

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

SIEW TE WONG,¹ Wildlife Biology Program, School of Forestry, University of Montana, Missoula, MT 59812, USA, email: wongsiew@hotmail.com

CHRISTOPHER SERVHEEN, Wildlife Biology Program, School of Forestry, University of Montana, Missoula, MT 59812, USA, email: grizz@selway.umt.edu

LAURENTIUS AMBU, Sabah Wildlife Department, 5th floor, Block B, MUIS Complex, 88100 Kota Kinabalu, Sabah, Malaysia

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 directly observing bears. Invertebrates such as termites (Isoptera), beetles (Coleoptera), and beetle larvae (Coleoptera) were the predominant food items, occurring in 57% of the scat samples. Figs (*Ficus* sp.) were the most common fruit consumed (in 61% of the samples) during the non-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.

Ursus 13:127–136 (2002)

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

The Malayan sun bear is the smallest of the 8 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 seriously 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 3-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 on the eastern side of the Malaysian state of Sabah, island of Borneo (Fig. 1; 4°57'40"N, 117°48'00"E, 100–1,200 m



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

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 750–1,500 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 is 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 m³/hectare since the 1960s (Marsh and Greer 1992). Compared to other selectively logged forests in Southeast Asia, these forests can be considered good quality logged forest because of rapid forest regeneration and reduced human disturbance after logging. Many large mammals are present in the study area such as clouded leopards (*Neofelis nebulosa*), Asian elephants (*Elaphas 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 2 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 2,700 mm (Royal Society SE Asia Rainforest Research Program: Hydrology Project [University of Manchester, University of Wales Swansea, University of Lancaster, University Malaysia Sabah], unpublished station records 1986–2000), with the wettest period 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°C.

The study was concentrated in approximately 15,000 ha of 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 24 February 1999 and ended on 11 December 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 radiocollar transmitters (Telonics, Inc., Mesa, Arizona, USA). We located radiocollared 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. Radiocollared bears were located daily using ground triangulation. A total of 353 locations of 5 radiocollared 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 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 directly 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 because they dissolve in the frequent heavy rain and dung beetles (Order Coleoptera, Family Scarabaeidae) 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, which are not commonly attractive to dung beetles.

We also collected feeding evidence and scats from non-radiocollared bears when possible. Some bears were known to have fed at the Danum garbage dump during the study period. We removed rice, pumpkin and watermelon seeds, chicken bones, and other human-food items from scats prior to analysis to avoid reporting food habits resulting from use of garbage dumps. 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, oven dried for 24 hours at 70°C, and reweighed. Dried scats were 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°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 (*Musca* spp.), and dead leaves and twigs (sometimes attached to scat samples when collected from the forest floor). These materials were removed from the scat

Table 1. Frequency of occurrence of food items by month in Malayan sun bear scats at Ulu Segama Forest Reserve, Sabah, Malaysia, August 1999–December 2000 ($n = 56$).

Food 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	

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 is the total number of times a 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. Fifty-three of the 56 scat samples were collected between May 2000 and December 2000 from Bear #122 and Bear #120. We did not compare the analysis results between these 2 bears due to limits on sample size and non-random scat collection.

We attempted to get as close as possible to radiocollared bears without disturbing them while tracking them in the forest. Nevertheless, it was extremely difficult to get close to these bears. In addition, the dense undergrowth in the study made it impossible to observe radiocollared bears from a long distance. Visual sightings of radiocollared bears occurred on rare occasions when bears failed to detect our presence within 2–20 m on the ground ($n = 13$), or a greater distance (>30 m; $n = 4$) when bears were resting or feeding in trees. After a 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*]) created similar feeding evidence when they feed on termites, earthworms (*Pheretima*

spp.), 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 radiocollared 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 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 bark. 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 and recorded fruiting condition and tree height and size.

