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
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Chapter 8

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The Malayan sun bear, *Helarctos malayanus*, is the smallest of the eight extant bear species, and is distributed throughout Southeast Asia including the large islands of Sumatra and Borneo. Research on sun bears in the wild, including those in Kalimantan (Indonesian Borneo), was non-existent before the work that is presented in this thesis commenced in 1997, in a small lowland reserve in East Kalimantan. Apart from a few anecdotal records, virtually nothing was known about basic aspects of sun bear ecology and they were listed as Data Deficient by the IUCN Red list at the time. The results of this study have filled some of the bigger gaps in our knowledge on various aspects of sun bear behaviour, ecology, and conservation.

Setting the stage: El Niño-Southern Oscillation and forest fires

The start of this research in the Sungai Wain Protection Forest (SWPF) coincided with a strong El Niño-Southern Oscillation (ENSO) episode. Global climatic cycles, such as ENSO, affect diverse ecological processes including community dynamics and landscape disturbances in tropical regions (Webster and Palmer 1997). The onset of ENSO events in Asia is marked by a reduction in rainfall, resulting in drought conditions (Walsh 1996, Walsh and Newbery 1999). Furthermore, climatic conditions associated with ENSO provide an irregular supra-annual, regional trigger which initiates asynchronous, widespread flowering in Bornean Dipterocarpaceae (Curran et al. 1999). Interestingly, a variety of other taxonomic groups flower and fruit synchronously with these dipterocarps (Appanah 1985, Sakai et al. 1999, Cannon et al. 2007). One of these rare community mast fruiting events [supra-annual production of large seed crops interspersed by irregular periods of low seed production] triggered by the 1997-98 ENSO took place at our study site towards the end of 1997 (Chapter 2).

This same ENSO event also provided the enabling conditions, through prolonged drought, for the catastrophic forest fires of 1997-98. This fire event affected circa 5 million hectares (Mha) of land in the province of East Kalimantan (Indonesian Borneo) alone, including 2.6Mha of forest (Hoffmann et al. 1999, Siegert et al. 2001). In March 1998, fires burned half of the forest in the reserve where this research project had started. Between 1997-2006, a total of 16.2 Mha of Borneo’s landmass (21% of total land surface area) was affected by fires (Langner and Siegert 2009). Habitat degradation due to large-scale forest fires, combined with a prolonged fruiting low after the ENSO event, put large strains on the sun bear population in the area.
Sun bear responses to large-scale fluctuations in food availability

Sun bears, like most bear species, are omnivores. During rare mast-fruiting events in East Kalimantan, sun bears opportunistically switched their diet to become frugivores (Chapter 2). During these short periods, when calorie-rich fruits are available, sun bears gorged themselves on large quantities of large-seeded fruits, for which they are effective seed dispersers (McConkey and Galetti 1999, Chapter 2). In SWPF this brief glut only lasted two months, followed by almost four years with very little fruit available (Chapter 2). This fruiting low was probably caused by exhausted energy reserves after the mast fruiting event (van Schaik 1986, Sork et al. 1993), but might have been aggravated by disrupted phenologies after the prolonged El Niño drought (Harrison 2000, 2001).

The extent of frugivory in sun bears will vary considerably throughout their distribution range as patterns of fruit production differ substantially among tropical forests (van Schaik et al. 1993, Wich and van Schaik 2000, Clark et al. 2001, Cannon et al. 2007). Bornean forests, despite their food-rich appearance, display a significantly lower productivity than Sumatran forests (Wich et al. 2011). Fruit productivity is generally thought to set carrying capacity for rainforest vertebrates, which in turn may affect plant life history, seed dispersal, and vertebrate population dynamics (Janzen 1974, Curran and Leighton 2000, Wich et al. 2004).

During the prolonged inter-mast period, sun bears shifted their diet to insects, primarily termites and ants, complemented by a large variety of other saproxylic insects like beetle grubs, cockroaches, and adult beetles. Although food resources in lowland tropical forests in general are considered to be widely scattered and scarce, termites and ants are found to be relatively abundant (Collins 1980, Kikkawa and Dwyer 1992). However, a large amount of energy is expended in obtaining these small quantities of food.

