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Front cover: Margot Marsh's or Antafondro mouse lemur, *Microcebus margotmarshae*, sp. n. at Antafondro Classified Forest (Maromiandra). Photo by Rambinintsoa Andriantompohavana. See page 19.

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Notes on the Natural History, Distribution and Conservation Status of the Andean Night Monkey, *Aotus miconax* Thomas, 1927

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Abstract: The Andean night monkey *Aotus miconax* is found only in Peru's northeastern cloud forests, and is one of the country's three endemic primate species. Very little is known of this species; today largely limited to the records of Butchart *et al.* (1995) and a few museum specimens. Between 2005 and 2007, we observed *A. miconax* in various localities in the regions of Amazonas and San Martín, and recorded what we could of its natural history, distribution and conservation status. The Andean night monkey was observed to live in groups of two to four individuals, using sleeping sites at heights of 6 to 9 m. We have confirmed the presence of the species in 10 additional localities in Amazonas and San Martín, all between 900 and 2,788 m above sea level. It was recorded in various forests types, from primary to relict. Even though it is not hunted directly and can survive in disturbed habitats, the extremely high rate of deforestation in this area is threatening its long term survival. Research on the biology, natural history and ecological requirements of this species are much needed.

Key words: Andean night monkey, *Aotus miconax*, primate conservation, Tropical Andes, cloud forest, deforestation

Resumén: El mono nocturno andino es encontrado solo en los bosques montanos del nororiente del Perú, siendo uno de los tres primates endémicos del país. Aparte de los avistamientos de Butchart *et al.* en 1995 y unos pocos especímenes de museos, esta especie permanece desconocida. Entre 2005 y 2007, ocasionalmente observamos *A. miconax* en varias localidades de las regiones de Amazonas y San Martín, obteniendo información sobre su historia natural, distribución y estado de conservación. El mono nocturno andino fue observado en grupos de dos a cuatro individuos, usando sitios de dormir entre seis y nueve metros de altitud. Hemos confirmado la presencia de esta especie en diez localidades adicionales en Amazonas y San Martín, entre 900 y 2,788 m. sobre el nivel del mar, registrando la especie en una variedad de hábitats, desde bosques primarios a bosques relictos. Pese a que la especie no es cazada directamente y puede sobrevivir en hábitats perturbados, la extremadamente alta tasa de deforestación de estas áreas se encuentra amenazando su supervivencia a largo plazo. Es necesario realizar investigaciones sobre la biología, historia natural y requerimientos de esta especie.

Pablas claves: Mono nocturno andino, *Aotus miconax*, conservación de primates, Andes tropical, bosque nublado, deforestación

Introduction

The cloud forests of northeastern Peru are part of the Tropical Andes biodiversity hotspot, and home to three endemic Peruvian primates: the Andean night monkey (*Aotus miconax*), the Andean titi monkey (*Callicebus oenanthe*), and the Peruvian yellow-tailed woolly monkey (*Oreonax flavicauda*) (see Aquino and Encarnación 1994; Pacheco 2002; Rylands *et al*. 1995). The Andean night monkey is known only from collections by E. Heller in the region of Huánuco (Aquino and Encarnación 1994), and R. W. Hendee in the region of San Martín (Thomas 1927). It is believed to occur in a very restricted area, west and south of the Río Huallaga, to about 10°S on the eastern slope of the Andean highlands, in the departments of Amazonas, San Martín, La Libertad and Huánuco (Ford 1994; Hershkovitz 1983). It is sympatric with the two other endemic Peruvian primates. *Aotus miconax* belongs to the "red neck group" of night monkeys. (Hershkovitz 1983), presenting many similarities with *A. nancymaae* but, due to the lack of available information, no conclusive taxonomic arrangements could be provided by Hershkovitz (1983) or Ford (1994). It is categorized as Vulnerable on the *IUCN Red List of Threatened Species* (IUCN 2008), and as "Endangered" by Peruvian Law (Decreto Supremo 34-2004-AG; see Heymann 2004).

Besides museum specimens and field sightings by Butchart *et al*. (1995), nothing is known of its biology and natural history. In this note we are presenting some observations on the natural history of the species, as well as some remarks on the distribution and conservation status of this primate endemic to Peru.

Natural History Observations

Site 1. Abra Patricia – Alto Nieva

We occasionally saw *A. miconax* during the course of a study on the ecology and behavior of the yellow-tailed woolly monkey, *O. flavicauda,* in the Private Reserve Abra Patricia – Alto Nieva in the department of Amazonas (Cornejo in prep.). This reserve of 2,065 ha has primary and secondary cloud forest, with some small human settlements around it. We saw them 11 times in all, between the months of March and June 2007; the contact time ranged from seven to 33 minutes. *A. miconax* was observed in both primary cloud forest and in disturbed forest fragments very close to human settlements, between 1,980 and 2,348 m above sea level. Group size ranged from two to four, with an infant observed once (Table 1). Two sleeping sites were identified. We observed one group when entering a sleeping site at 06:05, and another group when leaving it at 18:15. One of the trees was of the genus *Ficus* (Moraceae) and the other *Ocotea* (Lauraceae). Both were heavily covered by epiphytes, climbers and vines, with the sleeping sites located at heights of 7 m and 9 m, respectively, among branches, epiphytes and vine tangles. Individuals were also observed eating fruits from the genus *Ficus* and flowers from an undetermined tree of the Melastomataceae family.

During one sighting, we saw two individuals moving approximately 10 m from a group of resting *O. flavicauda,* with no sign of reaction from either group regarding the presence of the other species. Another sighting was during daylight at 15:18. The night monkeys were moving through the tree branches until they settled in a *Cecropia* tree. After noticing our presence, they quickly fled. There was no apparent human disturbance prior to the encounter that may have caused the group to be out of its sleeping site.

Site 2. Huiquilla

We observed *A. miconax* twice during a biological assessment in the Private Reserve Huiquilla, also in the department of Amazonas, between July and August 2006. This protected area of 1,000 ha is of both primary and secondary cloud forest. One group had two and the other five individuals (Table 1). They were in primary forest at 2,681 and 2,788 m above sea level. The first encounter took place during the day, when a local field assistant shook the vines of their sleeping tree, and made them leave. The second group we saw leaving its sleeping tree between 18:20 and 18:40. It soon moved to an undetermined tree of the family Solanaceae to feed on fruits. The sleeping sites were at heights of 6 m and 8 m and consisted of very dense tangles of vines, epiphytes, climbers, and branches.

Distribution of *Aotus miconax* in the Departments of Amazonas and San Martín

Aotus miconax was described by Oldfield Thomas (Thomas, 1927a) from specimens collected by R.W. Hendee in the area of San Nicolas (in a valley called Huayabamba) in

Table 1. Sightings of *Aotus miconax*.

Date	Minimum group size	Adults	Infants/ juveniles	Time	Contact duration (minutes)	Activity	Altitude (m asl)	Average height of displacement	Notes	Locality
27 March 2007	2	2	-	20:33	33	Eating *Ficus* sp. fruits	1980	6		Abra Patricia
5 April 2007	3	3	-	19:15	10	Moving	2199	8		Abra Patricia
14 April 2007	4	4?	-	18:15	14	Leaving sleeping tree	2055	7	Possibly 1 juvenile	Abra Patricia
27 April 2007	4	4?		18:28	18	Moving	2245	8	Possibly 1 juvenile	Abra Patricia
30 April 2007	2	2	-	18:47	17	Moving, near *O. flavicauda*	2033	11		Abra Patricia
2 May 2007	2	2	-	6:05	25	Reaching sleeping tree	2198	9		Abra Patricia
3 May 2007	2	2	-	5:58	15	Eating flowers (Melastomataceae)	2314	14		Abra Patricia
3 May 2007	3	2	1	15:18	7	Moving	2257	11	Independent infant	Abra Patricia
25 May 2007	2?		-	21:14	7	Moving, vocalizing	2286	14		Abra Patricia
4 June 2007	3	3	-	6:05	22	Moving	2340	7		Abra Patricia
7 June 2007	2?	2?	-	2:35	9	Moving, vocalizing	2348	10		Abra Patricia
1 August 2006	2	2	-	10:00*	8	-	2681	9		Huiquilla

* Individuals forced to get out of sleeping tree

Peru's Department of Amazonas. Soon after this first collection, R. W. Hendee provided another specimen from Tingo María, in the Department of Huánuco (Thomas, 1927b). Other records of *A. miconax* were identified by Hershkovitz (1983) in his revision of the genus. He attributed specimens collected by E. Heller in 1922 along the Río Chinchao and from Tingo María, Huánuco (Field Museum of Natural History, Chicago) to *A. miconax*. *Aotus miconax* is also known from sightings in Comboca and San Cristóbal in Amazonas by Butchart *et al*. (1995). Mittermeier *et al*. (1975) and Leo Luna (1984) reported the presence of night monkeys (referred to then as *A. trivirgatus*) in the cloud forests of Pedro Ruiz Gallo and Venceremos, and these are probably referable to *A. miconax*. Tingo María is also the locality of some *A. nigriceps* collections, so whether these two species are sympatric in this area remains unknown.

Table 2. Records of *Aotus miconax.*

Locality	Altitude (m asl)	Type of Record[1]	Source
Abra Patricia	1980–2348	O, R, C	This paper
Chacapungo	~1550	O	This paper
Choccta	~2500	R	This paper
Comboca and San Cristóbal	1860–2300	O	Butchart *et al.*, 1995
Huamanpata	2460	C	This paper
Huayabamba	~2200	C	Thomas, 1927a
Huiquilla	2681, 2788	O, R	This paper
Leymebamba	~2250	R	This paper
Los Chilchos	~2400	R	This paper
Mashuyacu	~900	C	This paper
Ocal	~2650	R	This paper
Río Chinchao	~1350	C	Heller's collection, FMNH
Tingo María	~800	C	Thomas, 1927b
Tocache	~1350	O	This paper

[1] O = Observed, R = Report from local people, C = Collected from hunters

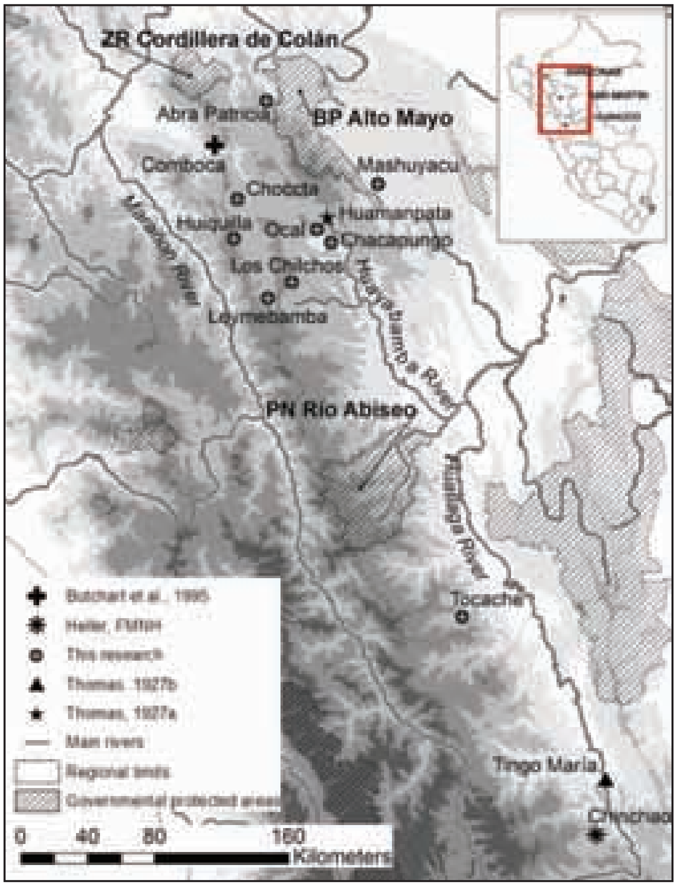

Figure 1. Localities where *A. miconax* has been recorded.

Further information on the occurrence of this species (sightings and interviews with local people) was collected during the course of faunal evaluations in the departments of San Martín and Amazonas between August and November of 2005. The surveys included a range of habitats between 900 and 2,600 m above sea level (Table 1). In San Martín, the presence of night monkeys was confirmed in the areas of Los Chilchos and Mashuyacu to the west, very close to the boundary with the department of Amazonas; and in the south, in the Río Tocache basin, from the Río Grueso to near the boundary with the department of La Libertad. In Amazonas, the species has been recorded in the eastern forests at the border with San Martín, from the headwaters of Los Chilchos and the Río Verde in the south, to the basin of the Río Nieva in the north, above 1,300 m above sea level. In the central area, the species occurs in the forests on the left bank of the Río Utcubamba, from Choccta to the headwaters of the Río Imaza in the north (Fig. 1).

Aotus miconax was seen to use a variety of habitats at all sites: primary and secondary montane forests on steep and very steep slopes; the ecotone with timberline forests, and relict forests.

Conservation Status

Locally known as "tutacho" or "mono de noche", *Aotus miconax* occurs in the governmental protected areas Parque Nacional Río Abiseo (274,520 ha, Aquino and Encarnación 1994) and possibly in the Zona Reservada Cordillera de Colán (64,115 ha, Butchart *et al.* 1995). Here the species has now been recorded in Bosque de Protección Alto Mayo (182,000 ha, local informants, near the town of Alto Nieva), the private reserves Abra Patricia – Alto Nieva (2,065 ha) and Huiquilla (1,000 ha), and in the Municipal Reserve Cuenca del Río Huamanpata (23,097 ha).

Being small and having pungent subcaudal scent glands, night monkeys are not hunted for food (Aquino and Encarnación 1994). Nonetheless, a skin was collected from a hunter living in the surroundings of the Abra Patricia – Alto Nieva reserve, and we have recorded at least four families with pets of *A. miconax* in the last two years. Butchart *et al*. (1995) also reported a pet in a village near the Zona Reservada Cordillera de Colán. Local people claim they do not hunt *A. miconax*, neither for the pet trade or food, nor because they eat their crops (as do *Cebus albifrons* and *O. flavicauda*). Individuals are caught, however, when their sleeping trees are cut down when clearing the forest for pasture or crops. They are usually then kept as pets, but tend to die within a few weeks.

Most of the primary cloud forest in the range of *A. miconax* has been destroyed and replaced by croplands and pastures. These forests were virtually inaccessible until the 70s, when highway construction was begun, traversing the departments of Amazonas and San Martín (Leo Luna 1984). This highway allows the immigration of thousands of people with agriculture and livestock practices incompatible with the characteristics of cloud forest soils. As a result, Amazonas and San Martín have the highest rates of deforestation and immigration in Peru (Elgegren 2005; Peru, INEI 2006). Although *A. miconax* is common where it occurs, and can persist in disturbed, secondary and relict forests, some areas of its supposed historical distribution are so deeply disturbed that the species has become locally extinct. The extremely high rates of deforestation pose a very real threat of the irreversible loss of this ecosystem, where not even officially protected areas provide guarantee for appropriate conservation of these forests. Urgent conservation measures are needed to protect these forests and the species they harbor. Further research on the habitats, range, habits and status of *A. miconax* is needed.

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Literature cited

Aquino, R. and Encarnación, F. 1994. Primates of Peru. *Primate Report* 40: 1–127.

Butchart, S. H. M., R. Barnes, C. W. N. Davies, M. Fernandez and N. Seddon. 1995. Observations of two threatened primates in the Peruvian Andes. *Primate Conserv.* (16): 15–19.

Elgegren, J. J. 2005. La Deforestación en el Perú. Website: <http://www.conam.gob.pe/documentos/TallerAnalisis_Ambiental/La_Deforestacion_en_el_Peru.pdf>. Accessed on 2 July 2008.

Ford, S. M. 1994. Taxonomy and distribution of the owl monkey. In: Aotus: *The Owl Monkey*, J. F. Baer, R. E. Weller and I. Kakoma (eds.), pp.1–57. Alan R. Liss, New York.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.

Hershkovitz, P. 1983. Two new species of night monkeys, genus *Aotus* (Cebidae, Platyrrhini): a preliminary report on *Aotus* taxonomy. *Am. J. Primatol*. 4: 209–243.

Heymann, E. W. 2004. Conservation categories of Peruvian primates – Categorias de conservación de los primates peruanos. *Neotrop. Primates* 12: 154–155.

IUCN. 2008. *2008 IUCN Red List of Threatened Species.* International Union for the Conservation of Nature and Natural Resources (IUCN), Species Survival Commission (SSC), Gland, Switzerland, and Cambridge, UK. Available at: <http://www.iucnredlist.org>. Accessed on 12 October 2007.

Leo Luna, M. 1984. The Effects of Hunting, Selective Logging and Clear-Cutting on the Conservation of the Yellow-Tailed Woolly Monkey (*Lagothrix flavicauda*). Master's thesis, University of Florida, Gainesville.

Mittermeier, R. A., H. de Macedo-Ruiz and A. Luscombe. 1975. A woolly monkey rediscovered in Peru. *Oryx* 13: 41–46.

Pacheco, V. 2002. Mamíferos del Perú. In: *Diversidad y Conservación de los Mamíferos Neotropicales*, G. Ceballos and J. Simonetti (eds.), pp.503–550. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) – Universidad Nacional Autónoma de México (UNAM), México, DF.

Peru, INEI. 2006. Instituto Nacional de Estadística e Informática (INEI), Lima, Peru. Website: <http://www.inei.gob.pe/>. Accessed 1 February 2008.

Rylands, A. B. 1995. A species list for the New World primates (Platyrrhini): distribution by country, endemism, and conservation status according to the Mace-Lande system. *Neotrop. Primates* 3(suppl.): 113–160.

Thomas, O. 1927a. The Godman-Thomas Expedition to Peru. On mammals collected by Mr. R. W. Hendee in the Province of San Martin, N. Peru, mostly at Yurac Yacu. *Ann. Mag. Nat. Hist., Ser. 9*, 19:361–375.

Thomas, O. 1927b. The Godman-Thomas Expedition to Peru. On mammals from the Upper Huallaga and neighbouring highlands. *Ann. Mag. Nat. Hist., Ser.* 9, 20: 594–608.

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The Crisis of the Critically Endangered Greater Bamboo Lemur (*Prolemur simus*)

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Abstract: *Prolemur simus* (the greater bamboo lemur) is the most abundant lemur in the northern subfossil sites of Madagascar. Living populations still persist, but in low numbers within a diminished range, making it one of the most critically endangered lemurs. Over the past twenty years scientists have searched the south- and central-eastern rain forests of Madagascar. Despite surveys that encompass over 500 km², less than 75 animals have been found, with a recent total count of 60. More encouraging is that in 2007 two new sites containing *P. simus* were found: Mahasoa an unprotected 150 ha fragment east of the Ranomafana/Andringitra corridor (17 *P. simus*), and Torotorofotsy, a RAMSAR site near Andasibe (~16 *P. simus*). *Prolemur simus* is a bamboo specialist with a patchy geographic distribution, which may be driven by the distribution of one or two bamboo species. Home ranges are large, group size has been observed to be from four to 26 individuals, and localities may be spaced hundreds of kilometers apart. Ranomafana National Park contains the only fully habituated group, and there are a total of three groups known in the park. We make recommendations for conservation action for these populations of *P. simus.* If immediate action is taken, we may be able to prevent the extinction of this species within the next decades.

Key Words: Population surveys, greater bamboo lemur, *Prolemur simus*, Ranomafana National Park, Madagascar, Mahasoa, Torotorofotsy

Introduction

The greater bamboo lemur (*Prolemur simus*), previously known as *Hapalemur simus* (see Groves, 2001), is arguably the most critically endangered lemur species in Madagascar (Ganzhorn *et al.* 1996/1997; Konstant *et al.* 2006; Mittermeier *et al*. 2006; Ganzhorn and Johnson 2007). From the subfossil record we know it was once widespread in Madagascar, including Anjohibe and Ankarana Massif in the north, the caves of the Bemaraha Tsingy in the west, and even on the high plateau at Ampasambazimba 25 km west of Antananarivo (Godfrey and Vuillaume-Randriamanantena 1986; Simons 1997; Godfrey *et al.* 2004). It also appears to have been abundant — *P. simus* was one of the most common subfossils in the caves in the limestone massif of Ankarana Special Reserve (Simons 1997). Unfortunately, little is known about the chronology of its decline. Using Carbon 14 dating methods, *P. simus* subfossils from Andrafiabe in the Ankarana Massif have been dated to 4,560 ± 70 years BP (Simons *et al.* 1995); however, none of the other subfossil sites has been dated. The measurements and dental casts of living animals (Meier 1987; Glander *et al.* 1992; Tan 1999; Yamashita *et al.* 2004) provide evidence that the subfossil specimens are similar in size and dentition to *P. simus* living today, and making it likely that the behavior and ecology would have been similar (Jernvall *et al.* 2008).

The only eyewitness accounts of living *P. simus* come from the eastern rainforest. Before the 1970s, greater bamboo lemurs were known from only two sites: a Kianjavato coffee plantation and the Vondrozo Forest (Petter *et al.* 1977; Meier and Rumpler 1987; Meier *et al*. 1987; Wright *et al.* 1987; Wright 1988). After a period of little research and much forest destruction during the 1970s and early 1980s, it was suspected that *P. simus* might be extinct (Godfrey and Vuillaume-Randriamanantena 1986). Two research teams, which arrived Madagascar in June 1986, sought to document living members of this species. A group of 12 greater bamboo lemurs was found on the edge of the Kianjavato coffee plantation (Wright *et al.* 1987), and possibly the same group (N = 6 individuals) was seen at the same location several months later (Meier and Rumpler 1987; Meier *et al.* 1987). A second group of 11 individuals was observed in the classified forest of Ranomafana (Meier *et al*. 1987; Wright *et al.* 1987; Wright 1988). One of the inspirations for setting aside this forest as a national park in 1991 was Ranomafana's potential for protecting populations of two rare lemur species, *Hapalemur aureus*, a recently described species (Meier *et al.* 1987), and *P. simus* (Wright 1992; Wright and Andriamihaja 2003).

Over the past 20 years research presence has increased and numerous lemur surveys have been conducted in the eastern rainforests of Madagascar. Sightings of greater bamboo lemurs, however, continue to be rare and the list of known localities has not increased appreciably (Irwin *et al.* 2005). The goal of this paper is to synthesize the results of these surveys, describe recent events concerning the attrition of the known groups, and examine data on captive *P. simus* populations. Finally, we make recommendations for conservation actions to save *P. simus* from immediate extinction.

Methods

Surveys were conducted in 69 sites over a 21-year period (1986–2007) from the Onive River in central Madagascar to the Mananara River in the south (Fig. 1). In addition, the Mitsinjo Project conducted species' incidence surveys further north, in the region of Mantadia National Park (Dolch *et al.* 2004). The study sites are rain forests, ranging in elevation from sea level to nearly 1,700 m. Surveys covered a wide range of habitat types, from isolated and degraded fragments (for example, Evendra, Sakanany) to large, relatively intact, protected areas (for example, Andringitra, Ranomafana). At each site, the forest was surveyed for lemurs, forest structure and habitat disturbance. Although all lemur species present were recorded, results here are confined to sightings or signs of *P. simus*. Sampling effort ranged from two days, during rapid assessments in isolated forest fragments, to long-term monitoring in Ranomafana National Park and its periphery over more than 21 years. The incidence and population densities of all species of lemurs sighted during most of these surveys are presented elsewhere (Irwin *et al.* 2005). In this paper we summarize these data, and present new data from repeat surveys conducted in 2007.

As discussed above at a subset of sites (N = 4), forests were surveyed briefly but intensively by a minimum of two observers as part of rapid assessments of primate species richness only. At the majority of sites (N = 65), however, transects were established and surveyed using standard line-transect methodology (Johnson and Overdorff 1999; Struhsaker 1981; Whitesides *et al.* 1988), with existing trails used whenever possible to minimize forest disturbance (Table 1). One to four transects (1–3.5 km in length) were established in each site, and transects were walked slowly (about 1 km/hour) by 1–2 observers during each survey. Three to 26 diurnal surveys were conducted per site, with replicates generally evenly split between morning and afternoon sampling periods. During each survey, all evidence of the presence of *P. simus* (sightings, vocalizations, and feeding remains) was recorded. It should be noted that even intensive line-transect sampling in areas where *P. simus* was known to be present consistently failed to record sufficient sightings for accurate population density estimates (Irwin *et al.* 2005).

Results

Survey results

Confirmed sightings of greater bamboo lemurs occurred in only 11 of 70 survey localities with a latitudinal range of 18°52' to 22°26'S (Table 1, Fig. 1). Five of these sightings were in or around the protected areas of Ranomafana National Park (Miaranony, Talatakely and Ambatolahy Dimy), and Andringitra National Park (Manambolo, Camp 2). An additional unconfirmed observation occurred here (Korokoto). Another five *P. simus* sightings were in unprotected forests at Kianjavato and Karianga, and outside Evendra, Morafeno and Mahasoa. Of all of these sites, Karianga, Evendra, Morafeno and Mahasoa are the most degraded. Finally, *Prolemur simus* has been observed in Torotorofotsy, the only locality north of Ranomafana National Park (its southern border is near Evendra, Karianga, and Mahasoa, south of Andringitra National Park and north of the Manampatrana River). The elevation range for confirmed *P. simus* sightings is considerable: 121–1,600 m, making it unlikely that the survey results have been biased due to altitudinal restrictions. Only three sites surveyed were higher (Andranofisaka and Garonina at Fandriana-Marolambo and Camp 4 at Andringitra), and three sites were lower (Manombo, Sakanany, and Mahabo) than the recorded elevational range of the species. In sum, we found *P. simus* within a relatively narrow latitudinal range but within a broad elevational range. This species is very patchily distributed (Fig. 1), and occupies forests ranging from small, unprotected fragments to large national parks, with differing levels of anthropogenic disturbance. In the following sections, we provide further details from localities where *P. simus* has been observed.

Ranomafana National Park

Three *P. simus* groups have been seen in total at Ranomafana National Park (Wright *et al*. 1987; Wright 1988; Goodman *et al.* 2001; Grassi 2001; Irwin *et al*. 2005; Ratelolahy *et al.* 2006), with a maximum of 20 individuals confirmed. One group, that has varied from 6 to 11 individuals, has been habituated and followed since 1992 at the Talatakely site (Tan 1999). A second group of 4–6 individuals lived at Ambatolahy Dimy (just across the Namorona River, about 2 km from Talatakely. This group has been followed intermittently for the past ten years, and continually since 2003. Its territory includes bamboo stands, both inside the national park and in the park's peripheral zone (Ratelolahy *et al*. 2006). A third group of *P. simus* was sighted briefly in 2001 in Miaranony, 15 km northeast of Talatakely and Ambatolahy Dimy, during a rapid assessment (Arrigo-Nelson and Wright 2004). In June 2007, during a 10-day resurvey, *P. simus* was not observed there, although discarded bamboo remains suggested that at least one group still exists at this site (R. Jacobs unpubl. data).

Recent observations of the two habituated *P. simus* groups at Ranomafana illustrate the vulnerability of small populations. From 1992–2004, the Talatakely group included two breeding females and two adult males. In December 2004, the two adult males disappeared, leaving a group with two adult females and two juveniles (one male and one female). It was unknown at the time if the males died from predation or

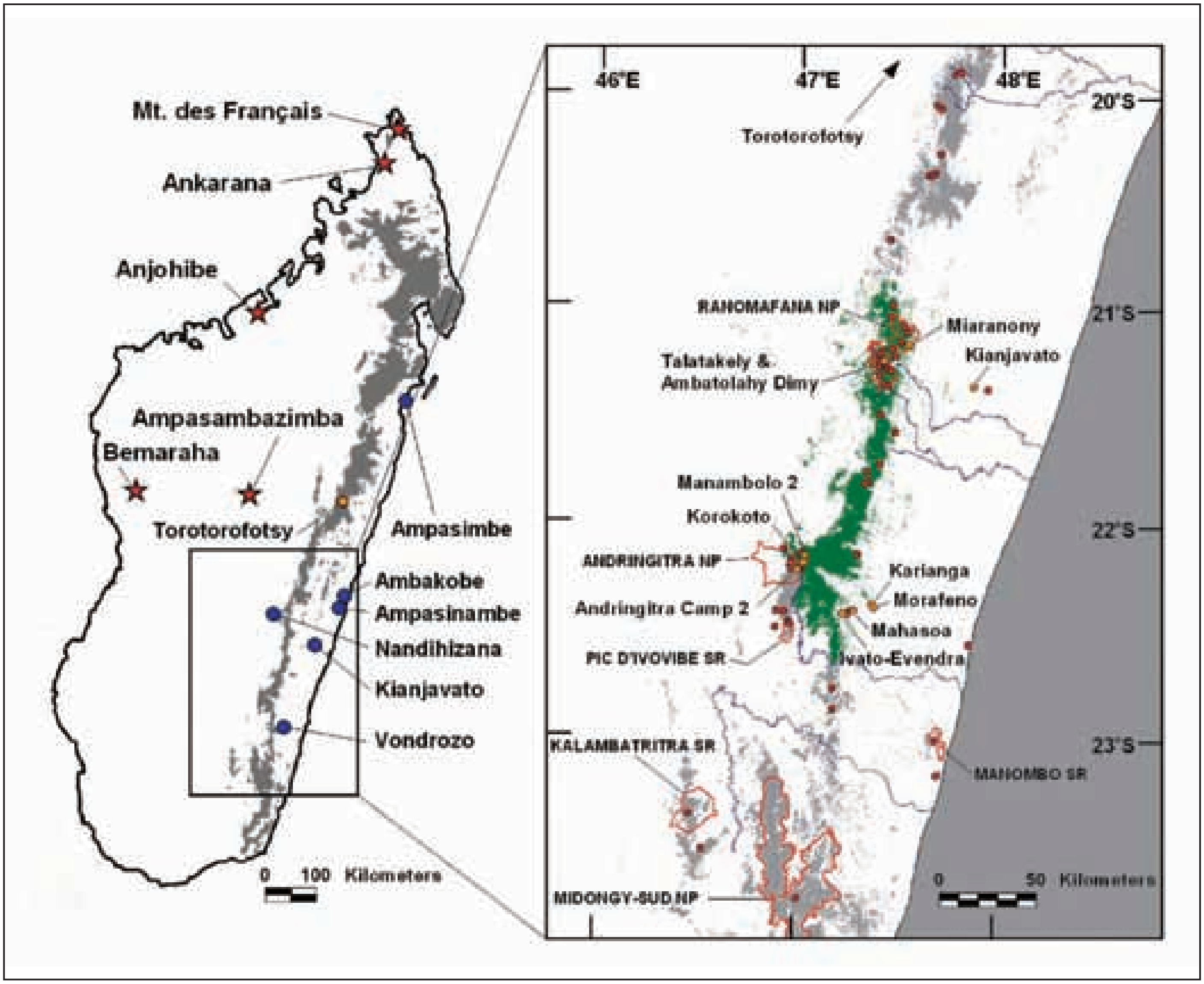

Figure 1. Past and present *P. simus* localities. Red stars are subfossil sites, blue circles are historic records, red circles are survey sites at which *P. simus* was absent, orange circles are survey sites at which *P. simus* was present. Grey represents remaining eastern rainforest (Irwin *et al.* 2005), green represents rainforest within recognized geographic range for *P. simus* based on confirmed sightings prior to 2007 (Irwin *et al*. 2005).

