CHAPTER II

FOOD HABITS OF MALAYAN SUN BEAR IN LOWLAND TROPICAL FORESTS OF BORNEO

ABSTRACT

Food habits of Malayan sun bears (*Helarctos malayanus*) in the Ulu Segama Forest Reserve, Sabah, Malaysia were studied from 1998-2000 by analyzing scats, examining feeding sites, and making direct observations. Invertebrates such as termites (Isoptera), beetles (Coleoptera), and beetle larvae (Coleoptera), were the predominant food items with 57% frequency of occurrence in scat samples. Figs (*Ficus* sp.) were the most common fruit consumed (61% frequency of occurrence) during the non mast fruiting season. Vertebrates were also consumed but less commonly. Most feeding sites (60%) were in decaying wood, where sun bears foraged for termites, beetles, and beetle larvae. Tree cavities with bee nests and decaying standing stumps were also recorded as feeding sites. We conclude that sun bears are opportunistic omnivores consuming a wide variety of food items.

Key words: sun bear, food habits, Malaysia, Sabah, *Helarctos malayanus*, tropical forest, Borneo

INTRODUCTION

The Malayan sun bear (*Helarctos malayanus*) is the smallest of the eight bear species. It remains the least known bear species in the world. Even basic biology such as food habits, home range size, and reproductive biology is unknown. Until recently, very little research has been devoted to investigating sun bear ecology, and there have been no organized surveys of its distribution and population densities (Meijaard 1997). The lack of biological information on the sun bear serious limits conservation efforts (Servheen 1999). Basic research on sun bears should be a high priority for bear biologists.

Food habits of Malayan sun bears are poorly documented, but have been briefly described by many authors (Shelford 1916; Bank 1931; Lekagul and McNeely 1977; Medway 1978; Tweedie 1978; Davies and Payne 1982; Payne *et al*. 1985; Domico 1988; Nowak 1991; Servheen 1993; MacKinnon *et al*. 1996; Kanchanasakha *et al*. 1998; Lim 1998; Sheng *et al.* 1998; Yasuma and Andau 2000; Fredriksson 2001). Their diet is described as bee nests, termites, earthworms, small rodents, small birds, lizards, animal carcasses, fruits, and the 'heart' of coconut palms. Documentation of sun bears as seed dispersers by Leighton (1990), and McConkey and Galetti (1999), were the only two scientific reports published to date regarding food habits.

We present data on food habits of Malayan sun bears in Ulu Segama Forest Reserve, Sabah. Data were collected during a three-year field study designed to gain basic information on the biology and ecology of the sun bear.

STUDY AREA

The study was conducted between May 1998 and December 2000 at the Ulu Segama Forest Reserve situated on the eastern side of the Malaysian state of Sabah, island of Borneo (Figure 1) (4^{o}57'40"N, 117^{o}48'00''E, 100-1200 m elevation). The reserve encompasses both selectively logged forest conceded to the Sabah Foundation on a 100-year timber license, and primary forest including the 43,800 ha Danum Valley Conservation Area (Marsh and Greer 1992). Lowland, evergreen dipterocarp forest comprises about 91% of the conservation area and the remaining area is lower montane forest (Marsh and Greer 1992). Lower montane forest extends from 750-1500 m and differs from lowland rainforest in having a lower canopy, with fewer, smaller emergent trees (Whitmore 1984). Approximately 88% of the total volume of large trees in the conservation area are dipterocarps (Marsh and Greer 1992).

The conservation area is surrounded by approximately one million hectares of selectively logged forest. Logging follows the monocyclic Unit System (MUS) (Poore 1989) with a 60-year rotation, in which all saleable timber is logged during the first cut and natural regeneration takes place thereafter. Both conventional tractor logging and cable yarding or highlead techniques are used on moderate terrain and on steeper slopes. Timber extraction rates have ranged from 73-166 m^3/hectare since the 1960s (Marsh & Greer 1992). If compared to other selectively logged forests in Southeast Asia, these logged forests can be considered as “good quality” logged forest because of rapid forest regeneration and reduced human disturbance after logging is complete. Many large mammals are present in the study area such as clouded leopards (*Neofelis nebulosa*), Asian elephants (*Elaphus maximus*), and orangutans (*Pongo pygmaeus*). Soils in the reserve include ultisols, inceptisols and alfisols (Marsh and Greer 1992; Newbery *et al*. 1992).

The climate of Ulu Segama Forest Reserve is weakly influenced by two monsoons (Marsh and Greer 1992). Annual rainfall at Danum Valley Field Center (located within Ulu Segama Forest Reserve and the center of the field effort) averages 2700 mm (unpubl. station records 1986-2000), with the wettest period between November and March, and the dry period between July and September. Mean daily temperature at the field center during 1999-2000 was 26.7^{o} C.

The study was concentrated in approximately 15,000 ha of both logged and unlogged forest adjacent to the Danum Valley Field Center. Primary forest existed in the conservation area and the water catchment area of the field center. Logged forest surrounded this conservation area and consisted of different logging coupes or cutting units, from which timber was extracted between 1981 and 1991.

METHODS

Sun bears were captured in culvert traps as per the methods described in Jonkel (1993). Trapping operations started on February 24, 1999 and ended on December 11, 2000. Trapping success was extremely low (1 bear / 396 trap nights) probably due to low density of sun bears in the study area and their wariness of entering traps. Monitoring and tracking of the bears' activity and movement began soon after bears were released. Bears were fitted with MOD-400 radio-collar transmitters (Telonics, Inc., Mesa, AZ, U.S.A.). We located radioed bears using standard methods of ground-based triangulation (White and Garrott 1990). Each location was taken from at least 2 directional fixes at approximately 90-degree angles from the bear's position within 30 minutes, or was simultaneously taken by 2 people in 2-way radio contact. Bear locations were visited within 2-4 hours after coordinates were taken. Radioed bears were located daily using ground triangulation. A total of 343 locations of five radioed bears were collected in the study. Bears were also tracked on foot when possible at a distance so as not to disturb the bear but to visit locations of activity soon after the bear left an activity site. At each activity site, we looked for any feeding evidence, such as bear scats, feeding sites, or claw marks on trees. Thirty-two bear encounters in the forest within 300 m of triangulated radio locations reinforced our confidence in tracking accuracy. In 8 cases, bears were observed feeding and foraging.

