Effects of El Niño and large-scale forest fires on the ecology and conservation of Malayan sun bears (Helarctos malayanus) in East Kalimantan, Indonesian Borneo

Fredriksson, G.M.

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Chapter 3

Movements and activity patterns of female sun bears in East Kalimantan, Indonesian Borneo: implications for conservation

With David L. Garshelis
Abstract

Sun bears (*Helarctos malayanus*) in Indonesia are primarily threatened by destruction of their forest habitat, with poaching for body parts a secondary threat. Protected areas are increasingly becoming important for the conservation of this species, as non-protected forest areas are rapidly being converted to other landuses, but relevant data on spatial and habitat requirements of sun bears are limited. Radio-telemetry was used to study the movements and activity patterns of Bornean sun bears (*H. m. euryspilus*) in a small lowland rain forest reserve in East Kalimantan, Indonesian Borneo. Three wild and two rehabilitated-released female bears were fitted with motion-sensitive VHF radio-collars; three of these bears were tracked continuously for 1-3 years during 1999-2003. A total of 5,470 locations were recorded. Home range sizes (12-month period) were 4-5 km² (95% MCP and 95% fixed kernel). Home range overlap was considerable. Small home ranges may have been related to a diet composed predominantly of insects. No mast fruiting event occurred during the period of study. Activity monitoring (169 days, 4,049 hours, 24,294 readings) revealed that sun bears were predominantly diurnal and crepuscular throughout the year with activity commencing about 0.5 h before sunrise and lasting until 2.5 h after sunset, and low levels (20-30%) of activity at night. Bears were active 61.6% of the day (14.8 ± 2.3 hours), on average, with higher levels of activity associated with insect feeding than fruit feeding.

A combination of relatively small home range size, bounded entirely within the reserve, and avoidance of areas with human disturbance (trails, burned forest) suggest that small reserves are still valuable for the conservation of sun bears. Long-term persistence will depend on prevention of poaching and maintaining connectivity to other forested areas.


**Introduction**

Habitat reduction, combined with unsustainable levels of hunting, has put many bear populations at risk (Garshelis, 2009). Ursids (bears) generally have large home ranges (Garshelis 2004), often with distinct movements to seasonal ranges in response to temporal variations in the distribution and availability of food (Garshelis and Pelton 1981, Blanchard and Knight 1991, Joshi et al. 1995, Ferguson et al. 1999, Liu et al. 2002, Hwang et al. 2010, Castellanos 2011). Radio-telemetry has provided important insights into the lives of bears, and has been instrumental for obtaining data on movement patterns and habitat use (Garshelis 2004) that has been of use for management and conservation planning. Although this technology has been used for several decades to study bears in northern regions (see Garshelis 2004) only a handful of radio-telemetry studies have been carried out on bears in the tropics (Nomura et al. 2004, Wong et al. 2004, Paisley and Garshelis 2006, Hwang et al. 2010, Castellanos 2011).

The sun bear (*Helarctos malayanus*), ranging throughout much of Southeast Asia (Fig. 1), has been listed as ‘Vulnerable’ based on significant habitat loss over the last 30 years (Fredriksson et al. 2008). Southeast Asia experiences some of the highest levels of forest conversion in the world including deforestation, forest degradation and fragmentation (FAO 2010, Sodhi et al. 2010, Broich et al. 2011, Miettinen et al. 2011), and clearing for rapid expansion of the plantation sector (Koh 2007, Butler and Laurance 2008, Fitzherbert et al. 2008). Levels of threat to this bear species vary across the region with poaching for body parts being the greatest threat on mainland Southeast Asia (Dang 2006, Nea and Nong 2006, Vinitpornsawan et al. 2006), whereas habitat loss and fragmentation are currently considered the greatest threat in Indonesia and Malaysia (Tumbelaka and Fredriksson 2006, Wong 2006).

Sun bears are a forest-dependent species, found in a variety of forest types (Fredriksson et al. 2006a, Steinmetz et al. 2011) up to 2500 m above sea level (a.s.l.) and have been found to persist in logged-over (Wong et al. 2004, Meijaard et al. 2005, Linkie et al. 2007), and other disturbed forest areas (Fredriksson et al. 2006b). They have even been found to make foraging excursions into oil palm plantations (Nomura et al. 2004). Sun bears on the island of Borneo have been recognized as a subspecies, *H. m. euryspilus*, substantially (~30%) smaller than their mainland and Sumatran counterpart *H. m. malayanus* (Horsfield 1825, Meijaard 2004).