Table 1. Survey localities and the incidence of *P. simus.*

No.	Site	Date Surveyed	Coordinates	Elevation (m)	Investigator(s)	Source	*P. simus* present	Notes
1	Torotorofotsy	Mar – Apr 2003 Nov 2003 Jul 2007	18°52'S 48°22'E	935	R. Dolch, R. Hilgartner, J.-N. Ndriamiary, H. Randriamahazo, E. E. Louis Jr.	Dolch *et al.* (2004); E. E. Louis Jr. (unpubl.)	Yes	At least 3 social groups
2	Betsakafandrika: Jangajilo	Oct 1999	19°54'22.0"S 47°47'15.0"E	1,277	S. Lehman	Lehman & Wright (2000)	-	
3	Betsakafandrika: Bezavona	Oct – Nov 1999	19°55'02.0"S 47°45'21.0"E	1,223	S. Lehman	Lehman & Wright (2000)	-	
4	Fandriana Marolambo: Garonina	Mar 2000	20°3' 49.1"S 47°40'18.0"E	1,670	S. Lehman, J. Ratsimbazafy	Lehman *et al*. (2005)	-	
5	Fandriana Marolambo: Andranofisaka	Mar – Apr 2000	20°4'35.0"S 47°41'27.0"E	1,685	S. Lehman, J. Ratsimbazafy	Lehman *et al*. (2005)	-	
6	Kirisiasy	Jul 1999	20°17'24.0"S 47°41'24.0"E	1,200 to 1,400	M. Irwin, T. Smith	Irwin *et al.* (2000)	-	
7	Fandriana Marolambo: Korikory	Mar 2000	20°22' 58.0"S 47°39' 57.0"E	1,555	S. Lehman, J. Ratsimbazafy	Lehman *et al*. (2005)	-	
8	Fandriana Marolambo: Mananjara	Feb 2000	20°23'24.9"S 47°38'3.8"E	1,353	S. Lehman, J. Ratsimbazafy	Lehman *et al*. (2005)	-	
9	Fandriana Marolambo: Ranomena	Feb – Mar 2000	20°23'37.4"S 47°39'10.8"E	1,345	S. Lehman, J. Ratsimbazafy	Lehman *et al*. (2005)	-	
10	Vohibola III Classified Forest	Jun 2003 – Dec 2005	20°41'25.9"S 47°26' 45.7"E	1,180	S. Lehman	Lehman *et al*. (2005, 2006a, 2006b)	-	
11	Marofotsy	Jun 1999	21° 00' 0.0"S 47°28'0.0"E	1,000 to 1,200	M. Irwin, T. Smith	Irwin *et al.* (2000)	-	
12	Ranomafana NP: Ampozasaha	Oct – Nov 2004	21°3'12.1"S 47°27'26.2"E	970 to 1,213	F. Ratelolahy	Johnson *et al*. (2005)	-	
13	Ranomafana NP: Tsinjorano	May 2004 May 2005	21°5'49.0"S 47°31'21.7"E	971 to 1,273	F. Ratelolahy	Johnson *et al*. (2005)	-	
14	Ranomafana NP: Namahoaka	Jun 1999	21°7'30.0"S 47°32'18.0"E	1,100 to 1,200	M. Irwin, T. Smith	Irwin *et al.* (2000)	-	
15	Ranomafana NP: Bevoahazo	Nov – Dec 2000	21°10'6.0"S 47°30'30.0"E	1,050 to 1,250	P. C. Wright	Irwin *et al.* (2005)	-	
16	Ranomafana NP: Miaranony	Jun 2001 Jun 2007	21°10'54.0"S 47°32'48.0"E	800 to 1,100	S. Arrigo-Nelson, R. Jacobs	Arrigo-Nelson & Wright (2004), Irwin *et al.* (2005), R. Jacobs (unpubl.)	Yes	One group sighted in 2001; no groups in 2007
17	Ranomafana NP: Ranomena	Nov – Dec 2000	21°12'7.0"S 47°27'42.0"E	970	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
18	Ranomafana NP: Sahateza	May 2004	21°12'20.7"S 47°24'58.5"E	1,153 to 1,258	S. Johnson, F. Ratelolahy	Johnson *et al*. (2005)	-	
19	Ranomafana NP: Vohiparara	Nov – Dec 2003 Nov – Dec 2004	21°13'23.8"S 47°24'20.9"E	1,114 to 1,198	S. Johnson, F. Ratelolahy	Johnson *et al*. (2005)	-	
20	Ranomafana NP: Torotosy	Oct 2003	21°14'12.0"S 47°28'42.9"E	872 to 1,156	S. Johnson, F. Ratelolahy	Johnson *et al*. (2005)	-	
21	Ranomafana NP: Ambatolahy Dimy	1996 – 2007	21°15'7.8"S 47°25'22.6"E	905	P. C. Wright, C. Tan	C. Tan (unpubl.)	Yes	Long-term study group monitored since 2000
22	Ranomafana NP: Talatakely	1986 – 2007	21°15'40.2"S 47°25'9.0"E	934	P. C. Wright, C. Tan, C. Grassi, F. Ratelolahy	Meier *et al*. (1987), Wright *et al*. (1987), Grassi (2001), Tan (2000)	Yes	Long-term study group monitored since 1986
23	Ranomafana NP: Sakaroa	Oct 2002	21°15'41.4"S 47°24'7.8"E	1,074	F. Ratelolahy	F. Ratelolahy (unpubl.)	-	
24	Ranomafana NP: Ambodiriana	Feb 2003	21°16'35.4"S 47°25'47.4"E	1,121	F. Ratelolahy	F. Ratelolahy (unpubl.)	-	
25	Ranomafana NP: Manidika	May 2001	21°16'54.0"S 47°23'54.0"E	1,100 to 1,300	S. Arrigo-Nelson	Arrigo-Nelson & Wright (2004), Irwin *et al.* (2005)	-	
26	Ranomafana NP: Vatoharanana	Jul 1995 Jun – Jul 1996 Aug 1998 – Aug 1999 Oct 2000	21°17'24.0"S 47°26'0.0"E	1,025	C. Grassi, S. Johnson, P. C. Wright, S. Goodman, V. Razafindratsita	Goodman *et al*. (2001), Grassi (2001), Johnson & Overdorff (1999)	-	

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Table 1. *continued*

No.	Site	Date Surveyed	Coordinates	Elevation (m)	Investigator(s)	Source	*P. simus* present	Notes
27	Ranomafana NP: Valohoaka	Oct 2002 – Dec 2003 Jan – Feb 2004 Jan – Feb 2005	21°17'48.9"S 47°26'20.4"E	827 to 1,215	F. Ratelolahy, S. Arrigo-Nelson	Johnson *et al*. (2004), Johnson *et al*. (2005), S. Arrigo-Nelson (unpubl.)	-	
28	Ranomafana NP: Marotreho	Dec 2000	21°18'14.0"S 47°27'42.0"E	910	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
29	Ranomafana NP: Maharira	Nov 2002	21°19'34.8"S 47°24'7.8"E	1,374	F. Ratelolahy	F. Ratelolahy (unpubl.)	-	
30	Ranomafana NP: Ambinandranfotaka	Sep – Oct 2004	21°22'1.8"S 47°25'30.6"E	628 to 1,199	F. Ratelolahy	Johnson *et al*. (2005)	-	
31	Ranomafana NP: Mangevo	Apr 2004, Apr – May 2005	21°22'31.4"S 47°26'47.7"E	690 to 1,178	S. Johnson, F. Ratelolahy	Johnson *et al*. (2005)	-	
32	Kianjavato	Winter (Jun – Aug) of 1986 – 1990 & 1995 Nov 1999 Jan 2000 Aug 2000 Apr – May 2002 Jun – Jul 2007	21°22'31.9"S 47°51'55.0"E	121 to 235	P. C. Wright, J. Ratsimbazafy, E. E. Louis Jr., R. Jacobs	Louis Jr. *et al*. (2005), E. E. Louis Jr. (unpubl.), P. C. Wright (unpubl.), R. Jacobs (unpubl.)	Yes	Wright surveys located groups of 6 – 8 individuals; Jacobs located ≥2 groups with ≥7 individuals
33	Vatovavy	Winter (Jun – Aug) of 1986 – 1990 & 1995 Jan 2000 May 2002	21°23'18.0"S 47°56'24.0"E	175	P. C. Wright, J. Ratsimbazafy, E. E. Louis Jr.	Louis Jr. *et al*. (2005), E. E. Louis Jr. (unpubl.), P. C. Wright (unpubl.)	-	
34	Andrambovato	Oct 2000	21°30'42.0"S 47°24'36.0"E	1,075	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
35	Tolongoina: Mandriandry	Oct 2000	21°35'30.0"S 47°29'6.0"E	750	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
36	Ambantofotsy: Ambahaka	Oct – Nov 2000	21°44'12.0"S 47°24'30.0"E	750	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
37	Vinantelo	Oct 2000	21°46'36.0"S 47°20'48.0"E	1,100	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
38	Ikongo: Ambatambe	Nov 2000	21°49'18.0"S 47°21'30.0"E	625	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
39	Ikongo: Ankopakopaka	Nov 2000	21°49'42.0"S 47°20'18.0"E	645	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
40	Andringitra NP: Imaitso	Aug – Sep 2000	22°8'0.0"S 46°56'0.0"E	1,500	S. Johnson, S. Razafimandimby	Johnson (2002)	-	
41	Manambolo 1	Nov 1999	22°8'58.0"S 4701'25.0"E	1,300	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	-	
42	Ankarimbelo: Sahabe	Aug 2006	22°9'25.2"S 47°18'8.4"E	683	S. Johnson, S. Martin	Johnson & Martin (unpubl.)	-	
43	Manambolo 2	Dec 1999	22°9'48.0"S E 47° 2' 30.0"	1,600	S. Goodman, V. Razafindratsita	Goodman *et al*. (2001)	Yes	
44	Andringitra NP: Camp 4	Oct 1993	22°11'39.0"S 46°58'16.0"E	1,625	E. Sterling, Ramaroson	Sterling & Ramaroson (1996)	-	
45	Andringitra NP: Korokoto	Jul 1997	22°11'44.2"S 47°01'55.6"E	850	S. Johnson	Johnson & Wyner (2000)	Yes	Calls were heard but individuals not observed; one individual found dead and strung up on trail
46	Andringitra NP: Camp 1	Sep – Oct 1993	22°13'20.0"S 47°01'29.0"E	720	E. Sterling, Ramaroson	Sterling & Ramaroson (1996)	-	
47	Andringitra NP: 'Parc'	Jun 1999 – Aug 2000	22°13'20.1"S 47°01'7.3"E	725 to 900	S. Johnson	Johnson (2002)	-	
48	Andringitra NP: Ambarongy	Apr – Jul 1999	22°13'21.4"S 47°01'15.9"E	725 to 1,100	S. Johnson	Johnson (2002)	-	
49	Andringitra NP: Camp 3	Oct 1993	22°13'22.0"S 46°58'18.0"E	1,210	E. Sterling, Ramaroson	Sterling & Ramaroson (1996)	-	

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Table 1. *continued*

No.	Site	Date Surveyed	Coordinates	Elevation (m)	Investigator(s)	Source	*P. simus* present	Notes
50	Andringitra NP: Camp 2	Oct 1993 Feb 2000	22º13'40.0"S 47º00'13.0"E	810	E. Sterling, Ramaroson, E. E. Louis Jr.	Sterling & Ramaroson (1996), E. E. Louis Jr. (unpubl.)	Yes	2 individuals sighted 3 times on transect at 810 m asl
51	Karianga	Jul 1995 Dec 1996 Nov 2000 Jul 2007	22º23'9.8"S 47º22'40.6"E	144	C. Spoegler, P. C. Wright, E. E. Louis Jr., R. Jacobs	Louis *et al.* (2006), E. E. Louis Jr. (unpubl.), P. C. Wright & C. Spoegler (unpubl.)	Yes	26 individuals counted in 1995, 18+ individuals in 1996, no sightings in 2007
52	Morafeno	Jul 2007	22º24'18.5"S 47º23'3.4"E	208	R. Jacobs	R. Jacobs (unpubl.)	Yes	At least one group with ≥ 3 individuals
53	Ambatovaky	Jul 2007	22º25'17.0"S 47º16'13.9"E	303	R. Jacobs	R. Jacobs (unpubl.)	-	
54	Mahasoa	Jul 2007	22º25'17.3"S 4717'3.5"E	259	R. Jacobs	R. Jacobs (unpubl.)	Yes	At least one group with ≥17 individuals
55	Ivohibe SR: Camp 4	Nov 1997	22º25'18.0"S 4653'54.0"E	1200	R. Rasoloarison, B. Rasolonandrasana	Rasoloarison & Rasolonandrasana (1999)	-	
56	Ivohibe SR: Camp 5	Nov 1997	22º25'36.0"S 46º56'18.0"E	900	R. Rasoloarison, B. Rasolonandrasana	Rasoloarison & Rasolonandrasana (1999)	-	
57	Evendra	Jun 1997	22º26'2.5"S 47º15'31.7"E	425	S. Johnson	Johnson & Wyner (2000)	-	
58	Ivato-Evendra Trail	Jun 1997	22º26'6.0"S 47º13'48.0"E	300	S. Johnson	Johnson & Wyner (2000)	Yes	Single individual sighted along stream outside forest fragment
59	Ivohibe SR: Camp 1	Oct 1997	22º28'12.0"S 46º57'36.0"E	900	R. Rasoloarison, B. Rasolonandrasana	Rasoloarison & Rasolonandrasana (1999)	-	
60	Ivohibe SR: Camp 2	Oct 1997	22º29'0.0"S 46º58'6.0"E	1200	R. Rasoloarison, B. Rasolonandrasana	Rasoloarison & Rasolonandrasana (1999)	-	
61	Ivohibe SR: Camp 3	Oct – Nov 1997	22º29'48.0"S 46º53'42.0"E	1575	R. Rasoloarison, B. Rasolonandrasana	Rasoloarison & Rasolonandrasana (1999)	-	
62	Sakanany	Aug 2006	22º34'20.5"S 47º51'44.8"E	18	S. Johnson, S. Martin	S. Johnson & S. Martin (unpubl.)	-	
63	Vevembe	Jun 1995 Jun 1997 May – Sep 2000	22º47'3.9"S 47º11'6.6"E	525	S. Johnson, C. Tan	Johnson & Overdorff (1999), Johnson & Wyner (2000), Johnson (2002)	-	
64	Lambohazo	Jun 1995	22º52'52.6"S 47º11'18.4"E	*c.* 300	S. Johnson	Johnson & Overdorff (1999)	-	
65	Manombo SR	Jun – Aug 1993 Jun – Jul 1995 Jun – Jul 1997 Feb 1999 – Jul 2000 Jul 2006	23º1'30.0"S 47º42'0.0"E	25	J. Ratsimbazafy, S. Johnson, P. C. Wright, N. Rowe, S. Martin	Johnson & Overdorff (1999), Ratsimbazafy (2002), S. Johnson & S. Martin (unpubl.), P. C. Wright & N. Rowe (unpubl.)	-	
66	Mahabo	Jul 2006	23º11'10.5"S 47º43'5.7"E	18	S. Johnson, S. Martin	S. Johnson & S. Martin (unpubl.)	-	
67	Kalambatritra SR	Jun 2000	23º22'24.0"S 46º28'12.0"E	1,400 to 1,680	M. Irwin, K. Samonds	Irwin *et al*. (2001)	-	
68	Beakora	Jan – Feb 2005	23º32'13.8"S 46º32'2.4"E	1100	P. Rabeson *et al.*	Rabeson *et al.* (2006)	-	
69	Midongy du Sud NP	Jun – Aug 1993 Jul 1995 Dec 2000	23º46'0.0"S 47º1'0.0"E	1050	P. C. Wright, S. Johnson, N. Rowe	Irwin *et al.* (2005), Johnson & Overdorff (1999); P. C. Wright & N. Rowe (unpubl.)	–	

other causes, or simply emigrated. In February 2005, a census revealed that the sole adult male and the two juveniles in the Ambatolahy Dimy group had also disappeared, leaving only a solitary adult female. In the birth season, November 2005, no offspring were born to either group. It is unlikely that the males came and went during this time, as the Talatakely group is followed by research assistants five days per week and no adult male was seen after December 2004. On 3 April 2005 (beginning of the breeding season), the remaining four animals (two adult females and two juveniles) of the Talatakely group migrated across the tourist bridge that crosses the Namorona River, and Route Nationale 25 (a paved highway), into the north parcel of the park. Several days later the Talatakely group was seen with the Ambatolahy Dimy solitary female. After a week with all five individuals feeding together in the Ambatolahy Dimy territory, the Talatakely group moved about 3 km west inside the northern parcel of the park. Then on 28 May 2005, the Talatakely group re-crossed the road and the river and returned to its original territory, without a male. In June 2005, one of the natal males who had disappeared three years previously returned and rejoined the Talatakely group. The adult female, the only remaining individual in the Ambatolahy Dimy group, remains solitary in her territory. Migration of an entire social group has never been observed in any lemur species, and this temporary migration may be an adaptation to demographic stochasticity in this historically patchily-distributed species. An infant was born on 18 December 2006 to one of the adult females in the Talatakely group, and the putative father is the male who joined the group in June 2006 (Fig. 2). We suspect that the other adult female did not give birth as well, because the new male is very likely her son, although these suspected relationships have yet to be confirmed. In June 2007, the reproducing female disappeared from the group, perhaps eaten by a predator. The infant remains an active member of the group as of September 2007, and group size is now five: one adult female, one adult male, one subadult natal male, one subadult natal female and the 9-month-old infant.

Figure 2. *Prolemur simus* mother and infant born December 18, 2007 at Talatakely, Ranomafana. Photo by J. Jernvall.

Kianjavato

Since 1986, *P. simus* individuals have been observed in the bamboo patches at the edge of the Kianjavato coffee plantation, 50 km due east of Ranomafana National Park. This forest is isolated from the main eastern escarpment forest that includes Ranomafana. Two small groups were recorded in 2004 (E. E. Louis Jr. unpubl. data) and, more recently, two groups of seven individuals each were sighted in July 2007 (R. Jacobs unpubl. data). Since 1986, *P. simus* individuals captured at Kianjavato were exported to Vincennes Zoo, Mulhouse Zoo, and Cologne Zoo (Table 2).

Andringitra National Park

Sterling and Ramaroson (1996) recorded three *P. simus* sightings during surveys at Camp 2 (810 m) in October, 1993. All three sightings were of two individuals (possibly the same group each time) (Sterling and Ramaroson 1996). *Prolemur simus* was never observed, however, during 16 months of fieldwork (April 1999–August 2000) in the same area and in the adjacent Ambarongy site across the Iantara River (Johnson 2002; Irwin *et al*. 2005). A single dead individual was sighted during this period on the trail to the Korokoto site. This individual was apparently the victim of hunting, as it was strung up with rope adjacent to the trail. *Prolemur simus* vocalizations were also heard at Korokoto in July 1997 (S. E. Johnson unpubl. data). These observations suggest that *P. simus* is present but rare at Andringitra.

Evendra and Mahasoa

Evendra is a small, degraded forest south of Andringitra (Fig. 1). In June 1997, a single *P. simus* individual was observed along a stream outside Evendra, near the village of Ivato, yet no individuals were sighted inside the forest itself (S. E. Johnson and C. Spoegler unpubl. data). No individuals were sighted in this area during resurveys in July 2007. However, one large group of *P. simus* with a minimum of 17 individuals was sighted in the nearby Mahasoa agricultural

Table 2. Status in captivity and development of *Prolemur simus* ISB population 2005. (information provided by Ingrid Porton)

Participants	Status 1 Jan 2004	Births	Transfers In Out	Deaths	Status 31 Dec 2004
Asson/F	1.2	-	- -	-	1.2
Besançon/F	1.1	1.0	- -	-	2.1
Edimburgh/E	1.1	-	- -	-	1.1
Ivoloina/M	3.1	-	- -	1.0	2.1
Köln/G	1.1	-	- -	-	1.1
Omega Parque	2.1	-	- -	-	2.1
Port Lympne/UK	1.1	-	- -	-	1.1
Paris/F	2.2	0.1	- -	-	2.3
Tsimbazaza/M	1.0	-	- -	-	1.0
Total	**13.10** **1.1**		- -	**1.0**	**13.11**

plantation (R. Jacobs unpubl. data; Figs. 3, 4). Virtually no forest persists in proximity to these sites (including Karianga; see below), with the landscape consisting largely of agricultural land and anthropogenic grasslands, interspersed with small, isolated bamboo patches. Remaining forests were being degraded during the study period, and are predicted to disappear completely in the near future (S. E. Johnson, E. E. Louis Jr., P. C. Wright unpubl. data).

Karianga and Morafeno

A group of 26 *P. simus* was recorded crossing a road in December 1995 in a forest fragment adjacent to Karianga village (P. C. Wright unpubl. data). Five of them were captured and housed at Ivoloina Park, near Toamasina. In June 1996, a minimum of 18 individuals were observed in the same locality (P. C. Wright unpubl. data). Three were captured: one was brought to Tsimbazaza Botanical Garden and Zoological Park in Antananarivo and two brought to Ivoloina Park. In 2000, six more animals were captured and delivered to Ivoloina Park (E. E. Louis Jr. unpubl. data; see Table 2). None of the *P. simus* captured at Karianga has been exported from Madagascar.

A two-day survey was conducted in July 2007 at this site. Unfortunately, this fragment was almost entirely converted to a coffee plantation in the intervening years, and there were no additional sightings of *P. simus* there. Moreover, no vocalizations were heard and no food traces were found (R. Jacobs unpubl. data).

Another two-day survey was conducted in July 2007 near the village of Morafeno, a few kilometers from Karianga in an agricultural plantation containing large stands of giant bamboo. One group of at least three individuals was sighted there (R. Jacobs unpubl. data).

Torotorofotsy

In the Torotorofotsy marshes, 10 km northwest of Andasibe, Dolch *et al.* (2004) observed giant bamboo remains (new shoots), and giant bamboo eaten by *P. simus* was documented in a photograph from this locality. At least three groups of *P. simus* have recently been recorded at this Ramsar site and a full description will be announced soon (E. E. Louis Jr. and R. Dolch pers. comm.). Rakotosamimanana *et al.* (2004) also described a possible sighting in nearby Maromizaha (near Andasibe). These sites are highly significant in that they substantially extend the northern range for extant populations of the species (Fig. 1). Torotorofotsy represents a habitat type (marshes) previously unrecorded for *P. simus*.

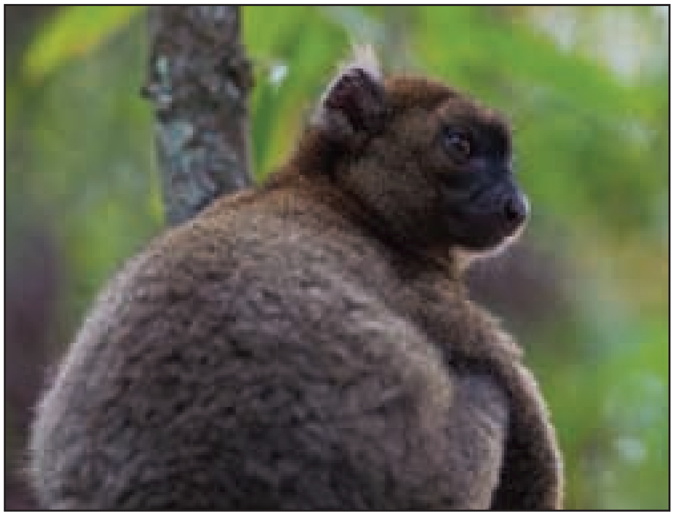

Figure 3. *Prolemur simus* adult male December, 2007 at Talatakely, Ranomafana. Photo by J. Jernvall.

Historic vs. Present Distribution

A reasonable first-order estimate of the historic distribution of *P. simus* is a minimum convex polygon drawn around all recent sightings, subfossil sites and museum specimen sites (Fig. 1). This polygon is about 300,000 km² (half of the island). A recent estimate of current range (excluding Torotorofotsy) was 3,125 km² (Irwin *et al.* 2005), and a minimum convex polygon around all recent confirmed sightings, including Torotorofotsy (Table 1) measures about 13,000 km². Thus, *P. simus* currently occupies approximately 1 to 4% of what we believe was its former range. Current habitat areas located within protected areas total 596 km² (Dolch *et al*. 2004; Irwin *et al*. 2005), though little of this area actually seems to be occupied by *P. simus* groups due to their apparent microhabitat preferences (Arrigo-Nelson and Wright 2004). Note that even these dramatically reduced ranges are over-estimates of suitable habitat, evidenced by their highly patchy distribution across study sites within this area.

Prolemur simus in captivity

Only 39 *P. simus* individuals have been kept in captivity. As of 2007, there were 22 in seven institutions (five in Europe and two in Madagascar) (Table 2). All *P. simus* in captivity in 2007 are from Karianga and Kianjavato.

Discussion

Our results indicate a dramatic reduction in the range of *P. simus*. Furthermore, within the narrow present-day range, *P. simus* is absent from the large majority of forest habitats. Excluding surveyed sites that may be outside of the current elevational and latitudinal limits of the species, greater bamboo lemurs have been confirmed in only 12 of 69 study sites (with Torotorofotsy treated as a disjunct locality). Furthermore, the fact that only about 12 groups, totaling less than 100 individuals, have been documented in over 20 years of regional surveys is indeed alarming. It suggests that *P. simus* is currently the lemur species (and genus) with the smallest overall population size across the entire island. Alarmingly, several of the known localities for this species have no official protection, and even within protected areas population numbers are exceedingly low (for example, Ranomafana). Habitat loss from slash-and-burn agriculture, and use of bamboo by village residents may be further reducing the wild *P. simus* populations (Arrigo-Nelson and Wright

2004; Wright *et al.* 2005). The long-term study of groups in Ranomafana National Park illustrates that stochastic events can deplete already small populations to critically low levels (Jernvall and Wright 1998; Wright and Jernvall 1999), suggesting that conservation planners should be aware of small population processes as an imminent cause of extinction in already-reduced and isolated subpopulations (Caughley 1994). These data corroborate other grim assessments indicating high extinction probability for *P. simus* (Konstant *et al*. 2006; Ganzhorn and Johnson 2007) and suggest that immediate action is required.

Reasons for rarity

One reason why *P. simus* is critically endangered may be its monotonous diet. Primates with a specialized diet often are at risk (Jernvall and Wright 1998; Wright and Jernvall 1999). In a long-term study of three species of bamboo lemur at Ranomafana, Tan (1999, 2000) found that the diet of greater bamboo lemurs is almost exclusively bamboo, and in fact 95% of the diet is just one species of bamboo (*Cathariostachys madagascariensis*), with 3% being provided by other bamboo and grass species, 0.5% by fruit, and 1.5% other foods (including soil and fungi). This feeding strategy varies with the seasons. Between July and November, *P. simus* opens the tough, woody stalks, or culms of the large bamboo by using premolars to strip the outside in order to consume the inner pith, but in December–March, it feeds on the new shoots and leaves of this same species. The group will typically feed in one small area of bamboo for a week and then move 1–2 km to a distant part of their territory to feed on another patch of *C. madagascariensis* stalks and shoots. The patchiness of this bamboo species may be one factor limiting the current distribution and population continuity of *P. simus*, as this key food species is not found in all forest microhabitats, and is apparently limited to forest near large rivers. It should be noted however, that this bamboo species was absent in Karianga, a small forest fragment where *P. simus* was observed feeding on the stalks of *Aframomum* sp., a ginger species (P. C. Wright pers. obs.). Further study of dietary breadth in other populations, therefore, is crucial to developing an understanding of this species' ecological flexibility, and eventually understanding its patchy distribution.

Figure 4. *Prolemur simus* photographed in July, 2007 at Mahasoa. Photo by P. Schlichting.

A second limiting factor for the distribution of *P. simus* could be the availability of drinking water. During dry months in Ranomafana National Park, *P. simus* is the only lemur species seen regularly coming to streams to drink water; other sympatric lemurs have not been observed to drink from streams, instead obtaining their water from leaves and fruits, with rainwater from foliage or tree hollows (P. C. Wright pers. obs.). This may be one explanation for the disappearance of greater bamboo lemurs from the northern part of Madagascar, as there is evidence that the north and west of Madagascar is drier now than in the past (Simons 1997; Godfrey *et al.* 2004).

Behavioral response to rarity

Recent observations of females leading a group in long-distance migration were quite notable. In other lemur species, groups maintain home ranges that change little over time, and only individual adults or subadults emigrate between groups (for example, *Propithecus edwardsi*: Pochron and Wright 2003). Because it was the mating season, and since a year without males had resulted in no offspring, we may infer that these females were searching for males, and the offspring, not yet capable of foraging independently, followed. The fact that, after presumably one month of searching, the Talatakely group did not find adult male conspecifics and returned to their original territory leads us to assume there are few if any extra-group males, and groups are spaced far apart. Although intragroup communication among individuals is frequent, there are no intergroup loud calls given by *P. simus,* as seen in sympatric *Hapalemur aureus* (see Wright 1999). These observations corroborate our survey results that very few *P. simus* exist in the area surrounding the Talatakely and Ambatolahy Dimy groups at Ranomafana National Park.

Conservation Recommendations

It is our opinion that swift action must be taken to prevent the extinction of this critically endangered species. The following are our recommendations for immediate research and conservation action.

1. Characterize the diet and microhabitat preferences of *P. simus* at known localities and use this information to identify habitats within the eastern rainforest which match known habitat preferences (i.e., are likely to contain or potentially sustain *P. simus*), and increase census efforts within these areas. The recent discovery of several groups at the Ramsar site near Torotorofotsy is very encouraging (Dolch *et al*. 2004; R. Dolch and E. E. Louis Jr. pers. comm.) and suggests surveying wetlands should be a priority.

2. Examine the levels of genetic variation over the entire population and within isolated subgroups, along with the levels of genetic relatedness within and between groups.

3. Investigate the feasibility of translocation and/or reintroduction in areas of impending habitat destruction. This would include an examination of all relevant disease and parasite issues.

Figure 5. *Prolemur simus* eating bamboo in July 2007 at Mahasoa. Photo by P. Schlichting.

4. Investigate the potential for endemic bamboo plantation and/or restocking programs in eastern forest areas to increase the area of suitable habitat and minimize future human exploitation of this resource.

5. Establish monitored protected areas in currently unprotected forests with known *P. simus* populations (Kianjavato Coffee Plantation, Ambatolahy Dimy, Mahasoa). Hire and train local people to follow these groups continually to protect them from poachers and predators.

6. Establish educational and public awareness programs in all sites where *P. simus* occurs.

Decisions need to be made in the very near future regarding a concerted effort to preserve this species. Rather than working disparately towards ill-defined goals, concerned organizations, governments, communities, and individuals need to make firm, collaborative decisions on which types of conservation strategy to pursue. Areas with known populations should immediately be gazetted as protected areas, with sufficient protection put in place. The data presented here suggest that a failure to make and act on such decisions in the immediate future may lead to the extinction of this monotypic genus.

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Literature Cited

Arrigo-Nelson, S. J. and P. C. Wright. 2004. Census and survey results from Ranomafana National Park: new evidence for the effects of habitat preference and disturbance on the genus *Hapalemur*. *Folia Primatol.* 75: 331–334.

Caughley, G. 1994. Directions in conservation biology. *J. Anim. Ecol*. 63: 215–244.

Dolch, R., R. D. Hilgartner, J. N. Ndriamiary and Randriamahazo H. 2004. The grandmother of all bamboo lemurs: evidence for the occurrence of *Hapalemur simus* in fragmented rainforest surrounding the Torotorofotsy marshes, central eastern Madagascar. *Lemur News* 9: 24–26.

Ganzhorn, J. U. and S. E. Johnson. 2007. Greater bamboo lemur *Prolemur simus* (Gray, 1871). In: Primates in Peril: The World's 25 Most Endangered Primates 2004–2006, R. A. Mittermeier *et al.* (compilers), pp.4, 21–22. *Primate Conserv.* (22): 1–40.

Ganzhorn, J. U., S. O'Connor, O. Langrand, B. Rakotosamimanana, A. T. C. Feistner, A. Katz, Y. Rumpler and P. C. Wright. 1996/1997. The state of lemur conservation in Madagascar. *Primate Conserv.* (17): 70–86.

Glander, K. E., P. C. Wright, P. S. Daniels and A. M. Merenlender. 1992. Morphometrics and testicle size of rain forest lemur species from southeastern Madagascar. *J. Hum. Evol.* 22: 1–17.

Godfrey, L. R., E. L. Simons, W. L. Jungers, D. D. De Blieus and P. S. Chatrath. 2004. New discovery of subfossil *Hapalemur simus*, the greater bamboo lemur in western Madagascar. *Lemur News* 9: 9–11.

Godfrey, L. R. and M. Vuillaume-Randriamanantena. 1986. *Hapalemur simus*: endangered lemur once widespread. *Primate Conserv*. (7): 92–96.

Goodman S. M., V. Razafindratsita, H. Schütz and R. Ratsimbazafy. 2001. Les lémuriens. In: *Inventaire Biologique du Parc National de Ranomafana et du Couloir Forestier qui la Relie au Parc National d'Andringitra*, S. M. Goodman and V. Razafindratsita (eds.), pp.231–243. CIDST, Antananarivo.

Grassi, C. 2001. The Behavioral Ecology of *Hapalemur griseus griseus*: The Influences of Microhabitat and Population Density on this Small-bodied Prosimian Folivore. PhD dissertation, University of Texas at Austin, Austin, TX.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.

Irwin, M. T., S. E. Johnson and P. C. Wright. 2005. The state of lemur conservation in south-eastern Madagascar: population and habitat assessments for diurnal and cathemeral lemurs using surveys, satellite imagery and GIS. *Oryx* 39: 204–218.

Irwin, M. T., K. E. Samonds and J. -L. Raharison. 2001. A biological inventory of the lemur community of Réserve Spéciale de Kalambatritra, south-central Madagascar. *Lemur News* 6: 24–28.

Irwin, M. T, T. M. Smith and P. C. Wright. 2000. Census of three eastern rainforest sites north of Ranomafana National Park: preliminary results and implications for lemur conservation. *Lemur News* 5: 20–23.

Jernvall, J. and P. C. Wright. 1998. Diversity components of impending primate extinctions. *Proc. Natl. Acad. Sci. USA* 95: 11279–11283.

Jernvall, J., C. Gilbert and P. C. Wright 2008. Peculiar tooth homologies of the greater bamboo lemur (*Prolemur* = *Hapalemur simus*): When is a paracone not a paracone? In: *Elwyn Simons: A Search for Origins*, J. G. Fleagle, and C. C. Gilbert (eds.), pp. 335–342. Springer, New York.

Johnson, S. and D. Overdorff. 1999. A census of brown lemurs (*Eulemur fulvus* sspp.) in southeastern Madagascar: methods-testing and conservation implications. *Am. J. Primatol.* 47: 51–60.

Johnson, S. and Y. Wyner. 2000. Notes on the biogeography of *E. f. albocollaris*. *Lemur News* 5: 25–28.

Johnson, S. E. 2002. Ecology and Speciation in Brown lemurs: White-collared Lemurs (*Eulemur albocollaris*) and Hybrids (*Eulemur albocollaris* × *Eulemur fulvus rufus*) in Southeastern Madagascar. PhD dissertation, University of Texas at Austin, Austin, TX.

Johnson S. E., P. C. Wright, T. H. Keitt, K. L. Kramer, F. J. Ratelohay, Ravalison, C. H. Holmes, W. Gordon and J. -P. Puyravaud. 2005. Predictors of local variation in lemur abundance at Ranomafana National Park, Madagascar. *Am. J. Phys. Anthropol.* Suppl. 40: 122.

Konstant, W. R., J. U. Ganzhorn and S. E. Johnson. 2006. Greater bamboo lemur *Prolemur simus* (Gray, 1871). In: Primates in Peril: The World's 25 Most Endangered Primates 2004–2006, R. A. Mittermeier, C. B. Valladares-Padua., A. B. Rylands, A. A. Eudey, T. M. Butynski, J. U. Ganzhorn, R. Kormos, J. M. Aguiar and S. Walker. (compilers), pp.3, 19. *Primate Conserv.* (20): 1–28.

Lehman, S. M., A. Rajaonson and S. Day. 2006a. Edge effects and their influence on lemur distribution and density in southeast Madagascar. *Am. J. Phys. Anthropol*. 129: 232–241.

Lehman, S. M., A. Rajaonson and S. Day 2006b. Lemur responses to edge effects in the Vohibola III Classified Forest, Madagascar. *Am. J. Primatol.* 68: 293–299.