Scats were collected on the forest floor at radiolocation sites, when tracking radioed bears, and by chance. Bear scats usually do not remain in the field for a long period due to the moist and soft texture of bear scats that causes the scat to dissolve in the frequent heavy rain, and the efficiency of dung beetles (Order Coleoptera, Fam. Scarabaeidae) that find and utilize feces in a short time. Thus, we believe that collected scats were usually very fresh (< 24 hours old). A possible exception is scats containing mostly figs (*Ficus* spp.), which are not commonly attractive to dung beetles.

We also collected feeding evidence and scats from non-radioed bears when possible. Some bears were known to feed at the Danum garbage dump during the study period. To avoid reporting food habits results from such garbage dump use, human-related food items such as rice, pumpkin or watermelon seeds, chicken bones, or garbage items were eliminated from scats prior to analysis. Four of 56 scats (7%) had some evidence of human-related foods.

Collected scats were placed in plastic bags and frozen before laboratory analysis. Scats were weighed wet, and then oven dried for 24 hours at 70^0 C and reweighed. Dried scats were then soaked in water for 1-3 hours, washed through 0.7 and 0.3 mm-mesh sieves, and dried again in an oven for 24 hours at 70^0 C. Dried materials from scat samples were sorted by using either a hand lens or a binocular dissecting scope (2x ~8x). Taxonomic classes of organisms (e.g. termites, ants, beetles) were sorted and grouped for further identification. Many scats were contaminated with items such as live ants, live dung beetles, live maggots, and dead leaves and twigs (sometimes attached to scat samples when collected from the forest floor). These materials were removed from the scat samples during analysis. Other items such as bear hair were not included in the analysis.

We present results of scat analysis as frequency of occurrence of an item within all samples. Frequency of occurrence is defined as the total number of times a specific food item appeared in a scat sample. “Percent frequency of occurrence” defines the total number of times a specific food item appeared in scats of the sample group divided by total number of scats collected. We did not analyze food habits by season or month due to limited sample size. However, seasonal data are presented on Table 1 for reference. 53 of the 56 scat samples were collected between May 2000 and December

2000 from Bear #122 and Bear #120. We did not compare the results between these two bears due to limits on sample size and non-random scat collection.

We attempted to get as close as possible to radioed bears but not to disturb them while tracking them in the forest. Nevertheless, it was extremely difficult to get close to these bears. In addition, the density of undergrowth in the study made it impossible to observe radioed bears from a long distance. Visual sightings of radioed bears occurred on rare occasions when bears failed to detect our presence within 2 to 20 m on the ground (n=13), or a greater distance (> 30 m) (n=4) when bears were resting or feeding in trees. After the bear left the feeding site, we looked for uneaten food items, examined the feeding site for possible foods, and collected samples. A sample unit was considered a feeding episode, which we defined as a site where a bear was feeding (i.e., decayed wood in a log, where a termite nest was found, or below a fruiting tree).

Only confirmed feeding sites known to be from a sun bear were recorded. Other mammals (e.g., bearded pig [*Sus barbatus*], pangolin [*Manis javanica*], and Malay badger [*Mydaus javanensis*]) were also known to create similar feeding evidence when they fed on termites, earthworms, and other invertebrates from decayed wood or soil (Payne *et al*. 1985; Yasuma and Andau 2000). To ensure that feeding sites were indeed sun bear feeding sites, we recorded only very fresh feeding sites where radioed bears were close by, or where we found bear claw marks and sun bear tracks. At such feeding sites, we also collected uneaten food items for identification .

Malayan sun bears are well known for their arboreal behavior. They climb trees in order to harvest ripe fruit and bee nests, to seek shelter, and to escape danger (Payne *et al*. 1985; Lim 1998; Yasuma and Andau 2000). At such trees, they leave distinct claw marks on the tree. This tree-climbing behavior provided us indirect evidence of sun bear feeding behavior. When we came across trees with sun bear claw marks, we attempted to identify tree species, recorded fruiting condition of the tree, and tree height and size.

RESULTS

Analysis of scats - Six Malayan sun bears (5 males and 1 females) were captured between June 1999 and October 2000 (Table 2). Fifty-six scats were collected from June 1999 to December 2000 during 760 field days (1 scat / 13.6 days). Scat collection was most successful during November 2000 (n=29), moderately successful during July, August, September 2000, and least successful during the rest of the time. Scat searching effort was the same each month except from November 1999 to April 2000 when there was no radioed bear in the study. Table 1 summarizes the monthly frequency of occurrence of food items found in Malayan sun bear scats. The average scat weight was 329 g (range 73 -1,119 g). Malayan sun bears were omnivorous, consuming both animal and plant items. Animal food consisted of 13 genera of termites (Isoptera), 8 families of beetles (Coleoptera), one genus of stingless bee (Apidae), two genera of ants (Formicidae), one genus of wasp (Vespidae), three other orders of insects, two other classes of arthropods, and small amount of reptiles, birds, and small mammals (Appendix 1). Among termite genera found in sun bear scats*, Bulbitermes, Coptotermes, Dicuspiditermes, Nasutitermes*, and *Schedorhinotermes* had > 37% of occurrence rate in the scat samples collected (Table 3). *Bulbitermes* and *Nasutitermes* (both wood-feeding Nasutitermitinae) had the highest above ground biomass densities at the study area (Eggleton *et al*. 2000). Plant food items mainly consisted of figs, 4 known species of fruits, and at least 14 species of unknown fruits (Appendix 1). Ten percent of scats contained only one food item, 23% contained 2 food items, and the remainder contained multiple food items. Among different major types of foods, invertebrates had the highest frequency of occurrence (57%), followed by plant origin food items (29%), and vertebrates (11%).