RESULTS

Analysis of scats.—Six Malayan sun bears (5 males, 1 female) 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 ($n = 29$) and moderately successful during July, August, September 2000 (Table 1). The average

Table 2. Sex and monitoring duration for 6 Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia.

Bear	Sex	Monitoring duration
125	M	Jun 1999–Oct 1999
124	M	Jul 1999–Sep 1999
123	M	Aug 1999–Sep 1999
122	M	May 2000–Dec 2000
121	F	Sep 2000
120	M	Oct 2000–Dec 2000

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 classes of arthropods, plus reptiles, birds, and small mammals (Appendix 1). Among termite genera found in sun bear scats, *Bulbitermes*, *Coptotermes*, *Dicuspitermes*, *Nasutitermes*, and *Schedorhinotermes* had >37% 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 major types of foods, invertebrates had the highest frequency of occurrence (57%), followed by plant 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 (*Panesthia* spp.) (6%), and scorpions (<5%; Table 4). Figs were the second most important food item, occurring in 61% of the samples. Other fruits found in scats but with lower frequencies included *Santiria* spp. (Burseraceae), *Polyalthia sumatrana* (Annonaceae), and *Lithocarpus* spp. (Fagaceae). Vertebrate food items were uncommon (11% of scats) and included Burmese brown tortoise (*Manouria emys*), pheasants, reptiles, birds, eggs, and fish.

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

Food items	Frequency of occurrence	Percent of scats containing item
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 Nesting material from stingless bee (*Trigona* spp.) nests, consumed when sun bears feed on a bee nest.

Analysis of feeding sites.—We found 82 confirmed sun bear feeding sites from June 1999 to December 2000. All feeding sites were a few hours to a day old. The sun bear feeding sites fell into 7 types: (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) termite mounds of different types, (6) tree cavities with bee nests, and (7) tree root cavities (Fig. 2). Decayed wood was the most common type of feeding site recorded ($n = 49$).

A total of 105 food items were collected from these 82 feeding sites. The most common food items collected were termites (48%). Other items included earthworms and

Table 3. Frequency of occurrence of termite species in sun bear scats in Ulu Segama Forest Reserve, Sabah, Malaysia, ($n = 24$), August 1999–December 2000.

Family	Subfamily	Species	Frequency of occurrence	%
Rhinotermitidae	Coptotermitinae	<i>Coptotermes curvignathus</i>	5	20.83
Rhinotermitidae	Coptotermitinae	<i>Coptotermes</i> sp.	10	41.67
Rhinotermitidae	Rhinotermitinae	<i>Schedorhinotermes</i>	9	37.50
Termitidae	Termitinae	<i>Globitermes globosus</i>	1	4.17
Termitidae	Macrotermitinae	<i>Hypotermes xenotermitis</i>	4	16.67
Termitidae	Macrotermitinae	<i>Macrotermes</i>	11	45.83
Termitidae	Macrotermitinae	<i>Odonotermes</i> sp.	2	8.33
Termitidae	Nasutitermitinae	<i>Bulbitermes</i> sp.	10	41.67
Termitidae	Nasutitermitinae	<i>Lacessitermes</i>	1	4.17
Termitidae	Nasutitermitinae	<i>Nasutitermes</i>	11	45.83
Termitidae	Nasutitermitinae	<i>Nasutitermes longinasus</i>	2	8.33
Termitidae	Termitinae	<i>Dicuspitermes</i>	10	41.67
Termitidae	Termitinae	<i>Homalotermes</i> sp.	3	12.50
Termitidae	Termitinae	<i>Microcerotermes dubius</i>	1	4.17
Termitidae	Termitinae	<i>Microcerotermes</i> sp.	1	4.17
Termitidae	Termitinae	<i>Pericapritermes</i>	1	4.17

