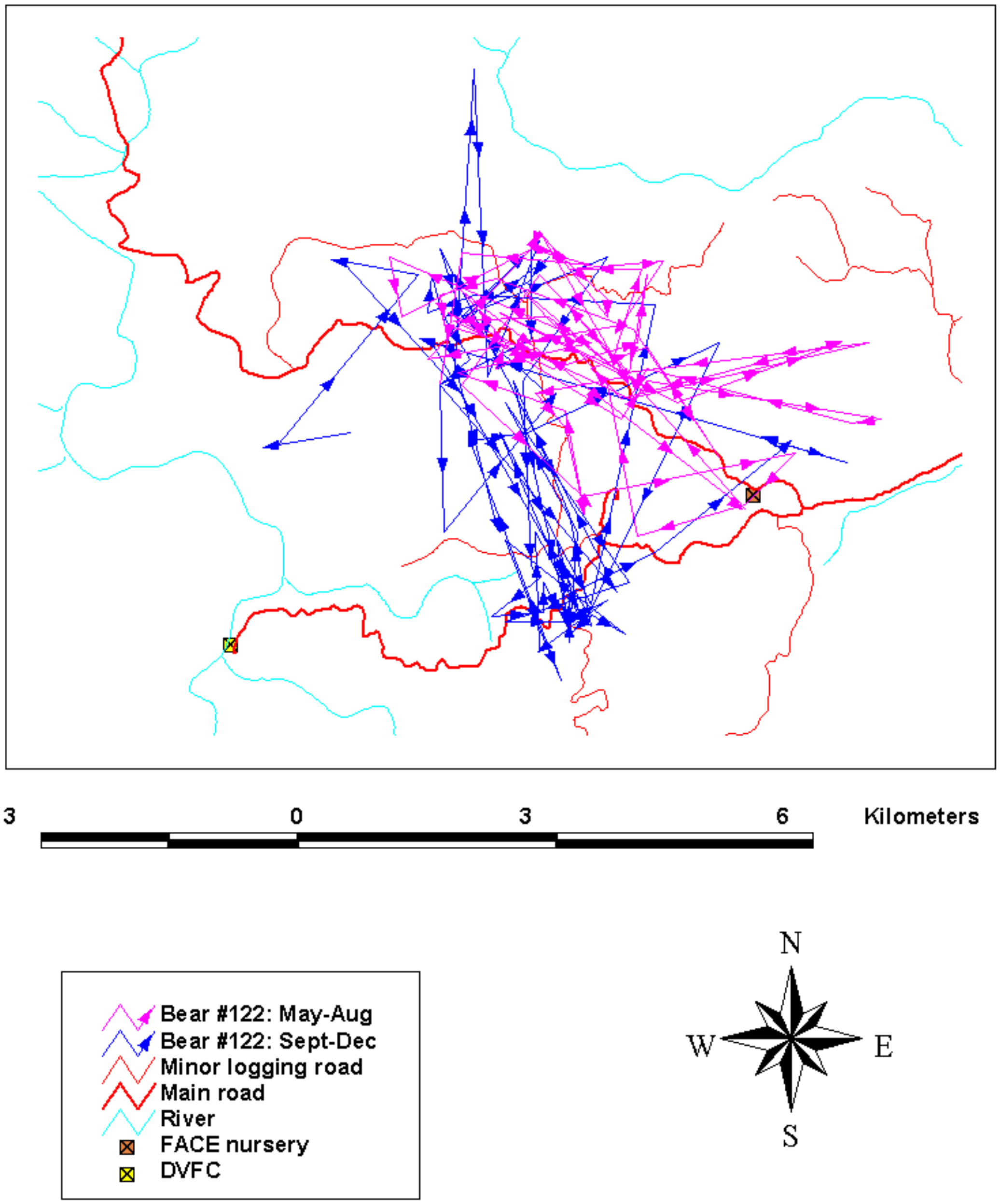

Figure 9. Movement patterns of Bear #122 between May – August 2000, and September – December 2000 in Ulu Segama Forest Reserve, Sabah, Malaysia.

