

# Home range, movement and activity patterns, and bedding sites of Malayan sun bears *Helarctos malayanus* in the Rainforest of Borneo

Siew Te Wong<sup>a,\*</sup>, Christopher W. Servheen<sup>a</sup>, Laurentius Ambu<sup>b</sup>

<sup>a</sup> Wildlife Biology Program, College of Forestry and Conservation, University of Montana, Missoula, Montana 59812, USA

<sup>b</sup> Sabah Wildlife Department, 5th floor, Block B, MUIS Complex, 88100 Kota Kinabalu, Sabah, Malaysia

Received 21 June 2002; received in revised form 10 September 2003; accepted 23 October 2003

## Abstract

Six Malayan sun bears were captured and radio-collared from June 1999 to December 2001 in Ulu Segama Forest Reserve, Sabah, Malaysia Borneo 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<sup>2</sup>. Bears 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. Male Malayan sun bears were primarily diurnal, but a few individuals were active at night for short periods. The majority of the 26 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 the ground. Malayan sun bears exist in primary and logged forests. Well-designed logging practices, maintenance of large trees with cavities, protection of fig trees, and strict control of poaching should be incorporated into forest management practices in logged forests.

© 2003 Elsevier Ltd. All rights reserved.

**Keywords:** Malayan sun bear; Home range; Activity patterns; Movement patterns; Beds; Borneo

## 1. Introduction

The Malayan sun bear (*Helarctos malayanus*) is the smallest of the eight extant bear species. Adults are about 120–150 cm long and weigh 27–65 kg (Stirling, 1993). They were historically found in the forest 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, and one of the most neglected large mammals in Southeast Asia (Servheen, 1999). Even basic biology such as food habits, home range size, and reproductive characteristics 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 den-

sities 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 for any bear species worldwide (Servheen, 1999).

Davies and Payne (1982) reported that sun bears are found at low densities throughout dipterocarp and the lower montane forests of Sabah, Malaysia from 0 to 1350 m in elevation. 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 were converted to human developments and agriculture, including rubber and oil palm plantations. Malaysia has become the world's largest producer and exporter of palm oil (World Rainforest Movement, 2001). Wilson and Wilson (1975), and Johns (1983a) suggested that sun bears exist only in primary forest as none were found in logged

\* Corresponding author. Fax: +1-406-329-3212.

E-mail address: [wongsiew@hotmail.com](mailto:wongsiew@hotmail.com) (S. Te Wong).

forests. With the rapid reduction of sun bear habitat, the conservation of the Malayan sun bear is challenging. Wise conservation planning requires information on the biological needs of this species. We present information on home range size, movement and activity patterns, 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.

## 2. The 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 (Fig. 1) ( $4^{\circ}57'40''\text{N}$   $117^{\circ}48'00\text{E}$ , 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 (DVCA) (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 has a lower canopy with fewer, smaller emergent trees than lowland rainforest (Whitmore, 1984). Approximately 88% of the total volume of large trees in the conservation area is dipterocarps (Marsh and Greer, 1992).

The DVCA is surrounded by approximately 1 million hectares of selectively logged forest. Logging follows the Monocyclic Unit System (Poore, 1989) with a 60-year rotation and involves harvesting all commercially valuable trees with a diameter at breast height (dbh)  $>60$  cm occurring on slope of  $<20^{\circ}$  (Marsh, 1995). Both tractor logging and overhead cable techniques are used on moderate terrain and steeper slopes. Using this method, harvesting 3–7% of the trees with  $>60$  cm dbh (translates to 8–18 trees  $\text{ha}^{-1}$ ) destroys over 50% of the trees  $>30$  cm dbh by log extraction and road building. (Wilson and Wilson, 1975; Johns, 1985, 1988, 1992). Timber extraction rates in the Ulu Segama Forest Reserve are typically high, averaging  $118 \text{ m}^3 \text{ ha}^{-1}$  (Marsh and Greer, 1992), compared to 8.4 and  $13.5 \text{ m}^3 \text{ ha}^{-1}$  in Neotropical and African rainforests (Yeom, 1984). Compared with other selectively logged forests in Sabah and Malaysia, parts of the logged forests in the study area have had relatively lower extraction rates and less human disturbance (such as illegal logging).

When logging is complete in an area, a mosaic of vegetation types remain from relatively undisturbed forest, through forests 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 (Ahmad, 2001; Hussin, 1994). In general, primary forests have taller (45 m compared to 15 m), better developed, and less open upper canopy (5.3% compared to 10.7%) than logged forest (Ahmad, 2001; Willott, 2000). Logged forests are usually dominated by tree species such as *Macaranga* and *Mallotus* with abundant vines, 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 higher than in logged forest, and during a mass fruiting period, fruit production was clearly higher in the primary forest than in the logged forest. Numbers of fig trees, which are an important food source for Malayan sun bears (Wong et al., 2002), 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

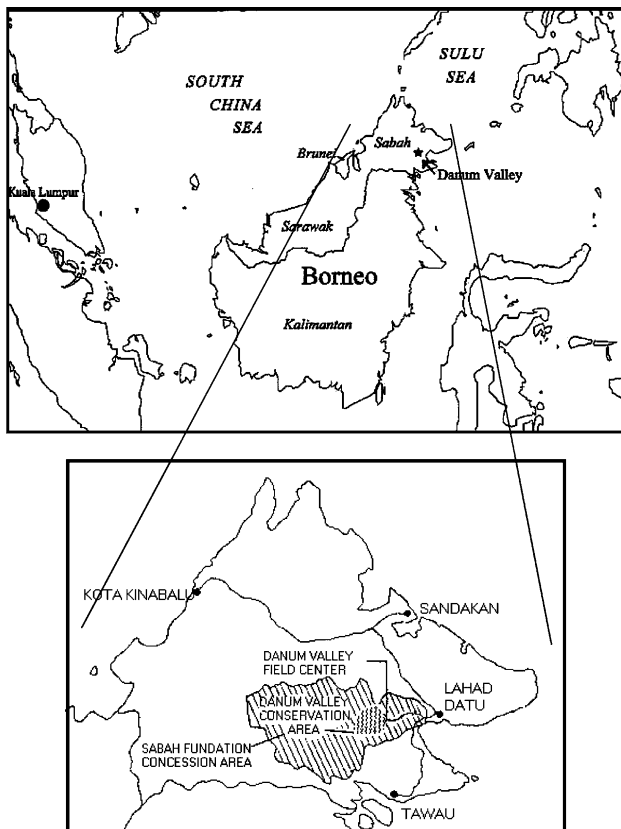


Fig. 1. Location of the study area at Danum Valley Field Center at the state of Sabah, Northern Borneo.