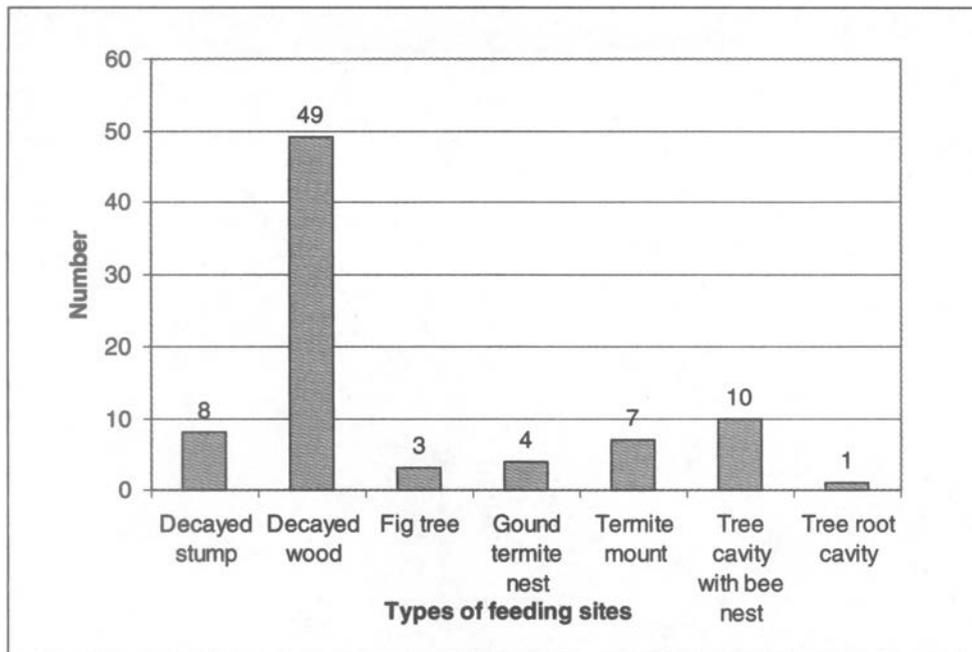


Fig. 2. Frequency of feeding sites of Malayan sun bear in Ulu Segama Forest Reserve, Sabah, Malaysia, 1999–2000 ($n = 82$).

beetle larvae (both 14%), bees (10%), beetles (7%), figs (3%), and other invertebrates (3%).

Foraging observations.—A total of 32 direct observations of radiocollared bears were made, 8 of which were feeding observations. We observed feeding on termites from termite mounds on 3 occasions. We twice saw sun bears breaking open decayed wood in search of termites, beetle larvae, and earthworms. On 2 occasions, Bear 122 was observed harvesting figs from fruiting fig trees. On 6 August 2000, Bear 122 was observed 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 some rare occasions, radiocollared bears were observed up to 45 minutes before the bears noted the field crews.

On 10 June 2000, STW observed Bear 122 resting for 40 minutes on a branch of a large mengaris tree (*Koompassia excelsa*) about 50 m above the ground. The bear was lying with his belly on the branch, with all legs hanging down. The mengaris tree was a host tree for a strangling fig (*Ficus* sp.) with many fruits. He then climbed down to another smaller branch opposite the previous branch to eat figs. The bear 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 an infant began throwing twigs at him. Other frugivores, such as a binturong (*Arctictis binturong*) with its young, 2 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 *Dicuspitermes* 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 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 (similar to bear in Fig. 3). 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 marks.—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 2 most frequently climbed (Table 5). Except for *Shorea* spp., the first 6 tree genera 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,



Fig. 3. A Malayan sun bear feeding on termite (*Dicuspiditermes* spp.) mounds. Photo taken by the remote sensing automatic camera on 23 August 2000 at Ulu Segama Forest Reserve, Sabah, Malaysia.