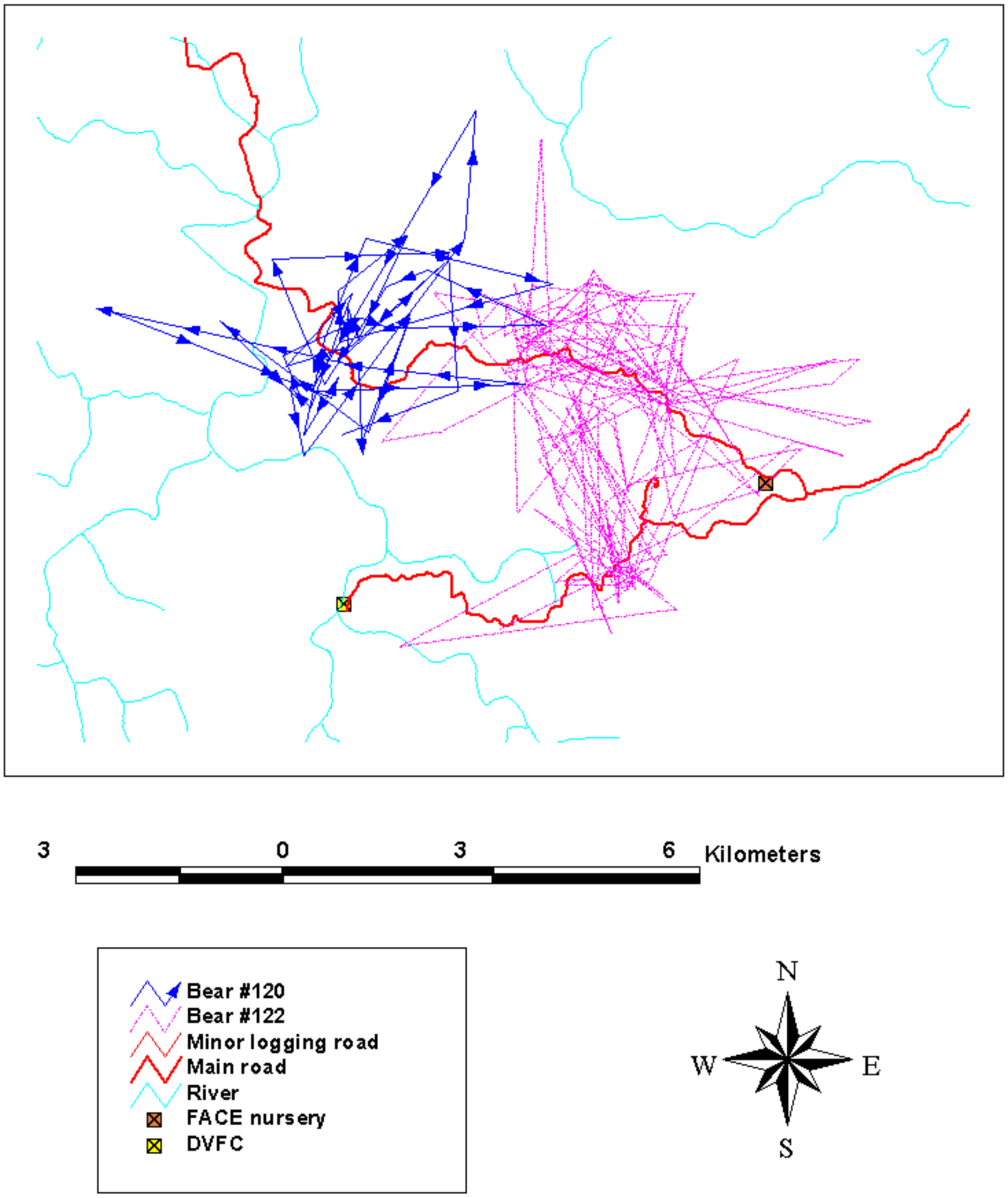

Figure 10. Movement patterns of Bear #122 and Bear #120 in Ulu Segama Forest Reserve, Sabah, Malaysia, from May to December 2000.