Some 45% of the extant distribution range of sun bears lies in Indonesia (IUCN Bear Specialist Group, Japan Mapping Workshop 2006), making it the single most important country for the conservation of this species. Some 24 million ha of forest are under some form of protected status on Sumatra and Kalimantan (Indonesian Borneo) (FWI/GFW 2002), although the area of forest under protection has not increased in the last decade (FAO 2011). Protected
areas are seen as one of the most effective tools for conservation in the tropics (Kramer et al. 1997, Bruner et al. 2001, Terborgh et al. 2002), despite the fact that the effectiveness of many of these protected areas is limited due to lack of, or weak, in-situ management implementation (e.g. FWI/GFW 2002, Kinnaird et al. 2003, Curran et al. 2004, Gaveau et al. 2009, Linkie et al. 2010, Harrison 2011). The conservation value of large expanses of unprotected logged-over areas in Borneo has also been highlighted (Meijaard et al. 2005, Meijaard and Sheil 2008), although many of these areas are under further threat by corporate conversion (Butler and Laurance 2008). The size of protected areas, or available safe habitat, is important for many species, especially those with large ranges (Powell et al. 1996, Beringer et al. 1998, Woodroffe and Ginsberg 1998, Woodroffe 2001, Wielgus 2002).

Figure 1. Sun bear distribution range in Southeast Asia and location of the Sungai Wain Protection Forest, East Kalimantan, Indonesian Borneo.
Movements and activity patterns of female sun bears

Lowland dipterocarp forest, richest in terms of biodiversity and previously covering large expanses of Borneo, is now becoming increasingly rare, fragmented, and affected by various forms of human disturbance (Curran et al. 2004). In order assess the spatial, ecological, and habitat requirements of sun bears in this threatened forest type in Kalimantan, we studied their ranging and activity patterns in relation to fruiting patterns and human disturbance in a small lowland forest reserve in East Kalimantan, Indonesian Borneo.

**Methods**

**Study site**

This study was carried out in a lowland dipterocarp forest, the Sungai Wain Protection Forest (SWPF), near Balikpapan, East Kalimantan, Indonesian Borneo (1° 05’ S and 116° 49’ E), at the easternmost edge of the sun bears’ distribution range (Fig. 1). The reserve covers a watercatchment area of circa 10,000 ha. Approximately 50% of the reserve was burned by forest fires in March-April 1998 (Fredriksson 2002), during one of the most severe El Niño-Southern Oscillation (ENSO) related droughts ever recorded (McPhaden 1999), leaving an unburned central core of 4,000 ha of primary forest as well as unburned forest along rivers. The geomorphology of the reserve is of eroded sedimentary formations with a relatively low elevational range (30 - 150m), intersected by many small rivers. No roads traverse the reserve and access is only by foot. One main trail leads northwards from the nearest village and forest edge following a ridge separating 2 main sub-watersheds in the reserve. Less than 2 km before this ends, the track splits with the west branch descending to a research station located in the middle of the reserve. This trail was used as the main access route to the research station, for ferrying logistical supplies to the research station twice a week by porters, as well as for varied research purposes. There was little other foot traffic on this trail.

**Fruiting phenology, and rainfall**

The most common tree families above 10 cm dbh (diameter at breast height) were Euphorbiaceae, Dipterocarpaceae, Sapotaceae and Myrtaceae. The relative dominance of Dipterocarpaceae increased substantially in the larger size classes. Together, the 25 most common species formed 40% of the total stem density (van Nieuwstadt 2002). Two phenology data sets were collected during this study, using the same methodology. Phenology studies commenced in January 1998 and continued until July 2002. Ten 0.1-ha phenology plots (100 x 10 m) were
established where all trees $\geq 10$ cm dbh were measured, labeled, and identified by botanists from the Wanariset Herbarium. The total number of live trees in the 1-ha plots at the start of the study was 549 individuals of 186 species. Every month around the same date (3rd week), all trees in these plots were observed with 10 x 40 binoculars. The relative abundance of flowers, young and mature fruits, and young and old leaves, in relation to size of the crown, was estimated, though for analysis here we only considered presence or absence of fruit. The second data set contained only trees known, or thought to be, important in the diet of the sun bear; we chose 104 trees of 11 species ($\geq 10$ cm dbh) at scattered sites throughout the forest (Fredriksson et al. 2006a). Trees in this forest undergo synchronized supra-annual flowering and fruiting (masting), providing a burst of food for sun bears (Fredriksson et al. 2006a), but no such events occurred during this portion of our study.

Daily rainfall, minimum-maximum temperature and humidity data were collected between January 1998 and October 2002, at ground level in the primary forest. Although rainfall patterns in the region are not consistent on an annual basis, a distinction could be made between a ‘wet’ season (Nov-April) and a ‘dry’ season (May-Oct) ($t=4.96$, df=6, $p=0.002$). Rainfall type falls within the category of ‘slightly seasonal’ according to Mohr’s index, with average annual rainfall $2968 \pm 510$ mm y$^{-1}$. Temperature was stable throughout the study period with average maximum of $29.7 \pm 0.7^\circ$C and minimum $23.2 \pm 0.4^\circ$C. The study area lies almost on the equator so there is little variation in the timing of sunrise ($\sim 06:00$ h) and sunset ($\sim 18:00$ h) year-round.