*Elaphus maximus*, orangutans *Pongo pygmaeus*, and Malayan sun bears, were still found in the logged forest during our study (S.T. Wong, unpublished data).

The climate of Ulu Segama Forest Reserve is weakly influenced by two monsoons (Marsh and Greer, 1992). Average annual rainfall at DVCA was 2700 mm [Royal Society SE Asia Rainforest Research Program: Hydrology Project (University of Manchester, University of Wales Swansea, University of Lancaster, University Malaysia Sabah), unpublished station records 1986–2000], with the wettest period from October to January and the dry period between July and September. Mean daily temperature at the field center during 1999–2000 was 26.7 °C. Soils in the reserve include ultisols, inceptisols and alfisols (Newbery et al., 1992).

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

### 3. 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. Phase II involved collecting information on the basic biology of sun bears through the capture and radio tracking of animals.

#### 3.1. Animal capture

We used an aluminum culvert trap (Teton Welding and Machine, Choteau, MT, USA) and three 55-gal. barrel traps to capture sun bears. We also built four wooden log traps but abandoned this method 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 once the trap's door was closed. Signals from the trap transmitters were monitored several times each day. We checked the traps immediately after receiving these signals to minimize the time captured animals were held. 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 (MOD-400; Telonics

Incorporated, Mesa, AZ, USA). Each radio transmitter was equipped with a mercury-tip switch that changed the pulse rate, 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.

#### 3.2. 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, USA) and a hand held RA-14K rubber-ducky "H" directional antenna (Telonics Incorporated, Mesa, AZ, USA). Each location was taken from at least two locations at approximately 90° angles from the bear's position within 30 min, or simultaneously taken by two people from different locations in two-way radio contact. All telemetry locations were taken from 0900 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 were also obtained from recaptures, sightings by field crews, and photographs taken by camera traps. Only one location per day per bear was used to estimate home range.

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 and core areas were calculated using the Adaptive Kernel method (Worton, 1989, 1995), with ArcView GIS 3.2a (Environmental Systems Research Institute, ESRI, Redlands, CA, USA). The home range core area in this study was defined as the smallest areas enclosing 25% of total use of the animal (Powell, 2000).

#### 3.3. 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.

#### 3.4. Activity patterns

Activity patterns of radioed bears were recorded manually through 24-h/day continuous monitoring once a week from a fire observation tower. Using criteria of Beier and McCullough (1988), the signal strength and pulse frequency was scored manually as active (1) or inactive (0) in 10-min 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-h monitoring period. Only 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 wild animals (Wildlife Research Laboratory, Department of Wildlife Conservation, National Pingtung University of Science and Technology, Taiwan, ROC). Sites for cameras were chosen near animal trails, water pools, mud wallows, and trap sites. Each camera unit was relocated every 6–10 weeks. A variety of baits 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. Time periods were pooled to 1-h intervals.

### 3.5. Bedding sites

Bear locations were visited 2–4 h after the coordinates were taken to look for feeding evidence, bear scats, or claw marks on trees and other activities. We also at-

tempted to track radioed bears on foot, at a distance to not disturb the bear but visit locations of activity soon after the bear left. Bears were sometime observed foraging, traveling, and resting. When we found bears resting, we waited until they woke and left the area. After the bears left, we recorded bedding site type, slope, tree species, took measurements of the bedding sites, and collected scats and hairs.

## 4. Results

### 4.1. Animal capture

Six bears (five males, one female) were trapped during 2372 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 1. The results presented below are based on four male bears (Bear #125, 124, 122, 120). Data from Bear #123 and #121 were excluded due to short monitoring period.

### 4.2. Home range

Between June 1999 and July 2001, 343 locations of four radio-collared male bears were collected. About 80% of these locations resulted from radio telemetry while the remaining locations were collected from trapping, camera traps, and sightings by field crews (Table 2). Home range

Table 1  
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 October 99	Old	Fair	44	121	20
124	M	10 July 99	20 September 99	Old	Fair	40	124	24
123	M	7 August 99	10 September 99	Old	Poor	34	124	20
122	M	4 May 00	25 July 01	Sub-Ad	Poor	30	117	
121	F	24 September 00	25 September 00	Adult	Very poor	20	110	20
120	M	11 October 00	11 June 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 five 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 2  
The number of locations of each bear collected from radio-telemetry, capture, camera trap, and sighting used in home range estimation

Bear #	Month monitored	Radio-telemetry	Capture	Camera trap	Sighting	Total number of locations	95% adaptive kernel home range (km <sup>2</sup> )	Core area* (km <sup>2</sup> )	Forest type
125	4	60	1	0	5	66	16.8	1.10	Primary and logged
124	2	28	2	12	1	43	6.2	0.32	Logged
122	14	143	9	9	15	176	20.6	0.65	Logged
120	10	44	2	10	2	58	15.5	0.65	Logged
Total		275	14	31	23	343	Mean = 14.8	Mean = 0.68	

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

was estimated using between 43 and 176 locations (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.

Average home range size of four male Malayan sun bears was 14.8 km<sup>2</sup> and ranged from 6.2 to 20.6 km<sup>2</sup> (Table 2). The home range size of Bear #125 for 4 months was 16.8 km<sup>2</sup> and incorporated both primary forest (40%) and secondary forest that had been logged in 1988 (Fig. 2). The home range of Bear #124 after 2 months of radio tracking was 6.2 km<sup>2</sup> and was directly north of Bear #125's range. A logging road was located at the center of Bear #124's home range that only occupied logged forest, which was also selectively logged in 1988. The home ranges of Bear #125 and Bear #124 overlapped by 0.54 km<sup>2</sup>.