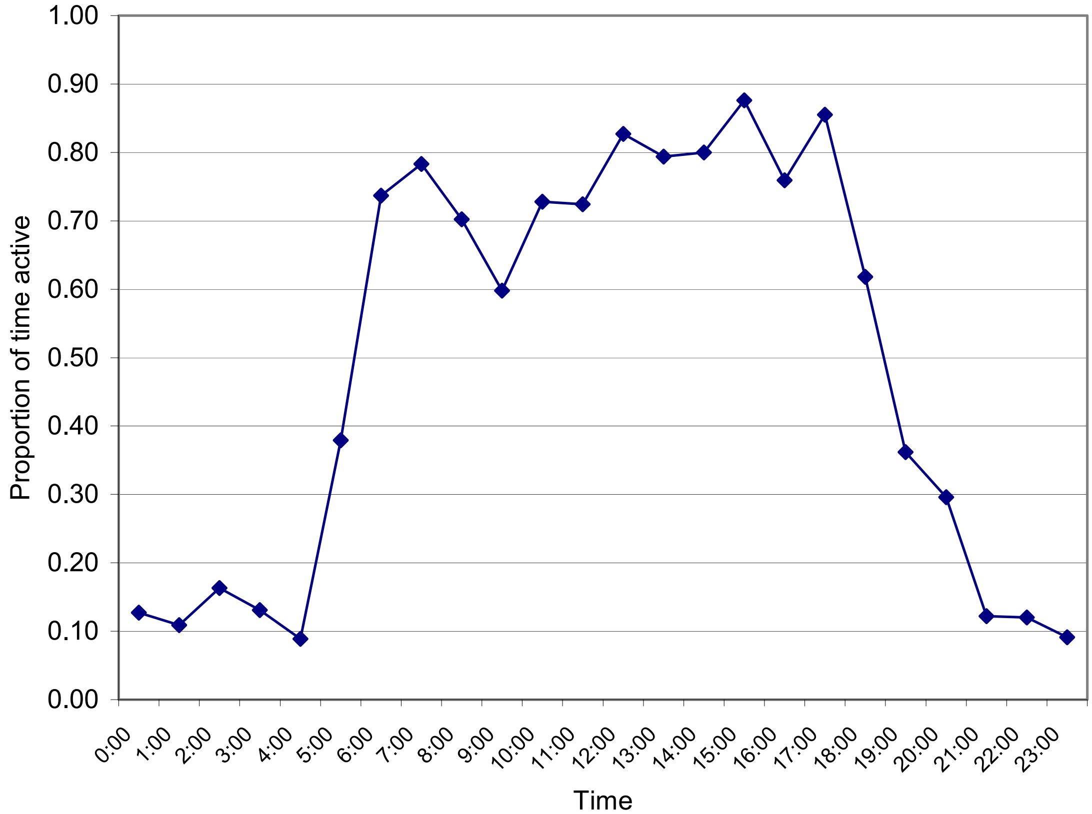

Figure 11. Combined 24-hour activity patterns of 4 male Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia (n = 5687) from June 1999 to December 2000.