**Bear captures and radio-tracking**

We captured sun bears in locally-constructed barrel traps spaced 1-2 km apart. We also set Aldrich spring-activated foot snares in cubby sets (Johnson and Pelton 1980). Traps were checked daily by foot along an 8-hour trapline. Traps were baited with a variety of food items, including honey, fruits, mixtures of cow blood and fish juices, with chicken intestines finally proving the most productive lure. We trapped from October 1998 until July 2000.

We immobilized captured bears with a mixture of Zolatil (tiletamineHCl/zolazepam-HCl; Virbac, France) at 5 mg/kg, and Domitor (medetomidine hydrochloride, Orion Pharma, Espoo, Finland) at 0.027 mg/kg via a blowpipe. Bears were weighed, ear tagged, measured, and fitted with conventional VHF (very high frequency; 164-166 MHz) radio-collars (Advanced Telemetry Systems, Isanti, MN, USA). Each collar contained an activity sensor that altered the base signal of approximately 65 pulses per minute (ppm) when stationary with additional pulses (170 ppm, range 138-210 ppm) when tilted or moved. We attached radio-collars with a leather
breakaway link that was designed to drop off the bear’s neck after about 1–2 years (Garshelis and McLaughlin 1998). We administered Antisedan (atipamezole hydrochloride, Orion Pharma, Espoo, Finland) at the capture site to reverse the anesthesia, after completion of handling.

We also radio-collared two female sun bears that had been orphaned in the wild as cubs and were undergoing a rehabilitation and release programme (Fredriksson 2001); they were incorporated into this study when they started becoming independent at 1.5-2 years of age, and able to live in the forest. These bears were habituated for behavioural observations by the primary investigator and one assistant, which aided in verifying activity associated with pulses emitted by the radio-collars, telemetry accuracy, movement patterns, and provided unique insight into various other aspects of sun bear ecology. The rehabilitated bears received supplemental food (primarily fruits) in the beginning of the study, which we gradually reduced and fully discontinued by the time these bears were 2-2.5 years of age.

We located collared bears by ground-based triangulation with a hand held 2-element directional antenna (Rubber duck, Telonics Inc., Mesa, AZ, USA). Radio-locations were taken along an extensive foot-trail system (~60 km), including the main ridge trail that was used for quick movement between telemetry readings and more efficient movement between distant locations in the forest. We attempted to obtain locations of all collared bears three times a day: morning (06:00-10:00 h), midday (10:00-14:00) and late afternoon (14:00-18:00). Bearings were plotted on a 1:35,000 topographic map. We assigned a precision rating to each location based on the size of the error polygon, and discounted those where the location could not be fixed within 150 m.

**Home range and movements**

Home range sizes were calculated using 3 methods: 100% and 95% minimum convex polygons (MCP) as well as a fixed kernel probability density estimator with a band width using least squares cross validation to calculate the smoothing parameter, and using the 95% isopleth to determine area (Powell 2000). The 95% MCP were generated by discarding the 5% of points furthest from the mean location of all points used for generation of the 100% MCP (Worton 1987). MCP ranges are indicative of the total area needed to sustain the bears, including some heavily-used patches separated by gaps with little use, whereas probabilistic home range models (kernel) estimate the area actually used most of the time; the former is more useful for conservation (our purpose), whereas the latter may be more biologically relevant. In addition, MCP is less sensitive than other methods to variations in sampling intensity and lack of independence among successive radiolocations (Garshelis 1983). We calculated home range
sizes for monthly and annual (12-month) periods. For monthly range calculations we only used months with more than 15 days of location data. In order to test whether fruiting patterns and rainfall had an effect on ranging patterns we used monthly phenology data (percentage of monitored trees in fruit) and monthly ranging data calculated by 100% MCP and kernel (95%), using a stepwise linear regression.

To test whether human traffic along the ridge-trail affected sun bear movement patterns, we generated a 70% minimum convex polygon using all combined locations, and compared all bear locations within that polygon to the same number of random points within the polygon. Specifically, we compared the distribution of bear locations to random points with respect to the main trail, using a raster grid with a 20-m cell size.

To test the accuracy of our triangulated movement data, we measured real distances traveled by one of our rehabilitated bears by closely following it for several hours on different days using a Walktax Distance Measurer (Forestry Suppliers Inc, Jackson, MS, USA). This created a step-by-step track of its travel route. We then estimated the total average distance that this bear traveled in a day by expanding the sampled distance during active hours to the average number of hours of total activity per day (see below). These distance measurements were compared with distances obtained from 4 subsequent 24-hour tracking sessions where locations of this same bear were obtained by triangulation. We used ArcGis 10/ArcView spatial analyst tool (ESRI Inc, Redlands, CA, USA) to plot and measure movements. MCP and kernels were generated using Geospatial Modeling Environment (Spatial Ecology LLC).

**Activity patterns**

We quantified diel activity by listening to radio signals at 10-minute intervals for 24-hour periods, once a week for each bear during Feb 1999 - Oct 2002. We categorized signals as either active or inactive. To test whether monthly activity patterns (percentage time active for all bears pooled) were affected by monthly changes in fruiting phenology or rainfall we carried out a linear regression, using reduced major axis regression.