Lehman, S. M., J. Ratsimbazafy, A. Rajaonson and S. Day. 2005. Decline of *Propithecus diadema edwardsi* and *Varecia variegata variegata* (Primates: Lemuridae) in south-east Madagascar. *Oryx* 40: 108–111.

Lehman, S. M. and P. C. Wright. 2000. Preliminary study of the conservation status of lemur communities Betsakafandrika region of eastern Madagascar. *Lemur News* 5: 23–25.

Louis, E. E., M. S. Coles, R. Andriantompohavana, J. A. Sommer, S. E. Engberg, J. R. Zaonarivelo, M. I. Mayor and R. A. Brenneman. 2006. Revision of the mouse lemurs (*Microcebus*) of Eastern Madagascar. *Int. J. Primatol.* 27: 347–389.

Louis, E. E., J. H. Ratsimbazafy, V. R. Razakamaharauo, D. J. Pierson, R. C. Barber and R. A. Brenneman. 2005. Conservation genetics of black-and-white ruffed lemurs, *Varecia variegata*, from southeastern Madagascar. *Anim. Conserv.* 8: 105–111.

Meier, B., R. Albignac, A. Peyrieras, Y. Rumpler and P. C. Wright. 1987. A new species of *Hapalemur* (Primates) from southeast Madagascar. *Folia Primatol.* 48: 211–215.

Meier, B. and Y. Rumpler. 1987. A preliminary survey of *Hapalemur simus* and a new species of *Hapalemur* in eastern Betsileo, Madagascar. *Primate Conserv.* (8): 40–43.

Mittermeier, R. A., W. R. Konstant, F. Hawkins, E. E. Louis, O. Langrand, J. Ratsimbazafy, R. Rasoloarison, J. U. Ganzhorn, S. Rajaobelina, I. Tattersall and D. M. Meyers. 2006. *Lemurs of Madagascar.* Conservation International, Washington, DC.

Petter, J.-J., R. Albignac and Y. Rumpler. 1977. Faune de Madagascar 44: Mammifères Lémuriens (Primates Prosimiens). ORSTROM/CNRS, Paris.

Pochron, S. T. and P. C. Wright. 2003. Variability in adult group compositions of a prosimian primate. *Behav. Ecol. Sociobiol.* 54: 285–293.

Rabeson, P., D. Randrianarisata, P. Rasabo, D. Andrianoely, G. Razafindrakoto, D. Razafindraibe, L. Rasabo and P. C. Wright. 2006. Surveys for lemurs and biodiversity in the Beakora forest southeast of Kalambatritra Reserve, Madagascar. *Lemur News* 11: 5–9.

Rakotosamimanana, B., R. R. Ralaiarison, R. C. Ralisoamalala, T. M. Rasolofoharivelo, V. Raharimanantsoa, R. M. Randrianarison, J. G. Rakotondratsimba, D. R. W. Rasolofoson, E. O. Rakotonirainy and T. M. Randriamboavonjy. 2004. Comment et pourquoi les lémuriens diurnes disparaissent peu à peu dans les forêts d'Ambato et de Moramanga (région de Moramanga) Madagascar? *Lemur News* 9: 19–24.

Rasoloarison, R. and B. P. N. Rasolonandrasana. 1999. Les lémuriens. In: *Inventaire biologique de la réserve spéciale du pic d'Ivohibe et du couloir forestier qui la relie au Parc National d'Andringitra*, S. M. Goodman and B. P. N. Rasolonandrasana (eds.), pp.159–169. CIDST, Antananarivo, Madagascar.

Ratelolahy, F. J., S. E. Johnson and P. C. Wright. 2006. Distribution and patchiness of endangered lemurs in the Ranomafana Rainforest of Madagascar: The crisis of the greater bamboo lemur. *Int. J. Primatol.* 27(suppl. 1): 501.

Ratsimbazafy, H. J. 2002. On the Brink of Extinction and the Process of Recovery: Responses of Black-and-White Ruffed Lemurs (*Varecia variegata variegata*) to Disturbance in Manombo Forest, Madagascar. PhD Dissertation, State University of New York at Stony Brook, Stony Brook, NY.

Simons, E. L. 1997. Lemurs old and new. In: *Natural Change and Human Impact in Madagascar*, S. M. Goodman and B. D. Patterson (eds.), pp.142–166. Smithsonian Institution Press, Washington, DC.

Simons, E. L., D. A. Burney, P. S. Chatrath, L. R. Godfrey, W. L. Jungers and B. Rakotosamimanana. 1995. AMS 14C dates for extinct lemurs from caves in the Ankarana Massif, Northern Madagascar. *Quat. Res*. 43: 249–254.

Sterling, E. J. and M. G. Ramaroson. 1996. Rapid assessment of the primate fauna of the eastern slope of the Réserve Naturelle Intégrale d'Andringitra, Madagascar. *Fieldiana Zool.* 85: 293–305.

Struhsaker. T. T. 1981. Census methods for estimating densities. In: *Techniques for the Study of Primate Population Ecology*, pp.36–80. National Research Council, National Academy Press, Washington, DC.

Tan, C. L. 1999. Group composition, home range size, and diet of three sympatric bamboo lemur species (genus *Hapalemur*) in Ranomafana National Park, Madagascar. *Int. J. Primatol.* 20: 547–566.

Tan, C. L. 2000. Behavior and Ecology of Three Sympatric Bamboo Lemur Species (Genus *Hapalemur*) in Ranomafana National Park, Madagascar. PhD dissertation, State University of New York at Stony Brook, Stony Brook, NY.

Whitesides, G., J. F. Oates, S. Green and R. Kluberdanz. 1988. Estimating primate densities from transects in a West African rain forest: a comparison of techniques. *J. Anim. Ecol.* 57: 345–367.

Wright, P. C. 1988. Lemurs lost and found: three species of these primates are discovered alive and well and living on bamboo. *Nat. Hist.* 97: 56–60.

Wright, P. C. 1992. Primate ecology, rainforest conservation, and economic development: building a national park in Madagascar. *Evol. Anthropol.* 1: 25–33.

Wright, P. C. 1999. Lemur traits and Madagascar ecology: coping with an island environment. *Yearb. Phys. Anthropol*. 42: 31–72.

Wright, P. C. and B. Andriamihaja. 2003. The conservation value of long-term research: a case study from the Parc National de Ranomafana. In: *The Natural History of Madagascar*. S. M. Goodman and J. P. Benstead (eds.), pp.1485–1488. University of Chicago, Chicago.

Wright, P. C. and J. Jernvall. 1999. The future of primate communities: A reflection of the present? In: *Primate Communities*, J. G. Fleagle, C. H. Janson and K. E. Reed (eds.). pp.295–309. Cambridge University Press, Cambridge, UK.

Wright, P. C., P. S. Daniels, D. M. Meyers, D. J. Overdorff and J. Rabasoa, J. 1987. A census and study of *Hapalemur* and *Propithecus* in southeastern Madagascar. *Primate Conserv.* (8): 84–88.

Wright, P. C., P. Daniels, D. M. Meyers, D. J. Overdorff and J. Rabesoa. 1987. A census and study of *Hapalemur* and *Propithecus* in southeastern Madagascar. *Primate Conserv*. (8): 84–88.

Wright, P. C., B. Andriamihaja and S. Raharimiandra. 2005. Tanala synecological relations with lemurs in southeast Madagascar. In: *Commensalism and Conflict: The Primate-Human Interface*, J. D. Paterson and J. Wallis (eds.), pp.118–145. American Society of Primatologists, Norman, OK.

Yamashita, N., C. Tan and C. Vinyard. 2004. Crushing abilities and jaw mechanics of *Hapalemur* species in Ranomafana National Park, Madagascar. *Am. J. Phys. Anthropol.* 127: 33–45.

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Revision of the Mouse Lemurs, *Microcebus* (Primates, Lemuriformes), of Northern and Northwestern Madagascar with Descriptions of Two New Species at Montagne d'Ambre National Park and Antafondro Classified Forest

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Abstract: Molecular genetic sequence variation of northern and northwestern mouse lemurs (*Microcebus*) was examined during a phylogenetic analysis of mitochondrial DNA (mtDNA) sequence data (*c*. 3,000 bp) for the entire genus. Phylogenetic inference of the mitochondrial DNA sequence data was generated from 132 individuals, representing 15 species of mouse lemurs. The database distinguished the 15 described *Microcebus* species and also provided diagnostic evidence for two further species. A comparison of the data for two mouse lemur species described from Nosy Be confirmed the existence of just one for this island population. The localities of the newly identified species are within the distributions previously recognized for *Microcebus sambiranensis* and *Microcebus tavaratra*. Formal descriptions, drawn from molecular genetic data, are presented for the two newly named species: one from Antafondro Classified Forest and the other from Montagne d'Ambre National Park. We revise the Inter-River-System hypothesis concerning the biogeographic patterns of the distributions of the northern and northwestern mouse lemurs according to our findings concerning the two species described here.

Key words: *Microcebus*, mouse lemur, systematics, Madagascar, prosimian, biogeography

Introduction

Due to its unique species biodiversity and to the continued pressure from human encroachment, Madagascar is among the highest conservation priorities worldwide (Myers *et al.* 2000). With 40% of the forest cover lost between the 1950s and 2000, rapid and comprehensive surveys of the remaining forest are essential (Harper *et al*. 2007). Dufils (2003) estimated that 90% of Madagascar's biodiversity is found exclusively in forest or woodland tracts, making these research efforts more urgent still. Recent molecular genetic and morphological studies of lemurs, particularly the mouse lemurs (*Microcebus*) and sportive lemurs (*Lepilemur*), have led to a great increase in the number of recognized species (Andriantompohavana *et al*. 2006; Craul *et al*. 2007; Kappeler *et al*. 2005; Louis *et al*. 2006a, 2006b; Olivieri *et al*. 2007; Radespiel *et al.* 2008). Even with these taxonomic revisions and the consequent realignments of the distributions of the species, regular re-evaluations are needed to monitor the conservation status of each taxon (Louis Jr. *et al*. 2006b).

All lemurs are currently protected under the Convention on International Trade in Endangered Species (CITES). Forty-one lemurs (43% of the 96 species and subspecies listed) were categorized on the *2008 IUCN Red List of Threatened Species* as threatened (IUCN 2008). The status of a further 43 lemurs (45%) were, however, too poorly known to be assessed and were classified as Data Deficient. Distributed throughout the island, lemurs are particularly susceptible to extinction from stochastic and deterministic factors due to their relatively small and fragmented geographic ranges (Jernvall and

Wright 1998). Mouse lemurs are adaptable, being found in secondary or otherwise degraded forest tracts, even along roads. They live in small social units, being solitary or forming small family groups (Guschanski *et al*. 2007), and are limited in their capacity to disperse because they are nocturnal and small (30–80 g) and have small home ranges of 0.3–1.5 ha (Schwab 2000; Weidt *et al*. 2004; Louis Jr. *et al*. 2006a).

Until recently, the northern and northwestern mouse lemurs were represented by the northern mouse lemur (*Microcebus tavaratra*) found at Ankarana National Park, and the Sambirano mouse lemur (*Microcebus sambiranensis*) found at Manongarivo Special Reserve (Rasoloarison *et al*. 2000). Based on phylogenetic inference of mitochondrial DNA (mtDNA) sequence data, Andriantompohavana *et al*. (2006) presented evidence for a new species of mouse lemur they named *M. mamiratra* in northwestern Madagascar at Nosy Be Island, and also indicated the probability of another, which they referred to as *Microcebus* sp. *nova* #5, at Antafondro Classified Forest. Olivieri *et al*. (2007) presented a biogeographic model for the northern mouse lemurs, and described three new species, including one, *M. lokobensis*, from Lokobe Special Reserve on Nosy Be Island and Manehoka on the mainland of Madagascar.

Three biogeographic models have been proposed for the distribution patterns of mouse lemurs, based on different relative contributions of factors that include large rivers (>50 m wide at 20 km inland), retreat dispersion watersheds, and topographical barriers such as mountains (Martin 1995; Wilmé *et al*. 2006; Craul *et al*. 2007; Olivieri *et al*. 2007). Olivieri *et al*. (2007) and Craul *et al*. (2008) presented biogeographic models which defined "centers of endemism" based on the isolation effects of paired rivers, or Inter-River-Systems (IRS; Fig. 1). During the course of a number of biogeographic reviews of northern and northwestern Madagascar, the number of Inter-River-Systems has increased from four (Martin 1995), to five (Wilmé *et al*. 2006) to nine (Craul *et al*. 2008).

In this paper, we present a comparative phylogenetic analysis of the northern and northwestern mouse lemurs. With comprehensive sampling in this region (novel samples and sites, along with accessioned published sequences), we re-evaluate the biogeographic partitions, define the relationship between *Microcebus mamiratra* and *Microcebus lokobensis* described independently from the island of Nosy Be, and provide descriptions of two mouse lemurs that we consider to be distinct species; one from Antafondro Classified Forest and the other from Montagne d'Ambre National Park.

Methods

Sample collection

All lemurs in this molecular study were free-ranging, wild-caught, adults (Fig. 1; Table 1; Appendix I(a)). All mouse lemurs were hand-caught and subsequently immobilized using 1.0–3.0 mg of Telazol® (Fort Dodge). Two 2.0-mm biopsies and 0.01–0.05 cc of whole blood were collected and stored in room temperature tissue preservative (Longmire *et al*. 1992). The lemurs designated as outgroups were immobilized with a CO_2 projection rifle or blowgun with 10mg/kg of Telazol® (Fort Dodge; Appendix I(a)), and four 2.0-mm biopsies and 1.0 ml/kg of blood were collected and stored in room temperature tissue preservative (Longmire *et al*. 1992). Genomic DNA was extracted from a 2.0-mm ear punch using a phenol-chloroform extraction (Sambrook *et al*. 1989). All measurements were taken on sedated animals as described in Andriantompohavana *et al*. (2006). We measured the weight (±0.1 g), head crown (total length from the tip of the nose [soft tissue of the nose is not included] to the occipital crown ±0.1 cm), body length (total length of body from the occipital condyle to the base of the tail ±0.1 cm), tail length (total length from the base of the tail to the end of the last caudal vertebra ±0.1 cm), ear length (total length from the tip of the ear to the base ±0.1 mm), ear width (total width across the widest portion of the pinna ±0.1 mm), and muzzle length (total length from the tip of the nose [soft tissue of the nose is not included] to the medial corner of the eye ±0.1 mm). For presentation purposes we provide the weight, head crown, body length, and tail length following the guidelines of Smith and Jungers (1997). (See Table 1. Appendices I(a–b).)

Data generation

To compare our data with previously published molecular studies, we analyzed the following regions of the mitochondrial DNA (mtDNA): D-loop or control region (D-loop; Baker *et al*. 1993; Wyner *et al*. 1999); and a fragment of the cytochrome oxidase subunit III gene (COIII); NADH-dehydrogenase subunits 3, 4L, and 4 (ND3, ND4L, and ND4); as well as the $tRNA^{Gly}$, $tRNA^{Arg}$, $tRNA^{His}$, $tRNA^{Ser}$, and partial $tRNA^{Leu}$ genes (PAST; Pastorini *et al*. 2000; Louis Jr. *et al*. 2006a). Using 50 ng of genomic DNA, the D-loop (487-531 base pairs (bp)) and the PAST fragments (2367 bp) were amplified by the polymerase chain reaction (PCR) using the following conditions: 94°C for 30 s, a primer-specific annealing temperature for 1 min, and 72°C for 5 min for 35 cycles. Since all potential sites or populations of mouse lemurs have not been collected, accessioned sequences were used to compare and augment the datasets to evaluate the current taxonomic knowledge of the genus *Microcebus* (Andriantompohavana *et al*. 2006; Yoder *et al*. 2000; Louis Jr. *et al*. 2006a; Olivieri *et al*. 2007; see Table 1; Appendix III(a)). The species described by Radespiel *et al*. (2008) were not included in these analyses since sequence fragments could not be compared at this time. To evaluate the two described species of Nosy Be, *Microcebus mamiratra* and *M. lokobensis*, representative sequences for the D-loop were added to the data file (Appendix III(a)).

PCR products were confirmed visually on a 1.2% agarose gel, and purified using QIAquick PCR purification kit (Qiagen, Valencia, CA). Using the BigDye terminator cycle sequencing ready reaction kit by Applied Biosystems, the sequence was generated with a 7% polyacrylamide gel by an ABI 3100 automated sequencer (Applied Biosystems, Inc; Foster City,

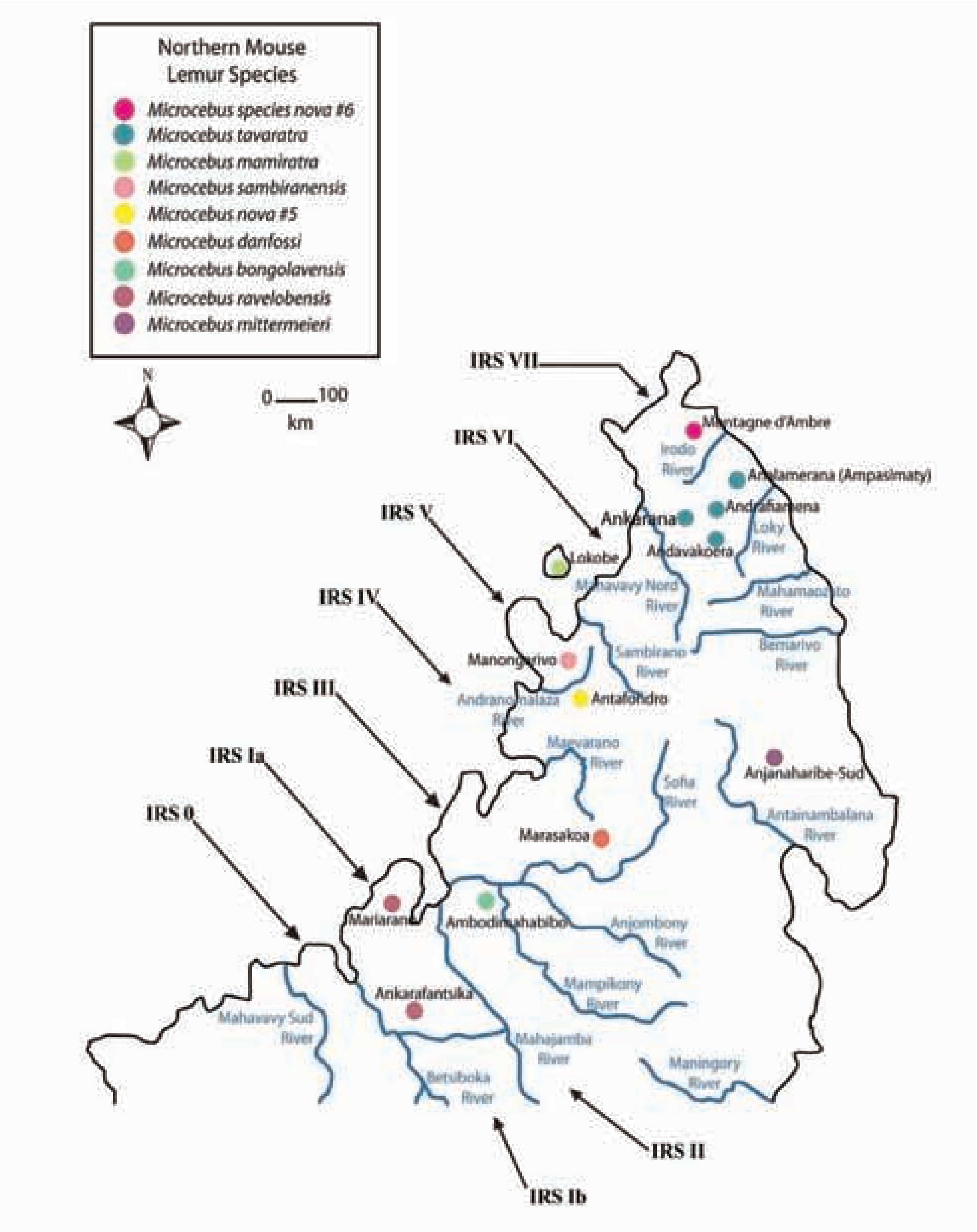

Figure 1. Distribution map of the mouse lemur (genus *Microcebus*) samples of northern and northwestern Madagascar. Each sample site is color-coded to a specific *Microcebus* species. The Inter-River-System (IRS) data is based on Olivieri *et al*. (2007).

CA). The sequence fragments were aligned to generate a consensus sequence using Sequencher (Gene Corp; Ann Arbor, MI), and the consensus sequences were aligned using ClustalX (Thompson *et al*. 1997). The consensus sequences were submitted to GenBank and Accession Numbers are listed in Table 1 (see Appendix I(a)). The sequence alignments for the data sets are available from the first author upon request.

Phylogenetic analysis

To examine the genetic diversity of the mouse lemurs of the northern region of Madagascar, maximum-parsimony (MP), maximum likelihood (ML), and neighbor-joining (NJ) analyses were implemented for the D-loop and PAST, and combined (D-loop//PAST) sequence data with PAUP software (Swofford 2001). The trees described in this paper are all consensus trees except for the bootstrap analysis (all trees were presented as phylograms for presentation purposes only). Bootstrap analyses were accomplished with 1000, 3000, and 4000 pseudoreplicates with the D-loop; PAST; and D-loop/PAST combined sequence files, respectively, with 10 random addition heuristic searches per replicate option selected. Only nodes with greater than 50% support were reported. The D-loop NJ tree was generated using the Tamura-Nei model (Tamura and Nei 1993). The stepwise addition option was selected for MP analyses, and corrections for nucleotide sequence data suggested by Kimura (1980) were used with the NJ analyses. Gaps were considered as a fifth character in MP analyses, whereas gaps were treated as missing data in the NJ analyses. The ML trees were estimated via the best-fit model selected by the hierarchical likelihood ratio test (hLRT) in ModelTest3.5 (Posada and Crandall 1998). The best-fit model selected by the hLRT criteria was the TrN+I+G model [(0.2750 0.0996 0.2552), Nst = 6, Rmat = (1.0000 13.5199 1.0000 1.0000 8.4486), Gamma = 1.0731, Pinvar = 0.4333]. In addition to character-based phylogenetic analysis of DNA sequences, PAUP software (Swofford 2001) was also used to calculate uncorrected pairwise distances (‘p’) and Kimura distance measures for D-loop and PAST fragments.

Bayesian inference analyses were conducted using MrBayes 3.0b4 (Huelsenbeck and Ronquist 2001; Ronquist and Huelsenbeck 2003). The model of evolution was selected by using MrModeltest 2.2, a modified version of Modeltest 3.6

Table 1. Samples (27 total) from free-ranging mouse lemurs (*Microcebus*) used in this study. MtDNA sequence data for each mouse lemur sample are available from GenBank under the listed accession numbers. The TK number is the catalogue of the paratype DNA sample stored at the Museum of Texas Tech University, Lubbock, Texas. Global Positioning System (GPS) shows the site where the animal was immobilized. The samples not listed in this manuscript are available in Louis *et al*. (2006a) and Andriantompohavana *et al*. (2006).

Accession number	TK Number	Species designation	Location	Global Positioning System (GPS)	D-loop fragment	PAST fragment
FIA5.30		*Microcebus tavaratra*	Andrafiamena (Anjakely)	S12°54'52.0" – E049°18'49.6"	DQ534961	DQ534992
MATY5.22		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°45'56.0" – E049°29'00.5"	DQ534962	DQ534993
MATY5.23		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°45'56.0" – E049°29'00.5"	DQ534963	DQ534994
MATY5.24		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°45'56.0"– E049°29'00.5"	DQ534964	DQ534995
MATY5.25		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°45'09.5" – E049°29'01.4"	DQ534965	EF175219
MATY5.35		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°45'47.3"– E049°29'06.9"	DQ534966	DQ534996
MATY5.38		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°46'10.1" – E049°29'00.5"	DQ534967	DQ534997
MATY5.39		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°46'11.7" – E049°29'03.0"	DQ534968	DQ534998
MATY5.41		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°46'11.7" – E049°29'00.9"	DQ534969	DQ534999
MATY5.43		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°46'18.0" – E049°29'00.9"	DQ534970	DQ535000
MATY5.44		*Microcebus tavaratra*	Analamera (Ampasimaty)	S12°46'18.0" – E049°29'00.9"	DQ534971	DQ535001
KOER6.5		*Microcebus tavaratra*	Andavakoera	S13°07'16.8" – E049°13'42.3"	EF175269	EF175220
AMB5.24		*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°31'28.1" – E049°10'22.8"	DQ534972	DQ535002
AMB5.25		*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°31'34.1" – E049°10'30.0"	DQ534973	DQ535003
AMB5.26		*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°31'05.8" – E049°10'33.0"	DQ534974	DQ535004
AMB5.33		*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°30'44.7" – E049°11'23.3"	DQ534975	DQ535005
AMB5.38		*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°28'43.7" – E049°12'58.2"	DQ534976	DQ535006
AMB5.39	TK145310	*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°28'43.7" – E049°12'58.2"	DQ534977	DQ535007
AMB5.40	TK145311	*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°30'28.2" – E049°11'38.1"	DQ534978	DQ535008
AMB5.41	TK145312	*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°28'38.2" – E049°13'20.8"	DQ534980	DQ535009
AMB5.42		*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°28'40.1" – E049°13'04.1"	DQ534981	DQ535010
AMB5.43		*Microcebus* sp. *nova* #6	Montagne d’Ambre	S12°30'44.6" – E049°11'21.5"	DQ534979	DQ535011
TAFO6.1	TK145314	*Microcebus* sp. *nova* #5	Antafondro (Maromiandra)	S14°02'44.5" – E048°13'23.4"	EF175273	EF175224
TAFO6.2	TK145315	*Microcebus* sp. *nova* #5	Antafondro (Maromiandra)	S14°02'35.7" – E048°13'21.7"	EF175274	EF175225
TAFO6.5		*Microcebus* sp. *nova* #5	Antafondro (Maromiandra)	S14°02'44.5" – E048°13"23.4"	EF175275	EF175226
TAFO6.6		*Microcebus* sp. *nova* #5	Antafondro (Maromiandra)	S14°02'48.8" – E048°13'10.3"	EF175276	EF175227
TAFO6.7		*Microcebus* sp. *nova* #5	Antafondro (Maromiandra)	S14°02'48.7" – E048°13'09.7"	EF175277	EF175228

(Nylander 2004; Posada and Crandall 1998). A Markov Chain Monte Carlo (MCMC) run with four simultaneous chains and 1,000,000 generations was performed. Every hundredth generation, the tree with the best likelihood score was saved, resulting in 4000 trees. The 4000 trees were condensed in a majority rule consensus tree using PAUP Version 4.0b10 software (Swofford 2001). Branch supports were assigned as posterior probabilities on the consensus tree. The pattern of sequence evolution was estimated by conducting a minimum spanning network generated with the program NETWORK Version 4.11 (Bandelt *et al*. 1999; Forster *et al*. 2001; Gonzales *et al*. 1998) and Arlequin, Version 2.0 (Schneider *et al*. 2000).

As described in Andriantompohavana *et al*. (2006), Davis and Nixon (1992), Wyner *et al*. (1999), Mayor *et al*. (2004), and Louis Jr. *et al*. (2006a, 2006b), we used MacClade 3.01 (Maddison and Maddison 1992) and MEGA version 2.0 (Kumar *et al*. 1993) in a diagnostic search to designate Evolutionary Significant Units (ESU) for the *Microcebus* species using a Population Aggregate Analysis (PAA) of the D-loop (487-531 bp) and PAST (2367 bp) sequence data. In this paper, the current *Microcebus* taxonomy for northern and northwestern Madagascar was examined according to the Phylogenetic Species Concept (PSC) *sensu* (Wheeler and Platnick *et al*. 2000; Louis Jr. *et al*. 2006; Mayor *et al*. 2004). With the sequential addition of each individual without an *a priori* species designation, a PAA distinguishes attributes or apomorphic characters according to the smallest definable unit (Andriantompohavana *et al*. 2006; Davis and Nixon 1992; Mayor *et al*. 2004; Louis Jr. *et al*. 2006a, 2006b; Ravaoarimanana *et al*. 2004).

Results

Mitochondrial DNA sequence data were completed for two fragments, D-loop and PAST (approximately 3,000 bp), for 121 individuals, representing all 15 recognized species of mouse lemurs from a total of 32 sites (Figs. 1–4, Appendices II(a–e)). Based on the phylogenetic inferences of the NJ, MP, and ML analyses of three sequence alignments (D-loop, PAST, and combined), the 15 *Microcebus* species were represented in 15 well-supported terminal clades (Figs. 2–4; the newly described species by Radespiel *et al*. (2008) were not included in these analyses since sequence fragments could not be correlated). All three phylogenetic methods corroborate the monophyly of *M. griseorufus* and *M. murinus* and the monophyly of *M. bongolavensis*, *M. danfossi*, and *M. ravelobensis* as presented in Radespiel *et al.* (2008). Additionally, the sister relationship between *M. myoxinus*, *M. berthae*, *M. lehilahytsara*, and *M. rufus* exists with all three methods for the D-loop sequence fragment, but cannot be confirmed for the PAST or D-loop/PAST concatenated due to the unavailability of samples sets for *M. bongolavensis* and *M. danfossi*. The mouse lemur samples from the island of Nosy Be, comprising *Microcebus* sp. *nova* #4 from Louis Jr. *et al*. (2006a), *M. mamiratra* from Andriantompohavana *et al*. (2006), and *M. lokobensis* from the IRS VI in Olivieri *et al*. (2007; Lokobe Special Reserve on Nosy Be and Manehoka from mainland Madagascar) were found to form a single terminal clade (Figs. 1 and 2). The minimum spanning network for the *Microcebus* D-loop haplotypes reveal a similar evolutionary pattern as the three phylogenetic methods (Fig. 5). Interestingly, *Microcebus jollyae*, an east coast reddish morph, is aligned intermediately between the *M. griseorufus* and *M. murinus* group, west coast gray forms, and the *M. mittermeieri* and *M. simmonsi*, east central coast reddish morphs. The samples from Nosy Be, representing the two described species, *M. mamiratra* and *M. lokobensis*, along with the samples from Manehoka (mainland Madagascar), clustered together as one well-supported terminal clade. Furthermore, all three phylogenetic methods support two distinct subpopulations, *Microcebus* sp. *nova* #5 (Antafondro) and *Microcebus* sp. *nova* #6 (Montagne d'Ambre; Figs. 1–4; Appendices II(a–e)).

A review of the morphometric data for 13 described species of mouse lemurs are presented in Table 2 (detailed morphological measurements of the novel individual mouse lemurs are available in Appendix I(b)). No extensive quantitative analyses were conducted on the morphometric data. Inherent inconsistencies found or produced within morphologic data sets prevent a statistically reliable conclusion. Numerous factors such as small sample sets, independent data sets, multiple data collectors, the variance between live, sedated individuals versus processed museum vouchers, along with seasonal and age differences of individual mouse lemurs, currently restrict any comprehensive analysis of the genus *Microcebus*. With that said, this morphometric information is provided as supplemental data, only complementing the partitioning of unique biodiversity (Table 2).

The results from the population aggregate analysis of the D-loop and PAST sequence data are presented in Tables 3 and 4, respectively (Appendices III(b–e)). Multiple diagnostic characters distinguish each established *Microcebus* species, along with *Microcebus* sp. *nova* #5 and *Microcebus* sp. *nova* #6 at Antafondro and Montagne d'Ambre, respectively (Tables 3 and 4; Appendices III(b–c)). *Microcebus* sp; *nova* #5 had seven diagnostic sites, whereas *Microcebus* sp. *nova* #6 had nine. The complete uncorrected 'p' distance and the Kimura two-parameter distance measures are presented in Tables 5a and 5b. The absolute pairwise distances generated between undefined terminal clades and described mouse lemur species corresponds to the observed interspecific values found between described species (Andriantompohavana *et al*. 2006; Louis Jr. *et al.* 2006a; Olivieri *et al*. 2007). Although the absolute pairwise distance between *M. mamiratra* and *Microcebus* sp. *nova* #5 is the smallest percentage between the terminal clades, the geographic distance between sampling sites is also reduced (Appendix II(h)). Values ranged mostly from 10% to 15% with the lowest percentage found between *Microcebus* sp. *nova* #5 and *M. mamiratra* (4.9% and 2.5%, D-loop and PAST, respectively) and the highest percentage was found between *M. ravelobensis* and *M. jollyae* (24.3% and 10.7%, D-loop and PAST, respectively).