A small number of plant taxa were still producing fruit during the inter-mast period, some of which were highly sought after by sun bears (Chapter 2). Sun bear ranging patterns during these inter-mast periods were influenced by the number of trees in fruit, with bears ranging over larger areas in search for these widely dispersed but highly sought after fruit resources (Chapter 3).

Female bears captured in the unburned forest core, 16 months after the fire event and well into the inter-mast period, showed signs of serious undernourishment and weighed 30-40% less than female bears caught simultaneously 700 km to the north in the Tabin Reserve, Sabah, Malaysian Borneo. Bears at Tabin were found to be foraging on oil palm fruits in plantations adjacent to the reserve (Nomura et al. 2004) during this period of fruit scarcity. At my study
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Site, few external food resources were available for bears, except for bears living near the forest edge, some of which were augmenting their diet with fruits grown in orchards neighbouring the forest edge (Chapter 5). The emaciated appearance of the female sun bears caught in SWPF, without access to additional food supplies, suggests that prolonged survival solely on insect resources was insufficient and that energy requirements were not met. Increased competition due to immigration of displaced bears from the fires might have been an additional strain factor. The predation of one of the bears by a large python might have been related to the poor nutritional condition of the bear, which might have rendered the bear less effective in fighting off an attack or having a lowered vigilance (Chapter 6).

Simultaneous to the period of fruit scarcity in SWPF, a prolonged fruiting low was also reported from the Danum Valley Conservation Area in Sabah, Malaysian Borneo: emaciated bears and bearded pigs (Sus barbatus) were encountered at the same time in primary forest there (Wong et al. 2005). In Danum, bears also had no access to human-related food resources like oil palm fruits, unlike bears living near the forest edges in Tabin Reserve (Nomura et al. 2004). Curran and Leighton (2000) reported on emaciated and dead pigs after a prolonged fruiting low during the same inter-mast period in West Kalimantan, further indicating that this famine was possibly an island-wide occurrence. They speculated that the length of the inter-mast cycle was long enough to suppress populations of bearded pigs, with piglets only seen during mast fruiting events. Survival during periods of fruit scarcity is viewed as the critical determinant of frugivore vertebrate densities in Southeast Asian forests (van Schaik et al. 1993). Famine following fruiting failures has also been reported from other parts of the world. Following a year of extremely low fruit production, mass mortality of Japanese macaques was reported by Hanya et al. (2004), when 56% of individual primates of several well-studied groups died. They hypothesized that the shortage of high-quality foods caused poor nutritional conditions for the primates, making them highly vulnerable to diseases, with death as the ultimate result. Wright et al. (1999) reported that on Barro Colorado Island, Panama, over a period of 49-years, four episodes of famine occurred every time an El Niño event was followed by a mild dry season with very low fruit production.

Reproductive behavior of Bornean sun bears has been found to be aseasonal and polyestrous (Schwarzenberger et al. 2004, Frederick et al. 2012). These breeding habits of sun bears might be an adaptation to the unpredictable availability of fruit, both in space and time, allowing female sun bears to come back into estrous soon after having lost a cub. In SWPF female sun bears were observed throughout the period of extreme fruit low as well as during mast fruiting events with small cubs. Two undernourished female sun bears caught during the peak of fruit
scarcity in SWPF for telemetry studies, both had small cubs. However, both female bears died subsequently leaving the fate of the cubs unknown. This indicates that these bears were still able to find sufficient food resources to give birth, but it seems that the extreme food scarcity following the ENSO event and fires, and possibly competition for food, meant that there was insufficient food to sustain both lactation and maintenance of themselves. For American black bears, which are seasonal breeders, a clear link between mast fruiting failure and a subsequent decline in reproduction has been shown in several regions (Jonkel and Cowen 1970, Elowe and Dodge 1989, Costello et al. 2003).