**Results**

**Study subjects**

We captured 3 female sun bears in barrel traps during 1,538 barrel-trapnights (513 barrel-trapnights/bear capture) over a period of 22 months. One of the rehabilitated sun bears
was also inadvertently captured in an Aldrich foot snare after 1,048 snare-trapnights. All foot snares were removed after this event and not redeployed, as the bear developed severe necrosis on the wrist after having been caught for less than 3 hours. Based on sign, we discerned that bears visited trapsites but were not captured on 66 occasions.

Two of the captured sun bears were caught on consecutive days (5-6 July, 1999), after almost one year of trapping. Both were emaciated, weighing 23-25 kg, ~35% less than two female sun bears caught at a similar time in Sabah (Malaysian Borneo) (35 and 39 kg; Nomura et al. 2004). One (Nenek) appeared to be at least 20 years old based on the extreme wear of her canine teeth and molars, and scattered white hairs covering her feet and flanks. The other (Bibi) also had worn canines but appeared to be somewhat younger (Table 1). These two females were each later found to have a cub, which we estimated to be 1-2 months and 3-4 months old, for Bibi and Nenek, respectively. Bibi was only monitored for 1 month, after which she was swallowed by a large reticulated python (Python reticulatus) (Fredriksson 2005a). Nenek was monitored for 2 months, after which she was found dead, partially scavenged by bearded pigs (Sus barbatus). Neither of the cubs was seen again but both were too small to have survived independently.

The third bear (Liar) was captured in March 2000. This female appeared in a better physical condition, both in terms of body mass (30 kg) and tooth condition. We estimated her age at 10-15 years. At the time of capture she did not appear to be lactating and no subsequent observations were made of this bear in the company of cub(s). This bear was monitored for almost 1 year (Table 1), at which time the leather breakaway link degraded and the collar dropped off.

Table 1. Identity, condition, period of monitoring and total number of locations (coordinates) obtained for 5 radio-collared female sun bears.

<table>
<thead>
<tr>
<th>Bear</th>
<th>Sex</th>
<th>Weight (in kg)</th>
<th>Physical Condition</th>
<th>Estimated Age</th>
<th>Monitoring period</th>
<th>Months monitored</th>
<th>Total number locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nenek</td>
<td>F</td>
<td>25</td>
<td>Very poor</td>
<td>Very old-20 yr+</td>
<td>5 July 1999-9 Sep 1999</td>
<td>2</td>
<td>162</td>
</tr>
<tr>
<td>Bibi</td>
<td>F</td>
<td>23</td>
<td>Very poor</td>
<td>Adult 15-20 yr</td>
<td>6 July 1999-31 July 1999</td>
<td>1</td>
<td>66</td>
</tr>
<tr>
<td>Liar</td>
<td>F</td>
<td>30</td>
<td>Fair</td>
<td>Adult 10-15 yr</td>
<td>13 March 2000-20 Feb 2001</td>
<td>11</td>
<td>877</td>
</tr>
<tr>
<td>Ganja</td>
<td>F</td>
<td>34</td>
<td>Fair (sub) adult (2-6 yr)</td>
<td>1 Nov 1998-24 April 2003</td>
<td>54 (35 A)*</td>
<td>2,579</td>
<td></td>
</tr>
<tr>
<td>Ucil</td>
<td>F</td>
<td>36</td>
<td>Fair (sub) adult (2-6 yr)</td>
<td>8 Jan 1999-8 June 2002</td>
<td>42 (27 A)*</td>
<td>1,786</td>
<td></td>
</tr>
</tbody>
</table>

* Data collected over the last 35 months (out of 54) and 27 (out of 42) months, respectively, were used for calculating activity patterns.
Table 2. Annual (12-month period) home range sizes (in km²) calculated by 100% and 95% Minimum Convex Polygon (MCP), and 95% fixed Kernel.

**Home ranges (in hectares) for 3 female sun bears with simultaneous monitoring over 12-month periods**

<table>
<thead>
<tr>
<th>Bear</th>
<th>Tracking period</th>
<th>100% MCP</th>
<th>95% MCP</th>
<th>95% Kernel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liar</td>
<td>March 2000-Feb 2001</td>
<td>12</td>
<td>762</td>
<td>449</td>
</tr>
<tr>
<td>Ganja</td>
<td>March 2000-Feb 2001</td>
<td>12</td>
<td>812</td>
<td>438</td>
</tr>
<tr>
<td>Ucil</td>
<td>March 2000-Feb 2001</td>
<td>12</td>
<td>708</td>
<td>452</td>
</tr>
<tr>
<td>average</td>
<td></td>
<td></td>
<td>760</td>
<td>445</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td>74</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bear</th>
<th>Tracking period</th>
<th>100% MCP</th>
<th>95% MCP</th>
<th>95% Kernel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ucil</td>
<td>May 2000-April 2001</td>
<td>12</td>
<td>864</td>
<td>466</td>
</tr>
<tr>
<td>Ucil</td>
<td>May 2001-April 2002</td>
<td>12</td>
<td>688</td>
<td>493</td>
</tr>
<tr>
<td>Ganja</td>
<td>May 2000-April 2001</td>
<td>12</td>
<td>825</td>
<td>478</td>
</tr>
<tr>
<td>Ganja</td>
<td>May 2001-April 2002</td>
<td>12</td>
<td>655</td>
<td>441</td>
</tr>
<tr>
<td>Ganja</td>
<td>May 2002-April 2003</td>
<td>12</td>
<td>584</td>
<td>451</td>
</tr>
<tr>
<td>average</td>
<td></td>
<td></td>
<td>723</td>
<td>466</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td>118</td>
<td>21</td>
</tr>
</tbody>
</table>

