

## Small Mammal Survey at Two Sites in Planted Forest Zone, Bintulu, Sarawak

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**Abstract:** A survey for small mammals was done at two sites within the Forest Department of Sarawak's Planted Forests Project in the Bintulu Division. Sampling was carried out in Bukit Sarang, a flooded swamp forest, and in Samarakan forest, an area of mixed 6-7 year old *Acacia mangium* blocks interspersed with remnants of disturbed logged forest. A total of twenty-two chiropteran species was recorded from these sites, including the first confirmed Sarawak records of *Hipposideros bicolor* and *Myotis montivagus*, and two bat species possibly new to science. In addition, sixteen species of small mammals were recorded at both sites. A short taxonomic discussion including the regional significance is given for each species collected. The annotated checklist from these two areas revealed that certain mammal species do survive within *Acacia* plantings, while mammal species richness was high in designated conservation zones such as Bukit Sarang.

**Keywords.** Bats, Small Mammals, Bukit Sarang, *Acacia mangium*, Planted Forest Zone Bintulu, Sarawak.

### INTRODUCTION

During the late 1990s, the Sarawak State government began a major initiative to enhance the supply of industrial wood in its Planted Forests (Pulp and Paper) Project, and employed Grand Perfect Sdn Bhd as its principal contractor. The Planted Forest Zone (PFZ), located in the Bintulu Division, covers approximately 490,000 ha. Of this total, approximately 45% will be planted with the fast growing tree, *Acacia mangium*, while 30-35% has been set aside as conservation areas, either as large blocks (20,000-25,000 ha) or smaller forested riverine buffers or forest remnants within the acacia blocks. A conservation programme has been incorporated into plantation management to ensure biodiversity conservation throughout the landscape of the PFZ. The conservation programme consists of biological inventories and monitoring, community awareness and participation and a set of rules for the long-term protection of soils and waterways.

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The Smithsonian Institution and Grand Perfect Sdn Bhd have begun a long-term collaborative partnership to provide baseline data on mammal species distribution and abundance in the PFZ, and to promote training of local staff and students through field research. As part of this effort, from late January to early February, 2005, we made a collection of small mammals at two separate sites in the PFZ.

The PFZ itself lies in a gently rolling lowland landscape, bordered by several steep southeastern ridges, but with most topological features rarely exceeding 200m in elevation. The PFZ's easily eroded red and yellow podsol soils vary from relatively deep, up to a meter or more in flatter terrain, to shallower to skeletal soils (<50cm) in drier areas, or on hill slopes. In some areas, a thick layer of hard sandstone lies beneath these shallow soils. Scattered throughout the PFA are nutrient poor, fine white sands upon which developed a stunted heath, or *kerangas* vegetation. These areas have few minerals and little organic matter (Grand Perfect, Conservation unpublished data 2004).

The original flora of the PFZ comprised peat or freshwater swamp and *kerangas* assemblages, intermixed with riverine and lowland dipterocarp forest along rivers and further inland. Species composition varies greatly, although much of the dipterocarp forests have been removed or disturbed, either from years of shifting cultivation by local people or from extraction of economically valuable timber since the early 1970s. Older swidden plots called "temuda" are generally dominated by trees of non-timber families, such as the Euphorbiaceae, and a variety of fruit tree species.

The area now under development for *Acacia mangium* planting was mostly disturbed or logged over forests throughout the Tatau, Kakus and Anap river drainages, and the Sg. Pandan and Binyo portions of the upper Kemena drainage. There are remnants of peat and freshwater swamps located in shallow alluvial basins within the PFZ, such as the southwestern (Sg. Mayeng and Sg. Sarang, now the Bukit Sarang Conservation Area), and northeastern section (Sg. Pandan and Sg. Binyo, now known as the Binyo-Penyilam Conservation Area).

The majority of our specimens were obtained from the area surrounding limestone outcrops at Bukit Sarang, upriver of the Mayeng, a tributary of the Kakus River. Bukit Sarang is an approximately 700m long, and 80m high limestone outcrop, surrounded by a freshwater swamp forest that is inundated to a depth of 0.5-1.0 m several times per year. There is a boardwalk that parallels the hillside, with clearings of various ages on the other side.

Samarakan forest is an area of mixed 6-7 year old *Acacia mangium* blocks interspersed with remnants of disturbed logged forest. Both the natural forest remnants and the *Acacia* forest are markedly drier than the forest at Bukit Sarang (that is flooded episodically throughout most of the year), and supports only thinner and shorter trees, with little or no canopy development. Only a few small flowing streams were observed in the Samarakan area, and according to our informants, no caves are known to be nearby.

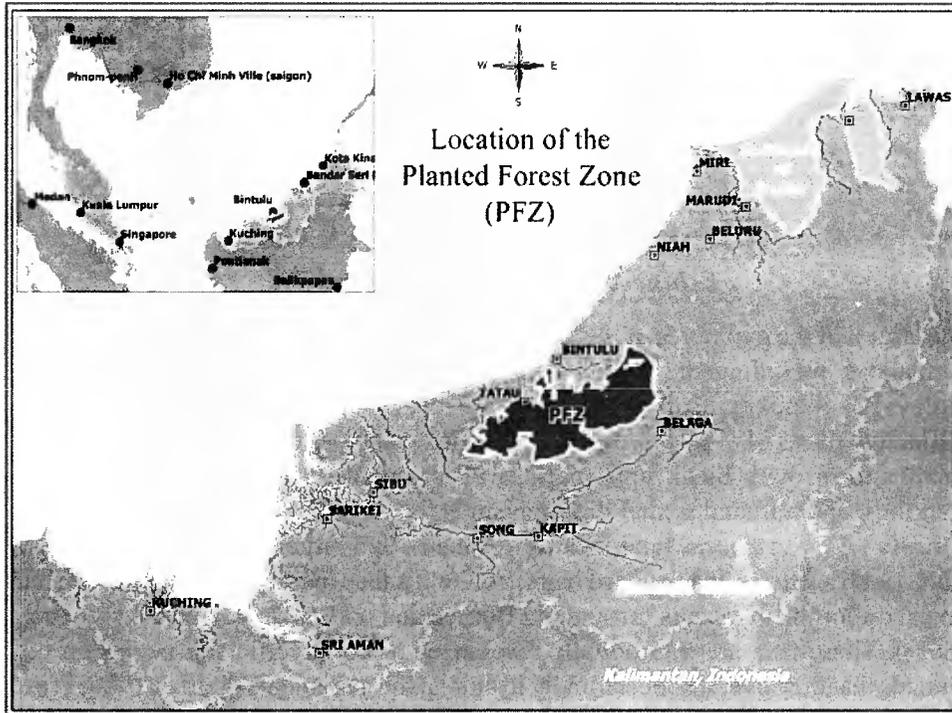


Figure 1. Location of the Planted Forest Zone, Bintulu, Sarawak.