Beetles were the most common food and the most common invertebrates in the scat samples. Overall, 63% of the scat samples collected contained beetles, 56% contained beetle larvae, 50% termites, and 25% ants. Other invertebrates found in scats included bees and wasps (10%), forest cockroaches (6%), and scorpions (<5%) (Table 4). Figs were the second most important food item accounting for 61% of frequency of occurrence. Other fruits found in scats but with lower frequencies included *Santiria* spp. (Burceraceae), *Polyalthia sumatrana* (Annonaceae), and *Lithocarpus* spp. (Fagaceae). Vertebrate food items were uncommon (11% of scats). Vertebrates included Burmese brown tortoise (*Manouria emys*), pheasants, reptiles, birds, eggs, and fish.

Analysis of feeding sites - We found 82 confirmed sun bear feeding sites from June 1999 to December 2000. All feeding sites were very fresh, which we estimated within a few hours to a day old. Seven types of sun bear feeding sites were found in the study area: 1) decayed standing tree stumps (usually with broken tops), 2) decayed wood or decayed logs on forest floor, 3) fruiting trees, 4) underground termite nests, 5) many different kinds of termite mounds, 6) tree cavities with bee nests, and 7) tree root cavity (Figure 2). Decayed wood was the most common feeding site recorded (n=49). Other types of feeding sites were less common with 1 to 10 sites found (Figure 2).

A total of 105 food items were collected from these 82 feeding sites. The most common food items collected were termites (48%). Earthworms and beetle larvae (both 14%), bees (10%), beetles (7%), figs (3%) and other invertebrates were less common (3%).

Foraging observations – We made 32 direct observations of radioed bears during the entire study; 8 of which were feeding observations. We observed feeding on termites from termite mounds on three occasions. We twice saw sun bears breaking open decayed wood, in search of termites, beetle larvae, and earthworms. On two occasions, Bear #122 was observed harvesting figs from fruiting fig trees. On 6 August 2000, Bear

#122 was found feeding on a Burmese brown tortoise carcass inside a tree cavity for several minutes. These observations lasted a few seconds to a few minutes, but on one rare occasion, radioed bears were observed up to 45 minutes without noticing the presence of field crews.

On 10 June 2000, STW observed Bear #122 resting on a tree branch of a large mengaris tree (*Koompassia excelsa*) about 50 m above the ground. He was lying with his belly on the tree branch, with all legs hanging down. The mengaris tree was a host tree for a strangling fig tree (*Ficus* sp.) with many fruits. He was observed resting for 40 minutes. He then climbed down to another smaller branch opposite the previous branch to eat figs. He used his right paw to reach the end branches of the fig tree and to bring the figs into his mouth. Figs were consumed as whole fruits. He continued feeding on figs for another 5 min, until the observer was forced to leave the scene when a female orangutan with infant began throwing twigs at him. Other frugivores, such as a binturong (*Arctictis binturong*) with its young, two helmeted hornbills (*Buceros vigil*) and many other birds, were also seen feeding at the same fruiting fig tree at the same time.

On 10 October 2000, STW observed Bear #122 feeding for 1 minute on 2 termite mounds of *Dicuspiditermes sp.* in a secondary forest with very dense undergrowth. The bear used its claws and teeth to break the standing termite mound into a few pieces and quickly licked and sucked the contents from the exposed mound. He later sat down on the ground with his body straight up, and held one of the broken mounds with his front paws and licked the termites from the surface of the mounds. Figure 3 shows a bear feeding at similar termites mound with similar posture. After the bear left the area, we found many termite eggs, alates (winged reproductive stages), and a few soldiers at the feeding site.

Trees with bear claw mark- Of 190 trees with sun bear claw marks, 69 trees were climbed repeatedly, as indicated by healed scars and overlapping claw marks on tree bark. This suggested that sun bears are attracted to certain resources from these trees, such as fruits, bee nests, or bedding sites. From 91 trees we were able to identify, *Lithocarpus* spp. (33 trees) and *Ficus* spp. (13 trees) were the two most frequently climbed (Table 5). Except for *Shorea* spp., the first six tree genera listed in Table 5 have fruits that may be important food for sun bears, especially acorns and figs produced by *Lithocarpus* spp. and *Ficus* spp., respectively. In addition, we found 10 trees with bear claw marks that had a tree cavity (probably containing bee nests) with a shattered entrance. Large dipterocarps, such as *Shorea* spp. provide comfortable and safe bedding sites for sun bears, rather than offering fruits. On 14 June 2000 at 1000, STW observed Bear #122 roosting on the first branch of a *Shorea johorensis*, about 30 m above the ground, for 20 minutes. The tree was about 50 m from a busy logging road, and measured 40 m in height and 156 cm DBH. Bear #122 was laying on the branch, with his four legs hanging down. He lifted his head occasionally to observe passing vehicles without paying much attention to them.

DISCUSSION

Food items of Malayan sun bear reported in this study (Appendix 1) are limited and represent a small proportion of the total diet eaten by wild sun bears. Fredriksson (2001) reported that Malayan sun bears have been recorded to feed on more than 50 plant species and more than 100 species of insects in the Sugai Wain Protection Forest, East Kalimantan, Indonesian Borneo. Low numbers of food items presented here were due to the small sample size of bear scats collected and limited number of feeding observations. Low numbers of fruit items in sun bear diets were probably due to the lack of a normal mass fruiting season during the study period (Chapter 4).