**Impacts of fire on sun bear populations**

The fires in 1998 burned 40% of SWPF in six weeks, depriving the sun bears living there of their habitat. Forest fires had a destructive effect on the main sun bear food resources (tree-borne fruits and social insects), with a decrease of > 80% in the density of sun bear fruit trees (Chapter 4), as well as a significant reduction of densities of above- and underground termite nests. Besides a decrease in food resources, reduced canopy cover due to high post-fire tree mortality caused large changes in the micro-climate of the burned forest areas. Temperatures during daytime were several degrees higher than in unburned forest, and a smothering thicket of ferns dominated the understory in once burned areas (Slik and Eichhorn 2003), creating a physical barrier for large ground-dwelling mammals.

While it is possible that some bears could have become trapped and burned, there are a number of possibilities as to what happened to bears displaced from burned forest areas. During the period of active fires, a high rate of sun bear roaring calls were heard near the fire front indicating an increase in antagonistic encounters between bears, suggesting that bears were displaced by fires and moved into home ranges of bears living in unburned forest. It is possible that some bears subsequently were able to fit into the remaining unburned forest, thus increasing densities of bears in the central core of the reserve. Sign transects, developed in order to monitor relative abundance of sun bears (Chapter 7), only commenced after the fire event and hence any increase in sign densities that would have occurred could not be detected. The diffuse but abundant distribution of termites and ants, the main inter-mast food resource, as opposed to highly sought after but low density fruit resources, might have allowed bears from burned areas to fit into the homeranges of resident bears in unburned forest.

Crop-raiding activity increased in gardens adjacent to the forest edge after the forest fires (Chapter 5), suggesting that bears were being displaced either from the core remaining forest or from burned areas. In response to the crop-raiding certain farmers laid out poisoned
baits and snares, and it is possible that bears were killed due to this increased encounter rate with humans. Another possibility is that certain bears survived in unburned forest islands within the burned forest matrix. Between 7-18% of the burned forest remained unscathed by the fires as unburned patches, primarily near rivers or swamps (van Nieuwstadt 2002, Fredriksson and Nijman 2004). The use of such unburned patches and avoidance of burned areas has also been reported for black bears in Arizona after fires (Cunningham et al. 2003).

**Ranging and Activity**

Annual ranging patterns for female sun bears measured during this study were 4-5 km\(^2\) (Chapter 3), with ranging patterns of collared bears entirely encompassed within the reserve boundaries. Home range sizes of bears are related to body size (McNab 1963, Gittleman and Harvey 1982, Gompper 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 ursid, appears to have the smallest home ranges of any species of bear (Ratnayake et al. 2007). During our study, sun bears had a comparable diet to sloth bears, spending up to 90% of their foraging time consuming insects. It is possible that ranging patterns were slightly enlarged during the inter-mast period due to the bears searching over a wider area for the few available, scattered fruit trees, as opposed to smaller ranging patterns which would have been expected on a predominantly insect diet (Gittleman and Harvey 1982).

Sun bears were found to display diurnal activity patterns within the SWPF (Chapter 3), although more nocturnal behavior was reported for bears living near the forest edges (Chapter 5). Consistent with their temporal response to humans, sun bears living in the core of the reserve also showed spatial avoidance of human activity. 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).

**Re-colonization of burned forest areas**

Our comparison of sun bear sign densities between adjacent unburned and burned areas showed that sun bears are slowly re-colonizing these once-burned areas, although they did not yet recover to pre-fire levels after more than a decade of forest regeneration. Sign
densities increased from close to zero 2 years after the fire event, to 65% of that encountered in adjacent unburned forest habitat 12 years after the fire event. Sign densities in unburned forest remained relatively stable (44.1 ± 16.1 (SD) sign/ha) over the decade of monitoring (Chapter 7).

In burned forest areas, claw marks and dug up underground termite nests dominated sign density, but density of foraging sign of aboveground termite nests was still very low 12 years after the fire event. Densities of active epigal nests were still 60% lower than in adjacent unburned forest, indicating that recovery of aboveground termite species after fire disturbance is a slow process. Jones et al. (2003) reported the collapse of termite assemblages along a disturbance gradient in Sumatra related to changes in forest canopies, which normally buffer the forest interior from extreme variations in microclimate. Temperature, relative humidity, wind speed and solar radiation at ground level are all highly sensitive to changes in canopy depth and structure (Chen et al. 1999). In burned forest areas the buffering capacity of the canopy was much reduced as almost 80% of trees (>10 cm DBH) died after the fire event (van Nieuwstadt 2002, Chapter 4). Gathorne-Hardy et al. (2002) hypothesized that termite recovery after heavy disturbance might take 60 years, if source populations of forest termites are found nearby.