Table 5. Frequency 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	
<i>Lithocarpus</i> spp.	33	17.37	35.48
<i>Ficus</i> spp.	13	6.84	13.98
<i>Shorea</i> spp.	7	3.68	7.53
<i>Polyalthia sumatrana</i>	5	2.63	5.38
<i>Duabanga moluccana</i>	4	2.11	4.30
<i>Eugenia</i> spp.	4	2.11	4.30
<i>Dryobalanops</i> spp.	3	1.58	3.23
Lauraceae	3	1.58	3.23
<i>Macaranga hypoleuca</i>	3	1.58	3.23
<i>Scorodocarpus borneensis</i>	2	1.05	2.15
<i>Stemonurus scorpioides</i>	2	1.05	2.15
<i>Aglaia</i> spp.	1	0.53	1.08
<i>Alangium javanicum</i>	1	0.53	1.08
<i>Baccaurea</i> spp.	1	0.53	1.08
<i>Dillenia</i> spp.	1	0.53	1.08
<i>Durio</i> spp.	1	0.53	1.08
<i>Hopea dryobalanoides</i>	1	0.53	1.08
<i>Intsia palembanica</i>	1	0.53	1.08
<i>Neolamarckia cadamba</i>	1	0.53	1.08
<i>Octomeles sumatrana</i>	1	0.53	1.08
<i>Paranephelium xestophyllum</i>	1	0.53	1.08
Fabaceae	1	0.53	1.08
Myristicaceae	1	0.53	1.08

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 lying on the branch with his 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 likely represent a small portion of the total diet eaten by wild sun bears. Fredriksson (2001) reported that Malayan sun bears have been recorded to feed on >50 plant species and >100 species of insects in the Sugai Wain Protection Forest, East Kalimantan, Indonesian Borneo. Low numbers of food items presented here may have been 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 fruiting season during the study period (Wong, unpublished data).

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 could have over-estimated of the importance of figs in sun bear diets because of 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 for 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 1990:23). 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. Andean (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).

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 claw marks of different 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 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 6 and Table 7 show the relative abundance of the top 15 tree

Table 6. Frequency, percent, and ranking of the top 15 tree genera in a 4-ha primary forest plot in Ulu Segama Forest Reserve, Sabah, Malaysia (Hussin 1994).

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

Table 7. Frequency, percent, and ranking of the top 15 tree genera in a 4-ha logged forest plot in Ulu Segama Forest Reserve, Sabah, Malaysia (Hussin 1994).

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

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 (Fig. 2). Unlike fruit production that fluctuated throughout the year, invertebrates were available year round with little fluctuation (Burghouts et al. 1992). Because most invertebrates are small (except beetle larvae of *Chalcosoma* 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 contrasts with consumption of fruit, which bears can consume in large quantity with minimal effort.

Presence of many termite wings from reproductive individuals (alates), 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 have higher fat levels (44%, 42%, and 40% body fat, respectively) than adult ant worker, termite worker, and adult beetle (13%, 11%, and 10% body fat, respectively; Phelps et al. 1975, Redford and Dorea 1984, Rawlins 1997).

Earthworms have been reported as 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). 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 in decayed wood together with beetles, beetle larvae, termites, and other invertebrates. Interestingly, 2 captive Malayan sun bears from Woodland Park Zoo, Seattle, Washington, USA, rejected earthworms when offered them (C. Frederick, Woodland Park Zoo, Seattle, USA, personal communication, 2001).

The Malayan sun bear is also known as "honey bear," which refers to its voracious appetite for honeycombs and honey. Thus, bees, beehives, and honey are other important food items (Lekagul and McNeely 1977, Medway 1978, Payne et al. 1985). Results from this study suggest that 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 (Tropenbos-Kalimantan, Balikpapan, Indonesia, personal communication, 2000) reported seeing Borneo ironwood trees (*Eusideroxylon zwageri*) with trunks shattered from sun bear foraging. Meijaard (1999) suggested this feeding habit explained why most older sun bears have damaged teeth, with the canines typically broken off. This may explain why the 3 adult sun bears captured in this study all had canines worn down or broken to the gum line.