## MATERIALS AND METHODS

As these surveys were done primarily to determine species richness and taxonomic investigations of the communities, traps were set more for effectiveness of capture than for ecological evaluation of the fauna. We used a variety of traps for small mammals including wire cages, Elliot traps, snap traps and pitfall traps along the trail, and extended our effort up onto the outcrop as well. Traps were placed at intervals of 20 meters on the ground as well as on lianas or branches. They were checked every morning and evening. A mixture of bait including banana, oil palm seed, coconut and rat carcass was used. In addition, we used mist nets and a small harp trap to capture bats along the trail and near the small stream that ran parallel to and within about 5-10 metres of the base of the Bukit Sarang limestone outcrop. Hand netting was used to capture bats in cleared areas. The harp trap and mistnets were opened only after dusk, and checked hourly until around midnight. Any small mammal species not trapped were identified through interviews with locals and by observing them or examining their tracks.

All captured animals were weighed, measured and voucher specimens were taken, either in the form of scientific museum skins or formalin preserved preparations. Skulls were prepared and at least one individual of each species was skeletonised for further study. Paired tissues samples were obtained from at least

six individuals of most species for DNA studies and blood dots to archive viral RNA, were taken. A complete set of tissues has been deposited at Universiti Malaysia Sarawak (bats) and Universiti Tunku Abdul Rahman (rats and squirrels). Dry and wet preserved specimens were sent for taxonomic verification to the Smithsonian Institution, National Museum of Natural History.

#### ANNOTATED CHECKLIST

##### *Echinosorex gymnura* (Raffles 1822)

The largest of the gymnures, *E. gymnura* occurs in the forested lowlands of northern Sundaland, including the Malay Peninsula (peninsular Burma, Thailand, and Malaysia), Sumatra, Borneo, and the adjacent small island of Labuan. Two distinctive forms of *E. gymnura* can be recognized across this geographic range. A smaller form, with black upperparts, well-pronounced black-and-white facial markings, and minimal sexual dimorphism is found on the Asian mainland and in Sumatra (*E. g. gymnura*, type locality “Sumatra”); a larger form, almost entirely white (with scattered black guard hairs), without a face mask, and with pronounced sexual dimorphism, occurs throughout Borneo and on Labuan (*E. g. alba* [Giebel, 1863]). These taxa are traditionally recognized as conspecific subspecies on the grounds that they overlap substantially in cranial measurements (Corbet 1988; Frost *et al.* 1991; Corbet and Hill 1992; Hutterer 2005). However, our own examinations of specimens in museums worldwide suggest that *gymnura* and *alba* differ substantially (even absolutely) in various cranial measurements when pairwise comparisons are limited to specimens of like sex. For example, 5 female *alba* from the USNM averaged 85.5mm in greatest skull length, and 7 *gymnura* averaged 78.1mm. Similarly, 3 male *alba* averaged 88.7mm and 4 *gymnura* averaged 78.0mm. Additional studies incorporating morphometric and genetic data are required to investigate further whether these taxa might be more appropriately ranked as distinct species.

A single subadult specimen of *E. g. alba* (basilar sutures unfused, last molars unerupted) was salvaged as a fresh roadkill one morning on a road at Samarakan (total length 614mm).

##### *Crocidura foetida* (Peters 1870)

This species, considered distinct from *C. fuliginosa* (cf. Payne *et al.* 1985) by Ruedi (1995), is apparently endemic to Bornean lowland and lower montane forests. Three specimens were taken in pitfall traps situated along buttress roots and limestone walls in the closed forest at Bukit Sarang (total length 151-163mm, weight 6.5-14 grams). Two subspecies were recognized, *C. f. doriae* Peters, 1870 and *C. f. kelabit* Medway, 1965. Although the limits of these two are poorly defined, we would tentatively assign our specimens to *C. f. doriae*.

***Tupaia tana*** (Raffles 1821)

*Tupaia tana* is a large and colourful treeshrew that occurs on the large islands of Borneo and Sumatra and on a number of small islands nearby, including Bangka, Banggi, Belitung, Tambelan, Serasan, and the Batu and Lingga Islands (Helgen 2005).

This species was common in the closed forest at Bukit Sarang and in adjacent areas, where it was trapped by day, especially with fresh fruit. Additionally, a single, very old specimen, with cataracts in both eyes, was taken in an acacia plantation at Samarakan (adults: total length 360-455 mm, weight 190-300 grams; 10 specimens). Given their geographic provenance, these specimens probably represent the subspecies *T. t. utara* (Lyon 1913), but further comparative study is needed. Another, smaller treeshrew (*T. minor* or *T. gracilis*) was observed one morning near the edge of the closed forest at Bukit Sarang, but was not collected.

***Nycticebus coucang*** (Boddaert 1785)

The slow loris of Southeast Asia (*N. coucang*) occurs throughout lowland and hill forests of Sundaland, including the Malay Peninsula, the major islands of the Sunda Shelf (Sumatra, Borneo, Natuna Islands, Bangka, and Java), and the islands of the Sulu Archipelago adjacent to Borneo in the far southern Philippines (Groves 2001). A single adult *N. coucang* was brought in by local hunters at Samarakan and was released into a small, degraded rainforest fragment. The subspecies here is most likely *N. c. menagensis* Trouessart, 1898.

***Macaca fascicularis*** (Raffles 1821)

This widespread and adaptable Asian macaque is common throughout Southeast Asia (southern Indochina and the Nicobar Islands to most islands of the Sunda Shelf, Lesser Sundas, and Philippines (Fooden 1995). It is particularly common in disturbed contexts, including plantations and other agricultural landscapes, village margins, regrowth, and various forest types (Payne *et al.* 1985).

We observed this species in trees on limestone hills at the edge of the closed forest at Bukit Sarang. The subspecies here is the nominate form, *M. f. fascicularis*.

***Callosciurus notatus*** (Boddaert 1785)

This squirrel is common and widespread in anthropogenic landscapes and other disturbed contexts (plantations, gardens, regrowth, etc.) throughout the Sundaic region (peninsular Thailand and Malaysia, Sumatra, Borneo, Java, Bali, and various small islands on the Sunda Shelf), as well as on Lombok and Salayer in Wallacea (its occurrence on the last island certainly reflects translocation by human agency (Corbet and Hill 1992). It is found throughout Borneo (Payne *et al.* 1985).