Figs are a keystone resource for tropical frugivorous species, especially birds, primates, and bats (Janzen 1979; Leighton and Leighton 1983; Kalko *et al*. 1996;

Kinnaird *et al*. 1999). In this study, figs were the most important fruit eaten by Malayan sun bears. Although we were aware of the possible over-estimate of the importance of figs in sun bear diets that resulted from non-random scat collection (many scats were collected under fruiting fig trees, and 17 scat samples were collected around a bear roosting site on 7 November 2000), the importance of figs could be seen from the relative amount of figs that a bear consumed. Four bear scats with fig seeds collected in the study contained 30, 47, 64, and 84 countable buds of figs. This indicated that bears were able to consume figs in large amounts. Additional evidence that sun bears could consume figs in large amounts at one time came from the amount of scat with fig seeds collected (wet weight=1.43 kg) inside a trap, where an adult female bear (Bear #121, body weight =20 kg) was caught in this study. The scats collected in the trap represent > 7% of the bear's body weight. Two direct observations of sun bears feeding on fig trees and bear claw marks on fig trees (Table 5) provide direct and indirect evidence of sun bear feeding on figs. Leighton (1990) showed a photograph of "a sun bear resting in a *Ficus dubia* tree, after eating the large dark red-purple figs" (Leighton 1990, p 23). The importance of figs in diets of sun bears is poorly documented. Only Leighton (1990), and McConkey and Galetti (1999) report sun bears feeding on figs. Spectacled bears (*Tremarctos ornatus*) in Peru, and sloth bears (*Melursus ursinus*) in Nepal, are also known to feed on figs in the wild (Peyton 1980; Joshi *et al*. 1997). Table 6 summarizes fruit species consumed by Malayan sun bear reported by other sources.

Other fruits that sun bears consumed (as indicated by scat analysis) include *Lithocarpus* spp., *Polyalthia sumatrana*, *Eugenia* spp., and *Santiria* spp. (Appendix 1). All of these trees were also found to have claw marks of sun bear, except *Santiria* spp. In addition, of 33 *Lithocarpus* spp. trees with sun bear claw marks, at least 11 trees had been climbed repeatedly over the years, (recognized from the different sets of claw marks of difference ages) suggesting that sun bears harvest acorns from *Lithocarpus* spp. trees. Although hard shells of acorns from the Fagaceae family only occurred once in the scat analysis, Davies and Payne (1982) stated that the sun bears feed on large quantities of the hard seeds of the Fagaceae family. The low encounter rate of Fagaceae's shells in our study was likely due to extremely low fruit production during the study period. Other species of bears, such as Asiatic black bear (*Ursus thibetanus*) and brown bear (*Ursus arctos*), are also known to consume acorns from this family (both *Lithocarpus* spp. and *Quercus* spp.) (Nozaki *et al*. 1983; Schaller *et. al* 1989; Clevenger *et al*. 1992). Table 7 and Table 8 show the relative abundance of the top 15 tree genera in primary forest plot and logged forest plot, respectively, in the study area reported by Hussin (1994).

In our study, invertebrates were the most important food items for Malayan sun bear in Ulu Segama Forest Reserve. Termites, beetle larvae, and beetles occurred in more than half of all scat samples. In addition, 60% of sun bear feeding sites found were in decayed wood on the forest floor housing termites, beetles, and larvae (Figure 2). Unlike fruit production that fluctuated throughout the year, numbers invertebrates were available year round with little fluctuation (Burghouts *et al*. 1992). Due to the fact that most invertebrates are small (except beetle larvae of *Cholcosoma* spp. which measured up to 10 cm in length and 3 cm in diameter), sun bears had to spend more effort in search of invertebrate food items to meet their energy requirements. This is in contrast to consumption of fruit where bears can consume a large quantity with minimal effort.

Presence of many termite wings from reproductive individuals (alates), and termite eggs, and beetle larvae in scat samples indicates sun bears do eat individual invertebrates that contain high levels of nutrients. For example, ant alate, termite alate, and large beetle larva contain more body fat (44%, 42%, and 40%, respectively), than adult ant worker, termite worker, and adult beetles (13%, 11%, and 10%, respectively) (Phelps *et al*. 1975; Redford and Dorea 1984; Rawlins 1997). The sun bear feeding site with termite eggs and alate we found on 10 October 2000 was a typical feeding site of a sun bear or of other myrmecophages (specialized termite- and ant-eating mammals), where these mammals consume mostly termite eggs, larvae, and alates with higher body fat and discard termite solders and workers (Lubin and Montgomery 1981; Redford and Dorea 1984).

Earthworms are an important food of sun bears (Shelford 1916; Lekagul and McNeely 1977; Tweedie 1978; Davies and Payne 1982; Domico 1988; Lim 1998; Sheng *et al*. 1998), although none of these authors ever studied ecology of sun bears. We failed to find any remains of earthworms during the scat analysis. Since earthworms only have soft tissue and do not possess an exoskeleton, they are probably digested completely. We believe that earthworms could be an important food item for sun bears, based on our frequent observation of earthworms at sun bear feeding sites (14%). Earthworms are found not only in soil, but also found in decayed wood, together with beetles, beetle larvae, termites and other invertebrates. Interestingly, two captive Malayan sun bears from Woodland Park Zoo, Seattle, USA, rejected earthworms when offered them (C. Frederick, Woodland Park Zoo, Seattle, USA, pers. comm.).

The Malayan sun bear is also know as “honey bear” which refers to its voracious appetite for honeycombs and honey. Thus, bees, beehives, and honey, are another important food item (Lekagul and McNeely 1977; Medway 1978; Payne *et al*. 1985). We found sun bears occasionally feed on wild bees, especially the stingless bee (*Trigona* spp.). Sun bears are known to tear open trees with their long, sharp claws and teeth in search of wild bees (*Apis dorsata, A. indica*, and *Trigona* spp.) and leave behind shattered tree trunks (MacKinnon *et al*. 1996; Lim 1998; G. Fredriksson in Meijaard 1999; Meijaard 1999). We found 10 similar foraging sites with shattered tree trunks in tropical hardwoods. G. Fredriksson (pers. comm., 2000) reported seeing Borneo ironwood trees (*Eusideroxylon zwageri*) with tree trunks shattered from sun bear foraging. Meijaard (1999) suggested this feeding habit explained why most older sun bears have damaged teeth, such as the canines being broken off. This may explain why the three adult sun bears we captured all had canines worn down or broken to the gum line.