Several studies on the impacts of selective logging on wildlife suggested that sun bears exist only in primary forest, and none were found in logged forests (Wilson and Wilson 1975, Wilson and Johns 1982). Our study showed that Malayan sun bears do exist in logged forest. 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 abun-

dance 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 sun bears can exist in a 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 logged, unlogged, or plantation habitat (Curran et al. 1999, Wong, unpublished data). Forest managers should consider the extent and distribution of logging for both human benefits and wildlife needs when managing the forests. These management practices should include (1) careful maintenance and adequate distribution of unlogged areas to provide habitat diversity, (2) well designed logging practices using environmentally friendly methods such as reduced-impact logging, (3) prohibitions on damaging mature fig trees and maintaining buffer zones around fig trees, and (4) controlling poaching, which often accelerates with the increased access resulting from logging roads.

ACKNOWLEDGMENTS

We thank the Economic Planning Unit of the Malaysian Federal Government, Danum Valley Management Committee, and Sabah Wildlife Department for permission to conduct this study in Sabah. We are grateful to B. McLellan, T. Radandt, K. Pei, E. Bosi, S.K.K.S. Nathan, A.Y.C. Chung, V.K. Chey, H. Rahman, N. Ahmad, T. Eltz, C. Burhl, G. Fedriksson, A.B. Aribin, G. Reynolds, C. Frederick, staff of Sabah Wildlife Department and Sabah Museum, and all staff and researchers at Danum Valley Field Center for their help in this project. Financial support was generously provided by a grant from the Barbara Delano Foundation, the Brookfield Zoo via the International Bear Association, and the National Fish and Wildlife Foundation, The Oxford University Expedition to Sumatra (1998), The Puget Sound American Association of Zookeepers (AAZK) Chapter, Sun Bear Species Survival Plan, The Walt Disney Foundation via the American Society for the Prevention of Cruelty to Animals (ASPCA), The Wildlife Conservation Society, and The Woodland Park Zoological Gardens.

LITERATURE CITED

- BANK, E. 1931. A popular account of the mammals of Borneo. *Journal of the Malayan British Royal Asiatic Society* 9:1-139.
- BURGHOUTS, T., G. ERNSTING, G. KORTHALS, AND T.D. VRIES. 1992. Litterfall, leaf litter decomposition and litter invertebrates in the primary and selectively logged dipterocarp forest in Sabah, Malaysia. *Philosophical Transaction of the Royal Society of London B* 335:407-416.