We collected only one specimen of this species in the closed forest at Bukit Sarang. Four others (including a pregnant female carrying two embryos on January

29) were taken in *Acacia* plantations and degraded rainforest fragments at Samarakan, where they seemed to be more common (adults: total length 400-410mm, weight 250-300 grams). All specimens were taken in traps placed on the ground or in low trees, baited with fresh fruit. Although there is an enormous number of named forms of this species, actual variation is relatively low. Our specimens likely belong to *C. n. suffusus* (Bonhote 1901).

***Callosciurus prevostii*** (Desmarest 1822)

This large tree squirrel occurs throughout the northern part of the Sundaic region, including peninsular Thailand and Malaysia, Sumatra, Borneo, and adjacent islands. It is also recorded from northern Sulawesi, where it has almost certainly been introduced by human agency (Musser 1987). Various strongly differentiated subspecies can be recognized within this species (e.g. see Payne *et al.* 1985). The type locality of *prevostii* is Malacca.

This species was observed in the canopy of the tall closed forest at Bukit Sarang, but not collected there. At Samarakan a single adult male representing the subspecies *C. p. caroli* (Bonhote 1901) was received from a local hunter (total length 510, weight 360 grams). We suspect that *C. p. caroli* may be a junior synonym of *C. p. sarawakensis* (Gray 1867).

***Exilisciurus exilis*** (Müller 1838)

This very small squirrel is endemic to closed lowland and lower montane forests of Borneo and the small adjacent island of Banggi (Heaney 1985; Payne *et al.* 1998). We observed it commonly in the closed forest at Bukit Sarang, but did not collect any specimens.

***Sundasciurus hippurus*** (I. Geoffroy 1831)

This medium-sized squirrel is an inhabitant of southern Indochina and the Sunda Shelf (southern Vietnam to Sumatra and Borneo). It occurs through much of Borneo, where it is represented by several well-differentiated subspecies (Corbet and Hill 1992; Payne *et al.* 1985).

We trapped a single specimen of this species in a live-trap placed on a log about one meter off the ground in the *Acacia* forest at Samarakan (total length 490 mm, weight 320 grams). The subspecies at Samarakan appears to be *S. h. hippurellus* (Lyon 1907), although we suspect it to be a junior synonym of *S. h. borneensis* (Gray 1867), since our examination of a large number of specimens in museums worldwide has revealed little difference in either colour or size.

***Maxomys whiteheadi*** (Thomas 1894)

This terrestrial rat is endemic to forests in northern Sundaland, including the Malay Peninsula, Sumatra, Borneo, and associated small islands (Musser *et al.* 1979;

Gorog *et al.* 2004).

Two specimens were trapped on the ground at Samarakan—a juvenile male in *Acacia* forest (weight 21.5 grams) and an adult female in a degraded forest fragment near a small stream (total length 265 mm, weight 250 grams).

***Niviventer cremoriventer*** (Miller 1900)

This scansorial rat is endemic to Sundaland, occurring throughout the Malay Peninsula, on the major islands of the Sunda Shelf (Borneo, Java, Bali, Sumatra, Beliton, Bangka, Nias) and on various associated smaller islands (Corbet and Hill 1992). It occurs throughout Borneo, usually in lowland forests.

We collected a single adult female *N. cremoriventer* in a live-trap on the ground at the edge of the secondary forest at Bukit Sarang (total length 320 mm, weight 65 grams).

***Rattus tiomanicus*** (Miller 1900)

This relatively small terrestrial rat occurs throughout the Sunda Shelf on essentially all islands, both large and small, including Borneo (Musser and Califfa 1982; Heaney *et al.* 1998). It is widespread in coastal and secondary forests, plantations, gardens, regrowth, and grassland, and less commonly found in homes or in mature forests (Payne *et al.* 1985).

We trapped two specimens of this species near the edge of the tall forest situated on limestone hills at Bukit Sarang, comprising an adult male (total length 360 mm, weight 150 grams) and a juvenile male (total length 215 mm, weight 33.5 grams).

***Sundamys muelleri*** (Jentink 1879)

This large-bodied rat is restricted to the Sundaland region, including the Malay Peninsula, Sumatra, Borneo, Palawan, and various associated islands. It is a common rat in the lowlands of Borneo (Payne *et al.* 1985).

We commonly observed and trapped this species both on the ground and in low trees at night at Bukit Sarang and at Samarakan. Specimens from both of these Sarawak localities are larger than other samples previously reported from mainland Borneo (head-body length 238-295 mm, weight 220-350 grams, greatest length of skull 49.0-55.6 mm; 23 specimens), and more similar in size to samples from certain islands that lie immediately adjacent to Borneo (cf. Musser and Newcomb 1983).

***Balionycteris maculata*** (Thomas 1893)

Among the smallest of all pteropodid bats, *Balionycteris maculata* is distributed in or near closed lowland forests across the northern portion of the Sunda Shelf, including peninsular Thailand and Malaya, the Riau Archipelago, Sumatra, and Borneo (Corbet and Hill 1992; Danielsen *et al.* 1997). The type locality of *maculata*

was given only as “Sarawak” (Thomas 1893; Andersen 1912). It can be immediately distinguished from all other pteropodids by its very small size, small pale spots on the wing membranes, and by the absence of a tail.

During our visit in January 2005, we discerned that *Balionycteris* was common in the understorey of the tall forest at Bukit Sarang, and was more commonly harp trapped than mistnetted. Both pregnant and unpregnant adult females were caught during this month. Forearm length among fully-grown specimens of the *Balionycteris* ranged from 38.5 to 45 (Andersen 1912; Payne *et al.* 1998; Danielsen *et al.* 1997; Kofron 2002). Forearm lengths in adults from our series from Bukit Sarang measured 40–44 (adults: condylobasal length 19.94–20.92 mm; weight 10.5–16 grams; 31 specimens). Our specimens belonged to the nominate form, *B. m. maculata*.

### *Cynopterus brachyotis* (Müller 1838)

As currently recognized, this species is widely distributed throughout south and Southeast Asia, from Sri Lanka and the Indian Subcontinent throughout Indochina, Sundaland (including Borneo), the Philippines, and Sulawesi, in most habitat types (Corbet and Hill 1992). However, the taxonomy of this species is extremely problematic, and recent genetic studies have conclusively demonstrated that multiple species are included in *brachyotis*, including two taxa with different habitat preferences, which are widely sympatric across Southeast Asia (e.g. Campbell *et al.* 2004, 2005).