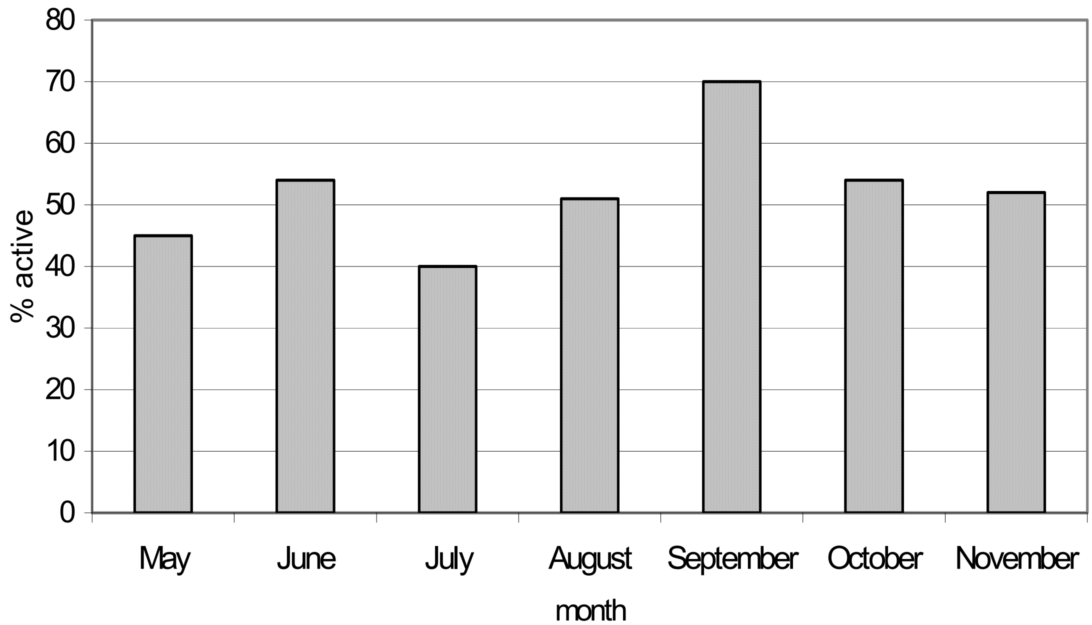

Figure 12. Mean monthly activity of Bear #122 in Ulu Segama Forest Reserve, Sabah, Malaysia, 2000.

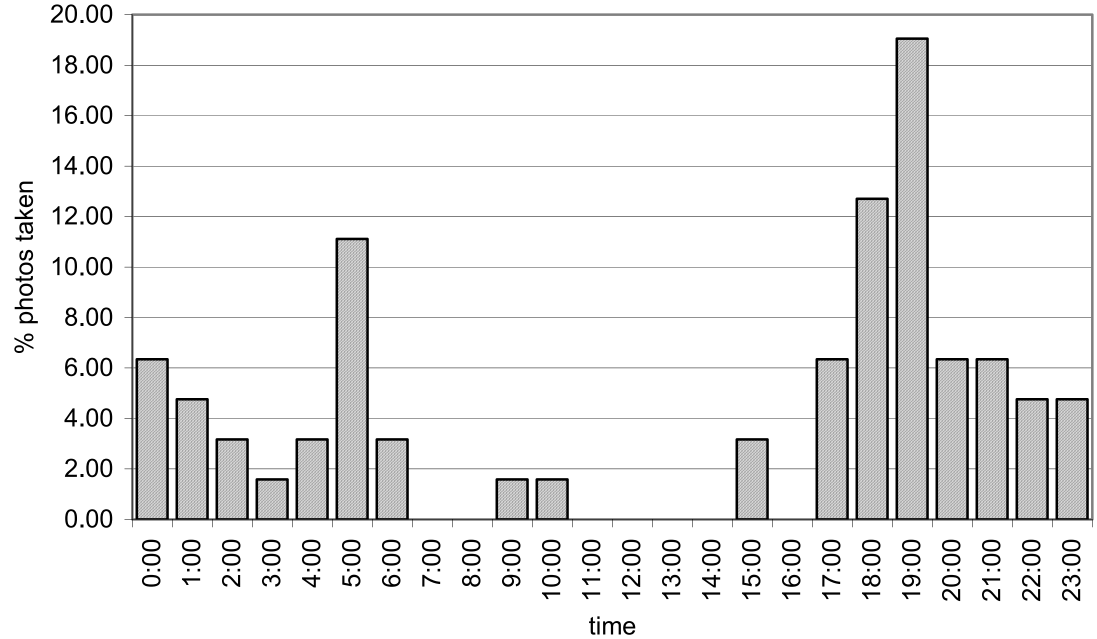

Figure 13. Frequency distribution of Malayan sun bear photographs taken by camera traps in Ulu Segama Forest reserve, Sabah, Malaysia (n= 63).

Figure 14. A typical hollow log in the study area used by sun bears as a daybed. This log was felled during a logging operation, but apparently discarded due to its hollow trunk.

Figure 15. Bear #122 photographed on August 2000, revealing his “very poor” physical condition. He has an emaciated body, sparse hair, and loose skin that indicate starvation and malnutrition.