Malayan sun bears are typical omnivores and opportunist feeders that utilize a broad range of resources in the ecological niche they occupy. Bank (1931) stated that almost anything served as bear food. Besides fruits and invertebrates, Malayan sun bears also are reported to feed on variety of vertebrates, animal carcasses, small animals, rodents, small birds, and reptiles (Shelford 1916; Bank 1931; Medway 1978; Tweedie 1978; Davies and Payne 1982; Payne *et al*. 1985; Domico 1988; MacKinnon *et al*. 1996; Lim 1998; Kanchanasakha *et al*. 1998; Sheng *et al*. 1998; Yasuma and Andau 2000). Lim (1998) reported only a desperately hungry bear would prey on vertebrates, such as pheasants, civets, cats, and rodents. However, fragments of bones, claws, scales, feathers and egg shells found in scat analysis suggest sun bears opportunistically prey upon small vertebrates in the study area.

Many reports state that sun bears eat the heart of coconut palm (*Cocos nucifera*), and may do serious damage to coconut plantations (Lekagul and McNeely 1977; Domico 1988; Payne et al. 1985; Servheen 1993; Yasuma and Andau 2000). N. Fuyuki (Hokkaido University, Sapporo, Japan, pers. comm., 1999) reported radioed sun bears captured at the edge of an oil palm (*Elaeis quineensis)* plantation next to Tabin Wildlife Reserve, Sabah, foraged in the oil palm plantation at night and spent their daytime in the reserve forest. Rapid conversion of lowland tropical rainforest into large-scale oil palm plantations in Sabah and other parts of Southeast Asia has caused many bears to access plantations to became pests and nuisance animals. This would be expected from an opportunistic omnivore when food diversity is reduced as forests are converted to monoculture plantation agriculture.

Wilson and Wilson (1975) and Wilson and Johns (1982) suggested that sun bears exist only in primary forest (they found none in logged forests. We showed that Malayan sun bears do exist in logged forest. Although our data are limited to assess the specific impacts of selective logging on the food availability of Malayan sun bears, Hussin (1994) reported that the number of fruit trees, especially fig trees, were significantly lower in logged forests in the study area. Burghouts *et al*. (1992) also reported that the abundance of invertebrates within our study area was higher in primary forest with a significantly higher abundance of termites. However, the proportion of beetles, millipedes, and cockroaches was higher in the logged forest than the primary forest (Burghouts *et al*. 1992). These data show that the food items of sun bears are found in the mixture of logged and unlogged forests. However, the complexities of food webs capable of supporting sun bears in tropical forests dominated by Dipterocaraceae are more complex than just whether the habitat is logged, unlogged or a plantation (Curran et al. 1999). Forest managers should consider the extent and distribution of logging for both human benefits and wildlife needs when managing the forests. These management implications should include careful maintenance and adequate distribution of unlogged areas to provide habitat diversity, well-designed logging practices using environmentally friendly methods such as practicing reduced impact logging, prohibitions on damaging mature fig trees and maintaining buffer zones around fig trees, and controlling poaching activities that often accelerate with the increased access resulting from logging roads.

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Table 1. Frequency of occurrence of monthly food items in Malayan sun bear scats at Ulu Segama Forest Reserve, Sabah, Malaysia. August 1999- December 2001 (n=56)

Foot items	*Apr*	%	Jun	%	Jul	%	Aug	%	Sep	%	Oct	%	Nov	%	Dec	%
Termites	1	16.7	1	20	2	10.5	9	19.6	4	14.3	2	10	8	12.12	1	25
Ants	1	16.7	1	20	1	5.26	4	8.7	2	7.14			2	3.03	1	25
Beetles	1	16.7	1	20	2	10.5	6	13	4	14.3	2	10	14	21.21	1	25
Beetle larvae	1	16.7	1	20	1	5.26	7	15.2	4	14.3	3	15	11	16.67		
Bees and wasps			1	20			1	2.17			1	5	2	3.03		
Forest Cockroach							1	2.17	1	3.57						
Other arthropods	1	16.7					2	4.35	1	3.57			2	3.03		
Turtle					1	5.26			2	7.14						
Reptiles							1	2.17			1	5				
Small vertebrates					1	5.26	2	4.35	3	10.7	3	15	2	3.03		
Birds' eggs											1	5				
Unidentified animals					2	10.5	2	4.35					2	3.03		
Figs					6	31.6	3	6.52	2	7.14	1	5	18	27.27		
Fruits					1	5.26	4	8.7	4	14.3	3	15	3	4.545		
Flowers							1	2.17								
Acorns							1	2.17								
Unidentified Plants	1	16.7			2	10.5	2	4.35	1	3.57	3	15	2	3.03	1	25
Number of scat (n)	2		1		7		7		6		3		29		1	

Table 2. Sexes and monitoring duration of the six captured Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia.