In light of the uncertainty that currently surrounds the morphological identification of taxa within this species-complex, we refer all of our *brachyotis*-like specimens to this species. This species was commonly netted in clearings adjacent to the closed forest at Bukit Sarang and on a bridge over a pond at Samarakan (forearm 56–66 mm, weight 25.5–37.5 grams, condylobasal length 25.6–28.0 mm; 25 specimens). If these specimens do ultimately turn out to be *C. brachyotis*, they are likely to be referable to the nominate form, given that the type locality is the Dewei River, Borneo.

### *Eonycteris spelaea* (Dobson 1871)

This widespread bat is a common species in caves throughout tropical south and Southeast Asia, from the Indian subcontinent to the Sunda Shelf, Philippines, Moluccas, and Lesser Sundas (including Borneo).

Maharadatunkamsi and Kichener (1997) recently proposed the subspecific *E. s. winnyae* for the Bornean population of this species. One adult female specimen of this taxon (forearm 65) was mistnetted in a clearing adjacent to the tall forest at Bukit Sarang. The widely sympatric, larger-bodied congener *Eonycteris major* is also recorded from the Ulu Kakus area (Fogden 1967), but we did not encounter this species.

***Macroglossus minimus*** (E. Geoffroy 1810)

This widespread and common bat occurs throughout Australasia from Thailand to the Philippines, Solomon Islands, and Australia (including in Borneo). It is one of the most common bats of the region, generally encountered in coastal and lowland areas such as mangroves or degraded landscapes such as local gardens and secondary forest, rather than in closed, mature forest.

This bat was commonly mistnetted in clearings at Samarakan, and a few were netted in clearings adjacent to the tall forest at Bukit Sarang (adults: forearm 39-42 mm, weight 13-15.5, condylobasal length 23.5-24.4 mm; 13 specimens). Specimens from Borneo have been referred to as *M. m. lagochilus* Matschie, 1899.

***Penthetor lucasi*** (Dobson 1880)

This species is a small-bodied cave-dwelling pteropodid classified in a monotypic genus. It is endemic to the forested lowlands of northern Sundaland, where it is found on the Malay Peninsula, Sumatra, the Riau Archipelago, and Borneo (Simmons 2005). The type locality of *lucasi* was given only as “Sarawak” (Andersen 1912).

*Penthetor lucasi* is a common species at Bukit Sarang, where a single (rather shallow) cave roost that we visited supported thousands of individuals. It was regularly taken by harp trapping and mistnetting in and near closed forest (adults: forearm 62-65 mm, weight 35-43 grams, condylobasal length 26.5-27.3; 15 specimens).

***Pteropus vampyrus*** (Linnaeus 1758)

This flying-fox is the largest-bodied bat of Sundaland. It has a relatively wide distribution in the coastal and riverine lowlands of Southeast Asia (especially insular Southeast Asia), being recorded from throughout much of Indochina, Sundaland (including Borneo), the Lesser Sundas, and the Philippines. This is the only species of *Pteropus* regularly recorded from the mainland of Borneo (Payne *et al.* 1985). It typically roosts in large colonies in nipah palm or mangroves along the coast, but migrates inland for the fruiting season. They are known to forage both in natural forest and agricultural areas for fruits, fresh shoots and flowers. (Stier 2003).

We sporadically observed several solitary individuals of this species during our visit to Bukit Sarang, but did not collect any specimens. The Borneo subspecies is *P. v. natunae* K. Andersen, 1908.

***Hipposideros bicolor*** (Temminck 1834)

This small horseshoe-bat occurs throughout the Malay Peninsula, on various islands associated with the Sunda Shelf (including Sumatra, Borneo, and Java), and in the Philippines and Lesser Sundas (Corbet and Hill 1992; Kitchener *et al.* 1996).

We collected this species at Bukit Sarang in harp traps situated along paths in closed forest and by hand-netting foraging bats in cleared areas. This was the least commonly collected of the four species of *Hipposideros* recorded at this site (adults: forearm 44-47 mm; weight 6.5-8.5 grams, condylobasal length 16.23-16.66 mm; 11 specimens). Our specimens were referable to the nominate form, *H. b. bicolor*.

***Hipposideros cervinus*** (Gould 1854)

This leaf-nosed bat is extremely widely distributed in the Australasian tropics, occurring throughout Sundaland (including Borneo), Wallacea, the Philippines, Melanesia (New Guinea to Vanuatu), and tropical north-eastern Australia (the type locality of *cervinus* is Cape York in Queensland). In the past this species has at times been confused with *H. galeritus*, with which it occurs in widespread sympatry (e.g. Jenkins and Hill 1981; see below).

This species is common in limestone caves at Bukit Sarang, where we collected many individuals in harp traps situated in closed forest and mistnets in and adjacent to the closed forest (adults: forearm 47-51mm, weight 6-10.5 grams, condylobasal length 15.53-16.24 mm; 32 specimens). We also mistnetted two specimens (both larger-skulled) in a clearing adjacent to a rainforest patch at Samarakan (forearm 42-48 mm, weight 8.5-9.5 grams, condylobasal length 16.30-16.39 mm). This species averaged slightly larger than the sympatric congener *H. bicolor* (see above) and slightly smaller than the sympatric *H. galeritus* (see below). The Borneo subspecies is *H. c. labuanensis* Tomes, 1859.

***Hipposideros diadema*** (E. Geoffroy 1813)

This large leaf-nosed bat is widely distributed throughout the Australasian region from southern Indochina, the Nicobar Islands, and the Sunda Shelf eastward throughout the Malay Archipelago to the Philippines, tropical northern Australia, New Guinea, and the Bismarck and Solomon archipelagos (Corbet and Hill 1992; Flannery 1995). It typically roosts in caves, and occurs in cave systems throughout Borneo (Payne *et al.* 1985). Andersen (1905) erected the name *H. d. vicarius* for Bornean populations (type locality “Sarawak”), but we suspect this to be a junior synonym of *H. d. nobilis* Horsfield, 1823 (type locality “Java”). Payne *et al.* (1985) referred Borneo material to *H. d. masoni* (Dobson 1872), with type locality Moulmein, Burma.