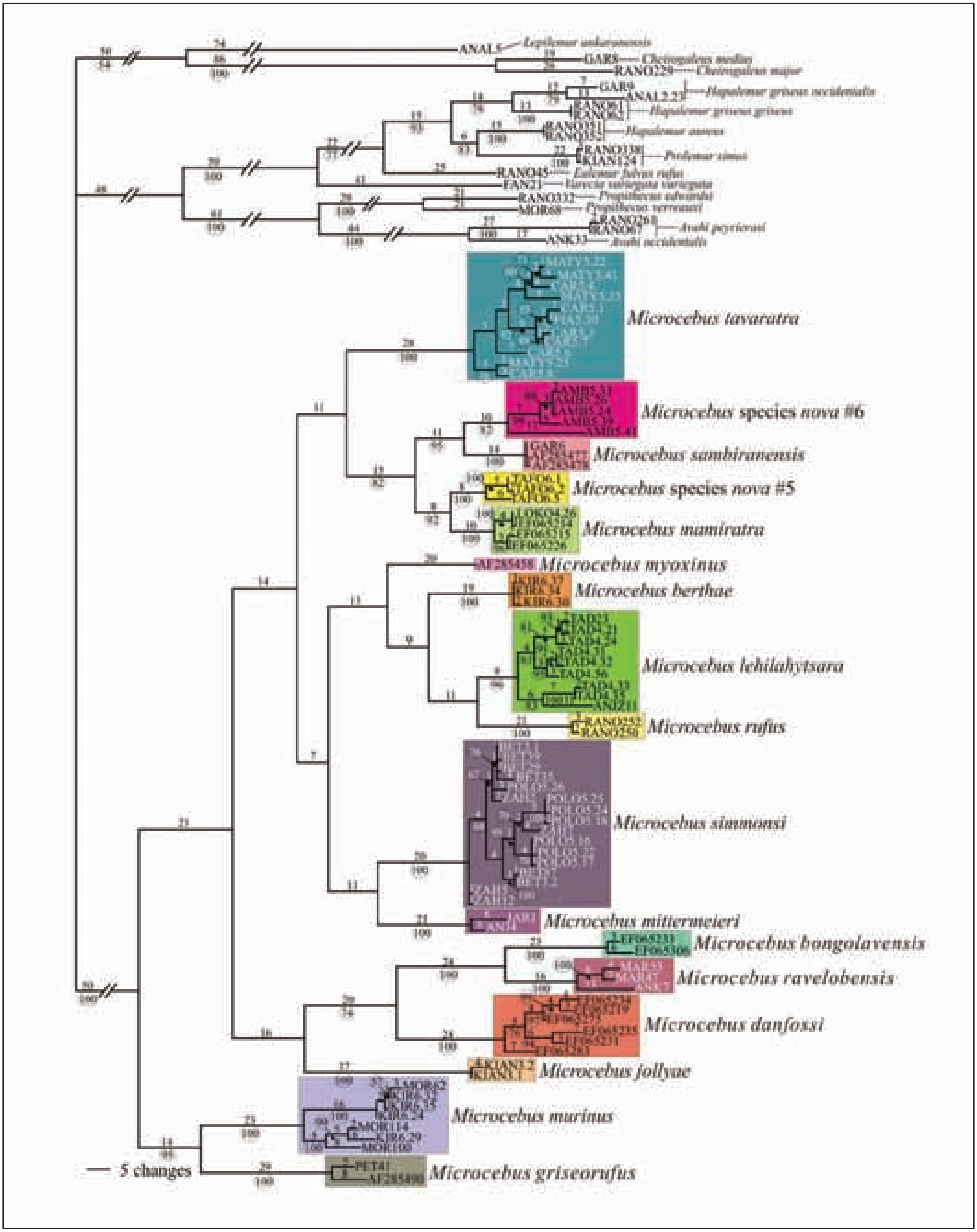

Figure 2. Neighbor-joining phylogram derived from the D-loop DNA sequence data from 82 *Microcebus* individuals with 18 out-group taxa. Species designated according to the distribution in the current literature (Andriantompohavana *et al*. 2006; Louis Jr. *et al*. 2006a; Mittermeier *et al*. 2006; Olivieri *et al*. 2007). Values above branches indicate number of changes between nodes. Values within circles indicate support of bootstrap pseudoreplicates.

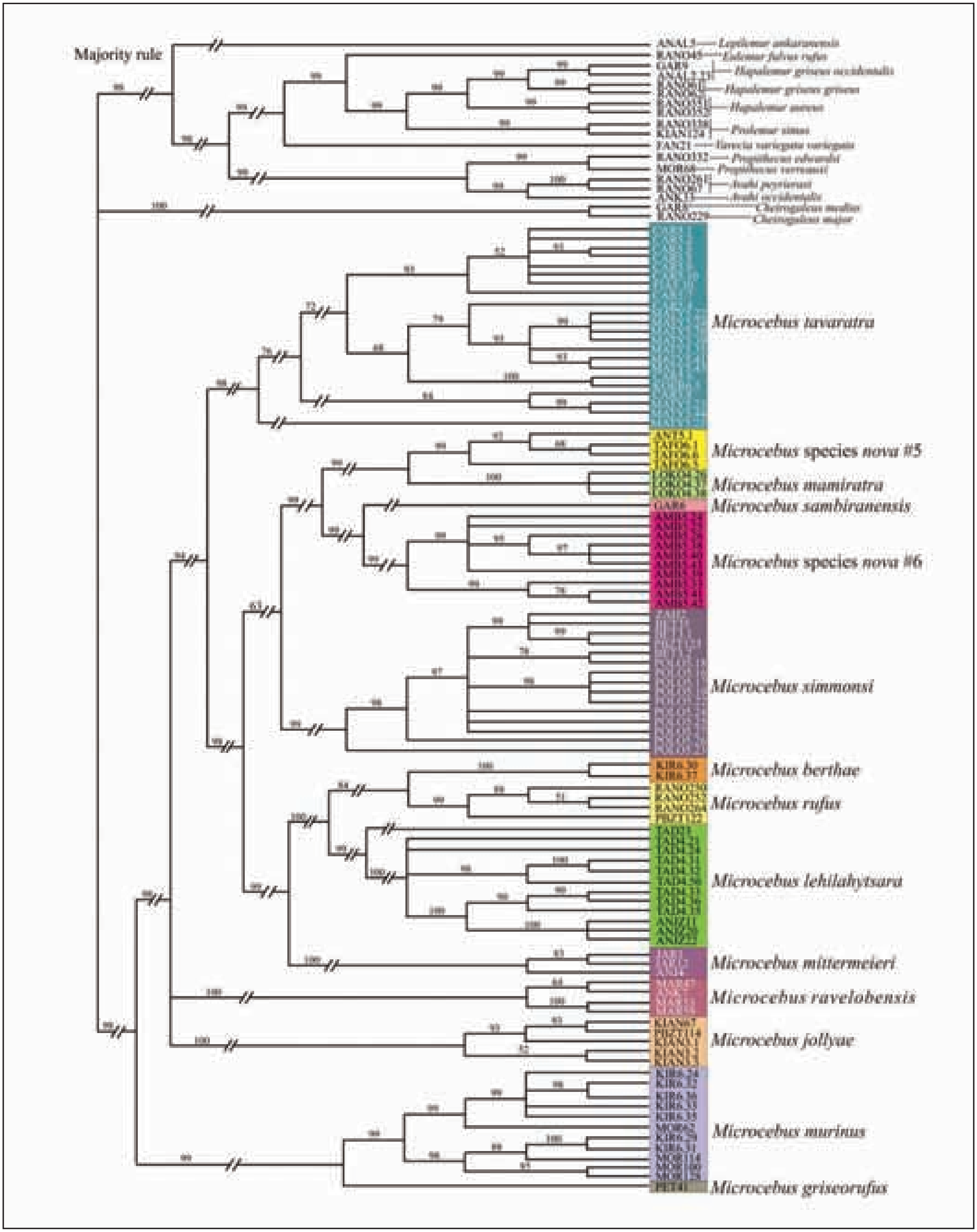

Figure 3. Fifty percent majority-rule consensus phylogenetic tree from the Bayesian analysis derived from the PAST sequence data from 97 haplotypes from 121 *Microcebus* individuals with 18 out-group taxa reconstructed using the computer program package MrBayes. Branches without posterior probability values are supported by less than 50% of the sampled trees.

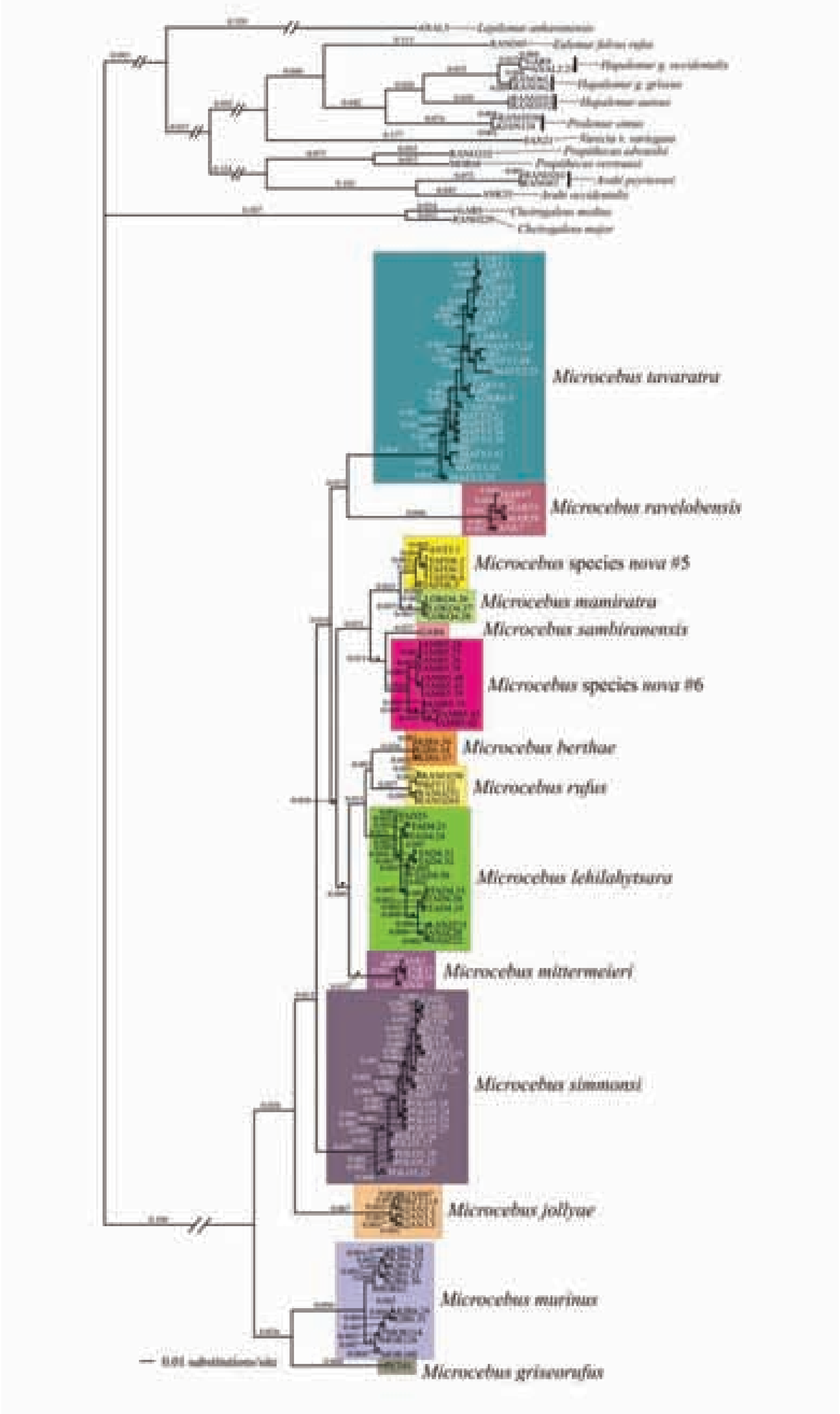

Figure 4. Maximum-likelihood phylogram derived from concatenated D-loop and PAST sequence data from 107 *Microcebus* haplotypes with 18 out-group taxa. The phylogram is presented with branch lengths proportional to the number of changes (values specified on the branches). We obtained the maximum likelihood phylogram (-ln likelihood=4921.54) from the D-loop and PAST concatenated alignment (K=7) and γ shape parameter of 1.07.

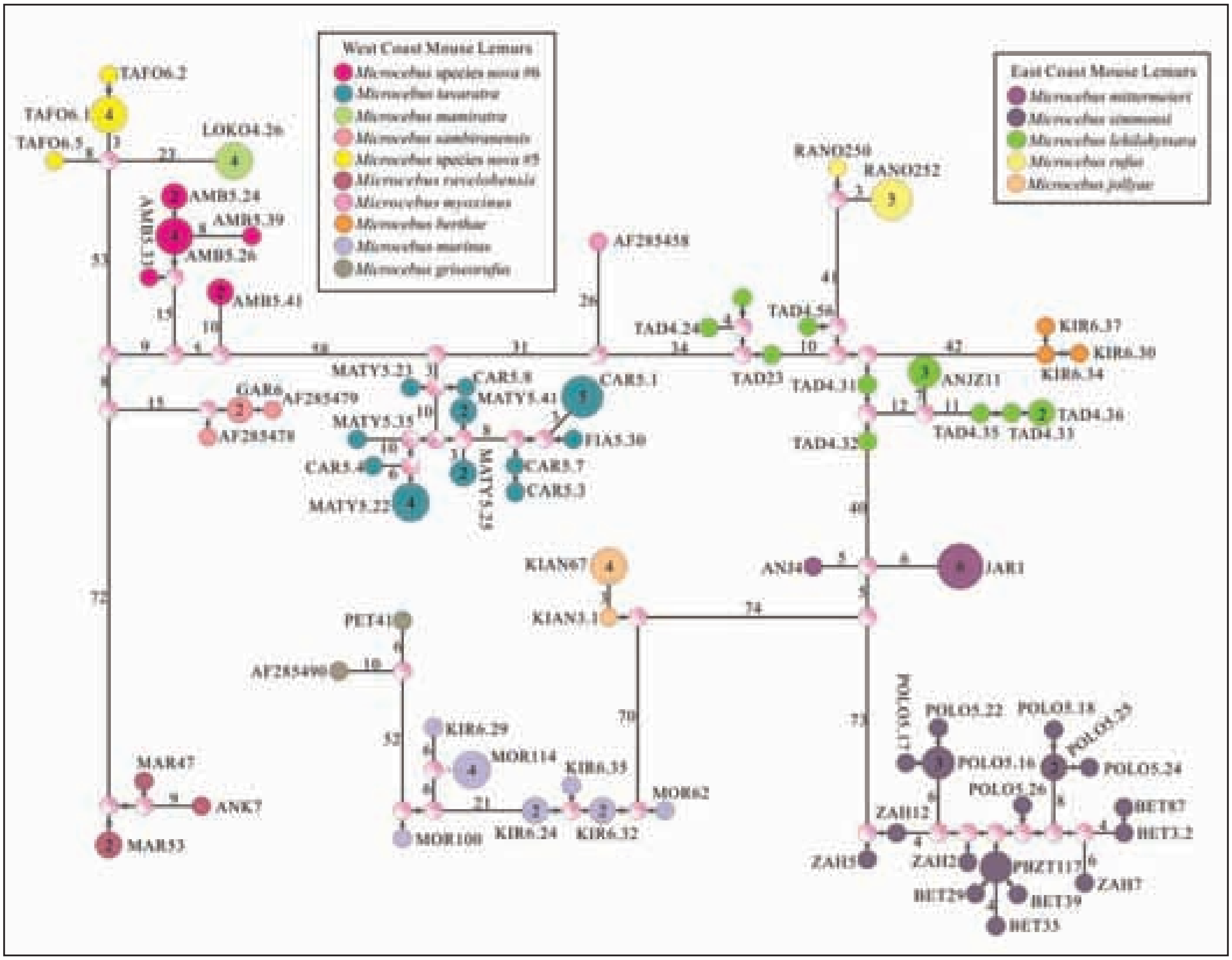

Figure 5. Minimum spanning network of *Microcebus* D-loop haplotypes calculated using Arlequin 2.0 and Network 4.11. Identification numbers denote unique haplotypes. The minimum number of mutational steps separating matriarchal lines is indicated above the branches. Nucleotide substitutions are indicated by dashes. The number of nucleotide differences (more than two) in their connecting lines of the network is indicated by the number at each connecting link. Missing intermediates are indicated by conical pink circles. The size of circles approximates the number of individuals with matching haplotypes corresponding to information in Appendix III(d) (circles without any number represent one individual).

Table 2. Morphometric data collected from sedated *Microcebus* individuals. (Individual morphological data available online; see Appendix I). Morphological data taken from immobilized animals.

Species	Common name	N	Weight (gm)	Head crown (cm)	Body length (cm)	Tail length (cm)
*Microcebus berthae**	Berthe's mouse lemur	3	30.6±0.6	N/A	9.2±0.3	N/A
Microcebus berthae	Berthe's mouse lemur	3	21.1±1.3	2.8±0.0	6.2±0.3	11.6±0.3
*Microcebus sambiranensis**	Sambirano mouse lemur	6	44.1±5.9	N/A	11.7±0.4	N/A
Microcebus sambiranensis	Sambirano mouse lemur	1	48.0	2.6	8.3	14.0
Microcebus mamiratra	Claire's or Nosy Be mouse lemur	4	60.8±8.3	3.4±0.1	9.4±0.5	15.8±1.1
Microcebus lehilahytsara	Goodman's mouse lemur	5	39.6±3.3	3.2±0.1	8.3±0.6	10.7±0.7
Microcebus mittermeieri	Mittermeier's mouse lemur	5	44.1±7.4	3.3±0.0	8.7±0.2	11.3±0.2
*Microcebus myoxinus**	Pygmy mouse lemur	15	49.0±6.3	N/A	12.4±0.5	N/A
Microcebus murinus	Grey mouse lemur	10	65.5±4.2	3.4±0.2	9.3±0.7	13.0±1.0
Microcebus ravelobensis	Golden-Brown mouse lemur	10	65.9±12.5	3.7±0.1	9.6±0.7	14.5±0.3
*Microcebus simmonsi***	Simmons' mouse lemur	6	64.8±17.5	3.6±0.1	9.2±1.0	14.2±1.0
Microcebus jollyae	Jolly's mouse lemur	3	61.3±4.5	3.6±0.1	9.3±0.3	12.2±0.1
*Microcebus griseorufus**	Reddish grey mouse lemur	6	62.6±5.91	N/A	12.3±0.6	N/A
Microcebus griseorufus	Reddish grey mouse lemur	3	43.7±3.1	3.3±0.1	8.7±0.4	13.9±1.6
Microcebus rufus	Brown or rufous mouse lemur	15	43.7±4.2	3.3±0.1	8.6±0.3	11.7±0.8
*Microcebus tavaratra**	Northern rufous mouse lemur	6	61.1±N/A	N/A	12.6±N/A	15.5±N/A
*Microcebus tavaratra**	Northern rufous mouse lemur	20	52.3±7.2	3.4±0.3	9.0±0.8	14.6±1.0
Microcebus sp. *nova* #5	-	10	41.0±14.0	3.1±0.4	7.4±1.8	13.2±2.2
Microcebus sp. *nova* #6	-	6	49.7±18.0	3.1±0.2	8.2±1.1	12.1±1.5

*Head and body length measurements are taken from Rasoloarison *et al*. (2000). Head crown is the total length from tip of the nose (soft tissue of the nose is not included) to the occipital crown (±0.1 cm); body length is from the occipital condyle to the base of the tail (±0.1 cm), and the tail length is from the base of the tail to the last caudal vertebra (±0.1 cm). All values (±) calculated as standard deviation.
**The data include mouse lemurs that are considered juveniles.

Table 3. Summary of Population Aggregate Analysis (PAA) D-Loop diagnostic sites for the genus *Microcebus*. Refer to Appendix III(b).

Species	Fragment size (bp)	PAA base pair location
M. tavaratra	515	367, 513, 514, 515, 517
M. ravelobensis	520	26, 146, 160, 161, 162, 166, 170, 171, 172, 173, 257, 261, 265, 266, 267, 268, 271, 272, 273, 274, 278, 279, 290, 294, 303, 306, 307, 311, 399, 401, 411, 446, 456, 476, 480, 481, 483, 484, 488, 490, 491, 493, 500, 501, 502, 509
M. sp. *nova* #5	490	490
M. sambiranensis	513-514	246, 281, 434, 523
M. sp. *nova* #6	515	476
M. mamiratra	487	199, 478, 481
M. berthae	521	73, 158, 506, 516
M. murinus	527-531	150, 158, 163, 164, 244, 245, 429, 497, 503
M. rufus	522	123, 244, 308, 356, 494
M. simmonsi	489	188, 189, 190, 191, 192, 198, 199, 200, 201, 202, 203, 204, 253, 337, 439, 480, 482
M. mittermeieri	518	124, 238, 349, 503, 522
M. jollyae	518	166, 190, 194, 195, 299, 327, 331, 418, 419, 475, 486, 487, 505, 508, 522
M. lehilahytsara	522	*
M. griseorufus	526	42, 149, 158, 192, 195, 220, 244, 325, 339, 438, 506, 517
M. myoxinus	520	122, 222, 289

*No character or attribute is available for this fragment.

Table 4. Summary of Population Aggregate Analysis (PAA) Pastorini fragment diagnostic sites for the genus *Microcebus*. Refer to Appendix III(c).

Species	**Fragment size (bp)**	**PAA base pair location**
M. tavaratra	2366	111, 134, 238, 834, 1062, 1218, 1266, 1290, 1291, 1303, 1349,1354, 1355, 1366, 1399, 1551, 1566, 1590, 1593, 1596, 1614, 1644, 1650, 1659, 1764, 1848, 1854, 1866, 1893, 2067, 2154, 2273
M. ravelobensis	2366	133, 143, 187, 211, 226, 313, 317, 335, 365, 376, 379, 525, 538, 559, 562, 598, 632, 715, 721, 779, 916, 918, 930, 990, 1121, 1170, 1186, 1258, 1260, 1321, 1434, 1956, 2031, 2034, 2037, 2040, 2088, 2175, 2238, 2259
M. sp. *nova* #5	2366	380, 814, 864, 1291, 1632, 1785
M. sambiranensis	2366	561, 658, 682, 763, 2307
M. sp. *nova* #6	2366	310, 503, 1479, 1491, 1898, 1992, 2001, 2243
M. mamiratra	2367	340, 671, 742, 1074, 2125, 2292
M. berthae	2366	907, 921, 1317, 1435, 1488, 1521, 1705, 1998, 2097, 2235
M. murinus	2366	46, 202, 304, 502, 506, 507, 546, 601, 652, 742, 743, 745, 749, 771, 790, 870, 943, 993, 1017, 1029, 1075, 1098, 1141, 1206, 1221, 1316, 1358, 1434, 1509, 1836, 1981, 1991, 2004, 2046, 2097, 2295, 2322
M. rufus	2366	103, 283, 376, 450, 872, 971, 1008, 1197, 1230, 1341, 1419, 1617, 1668, 2111
M. simmonsi	2367	172, 403, 449, 577, 613, 656, 868, 1639, 1818, 1824, 1920, 2229
M. mittermeieri	2366	274, 704, 1092, 1114, 1176, 1315, 1503, 1803, 1905, 1953, 1982, 1983, 2086, 2229
M. jollyae	2367	47, 82, 84, 121, 139, 187, 377, 436, 476, 495, 526, 566, 569, 739, 891, 923, 999, 1107, 1221, 1245, 1300, 1342, 1716, 1905, 1965, 1989, 2070, 2121, 2241, 2308
M. lehilahytsara	2366	14, 337, 1356, 1562
M. griseorufus	2366	115, 290, 366, 546, 574, 592, 604, 617, 643, 646, 672, 742, 771, 784, 827, 844, 873, 993, 1005, 1039, 1054, 1068, 1074, 1089, 1318, 1357, 1365, 1431, 1485, 1536, 1540, 1545, 1551, 1582, 1584, 1596, 1600, 1618, 1710, 1737, 1749, 1809, 1827, 1933, 2025, 2085, 2233, 2249

Table 5a. Genetic distance matrix for D-loop sequence data for the genus *Microcebus*. 1. *M. tavaratra*; 2. *M. ravelobensis*; 3. *M.* sp. *nova* #5; 4. *M. sambiranensis*; 5. *M.* sp. *nova* #6; 6. *M. mamiratra*; 7. *M. berthae*; 8. *M. murinus*; 9. *M. rufus*; 10. *M. simmonsi*; 11. *M. mittermeieri*; 12. *M. jollyae*; 13. *M. lehilahytsara*; 14. *M. griseorufus*; and 15. *M. myoxinus*. Genetic distance based on absolute differences is displayed above the diagonal, and genetic distance as a percentage is displayed below the diagonal.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1		111	73	81	91	72	80	114	80	98	84	101	85	94	69
2	19.1±2.2		95	93	109	88	107	128	105	107	104	116	122	105	102
3	10.2±1.5	20.3±2.4		42	57	23	52	89	55	80	58	75	73	75	61
4	12.5±1.7	20.2±2.4	8.8±1.4		53	46	69	98	66	80	68	88	83	84	68
5	11.0±1.5	20.0±2.5	7.9±1.3	6.4±1.2		60	86	115	82	92	80	94	93	98	82
6	10.4±1.4	19.8±2.4	3.7±1.0	9.6±1.5	8.4±1.4		57	90	56	78	62	72	74	73	53
7	11.3±1.7	20.6±2.4	10.1±1.6	13.1±1.6	13.2±1.7	10.6±1.6		97	52	84	58	91	66	79	48
8	17.0±2.0	22.9±2.6	15.4±1.9	17.0±1.9	17.8±2.1	15.0±1.8	15.2±1.8		103	94	106	93	119	74	110
9	11.0±1.6	19.8±2.6	11.2±1.8	13.1±2.0	13.0±2.0	10.5±1.7	10.2±1.9	15.6±2.0		79	51	78	63	82	45
10	15.0±2.0	21.1±2.4	14.8±2.3	14.8±2.1	14.1±2.1	14.1±2.2	15.2±2.0	15.2±1.8	13.8±2.0		77	79	92	76	94
11	12.5±1.7	20.7±2.7	11.8±1.7	13.2±1.9	13.5±1.9	12.4±1.8	10.6±1.6	18.0±2.1	8.5±1.5	14.6±2.1		80	65	81	60
12	16.2±1.7	24.3±2.7	15.9±2.0	16.7±2.1	15.1±1.8	14.9±2.0	16.7±2.1	14.6±2.0	13.7±1.8	14.4±1.9	13.9±1.6		95	72	76
13	10.0±1.4	20.9±2.3	10.4±1.5	12.5±1.8	13.1±1.8	10.4±1.6	8.5±1.4	16.6±2.0	8.2±1.4	13.6±1.8	9.4±1.4	14.1±1.7		101	66
14	15.4±1.9	21.9±2.6	16.1±2.0	17.2±2.2	16.2±2.1	16.2±2.0	14.7±2.0	10.5±1.4	15.8±2.2	15.7±2.0	16.4±2.2	14.1±2.0	16.2±2.1		91
15	8.7±1.5	19.7±2.3	11.5±1.8	12.9±1.8	12.9±1.8	10.1±1.6	7.4±1.3	16.6±2.0	8.3±1.6	14.7±1.9	11.8±2.0	13.9±1.9	8.0±1.3	15.4±1.9	

Table 5b. Genetic distance matrix for PAST fragment sequence data for the genus *Microcebus*. 1. *M. tavaratra*; 2. *M. ravelobensis*; 3. *M.* sp. *nova* #5; 4. *M. sambiranensis*; 5. *M.* sp. *nova* #6; 6. *M. mamiratra*; 7. *M. berthae*; 8. *M. murinus*; 9. *M. rufus*; 10. *M. simmonsi*; 11. *M. mittermeieri*; 12. *M. jollyae*; 13. *M. lehilahytsara*; and 14. *M. griseorufus*. Genetic distance based on absolute differences is displayed above the diagonal, and genetic distance as a percentage is displayed below the diagonal.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1		243	227	178	233	220	200	324	200	220	194	228	227	245
2	10.6±0.7		242	216	240	229	209	304	222	235	201	234	246	276
3	9.7±0.7	11.1±0.8		104	134	54	163	259	162	181	164	217	171	197
4	9.7±0.7	10.5±0.8	5.1±0.4		50	114	148	215	153	121	142	187	119	247
5	9.2±0.7	10.2±0.7	5.1±0.5	3.5±0.4		130	170	281	170	182	157	220	183	236
6	9.6±0.6	10.5±0.8	2.5±0.3	5.2±0.5	5.0±0.4		154	262	154	174	151	207	171	255
7	8.6±0.6	9.5±0.7	7.4±0.6	6.7±0.6	6.8±0.6	7.1±0.6		271	94	171	115	187	113	258
8	14.0±0.8	13.3±0.8	11.1±0.7	11.0±0.7	11.4±0.8	11.4±0.8	12.0±0.8		277	277	270	272	277	181
9	8.5±0.6	10.1±0.7	7.3±0.6	7.0±0.6	6.7±0.6	7.0±0.6	4.2±0.4	12.1±0.8		168	124	191	114	251
10	9.1±0.7	10.2±0.7	7.9±0.6	7.2±0.6	6.9±0.5	7.6±0.6	7.3±0.6	11.7±0.8	7.1±0.6		159	202	177	225
11	8.3±0.6	9.1±0.6	7.4±0.6	6.5±0.6	6.2±0.6	6.9±0.6	5.2±0.5	11.9±0.8	5.5±0.5	6.8±0.6		189	137	252
12	10.0±0.7	10.7±0.6	10.0±0.7	8.7±0.6	9.2±0.6	9.6±0.7	8.6±0.6	11.9±0.8	8.7±0.6	8.8±0.6	8.6±0.7		205	255
13	9.0±0.6	10.5±0.7	7.1±0.6	6.9±0.6	6.7±0.6	7.1±0.6	4.3±0.4	11.5±0.7	4.3±0.4	6.6±0.5	5.4±0.4	8.7±0.6		228
14	13.4±0.8	13.6±0.9	12.4±0.9	11.5±0.8	12.0±0.8	12.1±0.8	12.2±0.9	9.2±0.7	11.8±0.9	12.1±0.8	12.0±0.9	12.1±0.8	12.2±0.8	

Discussion

The persistent and rapid loss of habitat and the resulting fragmentation of panmictic populations have compelled wildlife and conservation agencies to define management decisions according to existing guidelines and data with the ultimate goal of prioritizing species and/or sites (Wilmé *et al*. 2006; Kremen *et al*. 2008). Many studies have shown that molecular genetics technology offers a reliable and rapid method of identifying unique and cryptic biodiversity (Louis Jr. *et al*. 2006a; Olivieri *et al*. 2007; Radespiel *et al*. 2008). With this in mind, we present another revision of the genus *Microcebus*, concentrating on the biogeographic distribution of the mouse lemurs in northern and northwestern Madagascar. Through the analyses of accessioned and novel sample sets, we found that each described mouse lemur clusters in distinct and well-supported terminal clades.

Since Radespiel *et al.* (2008) demonstrated the same result with an alternative data set, a singular terminal clade for both described mouse lemur species from the island of Nosy Be, we have established that *Microcebus mamiratra* has precedence over *M. lokobensis* Andriantompohavana *et al*. 2006, which should consequently be regarded as a junior synonym. Furthermore, the distribution of *M. mamiratra* not only extends throughout the island of Nosy Be, but also exists on mainland Madagascar, occupying IRS VI (Olivieri *et al*. 2007; see Fig. 1).

In addition to the well-supported terminal clades of the 15 acknowledged mouse lemur species, the data revealed a distinct clade for the mouse lemur initially proposed in Andriantompohavana *et al*. (2006) at Antafondro Classified Forest, and also showed a remarkable cryptic diversity from Montagne d'Ambre National Park (Figs. 2–4). Three main criteria provide support for the definition of the two new species indicated, as follows: molecular genetic parameters, geographic and topographic barriers, and relative partitions between species.

By providing the initial criterion for the justification of species-level status for the two undefined mouse lemur taxa, molecular genetic data and inference offers the first line of argument. According to the Phylogenetic Species Concept (PSC) *sensu* Wheeler and Platnick (2000; Groves 2001; Louis Jr. *et al*. 2006a), diagnostic characters or attributes define Evolutionary Significant Units (ESUs). Several authors suggest that ESUs are equivalent to species and reflect species barriers (Cracraft 1983). Given this criterion, the two undefined species had multiple molecular diagnostic sites (Tables 3 and 4). The constant addition of samples to the PAA data set will continue to test the distinction and diagnostic ability of these characters; and, therefore, the ongoing status of each species.

The second line of argument is as follows. The two undefined mouse lemur taxa, *Microcebus* sp. *nova* #5 and *Microcebus* sp. *nova* #6, have distributions defined by geographic and topographic barriers. Following the initial proposal in Andriantompohavana *et al*. (2006), *Microcebus* sp. *nova* #5 is bounded by the Andranomalaza River to the northwest, the Sambirano River to the northeast, and the Maevarano River to the south (Fig. 1). Although the Andranomalaza River does not meet the large river criterion (>50 m wide, 20 km inland), geographic barriers in combination with the small size of mouse lemurs and limited dispersal ability essentially could drive allopatric speciation (Wilmé *et al*. 2006). With the distribution of *M. mamiratra* extended to mainland Madagascar (directly east of the island of Nosy Be in IRS VI), the topographic presence of Tsaratanana, one of the three mountains in Madagascar with an altitude above 2,000 m, could create a significant geographic barrier to *Microcebus* sp. *nova* #5 just north of the Sambirano River. *Microcebus* sp. *nova* #6 is found in the montane rainforest of Montagne d'Ambre National Park, north of the Irodo River. Ankarana National Park and Analamerana Special Reserve establish the southern boundary to this undefined mouse lemur's range. As a limestone plateau and tsingy formation intermixed with dry deciduous forest, Ankarana and Analamerana could be acting as a significant barrier to dispersal (Fig. 1). Additionally, the Bobakindro River courses along the northern margin of Analamerana Special Reserve. Again, the Irodo and Bobakindro Rivers do not meet the criterion of a major river barrier, however the topographic features and habitat differences offer strong support for the uniqueness of this undefined species.

Third, each undefined mouse lemur is found paired geographically (smallest geographic distance) with a defined species that is also segregated by an Inter-River-System but is not its genetically most proximal sister taxon (Fig. 1). All three phylogenetic analyses, along with the spanning network, demonstrated the phylogenetic proximity between *Microcebus* sp. *nova* #5 and *M. mamiratra*, on the one hand, and *Microcebus* sp. *nova* #6 and *M. sambiranensis*, on the other. With *Microcebus* sp. *nova* #5 at Antafondro, the distribution of *M. sambiranensis* would be limited to the Manongarivo Special Reserve, north of the Andranomalaza River and south of the Sambirano River, placing its range in between the distribution of *M. mamiratra* and the undefined species. Similarly, the distribution of *M. tavaratra* in Ankarana, Andrafiamena, Analamerana, and Andavakoera and *M. mamiratra* in Manehoka provide a significant species barrier between *M. sambiranensis* and its genetically closest sister taxa *Microcebus* sp. *nova* #6.

Species Descriptions

Microcebus margotmarshae new species

Formerly *Microcebus* sp. *nova* #5; initially proposed in Andriantompohavana *et al*. (2006). See Fig. 6, Appendix II(f).