We had the highest number of locations on Bear #122. His locations were taken almost daily from the time of his capture on May 2000 to December 2000. After that, his locations were taken once every 2 weeks until June 2001. However, his home range size (20.6 km<sup>2</sup>) remained stable after the first 4 months and did not increase with addi-

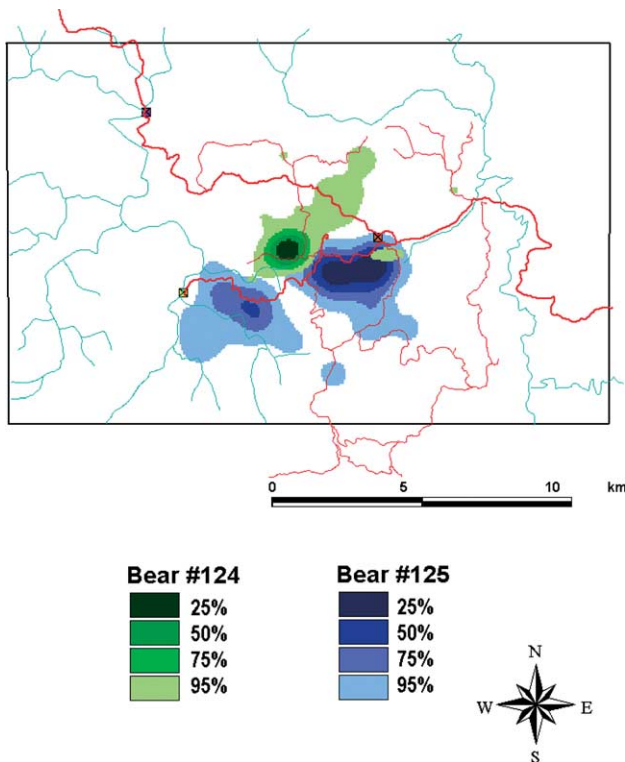


Fig. 2. Adaptive kernel home range for Bear #125 and Bear #124 in Ulu Segama Forest Reserve, Sabah, Malaysia, during 1999 showing various utilization isoclines (in %) and core areas.

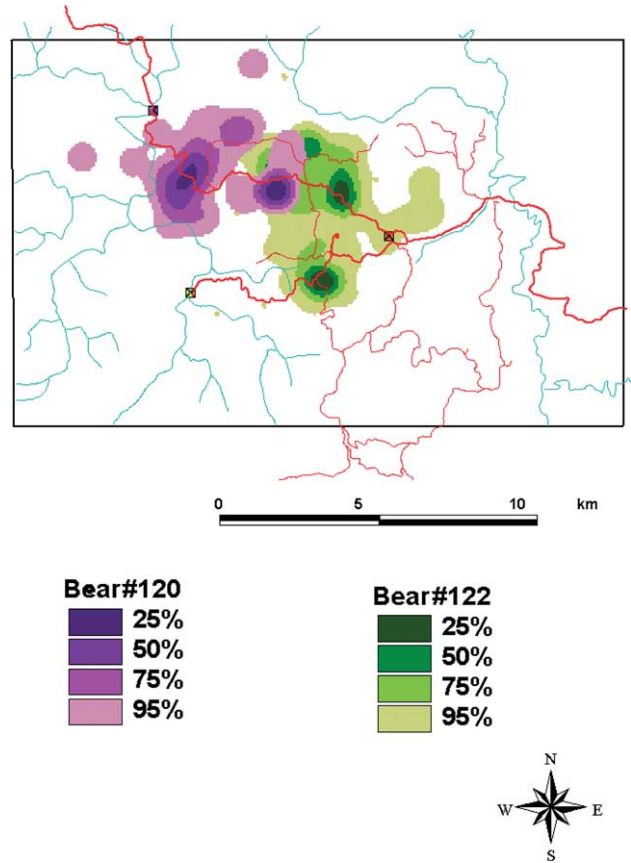


Fig. 3. Adaptive kernel home range for Bear #122 and Bear #120 in Ulu Segama Forest Reserve, Sabah, Malaysia, during 2000 showing various utilization isoclines (in %) and core areas.

tional locations beyond this time. Bear #122's range overlapped logged forest that had been logged in both 1988 and 1989, and incorporated the main logging road and Danum Road (Fig. 3). The home range size of Bear #120 was 15.56 km<sup>2</sup> and was found only in forest logged in 1989. However, Bear #120 probably has a larger home range because there were several occasions when we failed to find him, despite intensive search efforts. The home range of Bear #122 and Bear #120 overlapped over 3.45 km<sup>2</sup>.

Even though the 95% adaptive kernel home range of these bears overlapped, the 25% core areas did not (Figs. 2 and 3). Bear #125 and Bear #124 each had one core area within their home ranges, while Bears #122 and #120 had two core areas. These core areas ranged from 0.32 to 1.10 km<sup>2</sup> (mean = 0.68 km<sup>2</sup>, SD = 0.32 km<sup>2</sup>,  $n = 4$ ) (Table 2).

### 4.3. Movement patterns

The mean daily movement distance of the four radioed bears was 1454.5 ± 240.2 m and ranged from 141 to 5660 m (Table 3). Bear #125 traveled back and forth between the primary forest, where he was captured, and

Table 3

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

Bear ID	<i>n</i>	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

the logged forest at the West end of his range, where his core area was found.

We noticed a shift of area used by Bear #122 after the first 3 months of radio tracking. Thus, we divided his movement patterns into two different time periods: May–August 2000, and September–December 2000. During the first period, Bear #122 moved primarily in an East–West direction, North of the main logging road. He developed one core area North of the road, where he found at least four fruiting fig trees and remained close to fig resources until total depletion of the crop. 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 near 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 areas where the fig trees were. Bear #122 crossed the main logging road many times even during daytime.