		1999							2000											
Bear #	Sex	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
125	M	-	-	-	-															
124	M		-	-	-															
123	M			-	-															
122	M										-	-	-	-	-	-	-	-	-	-
121	F																-			
120	M																	-	-	-

Table 3. Frequency of occurrence of termite species found in sun bear scats in Ulu Segama Forest Reserve, Sabah, Malaysia. (n=24)

Family	Subfamily	Species	Frequency of occurrence	%
Rhinotermitidae	Coptotermitinae	*Coptotermes curvignathus*	5	20.83
Rhinotermitidae	Coptotermitinae	*Coptotermes sp 1*	10	41.67
Rhinotermitidae	Rhinotermitinae	*Schedorhinotermes*	9	37.50
Termitidae	Termitinae	*Globitermes globosus*	1	4.17
Termitidae	Macrotermitinae	*Hypotermes xenotermitis*	4	16.67
Termitidae	Macrotermitinae	*Macrotermes*	11	45.83
Termitidae	Macrotermitinae	*Odontotermes* sp	2	8.33
Termitidae	Nasutitermitinae	*Bulbitermes sp*	10	41.67
Termitidae	Nasutitermitinae	*Lacessititermes*	1	4.17
Termitidae	Nasutitermitinae	*Nasutitermes*	11	45.83
Termitidae	Nasutitermitinae	*Nasutitermes longinasus*	2	8.33
Termitidae	Termitinae	*Dicuspiditermes*	10	41.67
Termitidae	Termitinae	*Homallotermes* sp	3	12.50
Termitidae	Termitinae	*Microcerotermes dubius*	1	4.17
Termitidae	Termitinae	*Microcerotermes* sp	1	4.17
Termitidae	Termitinae	*Pericapritermes*	1	4.17

Table 4. Frequency of occurrence and percentage of food items found in 56 Malayan sun bear scats in Ulu Segama Forest Reserve, Sabah, Malaysia, 1999-2000.

Foot items	Frequency of occurrence	Percent frequency of occurrence
Invertebrates	***116***	***57.14***
Termites	26	50.00
Ants	13	25.00
Beetles	33	63.46
Beetle larvae	29	55.77
Bees and wasps	5	9.62
Forest Cockroach	3	5.77
Other arthropods	7	13.46
Vertebrates	***23***	***11.16***
Turtle	3	5.77
Reptiles	2	3.85
Small vertebrates	11	21.15
Birds' eggs	1	1.92
Unidentified animals	6	11.54
Plants	***61***	***29.61***
Figs	32	61.54
Fruits	15	28.85
Flowers	1	1.92
Acorns	1	1.92
Unidentified Plants	12	23.08
Non-organic	***3***	***0.14***
Resin[(a)]	3	5.77

(a) : Resin is nesting material from stingless bee (*Trigona* spp.) nests. It was consumed when sun bears feed on a bee nest.

Table 5. Frequencies of tree species with Malayan sun bear claw marks in Ulu Segama Forest reserve, Sabah, Malaysia. 1999-2000 (n=190)

Tree species	Number of trees with claw marks	% of tree species with claw marks	% of tree species (known species only)
Unknown tree species	99	52.11	
Lithocarpus spp.	33	17.37	35.48
Ficus spp.	13	6.84	13.98
Shorea spp.	7	3.68	7.53
Polyalthia sumatrana	5	2.63	5.38
Duabanga moluccana	4	2.11	4.30
Eugenia spp.	4	2.11	4.30
Dryobalanops spp.	3	1.58	3.23
Lauraceae	3	1.58	3.23
Macaranga hypoleuca	3	1.58	3.23
Scorodocarpus borneensis	2	1.05	2.15
Stemonurus scorpioides	2	1.05	2.15
Aglaia spp.	1	0.53	1.08
Alangium javanicum	1	0.53	1.08
Baccaurea spp.	1	0.53	1.08
Dillenia spp.	1	0.53	1.08
Durio spp.	1	0.53	1.08
Hopea dryobalanoides	1	0.53	1.08
Intsia palembanica	1	0.53	1.08
Neolamarckia cadamba	1	0.53	1.08
Octomeles sumatrana	1	0.53	1.08
Paranephelium xestophyllum	1	0.53	1.08
Fam. Leguminosae	1	0.53	1.08
Fam. Myristicaceae	1	0.53	1.08

Table 6. Fruit items in Malayan sun bear diets as reported in the literature.

Family	Genus	Species	Source
Bombacaceae	*Durio*	*zibethinus*	Ridley (1930) in McConkey and Galetti (1999)
Burseraceae	*Canarium*	*pilosum*	McConkey and Galetti (1999)
Burser aceae	*Santiria*	*spp.*	Leighton (1990)
Convolvulaceae	*Erycibe*	*Maingayi*	McConkey and Galetti (1999)
Fagaceae	*Lithocarpus*	*spp.*	Davies and Payne (1982)
Lauraceae	*Litsea*	*spp.*	Leighton (1990)
Moraceae	*Ficus*	*consociata*	McConkey and Galetti (1999)
Moraceae	*Ficus*	*stupenda*	S. Harrison in McConkey and Galetti (1999)
Moraceae	*Ficus*	*dubia*	Leighton (1990)
Palmae	*Cocos*	*nucifera*	Domico (1988); Lekagul and McNeely (1977); Payne at el. (1985); Servheen (1993); Yasuma and Andau (2000)
Palmae	*Elaeis*	*Guineensis*	F.Nomura (Hokkaido University, Japan, personal communication, 1999)
Rhizophoraceae	*Carallia*	*spp.*	Leighton (1990)
Sapindaceae	*Nephelium*	*spp.*	Leighton (1990)

Table 7. Frequency, percentage and ranking of the top 15 tree genera in a 4-ha primary forest plot in Ulu Segama Forest Reserve, Sabah, Malaysia.

Genus	Frequency	%	Rank
Shorea (Dipterocarpaceae)	227	10.34	1
Mallotus (Euphorbiaceae)	142	6.47	2
Aglaia (Meliaceae)	131	5.97	3
Ryparosa (Flacourtiaceae)	93	4.24	4
Litsea (Lauraceae)	89	4.06	5
Polyalthia (Annonaceae)	87	3.96	6
Eugenia (Myrtaceae)	86	3.92	7
Chisocheton (Meliaceae)	84	3.83	8
Aporusa (Euphorbiaceae)	81	3.69	9
Parashorea (Dipterocarpaceae)	78	3.55	10
Lithocarpus (Fagaceae)	66	3.01	11
Canarium (Burseraceae)	59	2.69	12
Alangium (Alangiaceae)	55	2.51	13
Diospyros (Ebenaceae)	55	2.51	13
Madhuca (Sapotaceae)	53	2.42	15
Total	1386	63.17	

Source: Hussin (1994)

Table 8. Frequency, percentage and ranking of the top 15 tree genera in a 4-ha logged forest plot in Ulu Segama Forest Reserve, Sabah, Malaysia.