Table 3. Monthly range sizes (in km²) calculated for months with >15 days data, between July 1999-October 2002.

<table>
<thead>
<tr>
<th>Bear</th>
<th>100% MCP</th>
<th>95% MCP</th>
<th>95% Kernel</th>
<th>Days</th>
<th># mo</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nenek</td>
<td>1.6 (0.6)</td>
<td>1.2 (0.3)</td>
<td>2.2 (0.8)</td>
<td>56</td>
<td>2</td>
<td>151</td>
</tr>
<tr>
<td>Bibi</td>
<td>3.0</td>
<td>2.3</td>
<td>4.1</td>
<td>25</td>
<td>1</td>
<td>66</td>
</tr>
<tr>
<td>Liar</td>
<td>2.7 (1.0)</td>
<td>2.1 (0.9)</td>
<td>4.1 (1.5)</td>
<td>321</td>
<td>12</td>
<td>877</td>
</tr>
<tr>
<td>Ganja</td>
<td>2.9 (0.9)</td>
<td>2.2 (0.7)</td>
<td>4.5 (1.3)</td>
<td>876</td>
<td>38</td>
<td>2,281</td>
</tr>
<tr>
<td>Ucil</td>
<td>2.9 (0.9)</td>
<td>2.3 (0.8)</td>
<td>4.4 (1.4)</td>
<td>580</td>
<td>25</td>
<td>1,548</td>
</tr>
<tr>
<td>Average</td>
<td>2.8</td>
<td>2.2</td>
<td>4.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>0.9</td>
<td>0.8</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>range</td>
<td>(1.1-5.5)</td>
<td>(0.9-4.4)</td>
<td>(1.7-8.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
During the period that these bears were radio-tracked another 6-8 sun bears, judged to be different independent individuals, were encountered in the study area, including at least 4 other females with different-aged cubs (one with twins). The two rehabilitated females (Ganja and Ucil) were monitored over a period of 4.5 and 3.5 years respectively.

**Ranging patterns**

We obtained 5,470 locations for the three wild and two rehabilitated bears during July 1999-June 2002 (Table 1). We were highly successful in obtaining radio-locations of the collared bears because of access to a trail system: location data were missing for only 9 days of 437 days (2.1%) of continuous attempted daily monitoring of the three wild sun bears.

Yearly ranges were calculated for the 12-month period Mar 2000-Feb 2001, during which we collected simultaneous data for 3 female sun bears monitored over the longest period of time (Table 2). Their 12-month 100% MCP home range sizes were 7-8 km². Home ranges were only 4-5 km² when calculated with the outer 5% of locations excluded (95% MCP) or using the 95% kernel method, indicating that a sizeable portion of the range was used infrequently. Home range sizes remained consistent through time (especially 95% MCP and kernel) for the 2 rehabilitated sun bears, which were tracked in multiple years (Table 2). Ranges of these two bears, Bibi and Nenek, overlapped each other by 54 and 43%, respectively, for the short period of time (1 month) they were radio-tracked simultaneously.

Each of the five bears had monthly home range sizes (95% MCP) of 2 km² (average 2.2 ± 0.8 [SD] km²; monthly variation 0.85-4.4 km²; Table 3). Monthly range sizes were slightly larger when more trees were fruiting (linear regression with 100% MCP: \( R^2=0.079, p=0.015 \); with 95% kernel: slope=55, \( R^2=0.073, p=0.020 \)), with range size increasing with increasing number of trees in fruit. Rainfall had a minor effect on monthly ranging patterns (linear regression with 100% MCP: \( p=0.302 \); with 95% kernel: \( p=0.041 \)).

**Distribution of locations**

Fewer bear locations (317 of 3818 = 8.3%) in the 70% MCP formed by pooling all bears were within 100 m of the main trail than would have been expected from a random distribution (910 locations, 23.8%, \( \chi^2 = 507, df=1, p=0.001 \)).

Very few bear locations (n=58, 1%) were obtained in the forest area that was affected by forest fires in 1998. Some of the locations that were mapped in the burned parts of the forest could have been in unburned river corridors or in burned forest areas close to rivers, as location error and coarseness of the GIS river layer precluded differentiation on this scale.
Figure 2. Annual home ranges of three radio-collared female sun bears in the SWPF, East Kalimantan, Indonesian Borneo, during March 2000-Feb 2001. Ranges were calculated using 100% and 95% MCP, and 95% fixed kernel. Within the 95% fixed kernel border, progressively darker gradients represent 80%, 60%, 40%, 20%, an 10% contours. Ganja and Ucil were rehabilitated and released, whereas Liar was wild-caught.