The home range of Bear #120 was located between Bear #122's range on the East and the Segama River on the West. Bear #120 concentrated his movements in his core areas where he was captured and later found a fruiting fig tree. Although the ranges of Bear #122 and Bear #120 showed minor overlap, we never located them closer than 1.5 km apart. The daily movement distance of Bear #120 were among the longest with a mean of 1810 m. The maximum travel distance in 24 h of 5.5 km was recorded for Bear #120.

#### 4.4. Activity patterns

##### 4.4.1. 24-h/day monitoring

A total of 792 h of continuous monitoring for daily activity was obtained in 1999 and 2000 that resulted in 5687 readings of activity. These included 10 days (1206 readings) of monitoring of Bear #125, nine days (1104 readings) of Bear #124, three days (238 readings) of Bear #123, and 23 days (3139 readings) of Bear #122. The analysis was based on these 45 samples.

Activity of male Malayan sun bears was unimodal with most activity in daytime (Fig. 4). Activity started at dawn, before sunrise, at 0530 and increased abruptly 30

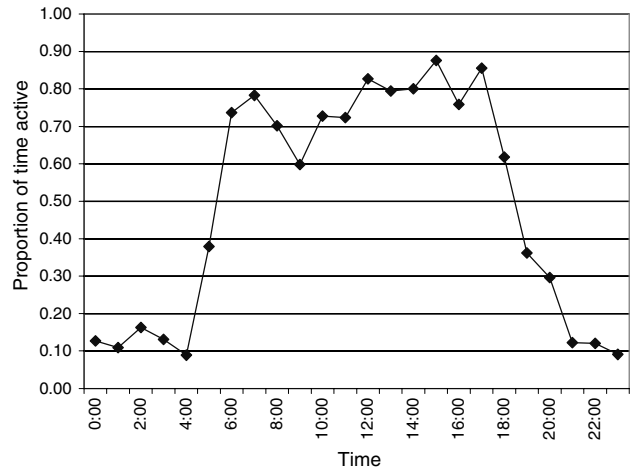


Fig. 4. Combined 24-h activity patterns of four male Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia ( $n = 5687$ ) from June 1999 to December 2000.

min later. The activity remained high until 1800 h in the evening and slowly decreased as dusk approached, with sunset at 1830 h. Due to a dense canopy layer of the forest, the forest floor becomes dark in the forest immediately after sunset at 1830 h. After 2100 h, 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 strictly diurnal. Bear #124 had two major resting periods at 0800 and 1400 h. Bear #124 also had two activity peaks, which reached about 60% probability of activity at 2000 and 0030 h. Despite these variations, male Malayan sun bears at Ulu Segama Forest Reserve were generally diurnal.

##### 4.4.2. Camera traps

A total of 49 camera trap stations accumulated 858 camera/nights (19,418 working hours). These cameras took 1957 photographs that contained at least one animal, including 198 photographs of Malayan sun bears. Since many of these photographs were of same bear taken continuously at one site visit, we only use one photo/day/site/bear. Only 46 photographs fulfilled this criterion and were used for the analysis of activity.

Results from camera traps show different activity patterns than the radio monitoring. Photographs of sun bears were taken predominantly at dawn and dusk and night (Fig. 5). Eight photographs (17%) and six photographs (13%) were taken at dusk and dawn, respectively, while only four were recorded between 0700 and 1700 h. Numbers of photographs taken at night ranged from one to five photos every hour. These data suggest that the Malayan sun bears were more active during the crepuscular period than diurnally.

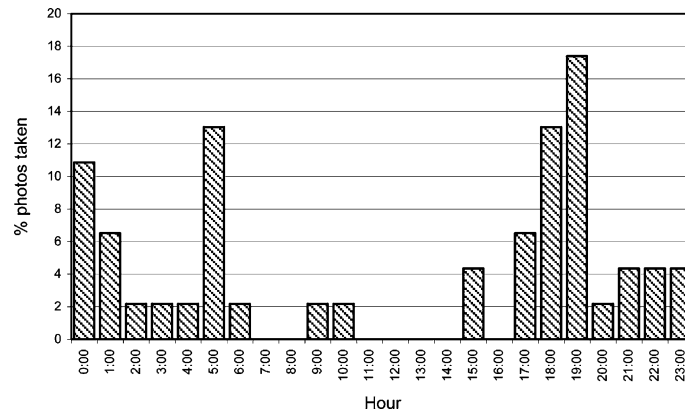


Fig. 5. Frequency distribution of Malayan sun bear photographs taken by camera traps in Ulu Segama Forest reserve, Sabah, Malaysia ( $n = 46$ ).

#### 4.5. Bedding sites

We found 26 bedding sites for Malayan sun bears. We sighted radioed bears using 17 of these bedding sites. Other bedding sites were determined from tracking radioed bears on foot and from radio signals transmitted from a hollowed log or cavity from close distance (<5 m). Bedding sites consisted of twelve cavities of hollowed-fallen logs (46%) (Table 4). They were either naturally fell, or felled during logging operations, but apparently discarded due to their hollow trunk. They usually had 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 4). The family and species of these tree logs were usually unidentifiable due to the decayed condition. However, based on their large size and being purposely felled, we suspected that many of the logs were 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.

Five beds (19%) were in a cavity inside the main trunk of a standing tree. We sighted radioed bears using all of the four standing tree cavities (Table 5) as bedding sites for >2 h. We found the skeleton and radio-collar of Bear #123 in a tree cavity. Bear #123 was suspected of dying from old age and malnutrition (Wong, 2002). Some entrances of these cavities were cracks on the main tree trunk with relatively narrow width. Others were tunnel-shaped, up to 170 cm deep cavity from the tree's buttress. 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 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 Dipterocarpaceae. Two beds (8%) were dirt holes under a tree where parts of the root system were exposed either on flat ground or on steep slopes.