Genus	Frequency	%	Rank
Shorea (Dipterocarpaceae)	153	9.57	1
Aglaia (Meliaceae)	92	5.75	2
Eugenia (Myrtaceae)	86	5.38	3
Litsea (Lauraceae)	77	4.82	4
Polyalthia (Annonaceae)	74	4.63	5
Xanthophyllum (Polygalaceae)	71	4.44	6
Lithocarpus (Fagaceae)	67	4.19	7
Mallotus (Euphorbiaceae)	63	3.94	8
Aporusa (Euphorbiaceae)	59	3.69	9
Alangium (Alangiaceae)	53	3.31	10
Parashorea (Dipterocarpaceae)	49	3.06	11
Microcos (Tiliaceae)	38	2.38	12
Diospyros (Ebenaceae)	37	2.31	13
Knema (Myristicaceae)	35	2.19	14
Canarium (Burseraceae)	35	2.19	14
Total	989	61.85	

Source: Hussin (1994)

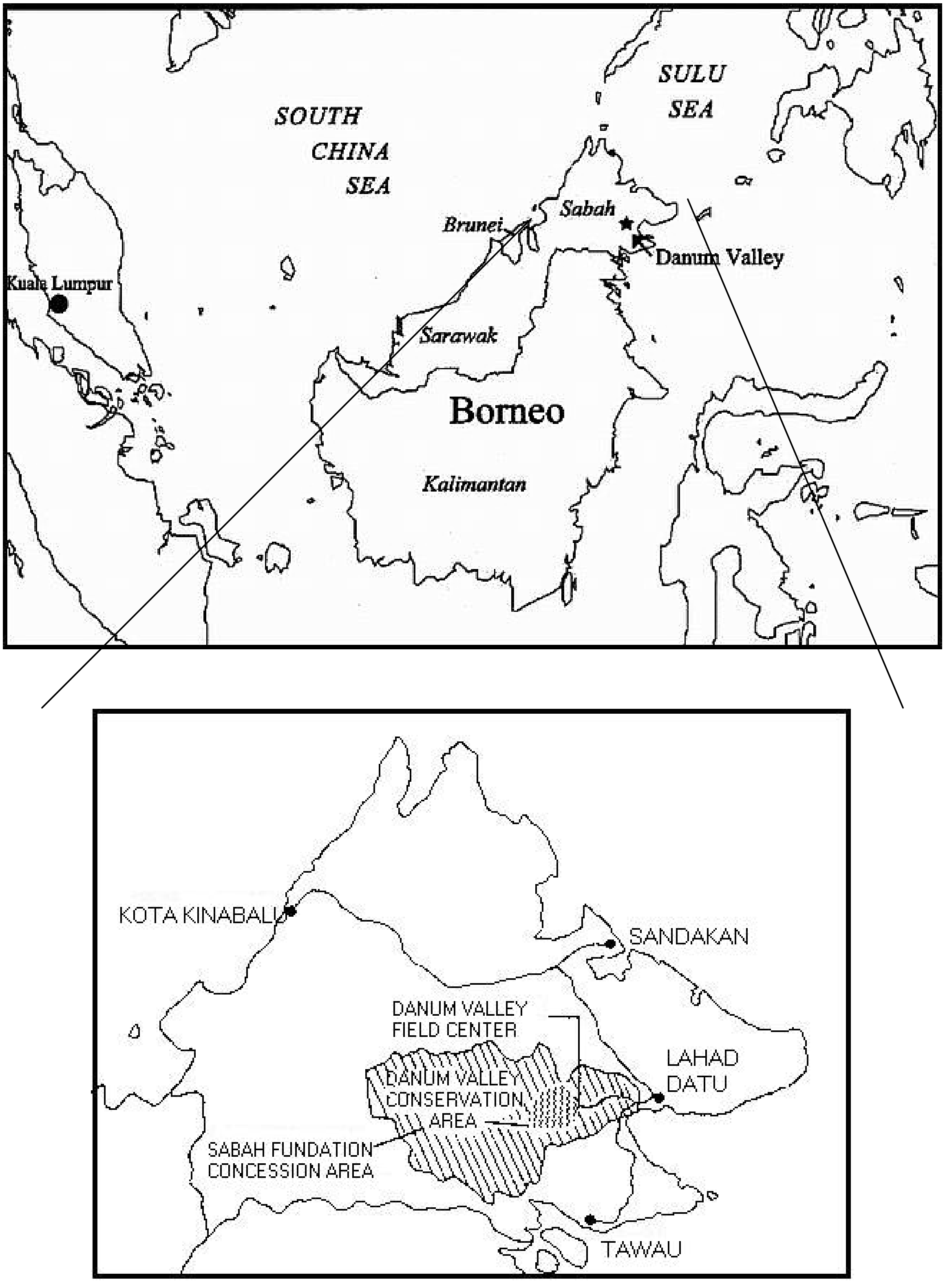

Figure 1. Location of the study area, based at Danum Valley Field Center at the state of Sabah, Malaysia, Northern Borneo.