Holotype. TAFO6.1; adult female captured in Antafondro Classified Forest on 21 May 2006. Material: Total genomic DNA (50 ng/µl) for TAFO6.1 (Bar Code 145314), adult female. Total genomic DNA materials are stored and curated at the Museum of Texas Tech University, Lubbock, Texas, USA. Two 2.0-mm biopsies from ear pinna tissue are stored at Henry Doorly Zoo, Omaha, Nebraska, USA. A microchip pit tag was placed subcutaneously between scapulas and recorded as 4722607B5D. TAFO6.1 was collected by Francois Randrianasolo, Richard Rakotonomenjanahary, Jean Amié Andriamihaja, and Rambinintsoa Andriantompohavana on 21 May 2006.

Paratypes. TAFO6.2 (Bar Code 145315), adult female and ANT5.1 (Bar Code 145313), adult male; captured in Antafondro Classified Forest. Total genomic DNA (50 ng/µl) TAFO6.2 (Bar Code 145315), adult female; and ANT5.1 (Bar Code 145313), adult male; are stored and curated at the Museum of Texas Tech University, Lubbock, Texas, USA. Two 2.0-mm biopsies from ear pinna tissues are stored at Henry Doorly Zoo, Omaha, Nebraska, USA. Individual measurements, e-voucher photos, and collection data are given in Appendix I(b) and are available at the Museum of Texas Tech University, Lubbock, Texas, USA. Francois Randrianasolo, Richard Rakotonomenjanahary, Jean Amié Andriamihaja, and Rambinintsoa Andriantompohavana collected TAFO6.2 and ANK5.1 on 21 May 2006 and 4 October 2005, respectively.

Type Locality. Madagascar: Province de Antsiranana, Antafondro Classified Forest Special Reserve (approximately 14°02'44.5"S, 48°13'23.4"E, 134 m above sea level).

Measurements of holotype. Recorded in the field catalog on 21 May 2006: weight: 49.0 g; head crown: 3.2 cm; body length: 8.4 cm; tail length: 14.3 cm; muzzle length: 9.5 mm; ear length: 15.4 mm; and ear width: 8.7 mm.

Description. *Microcebus margotmarshae* is a small mouse lemur (41.0 g). The dorsal and tail pelage is predominantly reddish-orange with gray undertones, (Fig. 6; Appendix II(g)). The ventral fur is white to cream. The head is largely bright reddish-orange. The ears are small. The muzzle and the area surrounding the eyes are light brown, and there is a small, bright white spot on the nose ridge between the eyes.

Diagnosis. In the D-loop and PAST sequence fragments, *M. margotmarshae* differs from its closest relatives, *M. tavaratra*, *M. sambiranensis*, *M. mamiratra* and *M. arnholdi*, by both genetic and geographic distance by 12.3% ±1.6% (73 informative sites), 9.5% ± 1.4% (42 informative sites), 4.9% ± 1.0% (23 informative sites) and 9.5% ± 1.3% (57 informative sites); 9.7% ± 0.7% (227 informative sites), 5.1% ± 0.5% (132 informative sites), 2.5% ± 0.3% (54 informative sites) and 5.1% ± 0.5% (134 informative sites), respectively. Even though *M. margotmarshae* is a rufous-type mouse lemur as *M. mamiratra* (genetically the closest related), *M. margotmarshae* (41.0 gm) is significantly smaller than *M. mamiratra* (60.8 gm).

Distribution. *Microcebus margotmarshae* is known from the Antafondro Classified Forest, south of the Andranomalaza River and north of the Maevarano River, Madagascar.

Comparisons and remarks. Andriantompohavana *et al*. (2006) proposed that the mouse lemurs from Antafondro Classified Forest should be considered a separate species (*Microcebus* sp. *nova* #5), based on the PAST sequence fragment from one individual that was included in the analyses (Table 3 and 4; Appendix III(b–c)). Of the recognized mouse lemurs that are in the adjacent regions of Madagascar, *Microcebus margotmarshae* (41.0 gm) is approximately the same size as *M. sambiranensis* (44.0 gm), but smaller than *M. mamiratra* (60.8 gm), *M. tavaratra* (52.3 gm), and *M. ravelobensis* (65.9 gm). Additional samples from the entire region south of the Andranomalaza River and north of the Maevarano River are needed to define the distribution of *M. margotmarshae*. Olivieri *et al*. (2007) presented the course of the Maevarano River in an east to west direction, when, in fact, this river travels in more of a northwest to southeast direction, increasing as such the size of IRS V (Fig. 1). Samples should be collected from mouse lemurs from Tsaratanana Special Reserve. It is possible that mouse lemurs can be found at high altitudes there.

Etymology. *Microcebus margotmarshae* is named in honor of the late Margot Marsh, who during her lifetime contributed very generously to primate conservation initiatives in many different countries, including the publication of the first edition of the field guide *Lemurs of Madagascar* in 1994 (Mittermeier *et al*. 1994). The Margot Marsh Biodiversity Foundation was created after her death in 1995, thus continuing support for efforts that help safeguard the future of threatened primates.

Vernacular names. Margot Marsh's mouse lemur or Antafondro mouse lemur.

Microcebus arnholdi new species

Formerly *Microcebus* sp. *nova* #6 (Fig. 7, Appendix II(g)).

Holotype. AMB5.39; adult female; collected on 27 November 2005, captured at Montagne d'Ambre National Park. Material: Total genomic DNA (50 ng/µl) for AMB5.39 (Bar Code 145310), adult female stored and curated at the Museum of Texas Tech University, Lubbock, Texas, USA. Two 2.0-mm biopsies from ear pinna, and 0.07 cc of whole blood tissues stored at Henry Doorly Zoo, Omaha, Nebraska, USA. A microchip pit tag was placed subcutaneously between the scapulas and recorded as 4657027B18. AMB5.39 was collected by Richard Randriamampionona, Richard Rakotonomenjanahary, Jean Amié Andriamihaja, Fidelis Razafimananjato Tsirivaliniaina, John R. Zaonarivelo, and Edward Louis Jr. on 27 November 2005.

Paratypes. AMB5.40 (Bar Code 145311), adult female; and AMB5.43 (Bar Code 145312), adult female; captured at Montagne d'Ambre National Park. Material: Total genomic DNA (50 ng/µl) for each are stored and curated at the Museum of Texas Tech University, Lubbock, Texas, USA. Two 2.0-mm biopsies from ear pinna, and 0.07 cc of whole blood tissues stored at Henry Doorly Zoo, Omaha, Nebraska, USA. Individual measurements, e-voucher photos, and collection data are given in Appendix I(b) and are available at the Museum of Texas Tech University, Lubbock, Texas, USA. Richard Randriamampionona, Richard Rakotonomenjanahary, Jean Amié

Figure 6. *Microcebus margotmarshae*, Margot Marsh's or Antafondro mouse lemur, at Antafondro Classified Forest (Maromiandra). Photo by Rambinintsoa Andriantompohavana.

Figure 7. *Microcebus arnholdi*, Arnhold's or Montagne d'Ambre mouse lemur, at Montagne d'Ambre National Park and Classified Forest. Photo by Edward E. Louis Jr.

Andriamihaja, Fidelis Razafimananjato Tsirivaliniaina, John R. Zaonarivelo, and Edward Louis Jr. collected AMB5.40 and AMB5.43 on 28 November 2005.

Type Locality. Madagascar: Province de Antsiranana, Montagne d'Ambre National Park and Montagne d'Ambre Special Reserve (approximately 12°31'28.1"S; 049°10'22.8"E, 990 m above sea level).

Measurements of holotype. AMB5.39; adult female. Recorded in the field catalog on 21 November 2005. Weight 71.0 grams; head crown 3.3 cm; body length 8.1 cm; tail length 12.9 cm; muzzle length 9.4 mm; ear length 17.8 mm; and ear width 10.1 mm.

Description. *Microcebus arnholdi* is a medium-sized mouse lemur (49.7 gm). The overall dorsal pelage is a mixture of dark brown, red and gray (Fig. 7; Appendix II(g)). There is a dark brown midline dorsal stripe that runs down to the base of the tail. The tail is dark brown near the tip. The ventral fur is white to cream, with gray undertones. The head is predominately red, with dark brown on the muzzle and surrounding the eyes and with a white nose ridge that stops at the distal end of the muzzle. The ear length of *M. arnholdi* (17.5 ± 0.4 mm) is smaller than *M. tavaratra* (21.7 ± 0.7 mm).

Diagnosis. In the D-loop and PAST sequence fragments, *M. arnholdi* differs from its closest relatives, *M. tavaratra*, *M. sambiranensis*, *M. mamiratra* and *M. margotmarshae*, in both genetic and geographic distance, by 12.6% ± 1.5% (91 informative sites), 6.9% ± 1.1% (53 informative sites), 9.6% ± 1.3% (60 informative sites) and 9.5% ± 1.3% (57 informative sites); 9.2% ± 0.7% (233 informative sites), 3.5% ± 0.4% (113 informative sites), 5.0% ± 0.5% (151 informative sites) and 5.1% ± 0.5% (134 informative sites, respectively). Of the recognized mouse lemurs that are in the adjacent regions of Madagascar, *Microcebus arnholdi* (49.7 gm) is smaller than *M. tavaratra* (52.3 gm), and

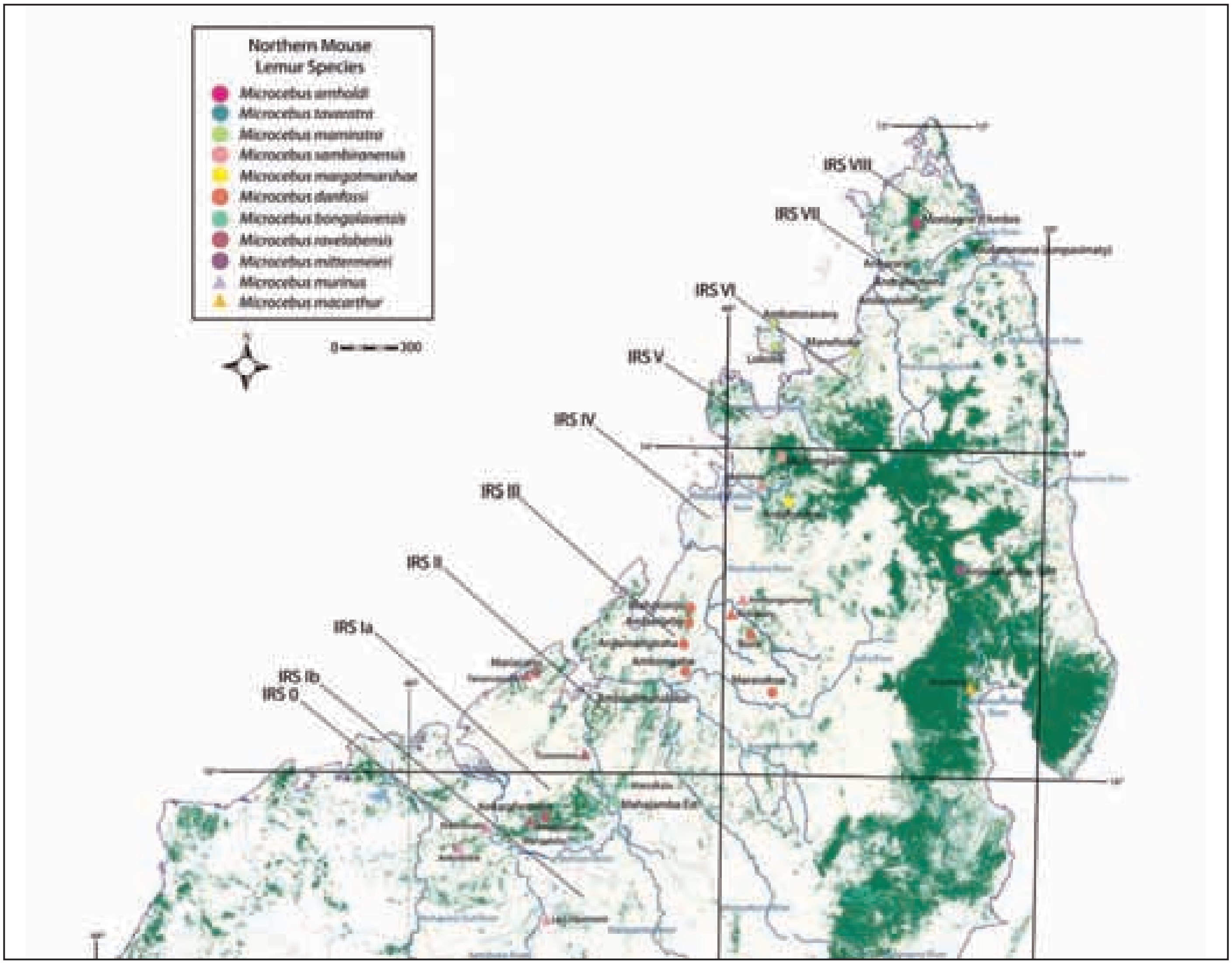

Figure 8. Distribution of the mouse lemurs (genus *Microcebus*) of northern and northwestern Madagascar. Color-coded circles represent the samples (sites) that were included in the analyses (these samples include accessioned GenBank sequences and the colors are species specific (see Appendices II(h) and III(a)). The map was modified from an image provided by Conservation International, Arlington, VA (Harper *et al.* 2007), and incorporates the Landsat Enhanced Thematic Mapper Plus (ETM+) data from 1999-2001, predominantly from 2000. Colored triangles represent accessioned samples not used in this study, but the color of the triangle is representative of a specific *Microcebus* species.

Microcebus mamiratra (60.8 gm). Even though *M. arnholdi* is a rufous type mouse lemur as *M. mamiratra*, the pelage of *M. arnholdi* is more grayish brown.

Distribution. *Microcebus arnholdi* is known from the Montagne d'Ambre National Park and Special Reserve, northwest of the Irodo River, Madagascar.

Comparisons and remarks. *Microcebus arnholdi* can be found in montane rainforest, whereas *M. tavaratra* occupies the dry deciduous forest in the Ankarana and Analamerana IRS VII; Fig. 8). As shown in Figure 8, *M. arnholdi* is a new species in a new Inter-River-System (IRS) VIII; the tenth IRS in northern and northwest Madagascar. Figure 8 also illustrates the need for comprehensive sampling in this intensely researched region of Madagascar, a detailed distribution map of the species sampled that correlates to the existing forest tracts, and accurate mapping of the course of all river systems. The distributions of other genera in the region should be overlaid to provide us with a better understanding the biogeography of lemurs in general. Lastly, molecular genetic data should be generated for the all lemur holotypes, and included in the phylogenetic inferences and diagnostic evaluations of lemur taxonomy. Of the recognized mouse lemurs that are in the adjacent regions of Madagascar, *Microcebus arnholdi* (49.7 gm) is slightly larger than *M. sambiranensis* (48.0 gm), but smaller than *M. tavaratra* (52.3 gm), *Microcebus mamiratra* (60.8 gm), and *M. ravelobensis* (65.9 gm).

Etymology. The name *arnholdi* honors Henry Arnhold of New York, who has supported conservation efforts throughout the developing world, with a particular focus on linking the well-being of the people with the protection of their environment. Conservation International's Healthy Communities Initiative and Conservation Stewards' Program has come into existence because of Mr. Arnhold's commitment to linking the well-being of people with the protection of critically important biodiversity hotspots. Madagascar has been among the places that have benefited substantially from the support that Henry Arnhold has provided. By naming this species after him, we recognize his great commitment and express the appreciation of the conservation community for all that he has done to further the cause for biodiversity conservation in Madagascar and around the world.

Vernacular names. Arnhold's mouse lemur or Montagne d'Ambre mouse lemur.

Note

As discussed in Andriantompohavana *et al*. (2006, 2007), Louis Jr *et al*. (2006a, 2006b), and Thalmann and Geissmann (2005), the use of whole vouchers as the designated holotype for a new species is not a prerequisite for describing an undefined species. Opportunistic collection, however, can later supplement morphological, and/or molecular data in combination with curated blood and/or tissue samples. Total genomic DNA for the holotypes and paratypes of the newly described *Microcebus margotmarshae* and *Microcebus arnholdi*, along with e-vouchers and field data, are currently curated at the Museum of Texas Tech University, Lubbock, Texas, USA, under the following catalogue numbers: TK145310; TK145311; TK145312; and TK145313; TK145314; TK145315, respectively; Appendix I(a).

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Literature Cited

Andriantompohavana, R., J. R. Zaonarivelo, R. Lei, G. Nalanirina, S. E. Engberg, S. M. McGuire, G. D. Shore, J. Andrianasolo, R. A. Brenneman and E. E. Louis Jr. 2007. Molecular phylogeny and taxonomic revision of the woolly lemurs, genus *Avahi* (Primates: Lemuriformes). *Spec. Publ. Mus. Tex. Tech Univ*. (51): 1–59.

Andriantompohavana, R., J. R. Zaonarivelo, S. E. Engberg, R. Randriamampionona, S. M. McGuire, G. D. Shore, R. Rakotonomenjanahary, R. A. Brenneman and E. E. Louis Jr. 2006. The mouse lemurs of northwestern Madagascar with a description of a new species at Lokobe Special Reserve. *Occ. Pap. Tex. Tech Univ. Mus*. (259): 1–23.

Baker, C. S., A. Perry, J. L. Bannister, M. T. Weinrich, R. B. Abernethy, J. Calambokidis, R. H. Lien, J. U. Lambersen, O. Ramirez, P. Vasquez, J. Clapham, A. Alling, S. J. O'Brien and S. R. Palumbi. 1993. Abundant mitochondrial DNA variation and world-wide population structure in humpback whales. *Proc. Natl. Acad. Sci. USA* 90: 8239–8243.

Bandelt, H.-J., P. Forster and A. Röhl. 1999. Median-joining networks for inferring intraspecific phylogenies. *Mol. Biol. Evol.* 16: 37–48.

Cracraft, J. 1983. Species concepts and speciation analysis. In: *Current Ornithology,* Vol. 1, R. F. Johnston (ed.), pp.159–187. Plenum Press, New York.

Craul, M., U. Radespiel, D. W. Rasolofoson, G. Rakotondratsimba, O. Rakotonirainy, S. Rasoloharijaona, B. Randrianambinina, J. Ratsimbazafy, F. Ratelolahy, T. Randrianamboavaonjy and L. Rakotozafy. 2008. Large rivers do not always act as species barriers for *Lepilemur* sp. *Primates* 49: 211–218.

Craul, M., E. Zimmermann, S. Rasoloharijaona, B. Randrianambinina and U. Radespiel. 2007. Unexpected species diversity of Malagasy primates (*Lepilemur* spp.) in the same biogeographical zone: a morphological and molecular approach with the description of two new species. *BMC Evol. Biol.* 83: 1–15.

Davis, J. I. and K. C. Nixon. 1992. Populations, genetic variation, and the delimitation of phylogenetic species. *Syst. Biol*. 41: 421–435.

Dufils, J. M. 2003. Remaining forest cover. In: *The Natural History of Madagascar*, S. M. Goodman and J. P. Benstead (eds.), pp.88–96. University of Chicago Press, Chicago.

Forster, P., A. Torroni, C. Renfrew and A. Rohl. 2001. Phylogenetic star contraction applied to Asian and Papuan mtDNA evolution. *Mol. Biol. Evol.* 18: 1864–1881.

Gonzales, S., J. E. Maldonado and J. A. Leonard. 1998. Conservation genetics of the endangered pampas deer (*Ozotoceros bezoarticus*). *Mol. Ecol*. 7: 47–57.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.

Guschanski, K., G. Olivieri, S. M. Funk and U. Radespiel. 2007. MtDNA reveals strong genetic differentiation among geographically isolated populations of the golden brown mouse lemur, *Microcebus ravelobensis*. *Conserv. Genet*. 8: 809–821.

Harper, G. J., M. K. Steininger, C. J. Tucker, D. Juhn and F. Hawkins. 2007. Fifty years of deforestation and forest fragmentation in Madagascar. *Environ. Conserv.* 34: 1–9.

Huelsenbeck, J. P. and F. Ronquist. 2001. MRBAYES: Bayesian inference of phylogeny. *Bioinformatics* 17: 754–755.

IUCN. 2008. *2008 IUCN Red List of Threatened Species*. International Union for Conservation of Nature and Natural Resources (IUCN), Species Survival Commission (SSC), Gland, Switzerland, and Cambridge, UK. Website: <www.iucnredlist.org>. Accessed 9 October 2008.

Jernvall, J. and P. C. Wright. 1998. Diversity components of impending primate extinctions. *Proc. Natl. Acad. Sci. USA* 95: 11279–11283.

Kappler, P. M., R. M. Rasoloarison, L. Razafimanantsoa, L. Walter and C. Roos. 2005. Morphology, behaviour and molecular evolution of giant mouse lemurs (*Mirza* spp.) Gray 1870, with description of a new species. *Primate Report* 71: 3–26.

Kimura, M. 1980. A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. *J. Mol. Evol.* 16: 111–120.

Kremen, C. *et al*. 2008. Aligning conservation priorities across taxa in Madagascar, a biodiversity hotspot, with high-resolution planning tools. *Science* 320: 220–226.

Kumar, S., K. Tamura and M. Nei. 2004. *MEGA3*: Integrated Software for Molecular Evolutionary Genetics Analysis and Sequence Alignment Briefings. *Bioinformatics* 5: 150–163.

Longmire, J. L., G. F. Gee, C. L. Hardekoff and G. A. Mark. 1992. Establishing paternity in whooping cranes (*Grus americana*) by DNA analysis. *Auk* 109: 522–529.

Louis, E. E. Jr., M. S. Coles, R. Andriantompohavana, J. A. Sommer, S. E. Engberg, J. R. Zaonarivelo, M. I. Mayor and R. A. Brenneman. 2006a. Revision of the mouse lemurs (Primates, *Microcebus*) of eastern Madagascar. *Int. J. Primatol.* 27: 347–389.

Louis, E. E. Jr., S. E. Engberg, R. Lei, H. Geng, J. A. Sommer, R. Randriamampionona, J. C. Randriamanana, J. R. Zaonarivelo, R. Andriantompohavana, G. Randria, Prosper, B. Ramaromilanto, G. Rakotoarisoa, A. Rooney and R. A. Brenneman. 2006b. Molecular and morphological analyses of the sportive lemurs (Family Megaladapidae: Genus *Lepilemur*) reveals 11 previously unrecognized species. *Spec. Publ. Mus. Tex. Tech Univ.* (49): 1–47.

Maddison, W. P. and D. R. Maddison. 1992. *MacClade: Analysis of Phylogeny and Character Evolution*. Sinauer Associates, Sunderland, MA.

Martin, R. D. 1995. Prosimians: from obscurity to extinction? In: *Creatures of the Dark: the Nocturnal Prosimians*, L. Alterman, G. A. Doyle and M. K. Izard (eds.), pp.535–563. Plenum Press, New York.

Mayor, M. I., J. A. Sommer, M. L. Houck, J. R. Zaonarivelo, P. C. Wright, C. Ingram, S. R. Engel and E. E. Louis Jr. 2004. Specific status of *Propithecus* spp. *Int. J. Primatol.* 25: 875–900.

Mittermeier, R. A., I. Tattersall, W. R. Konstant, D. M. Meyers and R. B. Mast. 1994. *Lemurs of Madagascar*. Tropical Field Guide Series, Conservation International, Washington, DC.

Mittermeier, R. A., W. R. Konstant, F. Hawkins, E. E. Louis Jr., O. Langrand, J. Ratsimbazafy, R. Rasoloarison, J. U. Ganzhorn, S. Rajaobelina, I. Tattersall and D. M. Meyers. 2006. Mouse lemurs. In: *Lemurs of Madagascar*, 2nd Edition, pp. 89–128. Tropical Field Guide Series, Conservation International, Washington, DC.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature, Lond.* 403: 853–858.

Nylander, J. A. A. 2004. MrModeltest v2. Program distributed by the author. Evolutionary Biology Centre, Uppsala University, Uppsala.

Olivieri, G., E. Zimmermann, B. Randrianambinina, S. Rasoloharijaona, D. Rakotondravony, K. Guschanski and

U. Radespiel. 2007. The ever-increasing diversity in mouse lemurs: three new species in north and northwestern Madagascar. *Mol. Phylogenet. Evol.* 43: 309–327.

Pastorini, J., M. R. J. Forstner and R. D. Martin. 2000. Relationships among brown lemurs (*Eulemur fulvus*) based on mitochondrial DNA sequences. *Mol. Phylogenet. Evol.* 16: 418–429.

Posada, D. and K.A. Crandall. 1998. Modeltest: testing the model of DNA substitution. *Bioinformatics* 14: 817–818.

Radespiel, U., G. Olivieri, D. W. Rasolofoson, G. Rakotondratsimba, O. Rakotonirainy, S. Rasoloharijaona, B. Randrianambinina, J. Ratsimbazafy, F. Ratelolahy, T. Randriamboavonjy, T. Rasolofoharivelo, M. Craul, L. Rakotozafy and R. Randrianarison. 2008. Exceptional diversity of mouse lemurs (*Microcebus* spp.) in the Makira region with a description of one new species. *Am. J. Primatol*. 70: 1033–1046.

Rasoloarison, R. M., S. M. Goodman and J. U. Ganzhorn. 2000. Taxonomic revision of mouse lemurs (*Microcebus*) in the western portions of Madagascar. *Int. J. Primatol.* 21: 963–1019.

Ravaoarimanana, B., R. Tiedemann, D. Montagnon and Y. Rumpler. 2004. Molecular and cytogenetic evidence for cryptic speciation within a rare endemic Malagasy lemur, the northern sportive lemur (*Lepilemur septentrionalis*). *Mol. Phylogenet. Evol.* 31: 440–448.

Ronquist, F. and J. P. Huelsenbeck. 2003. MRBAYES 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics* 19: 1572–1574.

Sambrook, J., E. F. Fritch and T. Maniatus. 1989. *Molecular Cloning: A Laboratory Manual.* 2nd edition. Cold Spring Harbor Press, New York.

Schneider, S., D. Roessli and L. Excofier. 2000. Arlequin: A Software for Population Genetics Data Analysis. Version 2.000. Genetics and Biometry Laboratory, Department of Anthropology, University of Geneva, Geneva.

Schwab, D. 2000. A preliminary study of spatial distribution and mating system of pygmy mouse lemurs (*Microcebus* cf. *myoxinus*). *Am. J. Primatol*. 51: 41–60.

Smith, R. J. and W. L. Jungers. 1997. Body mass in comparative primatology. *J. Hum. Evol.* 32: 523–559.

Swofford, D. L. 2001. *PAUP*. Phylogenetic Analysis Using Parsimony (*and Other Methods).* Version 4.0b5. Sinauer Associates, Sunderland, Massachusetts.

Tamura, K. and M. Nei. 1993. Estimation of the number of nucleotide substitutions in the control region of mitochondrial DNA in humans and chimpanzee. *Mol. Biol. Evol*. 10: 512–526.

Thalmann, U., and T. Geissmann. 2005. New species of woolly lemur *Avahi* (Primates: Lemuriformes) in Bemaraha (Central Western Madagascar). *Am. J. Primatol*. 67: 371–376.

Thompson, J. D., T. J. Gibson, F. Plewniak, F. Jeanmougin and D. G. Higgins. 1997. The ClustalX-Windows interface: flexible strategies for multiple sequence alignment aided by quality analysis tools. *Nucleic Acids Res*. 25: 4876–4882.

Weidt, A., N. Hagenah, B. Randrianambinina, U. Radespiel and E. Zimmermann. 2004. Social organization of the golden brown mouse lemur (*Microcebus ravelobensis*). *Am. J. Phys. Anthropol.* 123: 40–51.

Wheeler, Q. D. and N. I. Platnick. 2000. The phylogenetic species concept (*sensu* Wheeler and Platnick). In: *Species Concepts and Phylogenetic Theory: A Debate*, Q. D. Wheeler and R. Meier (eds.), pp.1–200. Columbia University Press, New York.

Wilmé, L., S. M. Goodman and J. U. Ganzhorn. 2006. Biogeographic evolution of Madagascar's microendemic biota. *Science* 312: 1063–1065.

Wyner, Y. M., G. Amato and R. DeSalle. 1999. Captive breeding, reintroduction, and the conservation genetics of black and white ruffed lemurs, *Varecia variegata variegata*. *Mol. Ecol*. 8: S107–S115.

Yoder, A. D., R. M. Rasoloarison, S. M. Goodman, J. A. Irwin, S. Atsalis, M. J. Ravosa and J. U. Ganzhorn. 2000. Remarkable species diversity of Malagasy mouse lemurs (Primates, *Microcebus). Proc. Natl. Acad. Sci*. 97: 11325–11330.

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The following Appendices are available online at the indicated website addresses and can be downloaded as pdf documents.

Appendix I

http://10.10.10.3/ccr/genetics/lemur/index.asp?page=ccr/genetics/lemur/appendixInorthernmouselemur.htm

Appendix I(a). *Microcebus* table of individual samples and corresponding information for each sample (bar code number, site, original species designation, current species designation, GenBank accession numbers of sequence data).

Appendix I(b). Field notes for *Microcebus margotmarshae* (formerly *Microcebus* sp. *nova* #5) and *Microcebus arnholdi* (formerly *Microcebus* sp. *nova* #6)

Appendix II

http://10.10.10.3/ccr/genetics/lemur/index.asp?page=ccr/genetics/lemur/appendixIInorthernmouselemurMS.htm

Appendix II(a). Maximum parsimony phylogram derived from the D-loop sequence data from 82 *Microcebus* individuals with 18 out-group taxa (one of 3886 most parsimonious trees). Values above branches indicate number of changes between nodes. Values within the circles along the branches indicate support of bootstrap pseudoreplicates. Length=2052; CI = 0.4235; RI = 0.8460; RC = 0.3583; HI = 0.5765.

Appendix II(b). Part A. Neighbor-joining phylogram derived the D-loop DNA sequence data from the 121 *Microcebus* individuals with18 out-group taxa. Values above branches indicate number of changes between nodes. Values within circles indicate support of bootstrap pseudoreplicates. Solid black circle indicates the branch that connects in-group taxa to the out-group taxa (displayed on next page (Part B)).

Appendix II(b). Part B. Neighbor-joining phylogram derived the D-loop DNA sequence data from the 121 *Microcebus* individuals with18 out-group taxa. Values above branches indicate number of changes between nodes. Values within circles indicate support of bootstrap pseudoreplicates. Solid black circle indicates the branch that connects to the in-group taxa (displayed on previous page (Part A)).

Appendix II(c). Maximum parsimony phylogram derived from the D-loop sequence data from 77 *Microcebus* haplotypes with 18 out-group taxa (one of 364 most parsimonious trees). Values above branches indicate number of changes between nodes. Values within the circles along the branches indicate support of bootstrap pseudoreplicates. Length=2138; CI = 0.4574; RI = 0.8578; RC = 0.3924; HI = 0.5426.

Appendix II(d). Fifty percent majority-rule consensus phylogenetic tree from the Bayesian analysis derived from the D-loop sequence data from 77 *Microcebus* individuals with 18 out-group taxa reconstructed using the program MrBayes. Branches without posterior probability values (PP) are supported by less than 50% of the sampled trees.

Appendix II(e). Maximum parsimony phylogram derived from the D-loop and PAST sequence data from 89 *Microcebus* individuals with 18 out-group taxa (one of 4112 most parsimonious trees). Values above branches indicate number of changes between nodes. Values within the circles along the branches indicate support of bootstrap pseudoreplicates. Length=6539; CI = 0.4271; RI = 0.8755; RC = 0.3739; HI = 0.5729.

Appendix II(f). *Microcebus margotmarshae*, Margot Marsh's or Antafondro mouse lemur at Antafondro Classified Forest (Maromiandra). Photo by Rambinintsoa Andriantompohavana.

Appendix II(g). *Microcebus arnholdi*, Arnhold's or Montagne d'Ambre mouse lemur at Montagne d'Ambre National Park and Classified Forest. Photo by Edward E. Louis Jr.

Appendix II(h). Distribution map of the mouse lemurs of Madagascar. Designated sites and species are based on molecular genetic data. The species legend corresponds to the color coded to the sites.

Appendix III

http://10.10.10.3/ccr/genetics/lemur/index.asp?page=ccr/genetics/lemur/appendixIIInorthernmouselemurMS.htm

Appendix III(a). Summary of the acronyms and GenBank accessioned sequences used in this study.

Appendix III(b). Table 1A. Diagnostic nucleotide sites from the D-loop Pairwise Aggregate Analysis (PAA) of genus *Microcebus*.

Appendix III(c). Table 1B. Diagnostic nucleotide sites from the PAST Pairwise Aggregate Analysis (PAA) of genus *Microcebus*.

Appendix III(d). Haplotypes for *Microcebus* D-loop Sequences

Appendix III(e). Haplotypes for *Microcebus* PAST Sequences.

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Detectability and Conservation of De Brazza's Monkey (*Cercopithecus neglectus*) in the Lesio-Louna and South-west Lefini Reserves, Bateke Plateau, Republic of Congo

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Abstract: The Lesio-Louna and south-west Lefini Reserves in the Bateke Plateau region of the Republic of Congo are not generally included as part of the geographic range of de Brazza's monkey (*Cercopithecus neglectus*). I present here observations made between 2002 and 2007 showing the species to be widely distributed within the gallery forests of the two reserves. Most sight records were of one or two individuals, although groups of up to six were also observed. De Brazza's monkeys could be heard calling on approximately 50% of days at project camps, and it was the most frequently detected large mammal during MacKinnon List surveys. Detectability was significantly lower during surveys that began after 07:00, a finding that may explain why the species has been largely overlooked during structured wildlife surveys. A review of grey literature suggests that the reserve management activities linked to a gorilla reintroduction program have led to recovery of the species following years of heavy hunting. However, the connectivity of the gallery forests of the Lefini watershed to the major forest areas to the east is threatened by human activity. The maintenance of forest corridors to avoid isolation of the gallery forests may be an important consideration for the long-term sustainable management of the region.