Malayan sun bears also rested on tree branches, high above the ground and exposed. We sighted Bear #122

Table 4

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 (m)	Diameter (cm)	Size of entrance (greatest width × height; cm)	Depth of cavity (m)	Remarks
RC05	Flat	Fam. Dipterocarpaceae	9.3	136	136 × 120	9.3	Chain-sawed
RC06	10°	<i>Shorea johorensis</i>	11.0	78	45 × 50	11.0	
RC07	Flat	Unknown	23.3	120	90 × 90	23.3	
RC08	40°	Fam. Dipterocarpaceae	26.0	124	50 × 44	9.3	
RC10	30°	Unknown	4.8	136	175 × 50	4.8	Chain-sawed
RC12	Flat	Unknown	15.0	110	62 × 40	14	Chain-sawed
RC14	30°	Unknown	49.3	104	40 × 37	6.0	
RC15	Flat	Unknown	6.3	110	40 × 60	4.0	
RC16	12°	Fam. Dipterocarpaceae	22.0	97	60 × 37	4.9	
RC17	12°	Unknown	7.1	77	70 × 54	2.3	
RC18	15°	Unknown	40.0	130	100 × 70	20.0	
RC20	18°	Unknown	11.3	113	63 × 53	11	Chain-sawed
RC19	30°	Unknown					Chain-sawed; cavity underneath the log

Table 5

Dimensions of cavities of standing trees and cavities underneath tree roots that served as bedding sites for Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia

Site no.	Slope	Tree spp.	Est. tree height (m)	DBH (cm)	Size of entrance (greatest width × height; cm)	Floor space (greatest length × width; cm)	Remarks
RC01	20°	<i>Shorea</i> sp.	40 (broken top)	160	30 × 30	100 × 100	Live tree; Bear #123's skeletons found here
RC03	10°	<i>Shorea</i> sp.	20 (broken top)	190	40 × 60	120 × 150	Dead tree
RC04	15°	<i>Dryobalanops lanceolata</i>	25	120	19 × 120	120 × 100	Dead tree
RC11	30°	Fam. Dipterocarpaceae	35	115	16 × 137	90 × 90	Live tree
RC02	Flat	Fam. Dipterocarpaceae	20	145	50 × 26	170 × 40	Dead tree, cavity in tree buttress
RC13	45°	<i>Macaranga hypoleuca</i>	10	35	80 × 38	2.1 m depth	Live tree, cavity underneath root system
RC09	Flat	Unknown	35	58	27 × 33	Not measured	Live tree, cavity underneath tree root system

five times resting in a tree, and made one sighting of an unmarked bear clinging to the branches of a tree.

## 5. Discussion

This study is one of the first conducted on wild Malayan sun bears, and there are no scientific reports available to make comparisons. We therefore make comparisons with other forest dwelling ursids such as American black bears *Ursus americanus*, Asiatic black bears *U. thebetanus*, and sloth bears *Melursus ursinus*, even though sun bear are half their size.

### 5.1. 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 distinct seasonal home ranges. As mobile and opportunistic mammals, bears show changing home range use in accordance with changes in resource abundance (Powell, 1987; Reid et al., 1991; 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 clear shifts in diet (Wong et al., 2002). The home ranges of male sun bears were much smaller compared to adult male adult American black bears with average annual 95% kernel home range of 44.1 km<sup>2</sup> (Powell et al., 1997).

Tropical rainforests give an impression of high food abundance throughout the year due to optimum growing conditions. However, our phenology data (Wong, 2002) documented prolonged low fruit production during the entire study period. This was a typical “non-

fruiting period” observed in dipterocarp forests in Borneo, Sumatra, and Peninsula Malaysia. These forests have “mass flowering” followed by “mass fruiting” (episodic synchronous reproduction interspersed with periods of little or no seed production) (Janzen, 1974; 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* (Wong, 2002). We suspect that two of the monitored bears and several bearded pigs died from starvation during this time (Wong, 2002).

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 2 weeks). Bear #122 returned to these areas frequently after the fruiting period had ceased. In mid-October 2000, Bear #122 moved southward to a garbage dump that was used by the Danum Valley Field Center (DVFC) 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.

Throughout the world bears exploit human food at garbage dumps. Many of these bears became nuisance animals (Howard and Marsh, 1972; Herrero, 1983; Rogers, 1989). In October 2001, a 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 kitchens to steal human food (S. Nathan, pers. comm.). Due to strict prohibitions on poaching in the vicinity of the field center, this bear was not killed. In other areas, nuisance sun bears at oil palm plantations and farms are usually killed by stockmen and farmers (Servheen, 1993a; Santiapillai and Santiapillai, 1996; Meijaard, 1999). Fredriksson (1998) reported three out of five ex-captive sun bears that were radio-collared and released into the wild were killed, 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.

### 5.2. Movement patterns

Many studies on the movement patterns of American black bears (Amstrup and Beecham, 1976; Garshelis and Pelton, 1981; Kasbohm et al., 1998) and brown bears or grizzly bears *U. arctos* (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 with an abundance of bear food occurred during our study. Thus, it was not possible to compare daily movement distances between fruiting season and non-fruiting season.

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., 2002). 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.

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., 2002). Figs are a keystone resource for tropical frugivorous species, especially birds, primates and bats (Janzen, 1979; Leighton and Leighton, 1983; Kinnaird et al., 1999). In general, 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). However, between June and October of 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. 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 believe that food availability, especially figs, has a strong influence on movement patterns of sun bears.

### 5.3. Activity patterns

Activity patterns of animals are considered an adaptation to seasonal and diurnal variation in 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. J. Holden reported photographs of sun bears taken by camera traps in Sumatra, Indonesia, were often made between 1200 and 1500 h (in Meijaard, 1999), 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 (Fig. 5). 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 disproportionate sampling efforts and strata sampled between radio-telemetry and camera traps. Telemetry sampled the radioed bears no matter where they were while cameras only sampled them when they were traveling along the ground. Thus, the camera samples were likely biased against bear behavior associated with intensive foraging and other activities in tree canopies. Another possibility for these contradictory results may be 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 may only approach camera sites during nighttime.

Activity patterns of bears may be associated with human activity patterns (Ayres et al., 1986). The nocturnal behavior of grizzly bears and American black bears feeding in orchards, garbage dumps, and campgrounds may reflect the diurnal behavior of humans (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, 1999).