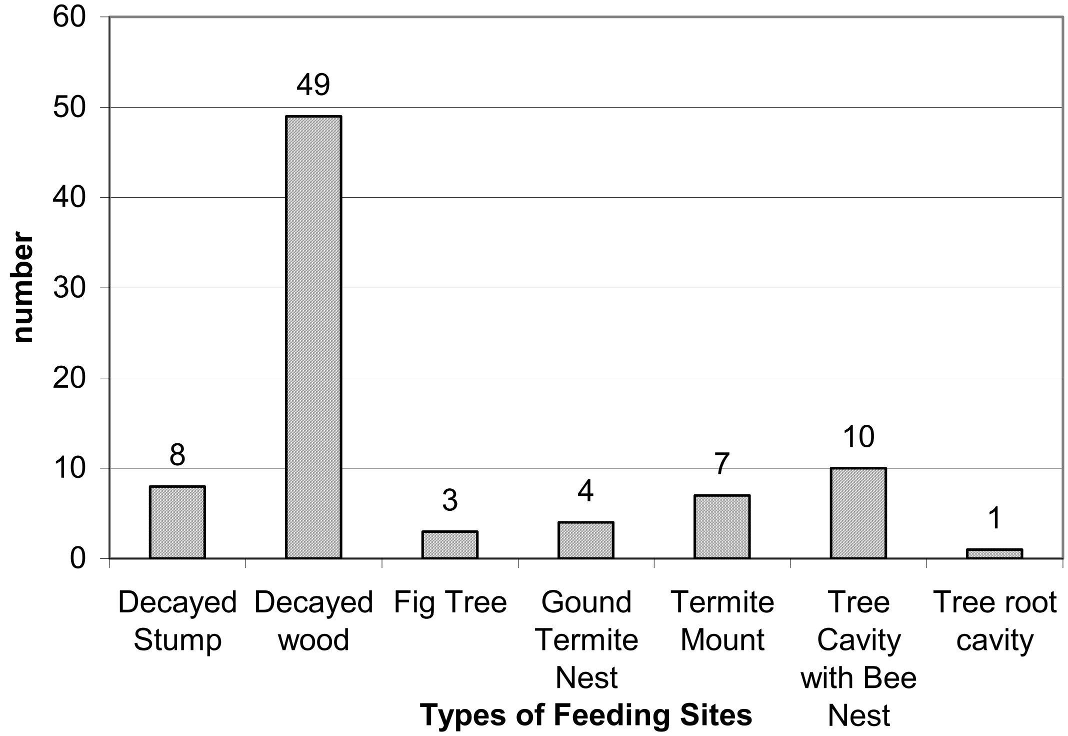

Figure 2. Frequency of feeding sites of Malayan sun bear feeding sites in Ulu Segama Forest Reserve, Sabah, Malaysia. 1999-2000 (n=82)

Figure 3. Photograph of a Malayan sun bear feeding on termite (*Dicuspiditermes* spp.) mounds taken by the remote sensing automatic camera at Ulu Segama Forest Reserve, Sabah, Malaysia.

Appendix 1. List of food items of Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia. 1999-2000

Class	Order	Family	Sub-Family	Species
Animal origin				
Arachnida	Scorpionida			
Insecta	Coleoptera	Carabidae or Tenebrionidae		
Insecta	Coleoptera	Chelonariidae		
Insecta	Coleoptera	Chrysomelidae		
Insecta	Coleoptera	Dytiscidae		
Insecta	Coleoptera	Histeridae		
Insecta	Coleoptera	Passalidae		*Aceraius spp.*
Insecta	Coleoptera	Scarabaeidae		*Chalcosoma spp.*
Insecta	Coleoptera	Tenebrionidae		
Insecta	Dictyoptera	Blattidae		*Panesthia spp.*
Insecta	Hymenoptera	Apidae		*Trigona collina*
Insecta	Hymenoptera	Apidae		*Trigona spp.*
Insecta	Hymenoptera	Apoidea		
Insecta	Hymenoptera	Formicidae		*Camponotus gigas*
Insecta	Hymenoptera	Formicidae		*Ccamponotus species*
Insecta	Hymenoptera	Formicidae		*Gnamptogenys menadensis*
Insecta	Hymenoptera	Vespidae		*Polistine spp.*
Insecta	Isoptera	Rhinotermitidae	Coptotermitinae	*Coptotermes curvignathus*
Insecta	Isoptera	Rhinotermitidae	Coptotermitinae	*Coptotermes sp1*
Insecta	Isoptera	Rhinotermitidae	Rhinotermitinae	*Schedorhinotermes*
Insecta	Isoptera	Termitidae	Termitinae	*Globitermes globosus*
Insecta	Isoptera	Termitidae	Macrotermitinae	*Hypotermes xenotermitis*
Insecta	Isoptera	Termitidae	Macrotermitinae	*Macrotermes*
Insecta	Isoptera	Termitidae	Macrotermitinae	*Odontotermes* sp
Insecta	Isoptera	Termitidae	Nasutitermitinae	*Bulbitermes sp*
Insecta	Isoptera	Termitidae	Nasutitermitinae	*Lacessititermes*
Insecta	Isoptera	Termitidae	Nasutitermitinae	*Nasutitermes*
Insecta	Isoptera	Termitidae	Nasutitermitinae	*Nasutitermes longinasus*
Insecta	Isoptera	Termitidae	Termitinae	*Dicuspiditermes*
Insecta	Isoptera	Termitidae	Termitinae	*Homallotermes* sp
Insecta	Isoptera	Termitidae	Termitinae	*Microcerotermes dubius*
Insecta	Isoptera	Termitidae	Termitinae	*Microcerotermes* sp
Insecta	Isoptera	Termitidae	Termitinae	*Pericapritermes*
Insecta	Lepidoptera			
Insecta	Orthoptera	Gryllotalpidae		
Mammalia	Rodentia			
Osteichtyes		Cyprinidae		
Reptilai	Chelonia	Testudinidae		*Manouria emys*
Reptilai	Chelonia			
Chordata	Reptilai	Squamata		

Class	Order	Family	Sub-Family	Species
Plant Origin				
		Annonaceae		*Polyalthia sumatrana*
		Burseraceae		*Santiria sp.*
		Fagaceae		*Lithocarpus spp.*
		Moraceae		*Ficus spp.*
		Myrtaceae		*Eugenia sp.*