Temporal changes in regeneration of the forest and re-colonization by sun bears in SWPF are still in flux, which emphasizes the importance of long-term studies. Had this study been carried out only within the first 4 years post-fires, the conclusion would have been that there was virtually no use of the burned areas by sun bears. While true at the time, this would not have documented the potential value of these areas for re-colonization.

**Conservation implications**

Few studies so far have looked at the recovery of large mammals after forest fires in Indonesia (O’Brien et al. 2003) despite the immense scale of the impacted area. The re-colonization of sun bears into these once-burned forest areas implies that these can still be important for sun bear conservation, if there is undisturbed forest nearby that supports a source population. Sun bears are known to persist in logged-over areas (Wong et al. 2004, Linkie et al. 2007), but fire causes much more severe damage to forest integrity than selective logging (Slik et al. 2002). Most sun bear fruit resources are tree-borne (versus shrubs or understory plants) and regeneration of this food resource after a fire probably takes several decades, if not longer.

Primary rainforest in Indonesia can rapidly be converted to savanna grasslands if affected by repeated fires (Goldammer 1999). Fire-return intervals of less than 90 years can eliminate rainforest species, whereas intervals of less than 20 years may eradicate trees entirely.
Cochrane et al. 1999). Many of these fire-disturbed areas have seen further fire damage during smaller drought events in subsequent years (2002, 2004), or have been converted to other uses altogether. Dennis and Colfer (2006) calculated that 70% of forest initially damaged by fire and drought during the 1982–83 El Niño event was classified as non-forest by 2000, following a degradation pathway driven by successive government policies starting with commercial logging, followed by government sponsored transmigration schemes, then by timber and oil palm plantations and, finally, the devastating fires of 1998. A similar, though faster, trajectory of conversion of degraded forests to plantations or wasteland was evident for many fire-affected forest areas after 1997-1998 (Fuller et al. 2004, Miettinen et al. 2011).

Thus remaining sun bear habitat has become increasingly fragmented, impairing post-fire immigration of bears from other habitat blocks. Recovery of populations in forest areas disturbed by severe ecological catastrophes, such as the combined effects of fires, fragmentation and fruiting failure discussed in this thesis, will now in many cases have to rely on recruitment from within remaining patches of less-disturbed habitat. Unfortunately, with the current minimal capacity to prevent or control forest fires in Indonesia, it seems unlikely in the near future that fire threat to forest areas will be reduced.

**Importance of monitoring population trends in the face of increasing conservation threats**

Sun bears are now listed as Vulnerable on the IUCN Red List (Fredriksson et al. 2008). Poaching for bears and their body parts is reaching alarming rates in mainland Southeast Asia (Foley et al. 2011). Although current poaching rates are lower in Sumatra and Borneo, where the main threat to sun bear populations comes from habitat loss, it is probable that the continuing economic growth in the primary markets for bear products, namely China, will lead to increased poaching in Indonesia, particularly as mainland populations become increasingly depleted. In this scenario, the track record of the conservation institutions in Indonesia responsible for species protection and control of wildlife trade does not provide much reassurance that they would be able to mitigate this threat.

Monitoring of sun bear population trends in key conservation areas will become the next imperative. Results from our research show that changes in sun bear relative abundance can be monitored using relatively simple and inexpensive sign surveys. At the moment, six medium sized to large (1,000-10,000 km²) protected areas have been designated in Kalimantan, still consisting of good quality habitat. Kalimantan still holds the largest contiguous expanse of forest in the Indo-Malayan realm, primarily in the mountainous interior of the island. These
remote, inaccessible, large protected areas provide the most secure future prospect for sun bears and other wildlife. Indonesia, with its remaining forests on Sumatra and Kalimantan, currently covers some 45% of the sun bears distribution range, making it the most important country for the conservation of this bear species.

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