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 alter the activity period of Malayan sun bears, even if unaccompanied by any disturbing activities such as logging, hunting and fire making (Meijaard, 1999). The low level of human activities in the home range of Bear #125 and Bear #123 may have resulted their diurnal activity patterns. In contrast, the home range of Bear #124 and Bear #122 included a 20-m wide logging road and associated human use (quantitative measures not available). The home range of these two bears also occurs in an intensively managed forest, where workers visited several times a year to maintain and monitor seedlings (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 (71%) of photographs taken by camera traps were nocturnal for Bear #124 and Bear #122, while no nocturnal photos 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 signal 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 because this hunting method was reported during our study despite hunting prohibition in the study area. We found shotgun shells along the logging roads. 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 Dabhan, 1995; Bennett and Nyaoi, 2000). Conversely, we had never heard of poaching from vehicles during daytime anywhere in Sabah, at least. If poaching pressure was high on bear whose home range incorporated forest roads, nocturnal behavior may have adverse impacts to their survival.

#### 5.4. Bedding sites

Malayan sun bears used several kinds of bedding sites. The use of "tree nests" by sun bears has been reported by Fetherstonehaugh (1940), Lekagul and McNeely (1977), Piether (in Santiapillai and Santiapillai, 1996), and McConkey and Galetti (1999). However, during our study, we did not find a tree nest. Pieters (in Santiapillai and Santiapillai, 1996) suggested that stick nests are used mostly in secondary forest. Similarly, G. Fredericksson (in Meijaard, 1999) observed 14 nests in plantations and gardens and none in the forest area. McConkey and Galetti (1999) found three sun bear nests in the tree canopy in 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 may be more common in areas with significant human disturbance and safe resting places are rare (Meijaard, 1999). In addition, the presence of big cats such as tigers *Panthera tigris* and leopards *Panthera pardus* in Sumatra and the Asia Mainland, may cause sun bears to seek safer beds.

In contrast to reports of sun bears using tree nests as beds, the use of tree cavities by sun bears has not been reported. These cavities 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 *Ailuropoda melanoleuca* (Schaller et al., 1989) also utilize hollow tree cavities, not as beds, but as denning sites. We believe that these tree cavities can also be denning sites for pregnant female sun bears. On May 1999, a forest worker sighted two Malayan sun bear cubs, probably at the age of 2–3 months, emerge from a 40 m hollowed-fallen log.

## 6. Conclusion

The Malayan sun bear is the least known bear in the world and the least studied large mammal in Southeast Asia. During the 27 months of field study, we learned that Malayan sun bears have large home ranges, move considerably in search of food, and use 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 food abundance of food. Our findings 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 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, 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 high priority for government authorities, non-government organizations (NGOs), and the scientific community. This conservation program should involve the various land management agencies, law enforcement agencies, the general public, and local communities. 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.

### Acknowledgements

We thank the Economic Planning Unit of the Malaysian Federal Government, Danum Valley Management Committee, and Sabah Wildlife Department (SWD) for the permission to conduct this study in Sabah. We are grateful to N. Ahmad, A.B. Aribin, E. Bosi, C. Burhl, V.K. Chey, A.Y.C. Chung, T. Eltz, G. Fredriksson, C. Frederick, T. Graves, W. Gustafson, B. McLellan, S.K.K.S. Nathan, M.B. Ola, K.J.C. Pei, T. Radandt, H. Rahman, G. Reynolds, J. Waller, S.W. Yap, staff of SWD from Kota Kinabalu Headquarter and Sepilok Orangutan Rehabilitation Center, and all staff and researchers at Danum Valley Field Center for their help in this project. We also thank two anonymous reviewers for critical comments on an earlier version of the manuscript. Financial support was generously provided by a grant from the Barbara Delano Foundation, the Brookfield Zoo via the International Bear Association, the National Fish and Wildlife Foundation, The Oxford University Expedition to Sumatra (1998), The

Puget Sound American Association of Zookeepers (AAZK) Chapter, The Lincoln Park AAZK Chapter, Sun Bear Species Survival Plan, The Walt Disney Foundation via the American Society for the Prevention of Cruelty to Animals (ASPCA), The Wildlife Conservation Society, Houston Zoo, Garden City AAZK Chapter and The Woodland Park Zoological Gardens.

### References

- Ahmad, N., 2001. Frugivores and fruit production in primary and logged tropical rainforests. Ph.D. Thesis, Faculty of Science and Technology, University Kebangsaan Malaysia, Bangi, Malaysia, 269pp (unpublished).
- Amstrup, S.C., Beecham, J.J., 1976. Activity patterns of radio-collared black bears in Idaho. *Journal of Wildlife Management* 40, 340–348.
- Aschoff, J., 1964. Survival value of diurnal rhythms. *Symposia of Zoological Society of London* 13, 79–98.
- Ayres, L.A., Chow, L.S., Graber, D.M., 1986. Black bear activity pattern and human induced modification in Sequoia National Park. *International Conference on Bear Research and Management* 6, 151–154.
- Beier, P., McCullough, D.R., 1988. Motion-sensitive radio collars for estimating white-tailed deer activity. *Journal of Wildlife Management* 52, 11–13.
- Bennett, E.L., Dabahan, Z., 1995. Wildlife responses to disturbances in Sarawak and their implication for forest management. In: Primack, R.B., Lovejoy, T.E. (Eds.), *Ecology, Conservation, and Management of Southeast Asian Rainforest*. Yale University Press, New Haven and London, pp. 66–85.
- Bennett, E.L., Nyaoi, A.J., Sompud, J., 2000. Saving Borneo's bacon: the sustainability of hunting in Sarawak and Sabah. In: Robinson, J.G., Bennett, E.L. (Eds.), *Hunting for Sustainability in Tropical Forest*. Columbia University Press, New York, pp. 305–324.
- Caldecott, J.O., 1986. Hunting and wildlife management in Sarawak: Final report of conservation management study for hunted wildlife in Sarawak. World Wildlife Fund, Kaula Lumpur, Malaysia.
- Clevenger, A.P., Purroy, F.J., Pelton, M.R., 1990. Movement and activity patterns of European brown bear in the Cantabrian Mountain, Spain. *International Conference on Bear Research and Management* 8, 205–211.
- Cloudsley-Thompson, J.L., 1961. Rhythmic activity in animal physiology and behavior. Academic Press, New York.
- Curran, L.M., Leighton, M., 2000. Vertebrate responses to spatial temporal variation in seed production of mast-fruiting Diptero-carpaceae. *Ecological Monographs* 70, 101–128.
- Davies, G., Payne, J., 1982. A faunal survey of Sabah. IUCN/WWF Project No. 1692, WWF-Malaysia, Kuala Lumpur, Malaysia.
- Fetherstonehaugh, A.H., 1940. Some notes on Malayan bears. *The Malayan Nature Journal* 1, 15–24.
- Fredriksson, G., 1998. Monitoring the adaptation process of reintroduced sun bears (*Ursus (Helarctos) malayanus eurtspilus*), East Kalimantan, Indonesia. Tropenbos-Kalimantan Project, University of Amsterdam, 11pp (unpublished report).
- Garshelis, D.L., Pelton, M.R., 1981. Movements of black bears in the Great Smoky Mountain National Park. *Journal of Wildlife Management* 45, 912–925.
- Griffiths, M., van Schaik, C., 1993a. Camera trapping: a new tool for the study of elusive rain forest animals. *Tropical Biodiversity* 1, 131–135.
- Griffiths, M., van Schaik, C., 1993b. The impact of human traffic on the abundance and activity periods of Sumatran rain forest wildlife. *Conservation Biology* 7, 623–626.