From the shape of the 95% kernel (Fig. 2) generated for bear Liar it appears that she avoided entering the burned forest bordering the southwestern part of her range.

All of the radio-collared bears remained within the boundaries of the reserve during the time they were monitored. However, based on interview data and surveys along forest edge areas (Fredriksson 2005b), a number of untagged bears ventured near the forest edge.

**Daily movement**

We obtained measurements of actual distance traveled by one bear (Ganja) on 16 days (during Nov 2000-Mar 2001) that she was visually observed. On these days we observed the bear for an average of 6.5 hours (range 5-8 hours) during which she traveled an average of 2,025 ± 444 m (SD) (range 1,053-2,671 m). Based on an average of 14.8 hours activity per day, which excluded all periods of non-activity (see below), this extrapolated to 4,604 ± 888 m (SD) travelled daily. In fact, this is an under-estimate as during each day of direct observations, the bear would usually be “inactive” for some of the time, thus the “active” period in which she travelled the average 2,025 m would be obtained in less than 6.5 hour. During this active time the bear fed at a rapid rate, zigzagging between primarily invertebrate food resources. Distances measured using telemetry locations obtained 3x per day (n=604 days with locations in morning, midday, and afternoon and another location the next day) yielded a much lower estimate of 24-hour movements (1,481 ± 606 m (SD)).
Activity patterns

Activity patterns

We obtained 24-hour activity data during 169 days of monitoring (producing >24,000 readings, Table 4) over a period of 3 years (Feb 1999-Jan 2002). We were unable to categorize activity on only 42 attempts (0.2%).
Overall, female sun bears were active 14.8 ± 2.3 h (SD) per day (61.6 ± 9.4% SD, all 24-hour sessions combined, n=169). Average activity per day among four of the five bears was consistent (58–64%), with no indication that the rehabilitated bears were different than the wild bears. One wild bear (Bibi) had a higher level of activity (69%) for the 1-month that she was monitored, but this could have represented normal short-term variation.

Sun bears were distinctly more active during daylight hours (85.5 ± 4.8 % SD) than at night (37.9 ± 20.0% (SD), n=169, t=19.6, df=142, p=0.001). They tended to become active about 0.5 h before sunrise and ceased activity about 2.5 h after sunset (Fig. 3). Peaks of activity generally occurred during 07:00-09:00 and 16:00-18:00 h (Fig. 3), with diminished activity during 10:00-14:00 h. The human-habituated individuals that we visually observed frequently slept for brief periods during the hottest time of day on a fallen log or on the forest floor. When these bears were cubs (< 1 year), they spent large parts of the day resting alone in trees.

Activity levels were higher during the first 12-month period of data collection (Feb 1999-Jan 2000) than during the subsequent 2 years (average % activity = 69, 58, 57 for years 1-3, respectively; year 1 vs 2, t=6.7, df=21, p<0.001, 2-tailed; year 1 vs 3, t=5.1, df=21, p<0.001). This period of higher activity coincided with the period of lowest fruit availability, when bears were primarily foraging for invertebrates. Monthly activity decreased slightly with increased fruiting phenology, although not significantly so (R²=0.067, p=0.139). Rainfall did not seem to affect monthly activity levels (R²=0.063, p=0.151), although rain did seem to affect daily activities. Anecdotally we observed that bears occasionally sought refuge in a tree nest for several hours during persistent rainfall, whereas light rainfall after a hot dry day would trigger intense play activity among the rehabilitated bears.

Discussion

Home ranges

Our study presents the first year-round ranging and activity data of female sun bears in their range. Wong et al. (2004) presented similar data for male sun bears in northeastern Borneo. In this aseasonal lowland forest at the easternmost edge of their distribution range, where fruit resource availability is highly influenced by supra-annual community mast fruiting events, and where there is minimal seasonal variation in day length, ranges of female sun bears were relatively small, and entirely encompassed within the reserve boundaries. Home range sizes of bears are related to body size (McNab 1963, Gittleman and Harvey 1982, Gomp-
per and Gittleman 1991), metabolic needs (McNab 1983) and distribution and abundance of food (McLoughlin et al. 1999, 2000, Gompper and Gittleman 1991), resulting in large inter- and intraspecific variation. Insectivorous carnivores usually have relatively small home ranges (Gittleman and Harvey 1982) seemingly because protein-rich insect prey, especially ants and termites, are abundant and omnipresent over relatively small areas (e.g. Wood and Sands 1978, Redford 1987). As such, the sloth bear (Melursus ursinus), the most insectivorous (mymecophagus — ant and termite eating) ursid, appears to have the smallest home ranges of any species of bear. During our study, sun bears had a comparable diet to sloth bears, spending up to 90% of their foraging time consuming insects. Ants and termites are among the few food resources consistently common in lowland rainforests (Collins 1989, Kikkawa and Dwyer 1992) and sun bears rely heavily on this resource during prolonged inter-mast intervals that occur on Borneo (Wong et al. 2005, Fredriksson et al. 2006a). The female sun bears in our study had somewhat larger home ranges than female sloth bears during periods (5-12 months) when sloth bears relied predominantly on insects (Nepal \( \bar{X} = 4.7 \text{ km}^2 \) [100% MCP], Sri Lanka = 2.5 km² [fixed kernel]; Joshi et al. 1995, Ratnayeke et al. 2007). However, sloth bears significantly expanded their ranges during seasons, or in places, where fruits were common in their diet (Joshi et al. 1995, K. Yoganand, unpubl. report).