This species is common at Bukit Sarang, where we observed a colony numbering in the thousands in a limestone cave system. We regularly observed individuals foraging in the forest at night and commonly collected them in harp traps situated along paths and streams in the closed forest and in mistnets both in clearings adjacent to the forest (adults: forearm 80-93 mm, weight 36.5-49 grams, condylobasal length 28.21-31.13 mm; 19 specimens). This is the largest of the four species of *Hipposideros* collected syntopically at this site, by a considerable margin (see accounts of *H. bicolor*, *H. cervinus*, and *H. galeritus*).

### ***Hipposideros galeritus*** (Cantor 1846)

This leaf-nosed bat is widely distributed in tropical south and Southeast Asia, from Sri Lanka and the Indian subcontinent in the west to Sulawesi in the east (the type locality of *galeritus* is the island of Penang in Malaysia), including Borneo. In the past this species has at times been confused with *H. cervinus*, with which it occurs in widespread sympatry (e.g. Jenkins and Hill 1981; see above).

This species is common in limestone caves at Bukit Sarang, where we collected many individuals in harp traps situated in closed forest and mistnets in and adjacent to the closed forest (adults: forearm 50-54 mm, weight 6.5-10 grams, condylobasal length 15.62-16.36 mm; 13 specimens). The forearm and skull averaged larger than sympatric *H. cervinus*. The Borneo material is referable to *H. g. insolens* Lyon, 1911.

### ***Rhinolophus borneensis*** (Peters 1861)

The type locality of *Rhinolophus borneensis* is the small island of Labuan, situated off the northern coast of Sabah. Specimens identified as *borneensis* originate from various sites throughout Southeast Asia, including Borneo, the South Natuna Islands, Java and Karimata, Banggi Island, and scattered sites in Cambodia and Vietnam (Corbet and Hill 1992). However, the morphological limits of *borneensis* remain poorly defined, and we suspect that more than one species is represented under this current geographic concept of *borneensis* (see also Csorba *et al.* 2003). We confidently allocate our specimens to the nominate subspecies of true *R. borneensis* on the basis of their dimensions and their close provenance to the type locality.

*Rhinolophus borneensis* occurs throughout the island of Borneo (Payne *et al.* 1985). We found it to be very common in limestone caves at Bukit Sarang, and collected it both from cave walls and in harp traps situated in the closed forest (forearm 42-45; weight 6.5-10.5 grams; condylobasal length 17.10-18.08; 22 specimens). Though at least ten species of *Rhinolophus* occur in Borneo (Csorba *et al.* 2003; Payne *et al.* 1985), we recorded only two species at this site (*R. borneensis* and *R. philippinensis*, see below).

### ***Rhinolophus philippinensis*** (Waterhouse 1843)

The type locality of *Rhinolophus philippinensis* is the island of Luzon in the northern Philippines. This species is believed to be widely distributed, from Borneo in the west to Sulawesi, the Moluccas, New Guinea, tropical north-eastern Australia, and the Philippines (Csorba *et al.* 2003). However, various studies of the taxonomy and ecology of populations referred to *philippinensis* suggest that this “species” in fact comprises a complex of morphologically similar species that can occur in sympatry (Flannery 1995; Kingston and Rossiter 2004). Thus, we only tentatively associate the name *philippinensis* with our series of specimens from Sarawak, pending more detailed taxonomic comparisons. Specimens referable to *philippinensis* have been collected throughout Sabah and Sarawak (Payne *et al.*

1985), and the name *R. p. sanborni* Chasen, 1940 has been applied to a sample from Borneo (type locality Tapadong Caves, on the east coast of Sabah).

*Rhinolophus philippinensis* is considered a rare species throughout much of its geographic range, but we found it to be common in the vicinity of limestone caves at Bukit Sarang, where we harp trapped and mistnetted many individuals in the closed forest (adults: forearm 50-55 mm; weight 8-10 grams; condylobasal length 19.78-20.66 mm; 18 specimens).

### *Nycteris tragata* (Andersen 1912)

Only one species of *Nycteris* was recorded from Borneo. Payne *et al.* (1985), apparently following Chasen (1940), applied the name *Nycteris javanica* Geoffroy, 1813 to this species, but Corbet and Hill (1992) instead tentatively retained *Nycteris tragata* (Andersen 1912), with type locality in Sarawak (Bidi Caves), as a species distinct from *javanica*. On the basis of their examinations of a large number of specimens from the Sundaic region, van Cakenberghe and de Vree (1993) argued that *N. javanica* is restricted to Java and a handful of adjacent islands (also see Kock and Dobat 2000), and that the closely-related, allopatric species *Nycteris tragata* occurs in Sumatra, Borneo, and in the Malay Peninsula (north to Burma). We collected two adults representing *tragata* in a harp trap situated in the closed forest at Bukit Sarang (female, male; forearm 52, 51 mm, weight 10, 15 grams; condylobasal length 18.66, 18.82 mm).

### *Miniopterus australis* (Tomes 1858)

This widely distributed bentwing-bat occurs from various island groups of the south-west Pacific (New Caledonia and the Loyalty Islands, Vanuatu, the Solomons and Bismarcks, and New Guinea) to Australia, Wallacea, the Philippines, and Borneo and Java (the type locality lies in the Loyalty Islands, at the far eastern margin of this recorded geographic range). As currently defined, *M. australis* probably incorporates several distinct species across this wide geographic range, and extensive study of this seeming species-complex is needed (see Simmons 2005). The name *Miniopterus witkampii* Sody, 1930 (type locality in East Kalimantan) has been applied to Bornean populations currently assigned to this species, and is sometimes recognized as a valid subspecies (i.e. *M. a. witkampii*) endemic to Borneo (Payne *et al.* 1985; Corbet and Hill 1992). However, Kitchener and Suyanto (2002) recognized *witkampii* as a subspecies of *Miniopterus paululus*.

This cave-dwelling bat occurs in cave systems throughout Borneo. It is common at Bukit Sarang, where we harp trapped many individuals in the closed forest (adults: forearm 37-40 mm; weights 4.5-6 grams; condylobasal length 13.48-13.89 mm; 28 specimens). Five species of *Miniopterus* are thought to occur in Borneo (Payne *et al.* 1985), but only two species were encountered at Bukit Sarang (*M. australis* and *M. magnater*, see below).

***Miniopterus magnater*** (Sanborn 1931)

This is the largest species of *Miniopterus* in Borneo. Maeda (1982) erected a new species (*M. macrodens*) based on specimens from Borneo (type locality Madai Cave in Sabah), but Hill (1983) and later authors have regarded *macrodens* as a subspecies of *M. magnater* (type locality in northern New Guinea). As currently defined (Simmons 2005), *M. magnater* has an extremely wide distribution (China and Myanmar in the west to New Guinea and the Bismarck Archipelago in the east), but probably incorporates multiple species. Identification of this species relative to *M. schreibersii* (also recorded from Borneo) can be problematic (Payne *et al.* 1985), but in light of comparisons recorded by Hill (1983) and Payne *et al.* (1985), the large dimensions of our sample from Bukit Sarang (see below) leave no doubt that they should be referred to *M. magnater*.