- Hayes, S., Pelton, M., 1994. Habitat characteristics of female black dens in northwestern Arkansas. International Conference of Bear Research and Management 9, 411–418.
- Herrero, S., 1983. Social behaviour of black bear at a garbage dump in Jasper National Park. International Conference of Bear Research and Management 5, 54–70.
- Howard, W.E., Marsh, R.E., 1972. Bears and garbage. *BioScience* 22, 69.
- Hussin, M.Z., 1994. Ecological effects of selective logging in a lowland dipterocarp forest on avifauna, with special reference to frugivorous birds. Ph.D. Thesis, University Kebangsaan Malaysia, Bangi, Malaysia.
- Janzen, D.H., 1974. Tropical blackwater rivers, animals, and mast fruiting by Dipterocarpaceae. *Biotropica* 4, 69–103.
- Janzen, D.H., 1979. How to be a fig. *Annual Review of Ecology and Systematics* 10, 13–52.
- Johns, A.D., 1983a. Wildlife can live with logging. *New Science* 99, 206–211.
- Johns, A.D., 1983. Ecological effects of selective logging in a West Malaysia rain-forest. Ph.D. Thesis, University of Cambridge, Cambridge.
- Johns, A.D., 1985. Selective logging and wildlife conservation in tropical rain-forest: problems and recommendation. *Biological Conservation* 31, 355–375.
- Johns, A.D., 1988. Effects of “selective” timber extraction of rain forest structure and composition and some consequences for frugivores and folivores. *Biotropica* 20, 31–37.
- Johns, A.D., 1992. Vertebrate responses to selective logging: implication for the design of logging system. *Philosophical Transactions of the Royal Society of London Series B* 335, 437–442.
- Joshi, A.R., Garshelis, D.L., Smith, J.L.D., 1995. Home ranges of sloth bears in Nepal: implication for conservation. *Journal of Wildlife Management* 59, 204–214.
- Kasbohm, J.W., Vaughan, M.H., Kraus, J.G., 1998. Black bear home range dynamics and movement patterns during a gypsy moth infestation. *Ursus* 10, 259–267.
- Kinnaird, M.F., O'Brien, T.G., Suryadi, S., 1999. The importance of figs to Sulawesi's imperiled wildlife. *Tropical Biodiversity* 6, 5–18.
- Lekagul, B., McNeely, J.A., 1977. *Mammals of Thailand*. Kurasapha Ladprao Press, Thailand.
- Leighton, M., Leighton, D.R., 1983. Vertebrate responses to fruiting seasonally within a Bornean rain forest. In: Sutton, S.L., Whitmore, T.C., Chadwick, A.C. (Eds.), *Tropical rain forest – ecology and management*. Blackwell, Cambridge, pp. 181–196.
- Leighton, M., 1990. Seed dispersal syndromes of Bornean fruits: the dependence of plants on birds and mammals for seed dispersal and forest regeneration. A Preliminary Report on Research Results from Gunung Palung, Center for Research and development in Biology – LIPI and the Subdirectorate of Nature Conservation (PHPA), Ministry of Forestry, Indonesia.
- Li, X., Yiqing, M., Zhongxin, G., Fuyang, L., 1994. Characteristics of dens and selection of denning habitat for bears in the south Xiaoxinganling Mountain, China. International Conference on Bear Research and Management 9, 357–362.
- Marsh, C.W., 1995. Management plan (1995–2000): Danum Valley conservation area, Sabah, Malaysia. Kota Kinabalu: Yayasan Sabah/Innoprise Corporation Sdn. Bhd. Kota Kinabalu, Malaysia.
- 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 Series B* 335, 331–339.
- McConkey, K., Galetti, M., 1999. Seed dispersal by the sun bear *Helarctos malayanus* in Central Borneo. *Journal of Tropical Ecology* 15, 237–241.
- McLoughlin, P.D., Case, R.L., Gau, R.J., Ferguson, S.H., Messier, F., 1998. Annual and seasonal movement patterns of Barren-ground grizzly bears in the central Northwest Territories. *Ursus* 11, 79–86.
- Meijaard, E., 1997. The Malayan sun bear (*Helarctos malayanus*) on Borneo, with special emphasis on its conservation status in Kalimantan, Indonesia. International MOF Tropendos Kalimantan Project and the World Society of the Protection of Animal, London.
- Meijaard, E., 1999. *Ursus (Helarctos) malayanus*, the neglected Malayan sun bear. Netherland Commission for International Nature Protection, Mededelingen No. 34.
- Nielsen, E.T., 1983. Relation of behavioral activity rhythms to the changes of day and night: a revision of views. *Behaviour* 89, 147–173.
- Newbery, D.McC., Campbell, E.J.F., Lee, Y.F., Ridsdale, 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 Series B* 335, 341–356.
- Poore, D., 1989. No timber without trees: sustainability in the tropical forest. Earthscan, London, UK.
- Powell, R.A., 1987. Black bear home range overlap in North Carolina and the concept of home range applied to black bears. International Conference of Bear Research and Management 7, 235–242.
- Powell, R.A., 2000. Animal home range and territories and home range estimators. In: Boitani, L., Fuller, T.K. (Eds.), *Research Techniques in Animal Ecology – Controversies and Consequences*. Columbia University Press, New York, pp. 65–110.
- Powell, R.A., Zimmerman, J.W., Deaman, D.E., 1997. In: *Ecology and Behavior of North American Black Bears: Home Ranges, Habitat and Social Organization*. Chapman & Hall, London, 203pp.
- Reid, D., Jiang, M., Teng, Q., Qin, Z., Hu, J., 1991. Ecology of Asiatic black bear (*Ursus thibetanus*) in Sichuan, China. *Mammalia* 55, 221–237.
- Rogers, L.L., 1989. Black bears, people, and garbage dumps in Minnesota. In: Bromley, M. (Ed.), *Bear-People Conflicts: Proceedings of a Symposium on Management Strategies*, USA, pp. 43–46.
- Roth, H.U., Huber, D., 1986. Dial activity of brown bears in Plitvice Lakes National Park, Yugoslavia. *Journal of Wildlife Management* 6, 177–181.
- Santiapillai, A., Santiapillai, C., 1996. The status, distribution and conservation of the Malayan sun bear (*Helarctos malayanus*) in Indonesia. *Tiger Paper* 23, 11–16.
- Schaller, G.B., Teng, Q., Johnson, K.G., Wang, X., Shen, H., Hu, J., 1989. The feeding ecology of giant pandas and Asiatic black bears in the Tangjiahe Reserve, China. In: Gittleman, J. (Ed.), *Carnivore Behavior, Ecology, and Evolution*. Comstock Publishing Associates, Ithaca, New York, pp. 212–241.
- Servheen, C., 1993a. The sun bear. In: Stirling, I. (Ed.), *Bears, Majestic Creatures of the World*. Rodale Press, Emmaus, pp. 124–127.
- Servheen, C., 1993b. The future of bears in the wild. In: Stirling, I. (Ed.), *Bears, Majestic Creatures of the World*. Rodale Press, Emmaus, pp. 212–221.
- Servheen, C., 1999. Sun bear conservation action plan. In: Servheen, C., Herrero S., Peyton, B. (Compilers), 1999. *Bear-Status Survey and Conservation Action Plan*. IUCN, Gland, Switzerland, pp. 219–222.
- Stirling, I. (Ed.), 1993. *Bears, Majestic Creatures of the World*. Rodale Press, Emmaus.
- van Schaik, C., Griffiths, M., 1996. Activity periods of Indonesian Rain Forest Mammals. *Biotropica* 28, 105–112.
- Waddell, T.E., Brown, D.E., 1984. Exploitation of two subpopulation of black bear in an isolated mountain range. *Journal of Wildlife Management* 48, 933–938.
- Wang, X., 1988. Ecology of black bear. *Chinese Wildlife* 2, 16–17.
- Weaver, K., Pelton, M., 1994. Denning ecology of black bears in the Tensas River Basin of Louisiana. International Conference of Bear Research and Management 9, 427–433.
- White, G.C., Garrott, R.A., 1990. The analysis of wildlife radio-tracking data. Academic Press, New York.