Key words: Protected area management, species recovery, gorilla reintroduction, gallery forests

Résumé: Les Réserves de Lesio-Louna et sud-ouest Lefini, situées dans la région du Plateau Bateke de la République du Congo, ne sont généralement pas inclues au sein de l'aire de répartition géographique du cercopithèque de Brazza *Cercopithecus neglectus*. Je présente ici des observations faites entre 2002 et 2007, montrant que l'espèce est largement distribuée dans les forêts-galeries des deux réserves. La plupart des observations concernaient un ou deux individus, bien que des groupes contenant jusqu'à six animaux aient également été observés. Des cercopithèques de Brazza pouvaient être entendus depuis les camps du projet environ 50% des jours, et il était le grand mammifère le plus fréquemment détecté au cours des études effectuées pour les Listes MacKinnon. La détectabilité était sensiblement plus basse lors des études commencées après 07:00, ce qui pourrait expliquer pourquoi l'espèce a été largement négligée au cours d'études structurées de la faune. Une révision de la littérature grise suggère que les activités de gestion de la réserve liées à un programme de réintroduction de gorilles ont conduit au rétablissement de l'espèce après des années de pression de chasse énorme. Néanmoins, la connectivité entre les forêts-galeries du bassin de la Lefini et les principales zones forestières situées à l'est est menacée par l'activité humaine. Le maintien de corridors forestiers pour éviter l'isolement des galeries forestières peut être un facteur important à prendre en considération pour la gestion durable de la région à long terme.

Mots-clés: Gestion d'aire protégée, rétablissement d'espèce, réintroduction de gorilles, galeries forestières

Introduction

De Brazza's monkey (*Cercopithecus neglectus*) is a relatively widespread species closely associated with rivers across forested regions of central Africa. In most standard works, the Bateke Plateau region of the Republic of Congo is not included within the species' geographic range (for example, Gautier-Hion *et al.* 1999; Kingdon 2001), probably due in part to the region being largely grassland-dominated. A few recent records from the gallery forests of the Bateke Plateau prompted Maisels *et al.* (2007) to revise the recognized range limits of the species. These limits can be refined further by including records from the Lesio-Louna and south-west Lefini Reserves in Congo, where the species has been one of the most frequently observed large mammals during the past decade (this paper). Known in the local Teke language as Mbouni, it is also heavily hunted by local populations (F. Ikoli and R. Missilou-Boukaka in litt.). I present here an analysis of data collected on the species in the two reserves from 2002 to 2007, discuss why such a detectable species has been generally under-recorded during structured mammalian surveys in and around the reserves, and review the grey literature to try to evaluate past and future conservation issues regarding the species in the area.

Site Description

The Lesio-Louna and Lefini Reserves lie approximately 140 km north of Brazzaville in the Republic of Congo (Fig. 1). The Lefini Reserve was created in 1951, covering approximately 400,000 ha, and was enlarged to 630,000 ha in 1963. The Lesio-Louna Reserve is an area of 44,000 ha adjacent to the eastern boundary of the south-west portion of the Lefini Reserve (Fig. 1). It was created in 1993 as a sanctuary for the reintroduction of gorillas orphaned by the illegal bushmeat trade, and was upgraded to a Natural Reserve in 1999. The gorilla reintroduction program was gradually transferred from the original Lesio-Louna to the south-west portion of the Lefini Reserve between 2003 and 2007 (King and Chamberlan 2007a). The Lesio-Louna and south-west Lefini Reserves are currently managed through a joint partnership project between the UK-based charity The Aspinall Foundation and the government of Congo. The project employs over twenty patrol staff trained in anti-poaching and monitoring techniques, and its aims are fairly standard for protected areas in the region, except for the rather unique addition of gorilla reintroduction.

The two reserves form part of the Bateke Plateau, an expanse of savannah and gallery forests extending from south-east Gabon through central Congo and southern DRC to northern Angola. The Plateau is covered with deep Kalahari sands, which date from the Eocene period, around 50 million years ago, and extend south in a fairly narrow strip through western central Africa and Botswana to northern South Africa (Walters *et al.* 2006). Much of the plateau has been eroded away, leaving a mosaic of remaining smaller plateaus, often delimited by dramatic sandstone escarpments, separated by watercourses and extensive areas of gently rolling, grassy, sand dunes. The watercourses are bordered by gallery forest, up to 3 km wide in the south-west of Lefini, and made up of permanently or seasonally flooded swamp forest, grading into drier forest before the abrupt transition with lightly wooded grassland. The climate of the reserves is similar to that elsewhere on the plateau, with a dry season from late May to September, the heaviest rains in October–November and March–April, and a drier period around January–February. Rainfall in 2006 at two sites in the reserves was 1,500 and 2,000 mm (King 2008). The altitude ranges from 300 m to 750 m above sea level. The savannah in and outside the reserve is burned regularly by local users, perhaps four or five times per year in places. These fires sometimes spread into forest patches, particularly in the latter parts of the dry season.

In addition to de Brazza's monkeys, the Reserves support various forest and savannah mammals, including mustached monkey (*Cercopithecus cephus*), vervet monkey (*Cercopithecus aethiops pygerythrus*), side-striped jackal (*Canis adustus*), leopard (*Panthera pardus*), hippopotamus (*Hippopotamus amphibious*), red river hog (*Potamocherus porcus*), forest buffalo (*Syncerus caffer nanus*), bushbuck (*Tragelaphus*

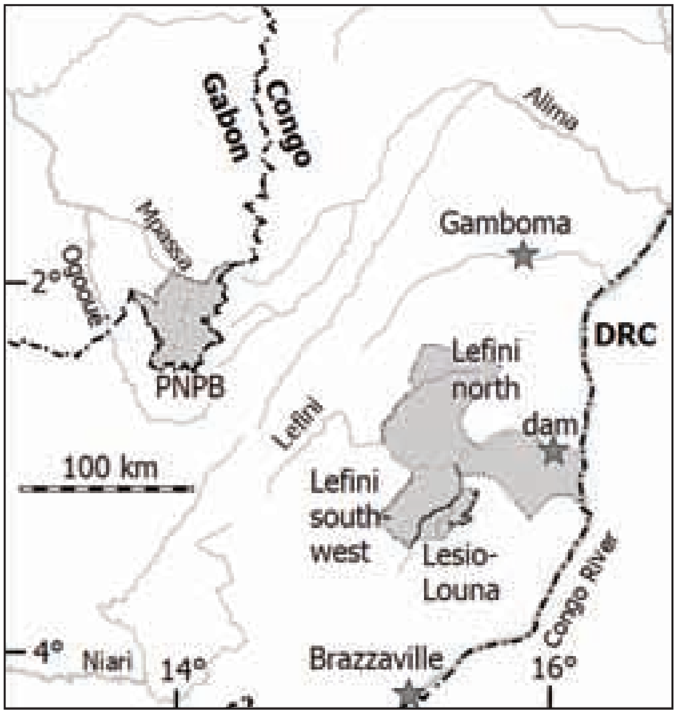

Figure 1. Location of the Lesio-Louna and south-west Lefini Reserves and other protected areas (shaded) in the Bateke Plateau region of Congo and Gabon, plus major rivers and the approximate location of the hydroelectric dam currently under construction on the Lefini River.

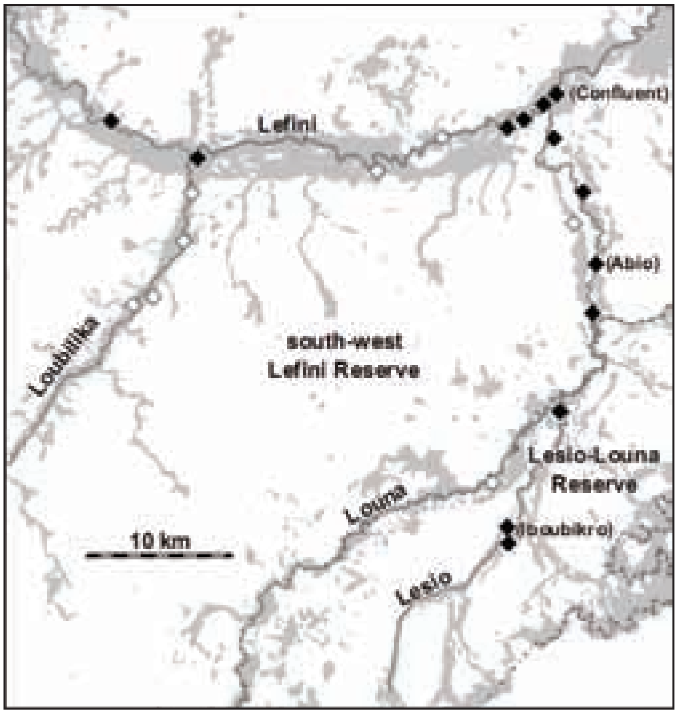

Figure 2. Locations of De Brazza's monkey observations presented in this paper (black diamonds), plus additional selected observations by project patrol teams (white diamonds, R. Missilou-Boukaka unpubl. data), forest cover (grey areas), rivers (dark grey), and project base-camps (in parentheses).

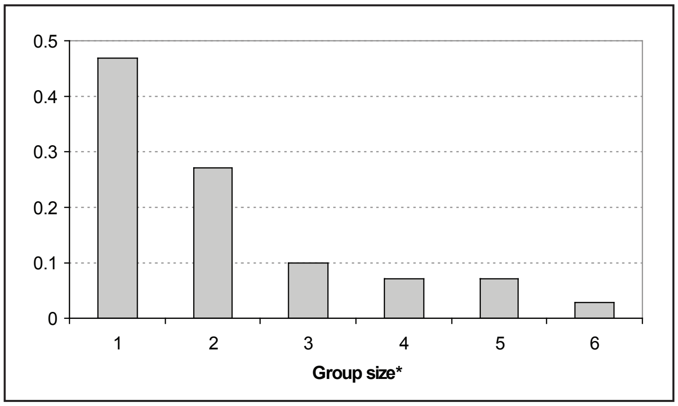

Figure 3. Proportion of direct observations of de Brazza's monkeys in the Lesio-Louna and south-west Lefini Reserves by group size (*in some sightings group members may have been overlooked).

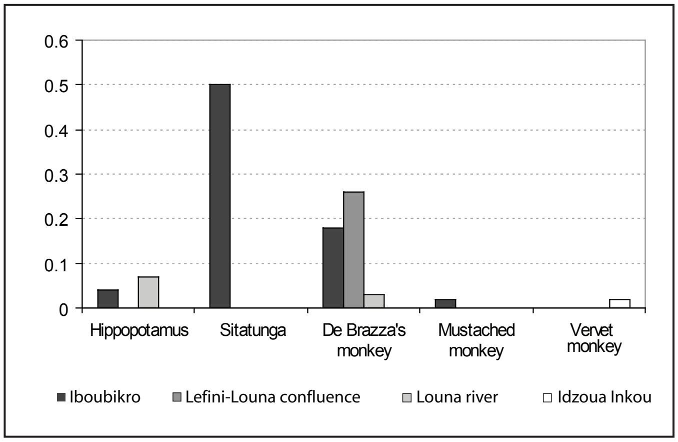

Figure 4. IRDs (Indices of Relative Detectability) for the five most detectable large mammal species during MacKinnon List bird surveys at four sites in the Lesio-Louna and south-west Lefini Reserves, 2003 to 2007. (Site locations given in Fig. 2, except Idzoua Inkou, which represents an area of wooded grassland near Iboubikro).

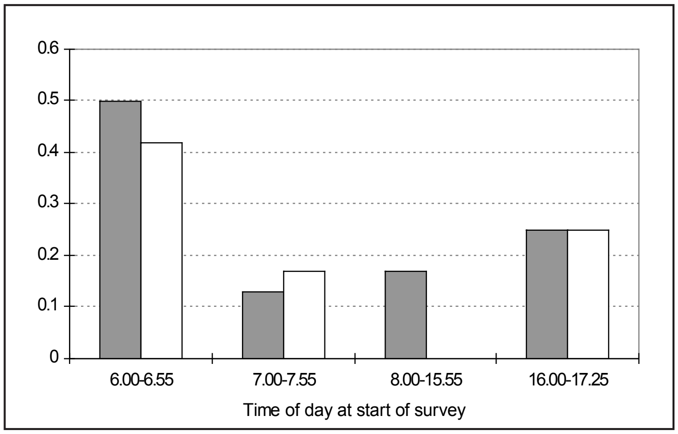

Figure 5. Impact of time of day of beginning MacKinnon List surveys on IRDs for de Brazza's monkeys at the Lefini-Louna confluence (grey bars) and Iboubikro (white bars).

scriptus), sitatunga (*T. spekei*), bush duiker (*Sylvicapra grimmia*) and various forest duikers (*Cephalophus* spp.). Some forest elephants (*Loxodonta africana cyclotis*) persist in the northern and eastern sectors of the Lefini Reserve, and chimpanzees (*Pan troglodytes*) can be found west of the southern sector.

Methods

The data presented here were collected between late 2002 and early 2007 through opportunistic observations while based in the reserves, and through two structured studies. In the first of these, daily records were kept of de Brazza's monkey observations at the Lesio-Louna management base-camp of Iboubikro during a five-month period from July to December 2002 in order to quantify monthly fluctuations in detectability. In the second, a variation on the MacKinnon List technique (Bibby *et al.* 1998) was used as a semi-quantitative method of surveying the birds of the two reserves from December 2003 to April 2007 (King 2008), during which mammal observations were also recorded. Five principle sites were visited on a regular basis over the three-year period, each visit lasting long enough to record at least ten bird species. The survey allowed the calculation of "Indices of Relative Detectability" (IRD) for the mammals, representing the proportion of combined sight and sound observations for each species recorded during the surveys at each site (other observations, such as tracks or feces, were not included).

Results

De Brazza's monkeys were seen 116 times in the Lesio-Louna and Lefini Reserves. We did not include the majority of vocalizations heard outside the specific survey periods as they were too numerous to note. This total consists of 77 records made during the five-month period in 2002 when daily observations were noted at the Iboubikro base-camp, 23 records during the semi-quantitative bird survey, and a further 16 that were opportunistic. Thirty of the records were sightings, 85 were vocalizations only, and one was of an adult found, half-swallowed by dead rock python (*Python sebae*) in July 2003, both animals evidently died during the encounter.

The species was seen at twelve locations spread throughout the two reserves, although always in gallery forest along watercourses, particularly the Lesio, Louna and Lefini rivers (Fig. 2). The Loubilika River was not adequately surveyed, although two observations along the Lefini River, on both sides of its confluence with the Loubilika, indicate that the species is likely to be equally abundant in the Loubilika gallery forests. This has been confirmed by a number of sightings by project monitoring teams along the Loubilika River (R. Missilou-Boukaka unpubl. data; Fig. 2). Previous wildlife surveys also recorded the species along the Nambouli River; the western boundary of the north Lefini Reserve (Downer 1998; Ikoli *et al.* 1998; Maisels *et al.* 2007; see Fig. 1).

Figure 6. Gallery, swamp and escarpment forest along the Louna valley, Lesio-Louna and Lefini Reserves, Congo. Photo by T. King.

Figure 7. De Brazza's monkey in typical riverside gallery forest vegetation at Iboubikro, Lesio-Louna Reserve. Photo by T. King.

Figure 8. De Brazza's monkeys are a popular target amongst local hunters living around the Lesio-Louna and Lefini Reserves. Photo by The Aspinall Foundation.

No more than six individuals were seen in any one group in the 30 recorded sightings. Most observations were of one (47%) or two (27%) individuals (Fig. 3), but these figures are minimum group sizes, as others may have been overlooked. In October 2002, we saw a female with a small baby in a group of about four. We detected de Brazza's monkeys on 77 of 140 observation days at Iboubikro (between 8 July and 16 December 2002); a combined observation rate of 55% of days. On the majority of occasions (65 of 77; 84%) we only heard them. Monthly observation rates were similar ($\chi^2_5 = 10.257$, n.s.).

De Brazza's monkeys were the most widely and frequently detected of the five large mammal species recorded during the MacKinnon List bird survey periods (Fig. 4), although it was not detected at survey sites far from gallery forests. The time of day that the surveys were carried out influenced the IRD values for the species (Fig. 5). At the two sites where the species was regularly recorded (Iboubikro and Lefini-Louna confluence), IRD values were significantly higher for surveys that started between 06:00 and 07:00 than for those begun after 07:00 (0.45 and 0.10 respectively, $\chi^2_1 = 9.867$, $P < 0.01$), although IRD values increased to some extent after 16:00 (Fig. 5).

Discussion

In recent years, de Brazza's monkeys have proven to be the most detectable mammal species in the Lesio-Louna and south-west Lefini Reserves of the Bateke Plateau region of Congo, based on sightings and calls heard at sites along major watercourses. Why, then, has the region only recently been recognized as within the species range (Maisels *et al.* 2007)? A review of the grey literature of the past fifteen years or so regarding the reserves suggests that the gorilla reintroduction program and the associated protected area management project have allowed the species to recover from excessive hunting in the reserves. Initial investigation of the proposed Lesio-Louna Reserve as a site for the gorilla project in the early 1990s concluded that de Brazza's monkeys had been locally extirpated (Bailey *et al.* 1996). In the mid-1990s, once the gorilla rehabilitation and reintroduction project had begun its activities near the Lesio River in the heart of the Reserve, de Brazza's and vervet monkeys were recorded as the only primates in the area, although both were regarded as "sparse" (Furley 1996). During 1998, four years after the installation of project activities in the Lesio-Louna, the species was found to be the only primate widespread in gallery forest along the Lesio River, with observations north to Lac Sampion (PPG 1998). By 1999, project staff from local villages were proud that wildlife in general, including de Brazza's monkeys, were visibly more abundant in the Lesio-Louna since the installation of the project in 1994 (King 2000). Around the same time, wildlife surveys in the neighboring Lefini Reserve recorded de Brazza's monkeys along the Nambouli and Lefini rivers (Downer 1998, Ikoli *et al.* 1998). It was the only primate actually sighted during the surveys (twice), although local guides claimed that both de Brazza's and mustached monkeys were more abundant than the few records suggested (Downer 1998). As had previously occurred in the Lesio-Louna, the initiation of the gorilla reintroduction program in the south-west Lefini Reserve in 2003, and the associated reserve management activities, appeared to promote the recovery of wildlife populations in the area, including de Brazza's monkeys (King 2005).

Despite this apparent recovery in recent years, a wildlife survey across the Lesio-Louna and Lefini Reserves in 2005 only recorded one vocalization of de Brazza's monkeys during the survey periods, along with two sightings outside the survey periods (Nganga *et al.* 2006; Maisels *et al.* 2007). Two aspects of the methodology used during the study can explain this lack of observations. The first was the coverage of the zone by foot, causing a survey bias away from the swampy riverside forest that is the preferred habitat of the species. Their calls, however, can carry several hundreds of meters (Gautier-Hion *et al.* 1999), and so can be recorded even from outside of the habitat. In the Lesio-Louna and south-west Lefini, vocalizations are concentrated in the early morning. Surveys begun before 07:00 were three times more likely to record de Brazza's monkeys than those begun between 07:00 and 08:00 (Fig. 5). Vocalizations were even rarer through the rest of the day, until after 16:00 when they were recorded at rates roughly half of those for surveys before 07:00. The 2005 mammal survey, which was based more on the frequency of tracks and sign than sightings and calls, was undertaken by daily surveys between 07:30 and 17:00 (Nganga *et al.* 2006). The primary opportunity to locate groups by their calls was therefore missed. Future surveys should consider a daily recording of calls between 06:00 and 07:00, perhaps by one team member while the others break camp and prepare for the day.

The observations given here refine further the known limits of the range of de Brazza's monkey. As Maisels *et al.* (2007) recognized, the species may well prove to be distributed throughout the major remaining gallery forests of the Bateke Plateau. The Aspinall Foundation also runs a western gorilla reintroduction project in the Bateke Plateau National Park (PNPB) in Gabon (Fig. 1); a program similar to that in the Lesio-Louna and south-west Lefini Reserves in Congo. Since establishing a base-camp in the heart of the park in 1998, project staff have still to hear or see de Brazza's monkeys along the Mpassa River, the major watercourse running through it (L. Pearson and P. Aczel pers. comm.; T. King pers. obs.). While intensive wildlife surveys have now recorded the species on a few occasions elsewhere in the park (Bout 2006; Maisels *et al.* 2007), the rarity of the species in the PNPB in the west of the Bateke Plateau, compared to its relative abundance in the Lesio-Louna and south-west Lefini Reserves, suggests that the population of the Lefini watershed region is, or at least was, connected primarily to populations to the east, along the Congo River, and probably also into the Democratic Republic of Congo, given the well known ability of the species to swim across rivers. Such connectivity of the Lefini fauna with the forests of the DRC has been demonstrated with the recent discovery of a breeding colony of Sladen's Barbet (*Gymnobucco sladeni*) in the Lesio-Louna Reserve, a bird otherwise virtually endemic to the forests of DRC (King and Chamberlan 2007b). This connectivity between the forests of the Congo River and the gallery forests of the Lefini watershed is now threatened, partly by the growing human population and related deforestation and hunting pressure along the Lefini River (for example, Downer 1998), but possibly even more importantly by the future flooding of a large forest area following the ongoing construction of a hydroelectric dam on the Lefini River towards its confluence with the Congo River (Fig. 1). The project, planned for completion in 2009, is likely to have many unforeseen environmental and socioeconomic impacts, some of which may not become apparent for many years (McCartney 2007). One is that the gallery forests of the Lefini watershed, and their associated forest fauna, may become virtually isolated from the major forest block to the east. The affect of such isolation may be unpredictable, but the maintenance of forest corridors between the Lefini watershed and the forest blocks to the east and west should be one of many considerations for the sustainable long-term management of the Bateke Plateau region as a whole.

Acknowledgments

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Literature Cited

Bailey, K. V., L. Ombou, R. Dowsett and F. Dowsett-Lemaire. 1996. Les mammifères de la région sud-Lefini. In: Synthèse des connaissances acquises sur la Réserve de Faune de la Lefini, C. Elenga and F. Ikoli. Report, GEF-Congo / PROGECAP, Brazzaville, Congo.

Bibby, C., M. Jones and S. Marsden. 1998. *Expedition Field Techniques: Bird Surveys*. Expedition Advisory Centre, London.

Bout, N. 2006. Parc National des Plateaux Batéké, Gabon: Suivi écologique des grands mammifères et de l'impact humain. Rapport final. Report, Wildlife Conservation Society, Libreville, Gabon. 108pp.

Downer, A. 1998. A Series of Preliminary Surveys: Ecological, Demographic and Socio-economic, and their Implications as Regards the Sustainability of the Lefini Game Reserve, Republic of Congo. Masters dissertation, University of Edinburgh, UK.

Furley, C. 1996. The gorilla rescue project, Brazzaville, Congo. *Int. Zoo News* 43(5): 299–300.

Gautier-Hion, A., M. Colyn and J.-P. Gautier. 1999. *Histoire Naturelle des Primates d'Afrique Centrale*. ECOFAC, Libreville, Gabon.

Ikoli, F., Y.C. Madzou and A. Moukassa. 1998. Répartition des grands mammifères dans la Réserve de Faune de la Léfini et ses environs. Report, Global Environment Facility / Wildlife Conservation Society, Brazzaville, Congo.

King, T. 2000. Is Mr A Saving the Gorilla? Gorilla rehabilitation and reintroduction as a conservation tool in Central Africa. Report, The Aspinall Foundation, Franceville, Gabon. 6pp.

King, T. 2005. Gorilla reintroduction programme, Republic of Congo. *Gorilla Gazette* 18: 28–31.

King, T. 2008. The birds of the Lesio-Louna and Lefini Reserves, Congo. Report, The Aspinall Foundation, Brazzaville, Congo. 103pp.

King, T. and C. Chamberlan. 2007a. Orphan gorilla management and reintroduction: progress and perspectives. *Gorilla Journal* 34: 21–25.

King, T. and C. Chamberlan. 2007b. First records for Congo-Brazzaville of Miombo Pied Barbet *Tricholaema frontata*, Yellow-fronted Tinkerbird *Pogoniulus chrysoconus* and Sladen's Barbet *Gymnobucco sladeni*. *Bull. Afr. Bird Club* 14 (2): 193–199.

Kingdon, J. 2001. *The Kingdon Field Guide to African Mammals*. Academic Press, London.

Maisels, F., N. Bout, C. Inkamba-Inkulu, L. Pearson, P. Aczel, R. Ambahe, E. Ambassa and R. Fotso. 2007. New northwestern and southwestern range limits of de Brazza's monkey, Mbam et Djerem National Park, Cameroon, and Bateke Plateau, Gabon and Congo. *Primate Conserv.* (22): 107–110.

McCartney, M. P. 2007. *Decision support systems for large dam planning and operation in Africa*. Report, International Water Management Institute, Colombo, Sri Lanka. 47pp. (IWMI Working Paper 119).

Nganga, I., C. Ikamba Kulu, A. Nongamani and A. Ampolo. 2006. Sondage faunique dans les Réserves de la Lefini et de Lesio-Louna. Report, Centre National d'Inventaire et d'Aménagement des Ressources Forestières et Fauniques / The Aspinall Foundation / Wildlife Conservation Society, Brazzaville, Congo. 56pp.

Projet Protection des Gorilles. 1998. Rapport d'Activités 1998. Report, Projet Protection des Gorilles (PPG), Brazzaville, Congo.

Walters, G., A. Bradley and R. Niangadouma. 2006. Floristics of Gabon's Batéké Plateaux: Guineo-Congolian plants on Kalahari Sands. In: *Taxonomy and Ecology of African Plants, Their Conservation and Sustainable Use*, S. A. Ghazanfar and H. J. Beentje (eds.), pp.259–266. Royal Botanic Gardens, Kew, UK.

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Beleaguered Chimpanzees in the Agricultural District of Hoima, Western Uganda

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Abstract: With approximately 5,000 chimpanzees, Uganda is important for the conservation of the eastern subspecies *Pan troglodytes schweinfurthii*. The population distribution is highly fragmented, however, and the prospects for the long-term viability of many populations will be greatly improved if dispersal opportunities are maintained between major forests via migratory corridors. Chimpanzees in unprotected human-dominated habitat outside the main forest blocks are often ignored by research and conservation efforts. This study assessed the status and distribution of chimpanzees in northern Hoima District, western Uganda. The survey region covered 400 km² between 1°26'–1°37'N and 31°09'–31°32'E, and separates two major forest blocks, Bugoma and Budongo. Chimpanzees use small forest fragments along watercourses throughout this region, both on private or communal land and in small government reserves, and a number of distinct groups ('communities') are present. There has been no evidence to indicate that chimpanzee populations are isolated; on the contrary chimpanzees appear highly mobile in this forest–farm habitat, confirming the region's corridor potential. At one site in the region, chimpanzees occur at an estimated density of 0.66 individuals/km² which, if extrapolated across the survey area, implies a larger population than previously thought. Recent and rapid habitat change resulting from unregulated timber extraction and clearance of fragments for agriculture — particularly for cash crops such as tobacco — has exposed the chimpanzees, causing increased negative interactions between apes and farming communities. The chimpanzees in northern Hoima are unlikely to survive without immediate intervention.

Key Words: Chimpanzee, corridors, deforestation, distribution, human-wildlife conflict, unprotected areas, Uganda

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Introduction

The eastern chimpanzee (*Pan troglodytes schweinfurthii*) occurs in the forests of north and north-eastern Democratic Republic of Congo (DRC) and southeast Central African Republic, as well as remnant forest and woodland in Uganda, Tanzania, Rwanda, Burundi and southwest Sudan (Butynski 2001). In Uganda, chimpanzees inhabit forests along the eastern edge of the Rift Valley in the west and southwest of the country (Stott and Selsor 1959; Reynolds and Reynolds 1965). (The single exception is a small relict population in the north on the Sudanese border [Davenport *et al*. 2001]). A recent census of all main forests within the chimpanzee range gave a population estimate of approximately 5,000 individuals (Plumptre *et al*. 2003), of which the majority inhabit gazetted forest reserves and national parks. The importance of Uganda for the conservation of the eastern subspecies was therefore confirmed by the census.

Although at first glance Uganda appears to harbour a healthy chimpanzee population, the country's tropical high forests are fragmented and the forest blocks are relatively small. In fact only four forests contain populations potentially large enough for mid-term viability (i.e., comprising >500 individuals [Plumptre *et al*. 2003]). Furthermore, recent surveys have demonstrated that, despite their protected status, illegal activities including agricultural encroachment, unlicensed timber harvesting, and hunting of mammals such as duikers and bushpigs are widespread in these and other major forests (Plumptre 2002; Gombya-Ssembajwe *et al.* 2007). Uganda currently has one of the highest annual deforestation rates in Africa (2.2% in 2000–2005 according to FAO [2007]). An estimated 70% of Uganda's woodland and forest occurs patchily outside the main forests on private and communal land, and it is there that most deforestation is presently taking place (Uganda, MWLE 2002). Nevertheless, small forests that support chimpanzees persist in some regions, typically along watercourses. Where habitat is being converted for agriculture, the chimpanzees' survival prospects are slim (Isabirye-Basuta 2004). From a conservation perspective, this is problematic since some outlying populations may play an important role in maintaining gene flow between main forest blocks. However, populations occupying fragmented, unprotected habitat are usually ignored by research and conservation activities.

Chimpanzees in Hoima

Hoima District was identified in an unpublished report by the Jane Goodall Institute and Uganda Wildlife Authority (UWA) as a region of growing conflict between chimpanzees and local farming communities (JGI/UWA 2002). Fragmentation and clearance of unprotected habitat for agriculture and timber has isolated ape populations and created a problem of crop-raiding, particularly with regard to cash crops such as cocoa. As a result, local intolerance towards chimpanzees was rising (JGI/UWA 2002).

The northern half of the district lies between two major forest blocks, separated by 50 km: Bugoma Forest in the south and Budongo Forest in the north (Fig. 1). Budongo lies across the district border in neighbouring Masindi District and has international standing as a long-term chimpanzee research site (Reynolds 2005). As forest reserves (FR), both Bugoma and Budongo are managed by the National Forest Authority (NFA) for sustainable production of domestic and commercial forest produce (for example, timber). Both forests also have important chimpanzee populations: recent surveys indicated populations of about 600 individuals each, equalling ~25% of the national total (Plumptre *et al*. 2003). According to the population viability analysis of Edroma *et al*. (1997), such numbers imply a low risk of extinction over the course of a century, with a human-induced catastrophe (for example, a disease or war) posing the greatest threat. But since such a catastrophe could feasibly occur in Uganda, the long-term viability of the Budongo and Bugoma populations would be greatly enhanced if managed as a metapopulation. One possibility is to establish or maintain a 'corridor' that links the two forests via a network of smaller FRs, savanna-woodlands and gallery forest (Plumptre 2002). Although the intervening region is settled and cultivated, small forests occur patchily along watercourses throughout northern Hoima (Fig. 1), yet the status and distribution of chimpanzees in this area are poorly known. Nevertheless, the existence of several potentially resident chimpanzee communities currently using forest fragments within the proposed corridor was confirmed in the JGI/UWA (2002) report.

Accordingly, this study aimed to (1) determine the distribution and status of chimpanzees within the proposed corridor area of northern Hoima; and (2) make preliminary assessments of numbers and migratory potential. The study comprises an initial component of a more detailed research project examining chimpanzee ecology and human–chimpanzee interactions at an unprotected, fragmented farm–forest site within the region (Bulindi), with a view to providing information necessary for management plans.

Methods

Study area

Hoima District forms part of the Bunyoro Kingdom of mid-western Uganda. It is bounded in the west by Lake Albert, across which lies the DRC. At an elevation of 620 m the lake is virtually the lowest and hottest area in Uganda (Uganda, Department of Lands and Surveys 1967). East of the lake, the topography in the north and northeast is weathered and undulating, characterized by broad hills and valleys. Elevations average 1,100 m above sea level, but reach 1,300 m or more on hilltops. For details of the geology, soils, and drainage of the Bunyoro region see Uganda, Department of Lands and Surveys (1967), Groves (1934), and Eggeling (1947). Above the dry and hot rift escarpment, Hoima enjoys a more moderate climate. Although rain falls throughout the year, its distribution follows a typical East African bimodal pattern, with wetter months from March to May and August to November. In the northeast corner of the district at Bulindi, mean annual precipitation was 1,461 mm in 2001–2007. Mean monthly maximum temperature was 29.5°C, remaining fairly constant year-round, with highest temperatures recorded in the driest months of December–February.

Most of Hoima's tropical high forest occurs in the south and southwest, in Bugoma and its outliers. Both Budongo and Bugoma are classified as medium-altitude, moist, semi-deciduous forests, with a tendency for the ironwood tree (*Cynometra alexandri*) to be dominant (Eggeling 1947;

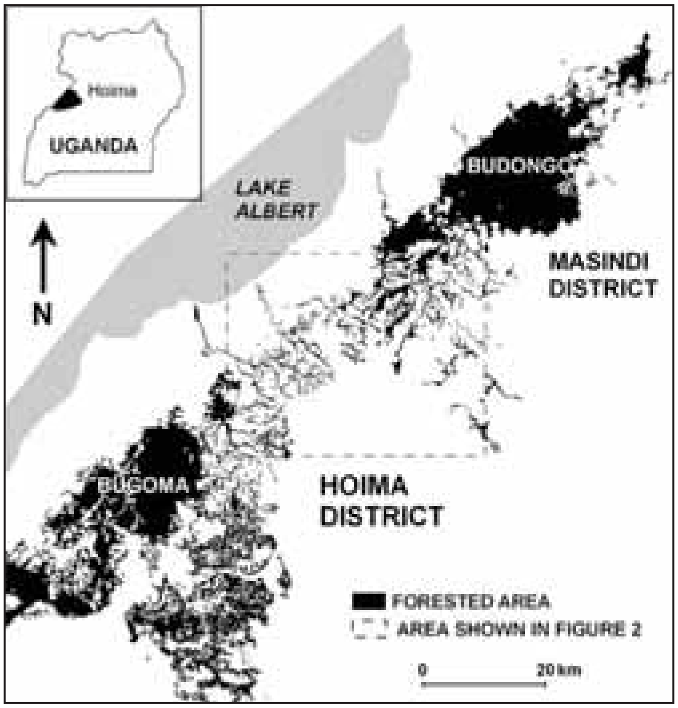

Figure 1. Map showing the main forest blocks referred to in this article: Bugoma (Hoima District) and Budongo (Masindi District).