- CLEVENGER, A.P., F.J. PURROY, AND M.R. PELTON. 1992. Food habits of brown bears (*Ursus arctos*) in the Cantabrian Mountains, Spain. *Journal Food Habits of Malayan Sun Bears in Lowland Tropical Forests of Borneo*
- CURRAN, L.M., I. CANIAGO, G.D. PAOLI, D. ASTIANI, M. KUSNETI, M. LEIGHTON, C.E. NIRARITA, AND H. HAERUMAN. 1999. Impact of El Niño and logging on canopy tree recruitment in Borneo. *Science* 286:2184–2188.
- DAVIES, G., AND J. PAYNE. 1982. A faunal survey of Sabah. IUCN/WWF (World Conservation Union/World Wide Fund for Nature) Project No. 1692. WWF-Malaysia, Kuala Lumpur, Malaysia.
- DOMICO, T. 1988. Bears of the world. Facts on File. New York, New York, USA.
- EGGLETON, P., R. HOMATHEVI, D.T. JONES, J.A. MACDONALD, D. JEEVA, D.E. BIGNELL, R.G. DAVIES, AND M. MARYATI. 2000. Termite assemblages, forest disturbance and greenhouse gas fluxes in Sabah, East Malaysia. Pages 67–78 in D.M. Newbery, T.H. Clutton-Brock, and G.T. Prance, editors. *Changes and disturbance in tropical rainforest in South-east Asia*. Imperial College Press, London, United Kingdom.
- FREDRIKSSON, G.M. 2001. Beruang madu. Sahabat Alam, LORIES. Jan 2001:3–6. (In Indonesian.)
- HUSSIN, M.Z. 1994. Ecological effects of selective logging in a lowland dipterocarp forest on avifauna, with special reference to frugivorous birds. Dissertation, University Kebangsaan Malaysia, Bangi, Malaysia.
- JANZEN, D.H. 1979. How to be a fig. *Annual Review of Ecology and Systematics* 10:13–52.
- JONKEL, J.J. 1993. A manual for handling bears for managers and researchers. Office of Grizzly Bear Recovery, U.S. Fish and Wildlife Service, University of Montana, Missoula, USA.
- JOSHI, A.R., D.L. GARSHELIS, AND J.L.D. SMITH. 1997. Seasonal and habitat-related diets of sloth bears in Nepal. *Journal of Mammalogy* 78:584–597.
- KALKO, E.J., E.A. HERRE, AND C.O. HANDLEY. 1996. Relation of fig fruit characteristics to fruit-eating bats in the New and Old World tropics. *Journal of Biogeography* 23:565–576.
- KANCHANASAKHA, B., S. SIMCHARAEN, AND U.T. THAN. 1998. Carnivores of mainland South East Asia. World Wide Fund for Nature-Thailand Project Office, Bangkok, Thailand.
- KINNAIRD, M.F., T.G. O'BRIEN, AND S. SURYADI. 1999. The importance of figs to Sulawesi's imperiled wildlife. *Tropical Biodiversity* 6:5–18.
- LEIGHTON, M. 1990. Seed dispersal syndromes of Bornean fruits: The dependence of plants on birds and mammals for seed dispersal and forest regeneration. A preliminary report on research results from Gunung Palung. Center for Research and Development in Biology-LIPI and the Subdirectorate of Nature Conservation (PHPA), Ministry of Forestry, Jakarta, Indonesia.
- , AND D.R. LEIGHTON. 1983. Vertebrate responses to fruiting seasonally within a Bornean rain forest. Pages 181–196 in S.L. Sutton, T.C. Whitmore, and A.C. Chadwick, editors. *Tropical rain forest—Ecology and management*. Blackwell Scientific Publications, Cambridge, United Kingdom.
- LEKAGUL, B., AND J.A. MCNEELY. 1977. *Mammals of Thailand*. Kurusapha Ladprao Press, Bangkok, Thailand.
- LIM, B.L. 1998. The sun bear. Pages 24–25 in Yong H.S., editor. *The Encyclopedia of Malaysia-Animals*. Archipelago Press, Kuala Lumpur, Malaysia.
- MACKINNON, K., G. HATTA, H. HALIM, AND A. MANGALIK. 1996. *The ecology of Kalimantan, Indonesia Borneo*. Periplus Editions, Hong Kong.
- MARSH, C.W., AND A.G. GREER. 1992. Forest land-use in Sabah, Malaysia: An introduction to Danum Valley. *Philosophical Transactions of the Royal Society of London B* 335:331–339.
- MCCONKEY, K., AND M. GALETTI. 1999. Seed dispersal by the sun bear (*Helarctos malayanus*) in central Borneo. *Journal of Tropical Ecology* 15:237–241.
- MEDWAY, L. 1978. *The wild mammals of Malaya (Peninsula Malaysia) and Singapore*. Oxford University Press, Kuala Lumpur, Malaysia.
- MEUJAARD, E. 1997. The Malayan sun bear (*Helarctos malayanus*) on Borneo, with special emphasis on its conservation status in Kalimantan, Indonesia. International Ministry of Forestry-Tropendos Kalimantan Project and the World Society for the Protection of Animals, London, United Kingdom.
- . 1999. *Ursus (Helarctos) malayanus*, the neglected Malayan sun bear. Mededelingen No. 34. Netherlands Commission for International Nature Protection. Leiden, Netherlands.
- NEWBERY, D.M., E.J.F. CAMPBELL, Y.F. LEE, C.E. RIDSDALE, AND M.J. STILL. 1992. Primary lowland dipterocarp forest at Danum Valley, Sabah, Malaysia: structure, relative abundance and family composition. *Philosophical Transactions of the Royal Society of London, Series B* 335:341–356.
- NOWAK, R.M. 1991. Walker's mammals of the world. Volume II. Fifth edition. The Johns Hopkins University Press, Baltimore, Maryland, USA.
- NOZAKI, E., S. AZUMA, T. AOI, H. TORII, T. ITO, AND K. MAEDA. 1983. Food habits of Japanese black bear. *International Conference on Bear Research and Management* 5:106–109.
- PAYNE, J., C.M. FRANCIS, AND K. PHILLIPPS. 1985. *A field guide to the mammals of Borneo*. World Wildlife Fund Malaysia, Kuala Lumpur, Malaysia.
- PEYTON, B. 1980. Ecology, distribution, and food habits of spectacled bears, *Tremarctos ornatus*, in Peru. *Journal of Mammalogy* 61:639–652.
- PHELPS, R.J., J.K. STRUTHERS, AND S.J.L. MOYO. 1975. Investigation into nutritive value of *Macrotermes falciger* (Isoptera: Termitidae). *Zoologica Africa* 10:123–132.
- POORE, D. 1989. No timber without trees: Sustainability in the tropical forest. Earthscan, London, United Kingdom.
- RAWLINS, D. 1997. The feeding ecology of the striped possum, *Dactylopsila trivirgata*, in north Queensland. Honors Thesis, University of Melbourne, Melbourne, Victoria, Australia.
- REDFORD, K.H., AND J.G. DOREA. 1984. The nutritional value of invertebrates with emphasis on ants and termites as food for mammals. *Journal of the Zoological Society of London* 203:385–395.
- SCHALLER, G.B., Q. TENG, K.G. JOHNSON, X. WANG, H. SHEN, AND J. HU. 1989. The feeding ecology of giant pandas and Asiatic black bears in the Tangjiahe Reserve, China. Pages