This cave-dwelling bat is common at Bukit Sarang, where we harp trapped many individuals in the closed forest (adults: forearm 49-51 mm; weights 12-14 grams; condylobasal length 16.36-16.68 mm; 7 specimens). It is considerably larger-bodied than the only other congener taken at this site (*M. australis*, see above).

***Myotis ater*** (Peters 1866)

As currently recognized (Francis and Hill 1998; Simmons 2005), this medium-sized *Myotis* is distributed throughout the tropical lowlands of Sundaland, Wallacea, the Philippines, New Guinea, and Australia. However, systematic relationships and taxonomic boundaries of *M. ater* and other similar *Myotis* in Southeast Asia remain confused and require considerable future study. This confusion prohibits firm identification of *ater*-like samples.

A single specimen harp trapped in the closed forest at Bukit Sarang (weight 7.5 grams) is tentatively referred to *M. ater* rather than to *M. gomantongensis* (see below). Its measurements are larger than measurements reported for Bornean *M. ater* by Francis and Hill (1998)—e.g. forearm 42 vs. 34.7-39.5 mm, condylobasal length 14.2 vs. 13.1-13.9 mm, and has a slightly smaller skull and relatively smaller third upper premolar than syntopically collected specimens referred to *M. gomantongensis* (see below). Further study is needed to clarify its identification. The Borneo subspecies is *M. a. nugax* Allen and Coolidge, 1940.

***Myotis gomantongensis*** (Francis and Hill 1998)

This relatively new described species was named by Francis and Hill (1998) based on specimens from several localities in Sabah (Gomantong Caves, Baturong Caves, and Sinoa). Before this, specimens of *M. gomantongensis* had been identified as *M. ater* (e.g. by Payne *et al.* 1985), but both species apparently occur in Borneo, and may occur syntopically (our data). A great deal of additional study is needed to confirm the identity and distributional limits of *M. ater*, *M. gomantongensis*, and various other related (or difficult to distinguish) taxa throughout Australasia, some of which are described (such as *M. mystacinus*, *M. muricola*, and “*M. ater nugax*”;

see Francis and Hill 1998) and some of which may not yet be characterized taxonomically (perhaps including the unknown species listed below).

Based on comparisons with the description of *M. gomantongensis*, we tentatively refer a series of specimens harp trapped in the closed forest at Bukit Sarang to this taxon. Measurements of adults in this series include (comparisons for the type series of *M. gomantongensis* taken from Francis and Hill, 1985): forearm 40-43 mm (vs. 40-43.1 in *M. gomantongensis* from Sabah), weight 6-8 grams (vs. 6.4-8.8 grams), condylobasal length 14.67-15.31 mm (vs. 14.3-15.3), breadth of braincase 7.27-7.94 mm (vs. 7.4-7.9). If correctly identified, these specimens represent the first confirmation of this species' occurrence in Sarawak (indeed, the first record from anywhere outside Sabah).

### *Myotis horsfieldii* (Temminck 1840)

This small *Myotis* is widespread in the tropics and subtropics of south and south-east Asia, occurring from India and the Andaman Islands to southern China, Indochina, and the islands of Sundaland (including Borneo), Wallacea, and the Philippines. Additional studies are needed to determine whether this wide-ranging taxon represents one or several distinct species. The type locality of *horsfieldii* is Mt. Gede in Java.

Harp trapping revealed this species to be common in the closed forest at Bukit Sarang. This is the smallest of the four or five species of *Myotis* taken syntopically at this location (adults: forearm 36-38 mm; weight 5-6 grams; condylobasal length 13.93-14.92 mm; 13 specimens). Our specimens are referable to the nominate subspecies.

### *Myotis montivagus* (Dobson 1874)

*Myotis montivagus* is a widespread Asian *Myotis*, at least as currently defined. Though records are scattered, it apparently occurs throughout Southeast Asia, from the Indian subcontinent and southern China south to Malaya and Borneo (Corbet and Hill 1992), but there is considerable cranial size variation across this range (Hill and Francis 1984). Compared to mainland Asian populations of *M. montivagus*, specimens from Borneo had absolutely larger skulls and were described as an endemic subspecies (*M. m. borneoensis*) by Hill and Francis (1984). Further study may show that *M. montivagus* is a complex of distinctive taxa (the type locality of *montivagus* is in Yunnan in southern China) and that, as we strongly suspect, *borneoensis* is better classified as a separate species.

In Borneo *M. montivagus* has previously been reported from Sepilok and Madai in eastern Sabah (Hill and Francis 1984; Payne *et al.* 1985). Two adult female specimens collected at Bukit Sarang represent the first record of this species from Sarawak. These were taken in a harp trap situated alongside a stream in the closed forest (adults: forearm 44-44mm, weight 9-10 grams, condylobasal length 15.76-15.89; and Payne *et al.* (1985) reported the species from similar contexts in Sabah. Several sympatric congeners were collected at the same harp trapping

location (see above and below).

***Myotis* sp.**

A single specimen of *Myotis* collected at Bukit Sarang cannot be immediately associated with any species of the genus currently recorded from Borneo or elsewhere in Southeast Asia. This specimen (which was identified as *M. ater* in the field) is an adult female (forearm 43mm; weight 7.8 grams); notably, this specimen lacks third upper premolars (present in *M. ater* and *M. gomantongensis*). It is slightly larger (cranially) than syntopically-collected specimens here referred to *M. gomantongensis* Francis and Hill, 1998 (see above), and has relatively heavier molars and a broader and higher-domed braincase compared to that taxon (condylobasal length 15.45, breadth of braincase 8.16; see above). This specimen was harp trapped along a path beside a small stream in the closed forest, in the vicinity of many limestone caves.