Langdale-Brown *et al.* 1964). In the north and northeast, the vegetation comprises a mosaic of forest, woodland and grassland, intermixed with the cultivated fields of subsistence farmers and bush fallow. Papyrus (*Cyperus papyrus*) swamps are a common feature in water-logged valleys. The forests in northern Hoima occur patchily, predominantly in swampy valleys along the Waki, Wambabya and Hoima rivers and their many tributaries flowing west to Lake Albert, and along tributaries of River Kafu which flows east to join the Nile. Trees common in the riparian forests include *Trilepisium madagascariensis*, *Antiaris toxicaria*, *Funtumia africana* and *Pseudospondias microcarpa*. The wild date palm (*Phoenix reclinata*) forms dense clumps along the edges of streams and swamps. Chimpanzees are sympatric with five other species of diurnal nonhuman primate: black-and-white colobus (*Colobus guereza occidentalis*), tantalus monkey (*Chlorocebus tantalus budetti*), blue monkey (*Cercopithecus mitis stuhlmanni*), red-tailed monkey (*Cercopithecus ascanius schmidti*) and olive baboon (*Papio anubis*). (The gray-cheeked mangabey *Lophocebus albigena johnstoni*, present in Bugoma but absent from Budongo, was not seen during surveys in northern Hoima; Bugoma and its outliers to the east probably mark the northerly limit of the species in Uganda).

Hoima's human population totalled 343,480 in 2002 (= 95.4 people per km²). At 4.7%, the average annual growth rate from 1991 to 2002 was high — the national figure is 3.2% — and the population is projected to rise to 546,000 by 2012 (Uganda, UBOS 2007). Over 90% of the population live in rural areas, of which 74% depend on subsistence agriculture for their livelihoods. Farming is generally accomplished by hand with hoes and *pangas* (machetes), and using fire. Over 95% of rural households use locally gathered firewood for cooking (Uganda, UBOS 2007).

Survey Methods

Field surveys were conducted between February and May 2006. These focused on the region northeast of Wambabya FR, a major forest outlier of Bugoma, across to the east and northeast toward the district border with Masindi. The survey area covered 400 km² between 1°26'–1°37'N and 31°09'–31°32'E (Fig. 2). Forests were identified using 1:50,000 topographic maps published by the Department of Land and Surveys in

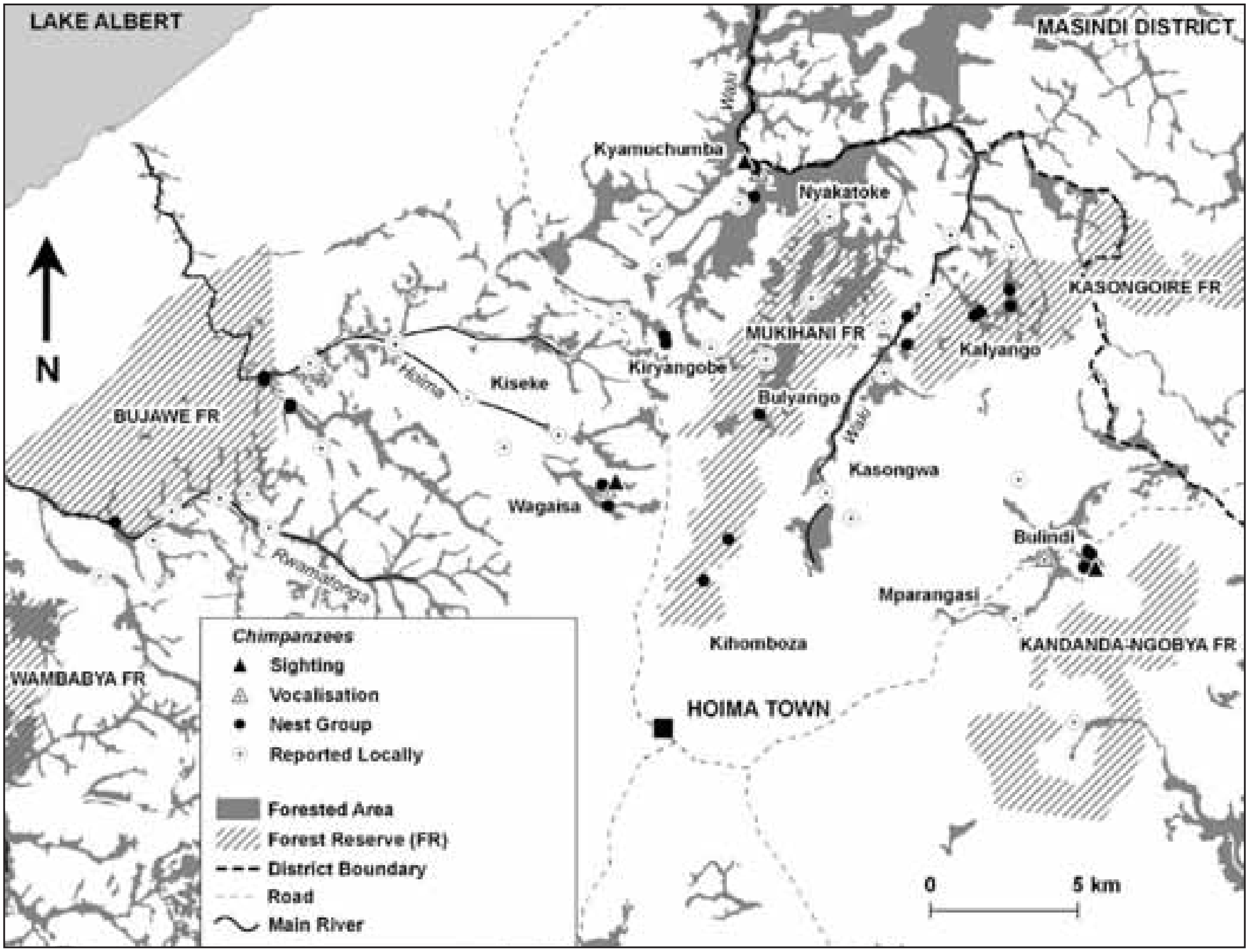

Figure 2. Northern Hoima District with locations of chimpanzee sign/sightings.

1966, and with assistance from Hoima forestry staff. It was appropriate for a forest ranger employed by the NFA or local government to accompany the survey team on initial visits to new areas. A research assistant from Hoima acted as a translator during all surveys. At each locality the following information was sought from local residents, and occasionally from pitsawyers and distillers encountered inside the forest: a) chimpanzee presence/absence, b) frequency of sightings and/or calls (i.e., regular, seasonal or infrequent), c) most recent sightings/vocalizations, d) numbers seen, and e) chimpanzee movements (for example, if chimpanzees are transient visitors, from which direction(s) did they travel to and from?). When we were informed about additional forest patches being used by chimpanzees, these were also visited. Local people tended to speak freely about their experiences with chimpanzees, and these were noted.

Forests were searched opportunistically for evidence of chimpanzees. Understorey vegetation was typically dense and the ground wet in many forest patches. No transects were cut. The locations of chimpanzee sign (nests, dung, knuckle prints, feeding remains) and sightings/vocalizations were recorded with a handheld GPS. As an indicator of the size of the chimpanzee parties using a particular area, we counted the number of same-age nests — assumed to have been built on the same night — occurring within a 50-m diameter circle. *Fresh* nests were less than two days old with only green leaves and, typically, dung sign below. *Recent* nests comprised a combination of green and browning leaves. Disintegrating nests or those comprised solely of brown, dried vegetation were *old*. We recorded information on the size and status of forest patches, and human activities in and around the forest, though we avoided asking direct questions about residents' forest use.

Results

Chimpanzee distribution

Chimpanzees were widely reported by local people to use forest patches along the region's watercourses. Evidence of chimpanzee presence — principally nests — was found at 10 sites across the survey area, confirming a wide distribution (Fig. 2; Table 1). In fact, nests were found at all localities where a more than cursory inspection inside the forest was made. (In some instances, an effort was made to follow the course of a river and assessment was limited to the forest edge). Further, fresh or recent sign of chimpanzees was recorded at nine of the 10 sites listed in Table 1. In total, 154 nests were recorded, though additional nests were sometimes observed but not documented (for example, where they occurred across a swamp). A variety of tree species were used for nesting, though larger nest groups occurred in *Pseudospondias microcarpa* and *Albizia zygia*. Mean size of the largest cluster of same-age nests observed at each site was seven, with the largest clusters found at Kasongoire FR and Bulindi (12 nests at both sites; Table 1). Across the survey area, local people most often reported seeing small parties of up to 10 individuals, though estimates of 15–20 chimpanzees were also given.

We saw chimpanzees on three occasions. On 5 February 2006 six chimpanzees — an adult male and two adult females with offspring — were seen in trees overlooking gardens at Bulindi. On 17 March 2006 chimpanzees were heard calling excitedly at the start of a thunderstorm at Wagaisa in Kitoba subcounty. Four adult males and a subadult subsequently emerged to travel a short distance on the ground along the forest edge before re-entering the forest, calling and drumming; an adult female with a juvenile appeared briefly behind them, but retreated after seeing observers in gardens nearby. During a previous visit to the same forest patch on 28 February, chimpanzees had exploded into calls at our direct approach through the gardens, but remained silent and hidden after we entered the forest. On 7 April 2006 two adults, probably both males, were glimpsed at Kyamuchumba where the Waki River forms a boundary between Hoima and Masindi districts. Subsequent calls suggested a small group was present.

Local reports indicated that chimpanzees were resident (seen regularly and throughout the year) at six localities. From west to east, they were: (1) the Rwamatonga River area, along the south and southeast boundary of Bujawe FR; (2) the River Hoima area, particularly between Kiseke and Wagaisa by Bwendero distillery (confirmed by K. Hiser in 2007, pers. comm.); (3) the Waki River area between Kyamuchumba and Nyakatoke, northwest of Mukihani FR; (4) within Mukihani FR (known locally as 'Rwampanga'), i.e., near Bulyango; (5) around Kalyango in the Hoima portion of Kasongoire FR; and (6) at Bulindi and Mparangasi and east into Kandanda–Ngobya FR (see Fig. 2). Some or all of these local chimpanzee groups probably correspond to discrete communities. Nevertheless, apparent from our surveys, and confirmed by subsequent detailed research at Bulindi during 2006–2008, is the marked mobility of chimpanzees in this fragmented farm–forest mosaic. Aside from regions where chimpanzees are regularly seen and heard, their use of other areas may be seasonal or infrequent. In several such cases villagers reported seeing chimpanzees travel to and from the direction of more than one 'resident area', suggesting the possibility of range overlap and the potential for migration. For example, during mango and *Maesopsis* seasons chimpanzees are attracted to the narrow gallery forest along the Waki River, east of Mukihani. At different localities along the river, locals reported seeing chimpanzees cross from Mukihani in the west, from Kasongoire in the northeast, and from further south along the river. There was no evidence to indicate that chimpanzee populations were isolated.

Forest status and human activities

The forest fragments used by chimpanzees include natural forest in FRs as well as on private and customary land. These forests are small, ranging in size from just a few hectares to several square kilometres (the largest patches are in Mukihani FR), but narrow strips of riparian vegetation extend long distances along watercourses, even where most large trees have been removed. Evident during the surveys was the extent of recent, ongoing and seemingly unregulated forest clearance in the region. All forest was highly degraded. Along the Rwamatonga, Hoima and Waki rivers forest was being burnt and cleared completely by farmers planting cash crops such as tobacco and rice, exposing wide stretches of riverbank. Men engaged in pit-sawing, charcoal production and distilling were encountered inside the forest throughout the survey area. Yet forest clearance was not limited to private and communal land. With the exception of Mukihani, the small FRs in the region (Bujawe, Kasongoire, Kandanda–Ngobya) contain little natural forest — the predominant vegetation is wooded grassland; all, however, contain riparian forest strips and/or dense hillside thickets used by chimpanzees. We encountered burning, recently burnt or recently converted natural forest within the Mukihani, Bujawe and Kasongoire FRs.

Human–chimpanzee conflict

Chimpanzees were widely reported to raid agricultural crops, including cocoa, sugarcane, jackfruit, paw-paw, bananas, mangoes, pineapple, maize and pumpkin. Low-level crop raiding of domestic fruits by chimpanzees is seemingly tolerated by many local people, and where baboons are present they are generally considered a more destructive pest. However, where chimpanzees raided cash crops such as sugarcane and cocoa, this was evidently considered a more serious matter (see ‘Discussion’). At two sites chimpanzees were reported to take domestic chickens. Several people claimed that chimpanzees had been deliberately killed, or caught in traps set to deter crop raiding animals. Many farmers were unaware of the legal status of chimpanzees.

Table 1. Evidence of chimpanzee presence in northern Hoima District, February–May 2006.

Subcounty Location	Coordinates	No. of nests[1]	Largest same-age nest group	No. of fresh nests	Tree species used[2]	Other fresh sign[3]	No. of chimps seen in encounter
Bugambe/Buseruka							
Rwamatonga River (southern boundary of Bujawe FR)	01°29'700"N 31°10'900"E	4	4	0 (nests recent 2–3 days old)	*Khaya anthotheca* *Phoenix reclinata*	–	–
Kitoba/Kigorobya							
Hoima River (eastern boundary of Bujawe FR)	01°31'900"N 31°14'000"E	15	5	0	*Pseudospondias microcarpa* *Phoenix reclinata*	Knuckle marks	–
Kitoba							
Wagaisa (by Bwendero distillery)	01°30'400"N 31°19'800"E	11	4?	4	*Pseudospondias microcarpa* *Funtumia africana*	Calls (group), feeding traces (jackfruit)	7 (4 adult males, 1 adult female, 1 subadult, 1 juvenile)
Kiryangobe (west of Mukihani FR)	01°33'100"N 31°20'900"E	10[1]	5	0 (5 nests recent)	*Pseudospondias microcarpa* *Pycnanthus angolensis*	–	–
Mukihani FR – south (Kihomboza area)	01°28'600"N 31°21'700"E	11[1]	5	5	No data	–	–
Mukihani FR – central (Bulyango area)	01°31'700"N 31°22'700"E	6	No data	0	No data	–	–
Kigorobya/Kitoba							
Waki River – north (Kyamuchumba area)	01°36'200"N 31°22'600"E	13	9	0	*Pseudospondias microcarpa* *Cordia* sp. *Alstonia boonei*	Knuckle marks	2 (adult males?)
Kitoba/Kyabigambire							
Waki River – east (Kasongwa area)	01°33'000"N 31°25'400"E	16	6	10	*Albizia zygia* *Maesopsis eminii* *Antiaris toxicaria* *Sapium ellipticum* *Funtumia africana* *Ficus* sp.	–	–
Kyabigambire							
Kasongoire FR (Kalyango)	01°34’000"N 31°27’200"E	43[1]	12	4 (+ many recent)	*Albizia zygia* *Trilepisium madagascariensis* *Funtumia africana* *Sapium ellipticum* *Khaya anthotheca* *Pycnanthus angolensis*	–	–
Bulindi (west of Kandanda-Ngobya FR)	01°29’000"N 31°28’800"E	25[1]	12	17[1]	*Pseudospondias microcarpa* *Antiaris toxicaria* *Maesopsis eminii*	Call (single), dung	6 (1 adult male, 2 adult females, 2 juveniles, 1 infant)

[1] Indicates additional nests seen but not recorded (for example, across swamp).

[2] Nest tree species: only identified species are listed.

[3] Other fresh sign: shown only if recorded independently of an encounter (i.e., on a different day) and, in the case of dung, independently of fresh nests.

FR = Forest Reserve

A common belief is that chimpanzees tend not to bother humans if left alone, but if threatened they are considered very dangerous. Reports of chimpanzee attacks on people in Hoima District (including two in the River Hoima region) seem to have involved a chimpanzee first being speared or attacked with pangas, or set upon by dogs. In these cases an attempt may have been made to take an infant chimpanzee from its mother or otherwise confront a crop raiding ape. However, it is difficult to obtain facts since people are reluctant to admit any wrongdoing. In 2005, a child was apparently fatally attacked by a chimpanzee southeast of Kasongoire FR in what was probably a predatory incident. At two sites women claimed to avoid going to forest wells to collect water when chimpanzees are nearby. Chimpanzees are known to threaten people by slapping the ground or tree-trunks, and may be difficult to chase from gardens (pers. obs.). Around Bulindi, it was claimed that they transmit an unknown skin disease to humans. Several villagers at different sites explicitly stated that chimpanzees do not belong in their forests and should be relocated to a sanctuary or wildlife reserve.

Discussion

Northern Hoima's chimpanzee population

The surveys indicated that chimpanzees have a wider distribution in northern Hoima than previously realized, and point to the existence of a number of distinct communities, resident to particular areas. The nest group data, together with reports of local people, suggest that chimpanzee communities in this region are relatively small, as might be expected in such a disturbed and fragmented habitat. Indeed, elsewhere where chimpanzees have been studied in small forest patches — at Kasokwa in Masindi, just north of the survey area, and at Bossou in Guinea — community size is small (i.e., 12–20 individuals), including just 1–3 adult males (Reynolds *et al.* 2003; Sugiyama 2004). Even so, data from Hoima suggest this may not always be the case. Following this survey, an 18-month ecological study was conducted at Bulindi, in the far east of the area surveyed. There, the chimpanzee community comprises a minimum of 25 individuals, including at least six adult males, and four adult males were encountered together at Wagaisa, as described above. One possibility is that the riparian forests are rich in chimpanzee foods. Vegetation surveys at Bulindi showed that some of the apes' most important fruit sources occur at high densities in the swampy conditions (for example, *Phoenix reclinata* and *Pseudospondias microcarpa*; McLennan unpubl. data).

Based on densities in larger outliers around Bugoma, Plumptre *et al.* (2003) estimated an overall population of ~70 individuals for the area between Budongo and Bugoma. Although the present study aimed to assess distribution rather than census the region's chimpanzee population, a crude estimate of numbers can be made. Preliminary analysis of habitat use indicates that the Bulindi chimpanzee community had a known range of approximately 20 km² during 2006–2007 (calculated by minimum convex polygon method), and a probable range of about 38 km² if locations of unconfirmed yet reliable reports are included. It is unlikely that this represents a significant underestimate of range size because the outer limits to the east and south include locations where these chimpanzees — which appear to have neighbors only in the north and west — have recently been sighted for the first time by local people (i.e., they appear to be expanding their range). Note that most of this territory comprises seldom-used wooded grassland (principally in Kandanda–Ngobya FR) as well as village areas, and only a small proportion is core habitat (i.e., riparian forest). A minimum community size of 25 occupying a range of 38 km² gives a density of 0.66 individuals/km² at Bulindi. If this estimate was applied to the whole 400 km² survey region it would imply a population of as many as 260 chimpanzees — considerably more than previously estimated. Of course, habitat quality and hence chimpanzee density may vary across the region and this needs to be investigated. Even so, the survey area did not include forest patches occurring inside the Masindi border around the southern periphery of Budongo, such as at Kasokwa (Reynolds *et al*. 2003). One or possibly two resident chimpanzee communities inhabit fragments to the southeast of Kasongoire FR, in the Kinyara sugar estate in Masindi — almost certainly these are different animals to those ranging on the Hoima side of the reserve more than 6 km to the west. In addition, there are unconfirmed reports of chimpanzees near Buhimba, further south of the survey region, and chimpanzees are also present in forested areas east of Bugoma around Munteme (JGI/UWA 2002; pers. obs.).

Threats to chimpanzees in Hoima

Although chimpanzees are undoubtedly more numerous between Budongo and Bugoma than previously recognized, current numbers across this region may be lower than the Bulindi data imply. Food density and availability, for example, could be higher at Bulindi than elsewhere in northern Hoima, thus supporting a greater density of chimpanzees. At any rate, the continuing existence of chimpanzees across this region is seriously threatened by recent and ongoing human activities. Two examples from the survey area illustrate their precarious status.

Case 1. During the 1960s, cocoa gardens (*shambas*) were established in private and communal forests across Hoima, but many were abandoned when the cocoa industry declined during the 1970s and 1980s. The chimpanzees that range around River Hoima at Kiseke and Wagaisa have raided this cocoa for years. A prominent farmer rehabilitated cocoa *shambas* along the river in the 1990s, but complains that chimpanzees eat a significant portion of his crop. He uses a pack of dogs to drive chimpanzees away from his cocoa and, at the time of the survey, was clearing riparian forest either side of his *shambas* as a buffer. He provided neighbours with dogs and recommended they too remove all large trees from in and around their *shambas*. He has repeatedly requested that the Uganda Wildlife Authority (UWA) remove the chimpanzees, and was plainly angry at what he perceives is a lack of action. During the main harvesting season in 2005 and 2006, UWA provided a ranger to guard the cocoa. The ranger also supervised community hunts, apparently to rid the area of baboons. In October 2006, two juvenile chimpanzees were caught in nets during separate hunts. The second was kept tethered for several days in an outside toilet (Fig. 3); both were subsequently released at the capture site. A year earlier two infants were captured in this same area and taken to Ngamba Island Chimpanzee Sanctuary in Lake Victoria, currently home to 44 rescued chimpanzees (L. Ajarova pers. comm.). Adjacent to the forest fragment at Wagaisa is a large distillery. When surveyed, the managers had recently planted sugarcane alongside the forest. When asked about likely crop raiding by chimpanzees, a manager replied that they were 'hunting them down'. Throughout 2007 this forest patch was further degraded and logged for timber (K. Hiser pers. comm.).

Case 2. During surveys along the Waki River, local people reported that chimpanzees were often found in a valley inside Kasongoire FR, known as Kalyango. There are permanent villages in this reserve, and most suitable land is cultivated. The 'main forest' was an approximately 2–3 ha patch of degraded forest on a slope, which contained a concentration of nests. Adjacent to this patch an area equivalent in size had recently been burnt and cleared for farming. Elsewhere, gallery forest had been cut down. Residents claimed the National Forest Authority (NFA) required households to plant several trees of fast growing species (for example, *Maesopsis*, pine or eucalyptus) each year, but no restrictions on clearing natural forest were apparent. A road passes through the reserve; local people have complained to the UWA about chimpanzees scaring children as they walk to school. The NFA were apparently unaware of the presence of chimpanzees in this reserve, although this information can be easily obtained from locals. The small FRs in northern Hoima are classified as 'production' reserves intended for development of industrial plantations (Uganda, NFA 2005), mainly of *Pinus* and *Eucalyptus* spp. Evidently, the status of endangered and protected wildlife is not a priority in this region of Uganda. As such, chimpanzee populations that range within these government reserves enjoy no more protection than those on private or communal land.

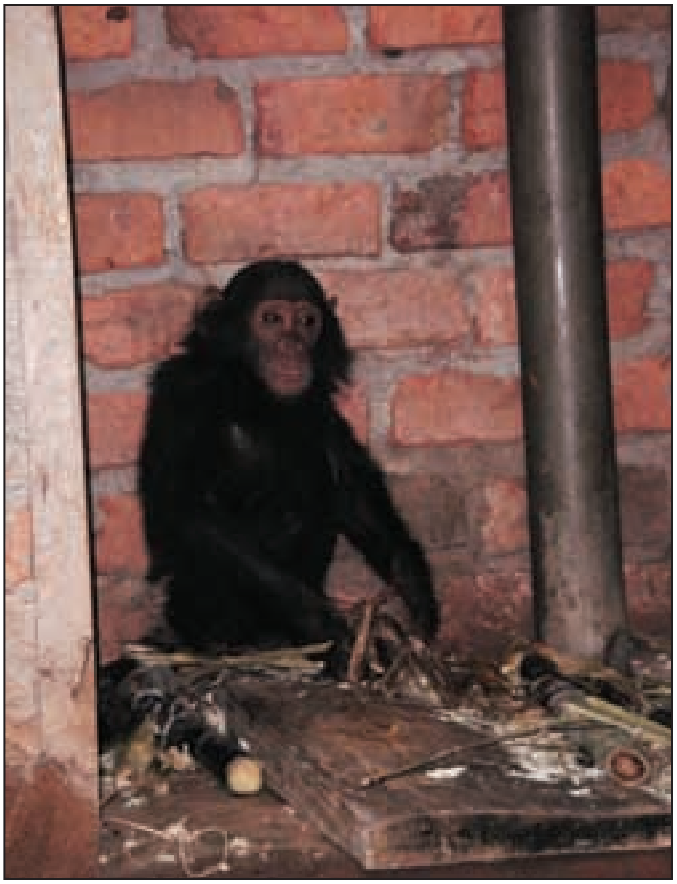

Figure 3. Captured chimpanzee in Kiseke village, Kitoba Subcounty, October 2006.

The pace of change has been fast in Hoima. Forest patches are rapidly depleted as subsistence farmers increasingly shift to cash crops. Currently, tracts of gallery forest throughout Hoima are being cleared for tobacco farming for sale to firms such as British American Tobacco. Further, during 2007 forests in the survey area were targeted by timber dealers and the sound of chainsaws could be heard throughout the region. Even small trees (for example, of 50-cm trunk diameter) of moderate timber value were being systematically removed, in a situation analogous to a 'gold rush'. The logging is seemingly unregulated and plainly unsustainable. In Uganda it is illegal to cut timber in natural forests with a chainsaw, but since many government officials are poorly trained and poorly paid there is little incentive for them to enforce laws and implement policies. Instead, some officials are tempted to make money themselves from the timber. For the local communities, insecurity over land tenure may motivate owners of private and communal forests to sell trees or clear forest quickly in order to get the land under cultivation (Banana and Gombya-Ssembajwe 2000; Romano 2007). Moreover, at Bulindi some local people evidently believe that conservation of chimpanzees and forest will result in a loss of land. Yet addressing land tenure issues was a central component of Uganda's recent forestry reforms. Specifically, local governments are to encourage owners of private or communal forests to legally register their forests so that land tenure is secured, thus promoting responsible management (Uganda, MWLE 2002). In addition to revenue collection, the District Forestry Services are required to provide advisory support to owners of natural forests outside FRs, including preparation of approved sustainable management plans for registered forests (Uganda, MWLE 2002; Uganda, Government of Uganda 2003). Presently, this appears not to be happening. It seems that the recent abolition of graduated tax — previously an important source of income for many local governments — may be prompting district governments such as Hoima, with relatively large expanses of forest on private and communal land, to focus their attention on income generation from forest produce (F. Babweteera, pers. comm.). Thus the need to generate short-term revenue to fund the District budget is at the expense of long-term conservation goals.

It is evident that Hoima's chimpanzees are being forced to adapt to rapid habitat change, including fragmentation, a significant reduction in forest area and loss of large fruit-bearing trees, alterations to forest structure and composition, ever-greater distances across agricultural land between patches, and an overall increase in human activity in and around forests. An inevitable consequence of these processes is a rise in human–chimpanzee interactions, which grow increasingly negative in character, as reflected by reports of farmers killing chimpanzees for raiding crops and chimpanzees attacking humans. It is common for farmers to place steel 'man traps' (or 'leg-hold' traps) at the forest edge and around cultivated fields to deter crop raiding animals (pers. obs.). A chimpanzee caught in such a trap, whether intended or accidental, may have great difficulty removing the device. By way of grim illustration, an adult male of the small Kasokwa community — already missing a foot from a previous trap encounter — died from septicaemia some 10 days after getting his hand caught in a trap (Munn and Kalema 2000). Other cases have recently occurred around Kasongoire (Reynolds 2005) and at Bulindi (McLennan unpubl. data), but undoubtedly many more go unreported. As such, trapping of chimpanzees in agricultural areas should be seen as both a conservation problem and a welfare issue. Moreover, the potential for chimpanzee attacks on humans, including predation on children, increases wherever chimpanzees are forced into a close, competitive relationship with humans. In such circumstances, adult male chimpanzees in particular may exhibit frequent aggressive behavior towards humans (pers. obs.). From a conservation perspective attacks are problematic since they generate fear and hostility towards chimpanzees locally, may trigger retaliatory killings, and affect local and public support for chimpanzee protection and related conservation efforts (see also Wrangham 2001).

With regard to hunting, the Ugandan taboo against eating primates probably explains the continuing presence of chimpanzees in northern Hoima despite the relatively high density of farmers. However, recent migrants to the area, such as from DRC, have different traditions and may hunt chimpanzees. For example, the northern tip of Mukihani has recently been settled by Congolese refugees who have encroached on the reserve. Their hunting trails lead deep into the forest. Chimpanzees are apparently nowadays rarely seen in the forest nearest this village, and a guide suggested that this was due to hunting pressure (though no evidence of this was seen). There are current reports of chimpanzees being hunted to supply body parts for traditional medicine in the Hoima–Masindi area (for example, around Kinyara).

Conclusion

The area surveyed falls within a proposed corridor linking two major forests blocks, Budongo and Bugoma. It is, therefore, important that this study found no evidence that chimpanzee populations were yet isolated within this region, confirming the corridor's potential. However, current human activities are expected to inflict a heavy toll on northern Hoima's apes leading to local extinctions within the next decade. Immediate action is required to reverse this state of affairs, and yet the combination of unprotected habitat, intensive and increasing human pressure on forest land and resources, and inadequate accountability of those involved in natural resource management regionally, offers no easy solutions. As a first step, both the NFA and local government must be publicly called upon to take into account the presence of chimpanzees — protected by Ugandan law — in the management of the district's forests. Likewise, tobacco and sugarcane companies must be made to conduct environmental impact assessments, performed by independent, external agencies. Policy guidelines should be strong on riparian forests to avoid the problem of farmers clearing forest up to the river banks. This is particularly relevant to Hoima where most forest patches are riparian.

Ultimately, however, the benefits to local communities living alongside potentially troublesome — and sometimes dangerous — mammals such as chimpanzees must outweigh the costs (Hill 2002). It seems likely that local people will require economic incentives if they are to manage forest on private and communal land sustainably, and it has been suggested that revenue generation from chimpanzee ecotourism in such areas might provide an answer. Yet it is difficult to imagine successful ape tourism in visibly impoverished, stressed habitats such as those in the area surveyed. Moreover, habituation for tourism is inappropriate where apes and people live in very close proximity, for reasons that include increased likelihood of crop-raiding, risk of aggression to local people and tourists by emboldened and/or stressed chimpanzees, and increased potential for disease transmission. Instead, habitat stabilization and enrichment must be the priority. To this end, novel strategies are required such as alternative income-generating projects and enrichment planting, developed with the full involvement of local communities and delivered with a strong educational emphasis. An additional strategy is to explore possibilities for payment for ecosystem services as an incentive for private forest owners to maintain forest on their land. In this context, it is crucial that land tenure issues are addressed to relieve local anxieties about land loss to conservation projects.

Finally, whilst maintaining gene flow between chimpanzee populations in the Budongo and Bugoma forests is an attractive conservation goal, we must remember that apes inhabiting the proposed corridor live in close contact with a growing human population. The danger is that these 'village' chimpanzees might introduce novel diseases to ape populations in the more remote forest blocks. Conservation projects will need to investigate the health status of chimpanzees within the Hoima corridor, and devise strategies for minimising the risk of disease transmission between apes and humans regionally.

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Literature Cited

Banana, A.Y. and W. Gombya-Ssembajwe. 2000. Successful forest management: the importance of security of tenure and rule enforcement in Ugandan forests. In: *People and Forests: Communities, Institutions, and Governance*, C. C. Gibson, M. A. McKean and E. Ostrom (eds.), pp.87–98. MIT Press, Cambridge, MA.

Butynski, T. M. 2001. Africa's great apes. In: *Great Apes and Humans: The Ethics of Coexistence*, B. B. Beck, T. S. Stoinski, M. Hutchins, T. L. Maple, B. Norton, A. Rowan, E. F. Stevens and A. Arluke (eds.), pp.3–56. Smithsonian Institution Press, Washington, DC.

Davenport, T. R. B., E. Lodu, P. C. Howard and A. J. Plumptre. 2001. Robust chimpanzee *Pan troglodytes schweinfurthii* in Otzi Forest Reserve, northern Uganda. *Afr. Primates* 5: 46–48.

Edroma, E., N. Rosen and P. Miller (eds.). 1997. *Conserving the Chimpanzees of Uganda: Population and Habitat Viability Assessment for* Pan troglodytes schweinfurthii. IUCN/SSC Conservation Breeding Specialist Group (CBSG), Apple Valley, MN.

Eggeling, W. J. 1947. Observations on the ecology of the Budongo rain forest, Uganda. *J. Ecol.* 34: 20–87.

FAO. 2007. *State of the World's Forests 2007*. Food and Agriculture Organization of the United Nations (FAO), Rome. Website: <http://www.fao.org/docrep/009/a0773e/a0773e00.htm>.

Gombya-Ssembajwe, W., M. Buyinza and O. V. Kakuru. 2007. Quantification of monetary losses due to illegal pitsawing in Budongo Forest, Uganda. *Int. Forest. Rev*. 9: 842–849.

Groves, A. W. 1934. The physiography of Uganda: the evolution of the Great Lakes and the Victoria Nile drainage system. *J. Roy. Afr. Soc*. 33: 59–69.

Hill, C. M. 2002. Primate conservation and local communities: ethical issues and debates. *Am. Anthropol*. 104: 1184–1194.

Isabirye-Basuta, G. 2004. The status and distribution of primates in Mubende-Toro woodlands and forests. *Afr. J. Ecol*. 42 (suppl. 1): 84–86.

JGI/UWA. 2002. Investigation into the human–chimpanzee conflict in Hoima District. Report, Jane Goodall Institute (JGI), Uganda Wildlife Authority (UWA), Uganda.

Langdale-Brown, I., H. A. Osmaston and J. G. Wilson. 1964. *The Vegetation of Uganda and Its Bearing on Land Use*. Government Printer, Entebbe, Uganda.