- White, T.H., Bowman, J.L., Jacobson, H.A., Leopold, B.D., Smith, W.P., 2001. Forest management and female black bear denning. *Journal of Wildlife Management* 65, 34–40.
- Whitmore, T.C., 1984. *Tropical Rain Forest of the Far East*, second ed. Oxford University Press, Oxford, UK.
- Wilson, W.L., Johns, A.D., 1982. Diversity and abundance of selected animal species in undisturbed forest, selective logged forest and plantation in East Kalimantan, Indonesia. *Biological Conservation* 24, 205–218.
- Wilson, C.C., Wilson, W.L., 1975. The influence of selective logging on primate and some other animals in East Kalimantan. *Folia Primatologica* 23, 245–275.
- Willott, S.J., 2000. The effects of selective logging on the distribution of moths in a Bornean rainforest. In: Newbery, D.M., Clutton-Brock, T.H., Pranve, G.T. (Eds.), *Changes and Disturbance in Tropical Rainforest in South-east Asia*. Imperial College Press, London, UK, pp. 59–66.
- World Rainforest Movement, 2001. Malaysia: Exporting social and environmental impacts of oil palm monocultures. *World Rainforest Movement Bulletin* 47(June).
- Wong, S.T., 2002. The ecology of Malayan sun bears (*Helarctos malayanus*) in lowland tropical rainforest of Sabah, Malaysian Borneo. M.Sc. Thesis, Wildlife Biology Program, University of Montana, Missoula, MT, USA.
- Wong, S.T., Servheen, C., Ambu, L., 2002. Food habit of Malayan sun bears in lowland tropical forest of Borneo. *Ursus* 13, 127–136.
- Worton, B.J., 1989. Kernel methods for estimating the utilization distribution in home range studies. *Ecology* 70, 164–168.
- Worton, B.J., 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. *Journal of Wildlife Management* 59, 794–800.
- Yap, S.W., Simmons, E., Hamzani, A.M., Mosigil, G., 1996. The research programme of a large scale enrichment planting project in Ulu Segama Forest Reserve, Sabah. Paper presented for the First Seminar On Tropical Ecosystem Research in Sabah, Kota Kinabalu Park, 13–14 August, 1996.
- Yap, S.W., Simmons, E., 2000. Rainforest rehabilitation for carbon sequestration, Sabah, Malaysia. Paper presented at the Effective Advances in Forestry World-wide, Commonwealth Forestry Association Summer Meeting, Oxford Forestry Institute, UK, 19–20 May, 2000.
- Yeom, F.B.C., 1984. Lesser-known tropical wood species: how bright is their future? *UNASYLVA* 36, 3–16.