***Kerivoula lenis* (Thomas 1916)**

Thomas (1916) named *Kerivoula lenis* based on a specimen collected near Calcutta. Most subsequent authors included *lenis* within the synonymy of *K. papillosa*, generally considered to be a widespread south and Southeast Asian taxon (e.g. Chasen 1940; Hill 1965; Tate 1941; Corbet and Hill 1992; Bates and Harrison 1997). However, Vanitharani *et al.* (2003) and Bates *et al.* (2004) have recently argued that *K. lenis* is a distinct species, smaller-bodied than *K. papillosa*, and that the two are widely sympatric in Southeast Asia. Previously, *Kerivoula lenis* was reported from widely separated localities in the Indian subcontinent, from Vietnam, from the Malay Peninsula, and from Sabah in northern Borneo (Vanitharani *et al.* 2003; Bates *et al.* 2004). Drawing from the morphological and morphometric characterization of *K. lenis* developed by Vanitharani *et al.* (2003) and Bates *et al.* (2004), we refer several specimens collected at Bukit Sarang to *lenis*, representing the first record of this species from Sarawak. However, our own preliminary investigations suggest that this current concept of *K. lenis* probably incorporates multiple species.

Our series of specimens referred to *K. lenis* (forearm 40-43 mm, weight 6-8.5 grams, condylobasal length 14.9-16.0 mm; 8 specimens) were collected in a harp trap situated along a path in the tall forest near a stream. A specimen referred to *Kerivoula papillosa* was also harp trapped at this location (see below).

***Kerivoula papillosa* (Temminck 1840)**

As currently defined, *Kerivoula papillosa* occurs throughout Sundaland and on the large Wallacean island of Sulawesi. However, our own preliminary investigations suggest that this current concept of *K. papillosa* probably incorporates multiple species.

One specimen referred to *K. papillosa* was taken in a harp trap in the closed forest at Bukit Sarang (forearm 50 mm, weight 13 grams, condylobasal length 17.7 mm). This specimen was unusually large and as far as we are aware, it is the largest individual specimen of *Kerivoula* on record. It may represent an undescribed taxon distinct from *K. papillosa*; and further study is needed to determine its status. The Borneo material has been referred to *K. p. malayana* Chasen, 1940.

### ***Manis javanica*** (Desmarest 1822)

The Malayan pangolin occurs throughout Southeast Asia, including Indochina, the Malay Peninsula, and on the islands of the Sunda Shelf (Borneo, Sumatra, Java, Palawan, and various adjacent smaller islands).

A single adult *M. javanica* was captured by local hunters at Samarakan; this animal was released into an area of regrowth forest, apparently near where it had been captured.

### ***Herpestes brachyurus*** (Gray 1837)

*Herpestes brachyurus* is a large mongoose endemic to Sundaland (where it is recorded from the Malay Peninsula, Sumatra, Borneo, and possibly Java). Mongooses from Palawan and adjacent islands in the Philippines are usually considered to be conspecific with *brachyurus*, but our museum-based research suggests that these populations are probably better considered a distinct species, the appropriate name for which is *Herpestes parvus* Jentink, 1895. The taxonomic status of *Herpestes hosei* Jentink, 1903 (type locality Baram River, Sarawak), which was recognized as a distinct species by Payne *et al.* (1985) but synonymized with *H. brachyurus* by Corbet and Hill (1992) and Wozencraft (2005), remains obscure.

This species occurs throughout the forested lowlands of Borneo (Payne *et al.* 1985). We collected a single adult male in a large cage-trap baited with a rat carcass, hidden in scrubby undergrowth along a dirt trail in the *Acacia* forest at Samarakan (total length 615 mm, condylobasal length 84.5 mm). Another individual was sighted running across the road in a similar habitat.

### ***Paradoxurus hermaphroditus*** (Pallas 1777)

This widespread Asian civet is common in lowland forests from the Indian subcontinent to Wallacea and the Philippines, including Borneo. We observed this species at night both in the closed forest at Bukit Sarang and in the *Acacia* forest at Samarakan, but did not collect any specimens. Payne *et al.* (1985) assigned the Borneo material to *P. h. sabanus* Thomas, 1909, but this form is likely synonymous with *P. h. philippinensis* Jourdan, 1837.

## RESULTS AND DISCUSSION

Sarawak has a diverse and biogeographically interesting mammalian fauna. For some groups, mainly small rodents and bats, our knowledge of the systematic relationships and limits of occurrence of many species is quite limited. Our collections will help to resolve some of the current questions about this fauna, and we have detailed studies underway based on many of the specimens described above.

The most striking feature of Bukit Sarang is its extensive system of limestone caves of varying sizes and depths, making it an important roosting area for many insectivorous bats (including species of the families Hipposideridae, Rhinolophidae, Nycteridae, Vespertilionidae) as well as for various small frugivorous bats (Pteropodidae). A total of 22 bat species was recorded from this site, including the first confirmed records of *Hipposideros bicolor* and *Myotis montivagus* in Sarawak, and a couple of species that may be new to science.

Vegetation in the vicinity of Bukit Sarang is a mosaic of tall and secondary lowland forest, in some areas supporting a tall canopy that supports a moderately diverse assemblage of squirrels and primates. The species encountered included *Exilisciurus exilis* (observed), *Callosciurus notatus* (collected), *Callosciurus prevostii* (observed), a flying squirrel (probably *Petinomys genibarbis*; observed), *Presbytis hosei* (observed) and *Macaca fascicularis* (observed). Small non-volant mammals collected in the area included the murine rodents *Rattus tiomanicus*, *Sundamys muelleri*, and *Niviventer cremoriventer*; the squirrel *Callosciurus notatus*, the shrew *Crociodura foetida*, and the treeshrew *Tupaia tana*, all of which are common and widespread inhabitants of Bornean lowland forests. One species of civet (*Paradoxurus hermaphroditus*) was additionally observed in the forest at night. Careful interviews with workers living in the forest revealed that a number of additional species occurred in the immediate area, including porcupines, otters, the moonrat (*Echinosorex gymnurus*), the giant squirrel (*Ratufa affinis*), wild pig (*Sus barbatus*), mouse deer (*Tragulus* sp.), and sambar deer (*Cervus unicolor*). Interestingly, locals also informed us that pangolins (*Manis javanica*) were not known to occur at Bukit Sarang.

We encountered very few bats at Samarakan: only two small pteropodid and one hipposiderid species were collected, and one additional small vespertilionid was observed but not identified or collected—a striking contrast to our bat-collecting success at Bukit Sarang. Characteristic arboreal inhabitants of tall lowland forest canopies, such as larger squirrels and larger primates, appear to be altogether absent at Samarakan, at least from areas of *Acacia* forest—another difference between this site and Bukit Sarang. However, study of spoor revealed that many medium-sized to large terrestrial mammals do utilize this forest, including the moonrat, wild pig, mouse deer, sambar, and sun bear (*Helarctos malayanus*), all of which were identified from tracks, and a number of small carnivores, including the *Paradoxurus hermaphroditus* and *Herpestes brachyurus*, which were observed in the wild. We were also informed that clouded leopard (*Neofelis nebulosa*) tracks were reliably recorded from Samarakan recently.