Sun bears on Borneo become much more frugivorous during rare mast fruiting events (Wong et al. 2002, 2005, Fredriksson et al. 2006a). Mast fruiting events occur 2-10 years apart (Medway 1972, Ashton et al. 1988, Curran and Leighton 2000). No mast fruiting event occurred within the period that we were radio-tracking, so we cannot assess ranging patterns during times when these bear are predominantly frugivorous. Nevertheless, we did observe a slight increase in their area of use when more trees were in fruit, suggesting that it is energetically profitable for sun bears to range farther to find fruit. Fruit trees favored by sun bears are widely scattered and found at low densities throughout this forest (Fredriksson et al. 2006a).

Yearly home range sizes (daily locations for 12-month period) for female sun bears in this study (\( \bar{X} = 5.1 \text{ km}^2 \), 95% fixed kernel) were smaller than those reported for male sun bears in Malaysian Borneo (\( \bar{X} = 14.8 \text{ km}^2 \), 95% adaptive kernel) during a period when they also fed largely on insects (Wong et al. 2004). This was true even though three of four male bears in Wong et al.’s (2004) study were tracked for <1 year and were periodically out of range of the tracking equipment. Nomura et al. (2004) also recorded smaller ranges for female than male sun bears, although home range size calculated during their study was affected by a limited number of locations and bears being frequently out of telemetry range. Ursids, in general, display large variation in home range sizes between individuals, sexes, species, and even among
populations within the same species (Garshelis 2004, 2009). Larger range size for male bears (2-5x) is a common trait seen in all bear species where range size has been studied. Typically, the ranges of adult males overlap those of several females (Koehler and Pierce 2003, Dahle and Swenson 2003, Garshelis 2004, 2009, Castellanos 2011).

No data are available yet on the effects of cub rearing on ranging patterns in sun bears. Although two emaciated female sun bears with small cubs were caught during this study, both died shortly after radio-tracking began, so our data on them are very limited. Moreover, the fact that we caught these two bears on consecutive days, after a year of unsuccessful trapping, suggested that they were in dire condition and finally succumbed to our bait. At the time when these bears were caught there had been a lack of fruits for almost 1.5 years (Fredriksson et al. 2006a). Hence, their movements may not have been indicative of healthy females with cubs.

Sun bears during this study displayed high levels of range overlap, which might have been exacerbated by potentially elevated densities due to an influx of bears from the uninhabitable burned areas. During the fires we heard frequent vocalizations (seemingly indicative of aggression), which were virtually never heard in subsequent years. Sun bear use of burned-over areas remained low for close to a decade post fires, based on repeated sign transects there (Fredriksson et al. in prep).

Both this study and the study by Wong et al. (2004) monitored only a small number of individuals in a limited geographical area. We expected home range sizes for sun bears to be relatively small due the small size of this subspecies and their predominantly insect dominated diet. It is possible that ranges of sun bears in western parts of their range (Sumatra and mainland Southeast Asia) are somewhat larger, due to more available fruit (Wich et al. 2011) and hence a higher proportion of fruit in their diet (Steinmetz et al. 2012).

Sun bears have long been considered the most arboreal species of bear (Ewer 1973), so this three-dimensional use of the forest might suggest that they would have correspondingly small home ranges. However, most of the foraging that we observed (75%) was on the forest floor, where bears found both insects and fallen fruits. This might be different during a mast-fruiting event, or in places where sun bears are more frugivorous.

**Activity patterns**

Sun bears at our study site had a clear diurnal activity pattern similar to that reported for sun bears in Sabah, approximately 700 km north of our study site (Wong et al. 2004). Daily activity rhythms and time budgets in bears have been related to seasonal changes in sunrise and sunset, weather conditions, food type and abundance, human disturbance, presence of other
bears (of the same or another species) and the bear’s sex, age and family associations (e.g., Amstrup and Beecham 1976, Garshelis and Pelton 1980, Ayers et al. 1986, Roth and Huber 1986, Clevenger et al. 1990, Reid et al. 1991, Lariviere et al. 1994, MacHutchon et al. 1998, Holm et al. 1999, MacHutchon 2001, Wagner et al. 2001, Paisley and Garshelis 2006, Hwang and Garshelis 2007). Our study area had minimal seasonal variation in day length and the sun bears showed only short-term changes in activity patterns related to rainfall.