- 212–241 in J. Gittleman, editor. Carnivore behavior, ecology, and evolution. Comstock Publishing Associates, Ithaca, New York, USA.
- SERVHEEN, C. 1993. The sun bear. Pages 124–127 in I. Stirling, editor. Bears, majestic creatures of the world. Rodale Press, Emmaus, Pennsylvania, USA.
- . 1999. Sun bear conservation action plan. Pages 219–222 in C. Servheen, S. Herrero, and B. Peyton, compilers. 1999. Bears—status survey and conservation action plan. IUCN-World Conservation Union, Gland, Switzerland.
- SHELFORD, R.W. 1916. A naturalist in Borneo. T. Fisher Unwin Ltd., London, United Kingdom.
- SHENG, H.L., C.C. TA, AND H.C. LU. 1998. The wild mammals of China. China Forestry Press, Beijing, China.
- TWEEDIE, M.W.F. 1978. Mammals of Malaysia. Longman Malaysia Sendirian Berhad, Kuala Lumpur, Malaysia.
- WHITE, G.C., AND R.A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc. New York, USA.
- WHITMORE, T.C. 1984. Tropical rain forest of the Far East. Second edition. Oxford University Press, Oxford, United Kingdom.
- WILSON, C.C., AND W.L. WILSON. 1975. The influence of selective logging on primate and some other animals in East Kalimantan. *Folia Primatology* 23:245–275.
- WILSON, W.L., AND A.D. JOHNS. 1982. Diversity and abundance of selected animal species in undisturbed forest, selective logged forest and plantation in East Kalimantan, Indonesia. *Biological Conservation* 24:205–218.
- YASUMA, S., AND M. ANDAU. 2000. Mammals of Sabah, Part 2, habitat and ecology. Japan International Cooperation Agency and Sabah Wildlife Department, Kota Kinabalu, Malaysia.