We were more successful in trapping small terrestrial and scansorial mammals at Samarakan than at Bukit Sarang, collecting the murines *Sundamys muelleri* and *Maxomys whiteheadi*, the squirrels *Callosciurus notatus*, *Callosciurus prevostii*, and *Sundasciurus hippurus*, the moonrat *Echinosorex gymnurus*, the treeshrew *Tupaia tana*, and the mongoose *Herpestes brachyurus*. In addition, a pangolin and a slow loris (*Nycticebus coucang*) were caught by workers but subsequently released, at our suggestion. According to local workers, pangolins are common animals at Samarakan, where the dry *Acacia* forests support large numbers of anthills. *Tupaia cf. gracilis*, *Sundamys muelleri*, *Leopoldamys sabanus*, *Sundasciurus cf. brookei*, *Thecurus crassispinis*, *Prionailurus bengalensis* and *Hemigalus derbyanus* have been recorded in *Acacia* forests of Samarakan in a separate camera trapping survey (Grand Perfect, Conservation unpublished data 2005). Dr. K.H. Han (Han 2005) has recorded a total of 10 scansorial mammals from the Samarakan area, representing six rats, two squirrels and two treeshrew species. Species that are new to the list presented in his report include *Tupaia picta*, *Maxomys rajah*, *Maxomys cf. baedon* and *Leopoldamys sabanus*.

Further documentation of the mammal species composition in the *Acacia* forest is currently underway by the Conservation Department of Grand Perfect Sdn Bhd.

## CONCLUSION

The diversity of small mammal species revealed by this brief survey is quite impressive, and speaks to the conservation potential of the Bukit Sarang area. The contrast between the less disturbed habitats at Bukit Sarang with the mostly planted *Acacia* forests of Samarakan and their associated forest remnants is striking, a lack of certain sampling habitats (e.g., caves, large stream) and fewer sampling techniques in Samarakan may have accounted for a substantial part of the difference. The caves that riddle the limestone outcrops at Bukit Sarang provide a home for countless thousands of bats belonging to more than a dozen species. Furthermore, the huge colonies of swiftlets that provide edible nests make this area even more important. Preserving the surrounding forest area, as well as remnants of the forest within the blocks of *Acacia* plantings near Samarakan, is absolutely essential to the well-being of the insect populations that support both the small mammal and bird densities of these areas.

## ACKNOWLEDGEMENTS

Logistics for the fieldwork were efficiently handled by personnel from the Bintulu Office of Grand Perfect Sdn Bhd. We are particularly grateful to Robert Stuebing for his help in arranging the fieldwork. We were ably assisted in the field by Nyegang Megum, Jaffit Majuakim, Matius Angkaus and Dr. Han Kwai Hin. In addition, the field crew in Bukit Sarang, under the able supervision of Ah Kong, was indispensable to our efforts.

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**Table 1:** Species recorded from Bukit Sarang and Samarakan in PFZ.

Species	Bukit Sarang	Samarakan	Remarks
<b>Bats</b>			
1 <i>Balionycteris maculata</i>	*		collected
2 <i>Cynopterus angulatus</i>	*		collected
3 <i>Cynopterus brachyotis</i>	*	*	collected
4 <i>Eonycteris spelaea</i>	*		collected
5 <i>Hipposideros bicolor</i>	*		collected
6 <i>Hipposideros cervinus</i>	*	*	collected
7 <i>Hipposideros didema</i>	*		collected
8 <i>Hipposideros galeritus</i>	*		collected
9 <i>Kerivoula lenis</i>	*		collected
10 <i>Kerivoula papillosa</i>	*		collected
11 <i>Macroglossus minimus</i>	*	*	collected
12 <i>Miniopterus australis</i>	*		collected
13 <i>Miniopterus magnater</i>	*		collected
14 <i>Myotis ater</i>	*		collected
15 <i>Myotis gomantongensis</i>	*		collected
16 <i>Myotis horsfieldii</i>	*		collected
17 <i>Myotis montivagus</i>	*		collected
18 <i>Myotis sp.</i>	*		collected
19 <i>Nycteris tragata</i>	*		collected
20 <i>Peuthetor lucasi</i>	*		collected
21 <i>Rhinolophus borneensis</i>	*		collected
22 <i>Rhinolophus philippinensis</i>	*		collected
<b>Total:</b>	<b>22</b>	<b>3</b>	
<b>Others small mammals</b>			
1 <i>Callosciurus notatus</i>	*	*	collected
2 <i>Callosciurus prevostii</i>	<i>observed</i>	*	collected
3 <i>Crocidura foetida/fuliginosa</i>	*		collected
4 <i>Echinosorex gymnurus</i>		*	collected
5 <i>Herpestes brachyurus</i>		*	collected
6 <i>Maxomys whiteheadi</i>		*	collected
7 <i>Niviventer cremoriventer</i>	*		collected
8 <i>Rattus tiomanicus</i>	*		collected
9 <i>Sundasciurus hippurus</i>		*	collected
10 <i>Sundamys muelleri</i>	*	*	collected
11 <i>Sundamys sp</i>	*		collected
12 <i>Tupaia tana</i>	*	*	collected
<b>Total:</b>	<b>7</b>	<b>8</b>	

Species	Bukit Sarang	Samarakan	Remarks
<b>Mammals</b>			
<i>Additional species through observation, interview and tracks</i>			
1 <i>Exillisciurus exilis</i>	observed		
2 <i>Macaca fascicularis</i>	observed		
3 <i>Manis javanica</i>		observed	
4 <i>Nycticebus coucang</i>		observed	
5 <i>Paradoxurus hermaphroditus</i>	observed	observed	
6 <i>Cervus unicolor</i>	Interviewed	Tracks	
7 <i>Echinosorex gymnurus</i>	Interviewed		
8 <i>Helarctos malayanus</i>		Tracks	
9 <i>Neofelis nebulosa</i>		Interviewed	
10 <i>Petinomys genibarbis</i>	observed		
11 <i>Presbytis hosei</i>	observed		
12 <i>Pteropus vampyrus</i>	observed		
13 <i>Ratufa affinis</i>	Interviewed		
14 <i>Sus barbatus</i>	Interviewed	Tracks	
15 <i>Tragulus sp.</i>	Interviewed	Tracks	