Contrary to the strictly diurnal pattern of activity among our radio-collared bears, sun bears that raided farmers’ crops adjacent to our study site were reported to be nocturnal (Fredriksson 2005b). This is consistent with other reports indicating a switch to nocturnal behavior when sun bears were near humans. Griffiths and van Schaik (1993) reported nocturnal activity among sun bears in a forest area with human activity in Aceh, Northern Sumatra, and Nomura et al. (2004) reported that sun bears forayed into oil palm plantations in Sabah only at night. Likewise, Wong et al. (2004) found that that camera trap photos of bears showed a more crepuscular-nocturnal pattern than the telemetry data, and suggested that this was because camera traps were set in places with more human odors. Other bear species are also known to become more nocturnal in areas with high human activity (Beckmann and Berger 2003, Kaczensky et al. 2006, Schwartz et al. 2010).

Activity levels were higher during the first year of monitoring, coinciding with the latter part of a prolonged period (1.5 years) when virtually no fruit was available in the forest (Fredriksson 2006a). Sun bears at this time were feeding predominantly on invertebrate food resources. To obtain sufficient quantities of this widely available, though frequently difficult to obtain food source (i.e. termites living in hard mounds, large logs) sun bears were active for longer periods of time. During this time they would travel relatively long distances (> 4.5 km over a 24-hour period) but in a small area, zigzagging between predominantly invertebrate food resources and feeding at rapid rates, a foraging behavior described for other insectivores (Gittleman and Harvey 1982).

**Distribution of locations**

Consistent with their temporal response to humans, sun bears also showed spatial avoidance of human activity. Collared sun bears in this study tended to avoid a ridge trail used by humans during day-time. Accordingly, we conjecture that the low capture rates during this study might also have been related to an aversion to human smells and objects, as sun bears in the interior of the Sungai Wain Protection Forest have little experience with humans. Sun bears that were apparently more desensitized to human influences (close to logging operations
or near oil palm plantations) were caught more easily in similar traps (Nomura et al. 2004).

Sun bears during this study also rarely ventured into forest areas that had previously been burned. Avoidance of these areas was probably caused by a variety of factors, starting with the inaccessible nature of burned forest areas for several years post-fire event due to a thick impenetrable understory of ferns. Secondly, food availability was significantly reduced, with close to 80% mortality in sun bear fruit trees (Fredriksson et al. 2006b), as well as a significant decrease in invertebrate food resources important in the diet of sun bears (Fredriksson et al. in prep). Reduced canopy cover due to high tree mortality post-fires, lack of cover and resultant changes in the micro-climate (i.e., higher temperature) in burned forest areas might also have affected sun bear use of these areas.

**Conservation implications**

Insular Southeast Asia still suffers the one of the highest deforestation rates in the tropics (Butler and Laurance 2008, Sodhi et al. 2010), with lowland and peat swamp areas disappearing fastest (e.g. Miettinen et al. 2011). Small patches of lowland forest, considered the richest in terms of biodiversity, are now becoming the last remaining examples of this habitat, one example of which is the SWPF. This small reserve is currently one of the last protected areas with (partially) unburned coastal lowland rainforest in East Kalimantan, a forest type previously covering several million ha. Can these small reserves continue to play a role for the conservation of sun bears? Several of the results from our study indicate that they can.

The sun bears monitored in SWPF were found to have relatively small home ranges, with significant home range overlap. Sun bears here did not display seasonal movements, nor did ranges of female sun bears monitored in the center of the reserve go near the forest edge. In addition, a considerable number of (breeding) sun bears were observed in the area.

Sun bears in SWPF also tended to avoid humans, both spatially as well as temporally, a useful trait as humans pose the prime threat to this species.

Sun bear populations can thus seemingly persist, even in such small reserves; the same result was found for mainly insectivorous sloth bears, which also have small ranges (Ratnayeke et al. 2007). However, persistence of large wildlife in these small reserves strongly depends on poaching pressure (Harrison 2011). Bears may be killed for their parts, or as a result of conflicts with humans. Bears living near forest edges are attracted to crops, especially when natural food supplies are low, making border areas potential demographic sinks (Woodroffe and Ginsberg 1998). Sun bears are also a frequent by-catch in snares placed for primarily for ungulates at forest edges in Kalimantan (G. Fredriksson pers. obs.). Poaching of bears for their
body parts has been on the rise in Southeast Asia (Mills et al. 1995, Dang 2006, Shepherd and Nijman 2007, Shepherd and Shepherd 2010, Foley et al. 2011) and in several parts of mainland Southeast Asia sun bears have been hunted close to extinction, even from large protected areas (Scotson 2011).

The long-term future of sun bears living in such small reserves will also depend on the habitat matrix surrounding these areas, and their connectivity to other forest areas. The fact that sun bears are a forest dependent species, combined with their tendency to avoid human disturbance, might hamper their movement though human-dominated areas between forest patches.

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**References**


Movements and activity patterns of female sun bears


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