Received: 5 September 2001.

Accepted: 1 March 2002.

Associated Editor: Shields.

Appendix 1. Food Items of Malayan sun bears in Ulu Segama Forest Reserve, Sabah, Malaysia, 1999–2000.

Kingdom	Class	Order	Family	Sub-Family	Species
Animal					
	Arachnida	Scorpionida			
	Insecta	Coleoptera	Carabidae or Tenebrionidae		
	Insecta	Coleoptera	Chelonariidae		
	Insecta	Coleoptera	Chrysomelidae		
	Insecta	Coleoptera	Dytiscidae		
	Insecta	Coleoptera	Histeridae		
	Insecta	Coleoptera	Passalidae		<i>Aceraulis</i> spp.
	Insecta	Coleoptera	Scarabaeidae		<i>Chalcosoma</i> spp.
	Insecta	Coleoptera	Tenebrionidae		
	Insecta	Dictyoptera	Blattidae		<i>Panesthia</i> spp.
	Insecta	Hymenoptera	Apidae		<i>Trigona collina</i>
	Insecta	Hymenoptera	Apidae		<i>Trigona</i> spp.
	Insecta	Hymenoptera	Apoidea		
	Insecta	Hymenoptera	Formicidae		<i>Camponotus gigas</i>
	Insecta	Hymenoptera	Formicidae		<i>Camponotus</i> sp.
	Insecta	Hymenoptera	Formicidae		<i>Gnamptogenys menadensis</i>
	Insecta	Hymenoptera	Vespidae		<i>Polistine</i> spp.
	Insecta	Isoptera	Rhinotermitidae	Coptotermitinae	<i>Coptotermes curvignathus</i>
	Insecta	Isoptera	Rhinotermitidae	Coptotermitinae	<i>Coptotermes</i> sp.
	Insecta	Isoptera	Rhinotermitidae	Rhinotermitinae	<i>Schedorhinotermes</i>
	Insecta	Isoptera	Termitidae	Termitinae	<i>Globitermes globosus</i>
	Insecta	Isoptera	Termitidae	Macrotermitinae	<i>Hypotermes xenotermis</i>
	Insecta	Isoptera	Termitidae	Macrotermitinae	<i>Macrotermes</i>
	Insecta	Isoptera	Termitidae	Macrotermitinae	<i>Odontotermes</i> sp.
	Insecta	Isoptera	Termitidae	Nasutitermitinae	<i>Bulbitermes</i> sp.
	Insecta	Isoptera	Termitidae	Nasutitermitinae	<i>Lacessitermes</i>
	Insecta	Isoptera	Termitidae	Nasutitermitinae	<i>Nasutitermes</i>
	Insecta	Isoptera	Termitidae	Nasutitermitinae	<i>Nasutitermes longinasus</i>
	Insecta	Isoptera	Termitidae	Termitinae	<i>Dicuspiditermes</i>
	Insecta	Isoptera	Termitidae	Termitinae	<i>Homalotermes</i> sp.
	Insecta	Isoptera	Termitidae	Termitinae	<i>Microcerotermes dubius</i>
	Insecta	Isoptera	Termitidae	Termitinae	<i>Microcerotermes</i> sp.
	Insecta	Isoptera	Termitidae	Termitinae	<i>Pericapritermes</i>
	Insecta	Lepidoptera			
	Insecta	Orthoptera	Gryllotalpidae		
	Mammalia	Rodentia			
	Osteichthyes		Cyprinidae		
	Reptilia	Chelonia	Testudinidae		<i>Munouria emys</i>
	Reptilia	Chelonia			
	Chordata	Reptilia	Squamata		
Plant			Annonaceae		<i>Polyalthia sumatrana</i>
			Burseraceae		<i>Santiria</i> sp.
			Fagaceae		<i>Lithocarpus</i> spp.
			Moraceae		<i>Ficus</i> spp.