Munn, J. and G. Kalema. 2000. Death of a chimpanzee *Pan troglodytes schweinfurthii* in a trap in Kasokwa Forest Reserve, Uganda. *Afr. Primates* 4: 58–62.

Plumptre, A. J. 2002. *Extent and Status of the Forests in the Ugandan Albertine Rift*. Wildlife Conservation Society (WCS), New York.

Plumptre, A. J., D. Cox and S. Mugume. 2003. The status of chimpanzees in Uganda. *Albertine Rift Technical Report Series* (2). Wildlife Conservation Society (WCS), New York.

Reynolds, V. 2005. *The Chimpanzees of the Budongo Forest: Ecology, Behaviour and Conservation*. Oxford University Press, New York.

Reynolds, V. and F. Reynolds. 1965. Chimpanzees of the Budongo Forest. In: *Primate Behaviour: Field Studies of Monkeys and Ape*s, I. DeVore (ed.), pp.368–424. Holt, Rinehart and Winston, New York.

Reynolds, V., Wallis, J. and Kyamanywa, R. 2003. Fragments, sugar, and chimpanzees in Masindi District, western Uganda. In: *Primates in Fragments: Ecology and Conservation*, L. K. Marsh (ed.), pp.309–320. Kluwer Academic / Plenum Publishers, New York.

Romano, F. 2007. Forest tenure changes in Africa: making locally based forest management work. *Unasylva* 228(58): 11–17.

Stott, K. and Selsor, C. J. 1959. Chimpanzees in western Uganda. *Oryx* 5: 108–115.

Sugiyama, Y. 2004. Demographic parameters and life history of chimpanzees at Bossou, Guinea. *Am. J. Phys. Anthropol*. 124: 154–165.

Uganda, Department of Lands and Surveys. 1967. *Atlas of Uganda*. 2nd edition. Government Press, Entebbe, Uganda.

Uganda, Government of Uganda. 2003. The National Forestry and Tree planting Act. *The Uganda Gazette* No.37, vol. XCVI, Acts Supplement No.5. Uganda Publishing and Printing Corporation, Entebbe, Uganda.

Uganda, MWLE. 2002. *The National Forest Plan*. Ministry of Water, Lands and Environment (MWLE), Kampala, Uganda.

Uganda, NFA. 2005. *Uganda's Forests, Functions and Classifications*. National Forest Authority (NFA), Kampala, Uganda.

Uganda, UBOS. 2007. *Hoima District 2002 Population and Housing Census Analytical Report*. Uganda Bureau of Statistics (UBOS), Kampala, Uganda.

Wrangham, R. W. 2001. Moral decisions about wild chimpanzees. In: *Great Apes and Humans: The Ethics of Coexistence*, B. B. Beck, T. S. Stoinski, M. Hutchins, T. L. Maple, B. Norton, A. Rowan, E. F. Stevens and A. Arluke (eds.), pp.230–244. Smithsonian Institution Press, Washington, DC.

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Tarsius tumpara: A New Tarsier Species from Siau Island, North Sulawesi

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Abstract: A new, critically endangered species of tarsier, one of the world's 25 most endangered primates, is described from the remote island of Siau, North Sulawesi, based on distinguishing characteristics of the tail tuft, pelage coloration, skull, and vocalizations. Siau is part of the Sangihe Island chain, a volcanic arc composed of islands that rise from the ocean floor. There is a single previous record of a tarsier from Siau; a skull in the Dresden Museum that Meyer (1897) classified with tarsiers from Sangihe Island as *Tarsius sangirensis*. Sangihe and Siau Islands are geologically separated by about 60 km of ocean that greatly exceeds 1,000 m in depth. Genetic data for the new species are not available, but genetic evidence indicates that its probable sister species, *T. sangirensis*, is a relatively ancient clade. The observations of Siau tarsier behavior seem to indicate adaptations for predator avoidance, which is intriguing, since the human inhabitants of Siau hunt and eat tarsiers for food, and tarsiers there seem to be under severe threat of extinction.

Key Words: *Tarsius sangirensis*, *Tarsius* new species, taxonomy, morphology, vocalization, Sangihe, biogeography

Introduction

Tarsiers are small nocturnal primates found on a scattering of Southeast Asian islands. Hill (1955) recognized a single genus, *Tarsius*, with three species groups, each endemic to a distinct biogeographic region. This broad-scale framework for tarsier classification has held until the present, and today taxonomists recognize the *Tarsius tarsier* complex (= *spectrum*), found throughout Sulawesi and several offshore islands groups, *T. syrichta*, from islands of the southern Philippines that formed the Ice Age landmass Greater Mindanao, and *T. bancanus*, from a restricted subset of islands that formed the Ice Age landmass Sundaland, including Borneo, Bangka, Belitung, southern parts of Sumatra, and several smaller islands (Brandon-Jones *et al*. 2004).

MacKinnon and MacKinnon (1980) provided the first reports of wild tarsiers from the *T. tarsier*-complex. They described an animal with a conspicuous sexually-dimorphic dawn chorus, which they termed a "duet call". They reported geographically-structured variation in tarsier duet calls that appeared to parallel the distribution of Sulawesi macaques, and suspected that each duet form diagnosed a distinct cryptic species. They also noted reports of the presence of tarsiers on several offshore island groups, and predicted unrecognized taxonomic diversity on those as well. Thus, they offered a biogeographic hypothesis that predicted that numerous unrecognized, cryptic, tarsier species were to be found within the distributions of Sulawesi macaques and on offshore islands. Numerous researchers have followed up on these predictions such that the population of lowland tarsiers (i.e., occurring up to 1,500 m altitude) that Niemitz (1984a) classified as *T. tarsier tarsier*, is now recognized to contain six species — *T. tarsier, T. sangirensis, T. dentatus* (= *dianae*), *T. pelengensis, T. lariang,* and what we describe here as *T. tumpara* (see Brandon-Jones *et al*. 2004; Merker and Groves 2006).

We describe a new species of tarsier from the tiny remote island of Siau, and focus global conservation priority setting on a little known island chain where human-mitigated extinctions might soon include a primate (Figs. 1 and 2). Siau is part of the Sangihe Islands, a volcanic arc stretching north from Sulawesi toward the Philippine island of Mindanao that are faunally related to Sulawesi. Sulawesi is the major landmass in Wallacea, a top hotspot for biodiversity conservation (Myers *et al.* 2000). One estimate rates Sulawesi the highest priority for the allocation of conservation resources, warranting the recommendation of "initially investing all resources in Sulawesi and no other place until all the species occurring in Sulawesi are conserved" (Wilson *et al.* 2006). As the focus of global conservation narrows to identifying the "hotspots within the hotspot", the Sangihe Island chain, and specifically Siau Island, appears as possibly the hottest hotspot within Sulawesi. Commensurately, the Siau Island tarsier was selected as one the World's 25 Most Endangered Primates 2006–2008 list (Mittermeier *et al*. 2007).

Tarsius tumpara new species

Holotype. Adult male, skin, skull and skeleton, MZB 27053, deposited in the Museum Zoologicum Bogoriense (MZB), Bogor, Indonesia. Captured alive on 1 April 2002, but died on 3 April 2005, in transit to the Museum Zoologicum Bogoriense (MZB).

Paratypes. None

Type locality. Siau Island (02°39.270'N, 125°23.944'E): the southern end of the island about 100 m from the north shore of a small lake.

Hypodigm. Only one other specimen of this species is known to exist in museums: Dresden B321, "*Tarsius spectrum sangirensis*" (Siao), skull. The specimen label includes the information "Di. Meyer Kf. 1875". Our research indicates that Meyer visited North Sulawesi and the Philippines in 1870, and that the museum in Dresden was founded in 1875. Thus, we conclude it most likely that Meyer himself collected the specimen, and placed it in the museum's collection upon its founding.

Diagnosis. A species of the genus *Tarsius* clearly allied with Sulawesian tarsiers of the *T. tarsier*-complex owing to the size of the tail tuft, the presence of postauricular white spots, and the presence of a vocal duet. *Tarsius tumpara* resembles its probable sister-taxon, *T. sangirensis*, and thereby differs from all other Sulawesian tarsiers, in (1) the tail tuft, which has shorter, sparser fur that is lighter in coloration, (2) the reduced furriness of the tarsal, and (3) in having paralabial hair that is white and pronounced (Figs. 3 and 4). *Tarsius tumpara* differs from *T. sangirensis* in characteristics of the pelage, skull, and vocalizations. (1) Pelage. *Tarsius tumpara* has dorsal fur that lacks the golden brown coloration that distinguishes *T. sangirensis*; the ventral fur of *T. tumpara* is grayer than the nearly white undercoat of *T. sangirensis* (Fig. 4). (2) Skull. The skull of *T. tumpara* is larger than three of the four available skulls of *T. sangirensis*, but relatively narrow across the orbits (Fig. 5, Tab. 1). (3) Vocalizations. In *T. tumpara*, the female contribution to the morning duet call lacks the two-note phrase that is diagnostic of *T. sangirensis*; most of the recordings of *T. tumpara* morning duet calls are of isolated one-note phrases, with one example of a multi-note phrase (Fig. 6). Furthermore, Sangihe and Siau Islands are geologically separated by approximately 60 km of ocean, where depths exceed 1,000 m (Shekelle and Salim in press) and there is no possibility of recurrent gene flow between tarsiers on these islands, nor any indication of a historical land

Figure 1. The Siau Island tarsier, *Tarsius tumpara*. Illustration ©Conservation International / Stephen D. Nash.

bridge. *Tarsius sangirensis* is separated from other Sulawesian tarsiers by genetic distances consistent with a separation of a few million years (Shekelle 2003).

Description of type. The body fur is mottled brown with dark gray undercoat; in this it is like many other tarsiers, but totally unlike *T. sangirensis*. The grey upper facial fur (mainly above and lateral to the eyes) is margined by a conspicuous, thick brown line, giving it a look unlike any other tarsier; in *T. sangirensis* there is a similar line, but it is very weakly marked and thin, and deflects downward between the brows forming a 'V' at the root of the nose, whereas it is straight in this region in *T. tumpara* n. sp. The paralabial hair is contrastingly white, as in *T. sangirensis*. The tail tuft is short and relatively sparsely developed, and the tarsal hair is sparse and inconspicuous, more or less as in *T. sangirensis* (Figs. 3 and 4).

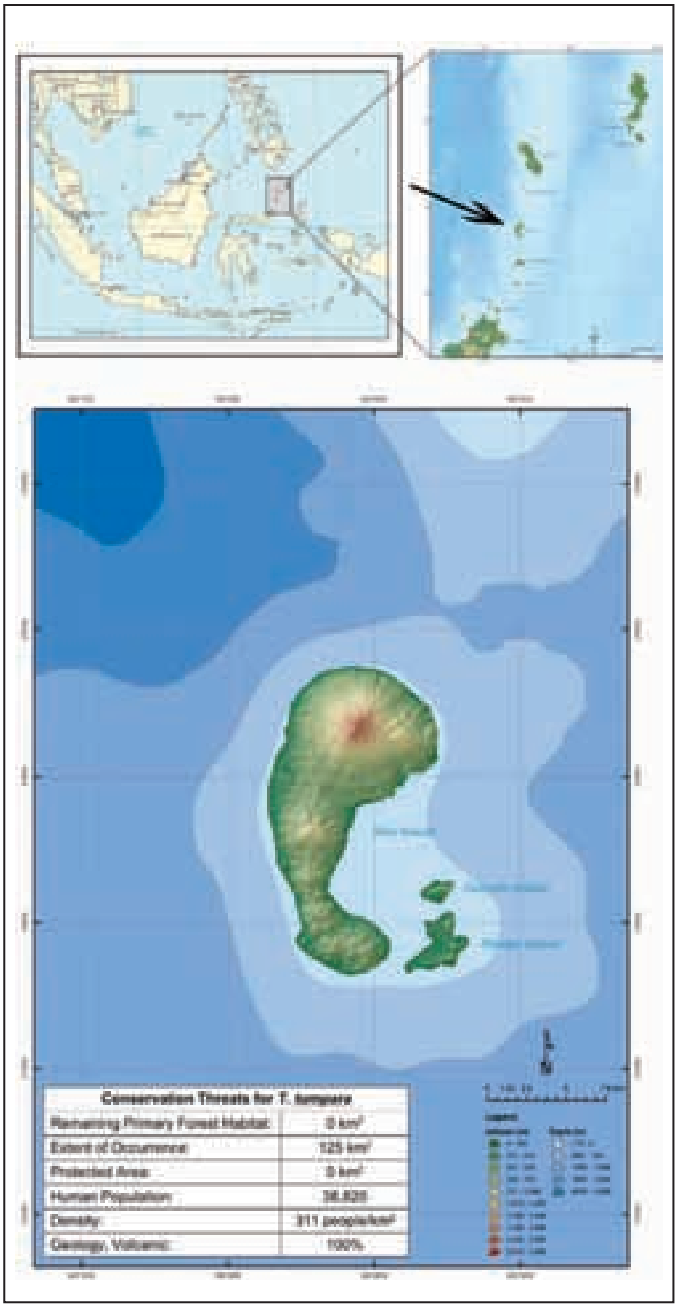

Figure 2. Maps of Siau, the Sangihe Island Chain, and SE Asia and conservation data (adapted from Shekelle and Salim, in prep.). The tiny island of Siau, showing the northern end dominated by the large, highly active volcano, Mt. Karengetang. Tarsiers were located on the extreme southern end of the island, where the holotype was captured. Tarsier scent was also located on a vertical cliff on the eastern coast.

The skull is large, but relatively narrow across the orbits. The bulla is wide, and strongly elongated anterior to the carotid foramen. The palate is wide in the region of the third molars, and the maxillary molars are not enlarged mesiodistally, but are strikingly wide buccolingually.

Description of Dresden B321. The only other known specimen of *T. tumpara*, Dresden B321 (skull only), differs from *T. sangirensis* in exactly the same way as does the type (reduced biorbital breadth; wide, anteriorly elongated bulla; posteriorly widened palate; buccolingually broad maxillary molars).

Etymology. The specific name *tumpara* comes from the word for tarsier used by the inhabitants of Siau Island. The language spoken is *Bahasa Sangihe*, but the dialect of Siau is distinct from Sangihe Island, where tarsiers are called *senggasi* or *higo*.

Distribution. Siau Island.

Previous field research. The only evidence of any previous research on tarsiers from Siau is a lone skull in the

Figure 3. *Tarsius tumpara* (left) and *T. sangirensis* (right), both showing a) a tail tuft that is sparsely furred with short light-colored hair, b) reduced furriness of the tarsal, and c) white paralabial fur. Photos [left] © Geoff Deehan; [right] © Myron Shekelle.

Figure 4. Comparisons of *Tarsius tumpara* (left) and *T. sangirensis* (right). Top – *Tarsius tumpara* lacks the golden brown dorsal fur and (bottom) nearly pure white ventral fur of *T. sangirensis*. Photos [left] © Geoff Deehan; [right] © Myron Shekelle.

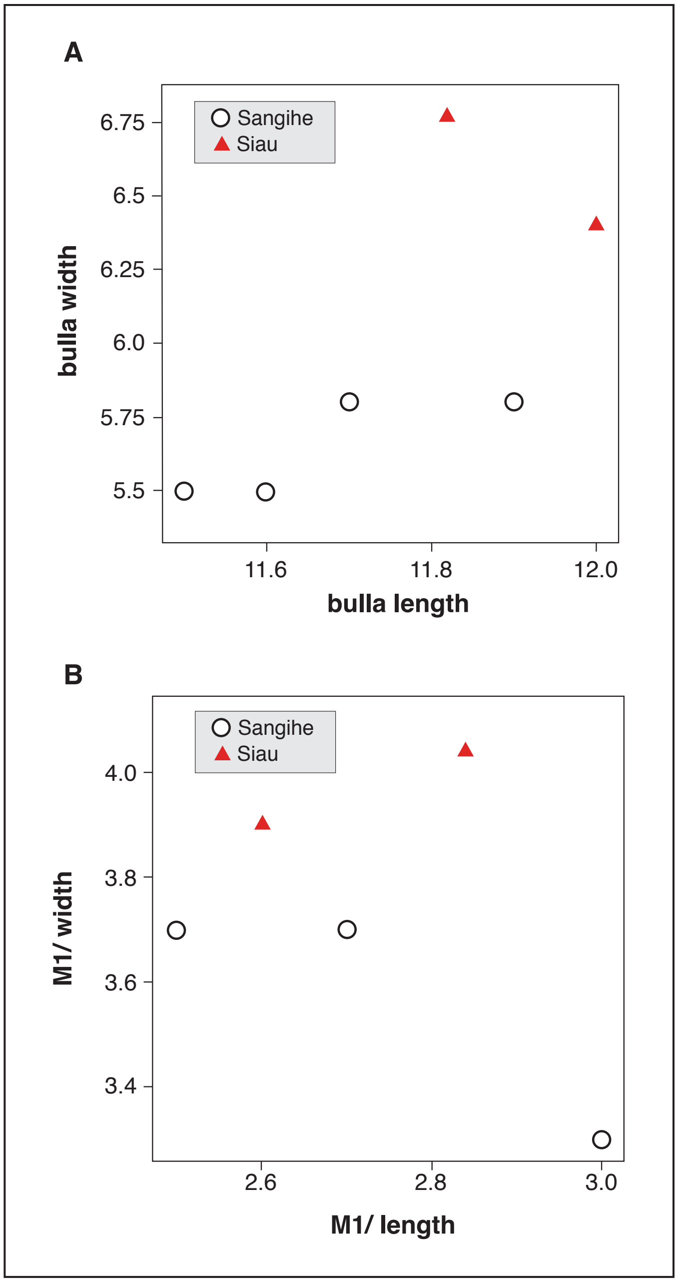

Figure 5. Representative comparisons of craniodental measurements of *Tarsius tumpara* compared with *Tarsius sangirensis*, (A) width versus length of auditory bulla (left), (B) width versus length of first maxillary molar (right).

Table 1. Measurements used in Fig. 5 (above), Australian Museum (AM), Museum für Tierkunde Dresden (DM), Museum Zoologicum Bogoriense (MZB).

Origin	Specimen	Bulla Length	Bulla Width	M1 Length	M1 Width
Sangihe	MZB 6606	11.9	5.8	3.0	3.3
	AM M9993	11.7	5.8	2.5	3.7
	MZB 3288	11.5	5.5	2.7	3.7
	MZB 6607	11.6	5.5	2.7	3.7
Siau					
	MD B321	11.8	6.8	2.8	4.0
	MZB 27053	12.0	6.4	2.6	3.9

collections of the Dresden Museum. Riley (2002) notes only their presence on Siau.

Notes. *Tarsius tumpara* is subtly distinct from *T. sangirensis*, but both of these are strikingly distinct from other tarsiers in the *T. tarsier*-complex. In their sparse tail tuft and sparsely haired tarsus, *T. tumpara* and *T. sangirensis* approach the condition seen in Philippine tarsiers (*T. syrichta*). However, molecular evidence and shared morphological characteristics show robust support that *T. sangirensis* is allied to the *T. tarsier*-complex and not to *T. syrichta* (Shekelle 2003). Thus, we hypothesize that *T. tumpara* and *T. sangirensis* are sister-taxa, and are allied to the *T. tarsier*-complex.

Erratum. Shekelle *et al.* (1997) noted behavioral peculiarities in *T. sangirensis* that distinguished them from other tarsiers in the study (i.e., north and central mainland Sulawesi and Togian Islands). In retrospect, these differences (social groups foraging and socializing together but sleeping in separate sites, choosing sleeping sites that are very high) represent behaviors that are associated with predator avoidance, specifically avoiding humans and predators such as feral cats. In *Tarsius tumpara*, such differences are even more extreme. The largest social group observed was the individual we captured in association with an adult female. Vocalizations were extremely limited and never were more than two tarsiers heard together. Sleeping sites were very high and inaccessible. Even the scent mark of *Tarsius tumpara* seems to fade more rapidly than is the case for other tarsiers of Sulawesi. Typically, a human can smell a scent mark that is several days old, sometimes from several meters away. The scent marks of *Tarsius tumpara* were noticed to fade dramatically within an hour, and were almost undetectable to the human nose the next day. These observations are particularly curious because Siau is the one locality where the prevalence of hunting tarsiers for food is very high. It is an intriguing possibility that tarsiers on Siau, and to a lesser extent Sangihe, have evolved adaptations to avoid hunting by humans.

Taxonomic History

Opinions on taxonomic diversity among tarsiers of Sulawesi have varied over the years, but it is becoming evident that biodiversity on Sulawesi in general, but especially among tarsiers, has been greatly underestimated. Hill (1955) classified the Sulawesi tarsiers as belonging to a single species, *Tarsius spectrum*, with five subspecies, *T. s. sangirensis*, *T. s. spectrum*, *T. s. pumilus*, *T. s. dentatus*, and *T. s. pelengensis*. Hill cautioned, however, that the justification for some of these seemed to him to be on "rather slender grounds", and Niemitz (1984a) synonymized all of these subspecies with *T. s. spectrum* except for *T. s. pumilus*, which he later (1985) accepted as a distinct species, *T. pumilus*. Musser and Dagosto (1987) presented abundant evidence to support the recognition of *T. pumilus*—a montane endemic approximately 75% the size of *T. spectrum* in linear measurements. Feiler (1990) argued for the resurrection of *T. sangirensis* as a distinct species, an opinion that was independently supported by

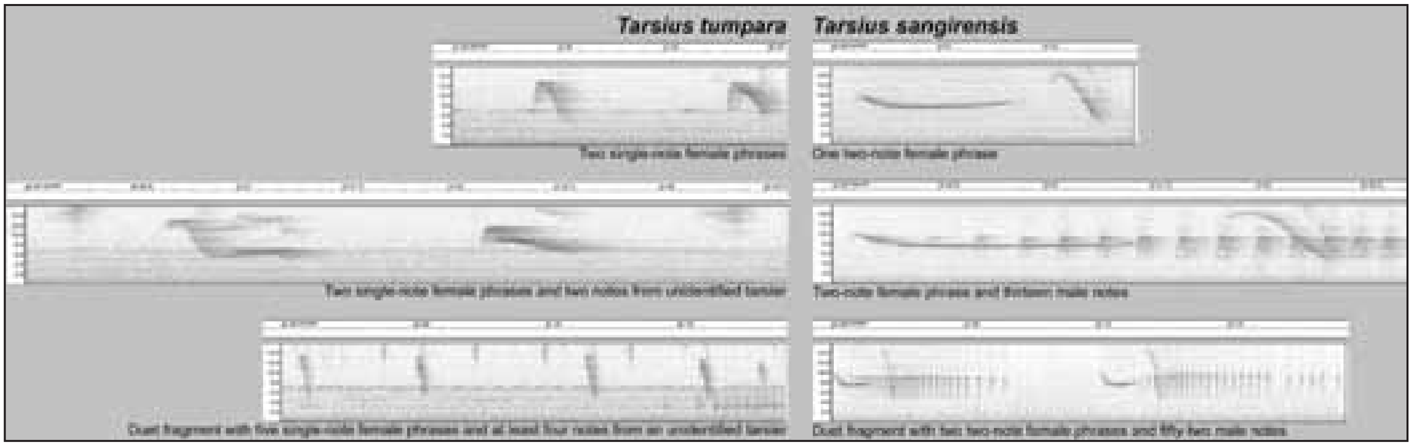

Figure 6. *Tarsius tumpara* lacks the characteristic two-note phrase of *T. sangirensis* females, nearly all of the recordings being one-note phrases (top and middle). The duet of *T. tumpara* is utterly different than that of *T. sangirensis*, having many more female notes and many fewer male notes (middle and bottom). (Sound recordings of wild tarsier calls were converted to spectrograms with SoundEdit. Brightness and contrast were adjusted for clarity.)

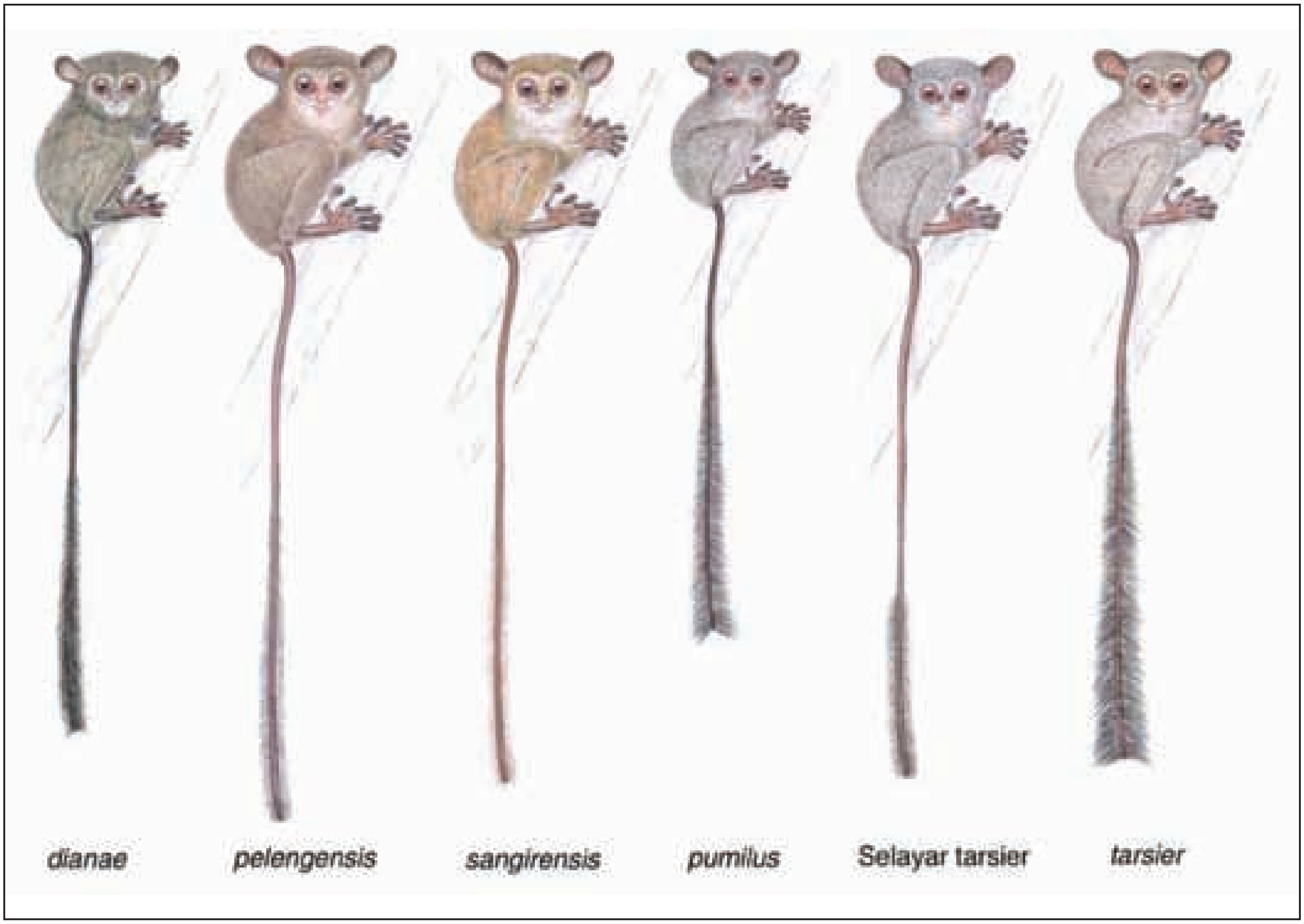

Figure 7. Six species of tarsiers from the *Tarsius tarsier*-complex. Otherwise cryptic species are diagnosable by often subtle variation in tail tuft, skin and pelage coloration. Illustration by © Conservation International / Stephen D. Nash.

Shekelle *et al.* (1997) and Groves (1998). Niemitz *et al.* (1991) described a new species, *T. dianae*, from central Sulawesi, but they unfortunately neglected to compare the new taxon with a senior taxon from the region. Shekelle *et al.* (1997) found the "*T. dianae*" duet form at the type locality of *T. fuscus dentatus* Miller and Hollister, 1821 (*T. spectrum dentatus* in Hill's (1955) combination), and suggested that the name *dianae* may be a junior synonym of *dentatus*. Groves (2001) accepted all of Hill's subspecies, and *T. dianae*, as distinct species, noting the problem with the name *T. dianae*. Brandon-Jones *et al.* (2004) used a taxonomy similar to that of Groves (2001), but argued that *T. tarsier* was a subjective senior synonym of *T. spectrum*. No evidence to contradict this opinion has been forthcoming, and more recent surveys in 2005 confirmed that the type locality of *T. dentatus* lies within the range of the acoustic form that diagnoses what had hitherto been designated *T. dianae* (Shekelle unpubl. data), virtually assuring that the latter is a subjective junior synonym of the former.

The taxonomy of the *T. tarsier* group may be far more complex than this, however. MacKinnon and MacKinnon (1980) published spectrograms of three distinct forms of tarsiers based upon recordings of their duet calls. Each of these forms came from a distinct biogeographic subregion of Sulawesi, and they interpreted this to indicate unrecognized taxonomic diversity. Niemitz (1984b) published a spectrogram of a tarsier from Gimpu (Central Sulawesi), which he identified *as T. t. pumilus*, but which has since been shown to be the Palu acoustic form of MacKinnon and MacKinnon (1980), recently described as *T. lariang* Merker and Groves, 2006. Nietsch and Niemitz (1993) identified a fourth acoustic form from the Togian Islands of Central Sulawesi. In subsequent work, Nietsch used acoustic evidence to argue for taxonomic separation of this population at the species level (Nietsch and Kopp 1988; Nietsch 1999), but did not name it. Shekelle *et al.* (1997) found two more acoustic forms from Central Sulawesi and a third from North Sulawesi, bringing the total number of known acoustic forms at the time to seven. Only two of these were associated with known taxa, Kamarora or "*T. dianae* form" (= *T. dentatus*) and the Sangihe form (= *T. sangirensis*). The other five acoustic forms were hypothesized to indicate unrecognized taxonomic diversity (Shekelle 2003).

Several daunting obstacles, however, befuddled a stable taxonomy for tarsiers, and prevented progress on naming the new forms. Type specimens and well-localized type localities were non-existent for both *T. tarsier* and *T. spectrum*. Hill (1955) suggested Makassar as the type locality for *T. spectrum*, and although the rationale for this is somewhat weak, it has become generally accepted (for example, Musser and Dagosto 1987; Groves 2001; Brandon-Jones *et al.* 2004). *Lemur spectrum* Pallas, 1778 is a junior objective synonym *of Lemur tarsier* Erxleben, 1777 (Brandon-Jones *et al*. 2004); accordingly, the correct name for the Makassar tarsier is *Tarsius tarsier* (Erxleben, 1777).

While the *T. tarsier* group has been extensively studied in the wild and is well represented in museum collections, Makassar is today a large city, from which there are no known field studies or museum specimens. Thus, putative new taxa could not be compared to the most senior name-bearer. A solution for this dilemma was proposed by Merker and Groves (2006). For comparative purposes, they represented *T. tarsier* in their study with four specimens from Lombasang, about 50 km ESE of Makassar, in the American Museum of Natural History (AMNH), along with two living specimens collected by one of us (Shekelle) from Maros, about 30 km NNE of Makassar, and kept at the Museum Zoologicum Bogoriense (MZB). Subsequently, another one of us (Groves, together with Jacques Cuisin and Cécile Callou) rediscovered the type specimen of *Lemur tarsier* and. although studies are ongoing, nothing about the specimen contradicts our hypotheses concerning *T. tumpara* (Groves, unpubl. data).

Our current taxonomy of tarsiers of the *T. tarsier*-complex thus currently includes six species:

Tarsius tarsier (Erxleben, 1777): Makassar. Includes synonyms *T. spectrum* (Pallas, 1778), and many others. Tarsiers from other parts of Sulawesi that are not classified as one of the species below are, by default, classified as *T. tarsier* but, as Brandon-Jones *et al*. (2004) observed, this leaves an improbably disjunct distribution. We are currently examining this issue in greater detail and expect to subdivide this taxon into numerous new taxa in the future.

Tarsius sangirensis Meyer, 1897: Sangihe Island, North Sulawesi

Tarsius pelengensis Sody, 1949: Peleng Island, Central Sulawesi

Tarsius dentatus Miller and Hollister, 1921 (a senior subjective synonym of *T. dianae* Niemitz *et al*., 1991): Central Sulawesi, northern and eastern portions of the central core, including Marantale (a few kilometers north of Labua Sore) on the east coast of the isthmus of Palu, Kamarora, Lake Poso, Ampana, Luwuk.

Tarsius lariang Merker and Groves, 2006: Central Sulawesi, western portion of the central core, from Gimpu to the west and south-west (including Gimpu, Marena, both banks of the Lariang River and the downstream part of its northern tributary, the Meweh River).

Tarsius tumpara new species: Siau Island, North Sulawesi.

Biogeography

The discovery of *Tarsius tumpara* was guided by the hybrid biogeographic hypothesis for Sulawesi, which predicted that 16 or more species of tarsier exist within the *T. tarsier*-complex, and which also highlighted a biogeographic discontinuity between the northern tip of Sulawesi and Sangihe Island, home of *T. sangirensis*, nearly 200 km away (Shekelle and Leksono 2004). Between these two tarsier populations lay a scattered island chain known as the Sangihe Islands. The Sangihe Islands are infamous for their critically endangered avifauna, including the Cerulean Flycatcher of Sangihe Island (Whitten *et al.* 1987, BirdLife International 2001, Whitten 2006). The combined pressures of habitat loss and hunting pressure are argued to be pushing some mammals towards local extinctions (Riley 2002).

The Sangihe Island chain stretches approximately 200 km from the northern tip of Sulawesi, north towards, the Philippine island of Mindanao. The chain is a volcanic arc of oceanic islands that arise from a sea floor over 1000 m deep. Five major islands, or island groups, are each spaced about 40 km apart. Nearest to Sulawesi is Biaro, followed by Tagulandang and Ruang, then comes Siau, then a complex cluster of many small islands, and finally, Sangihe, sometimes called Great Sangihe (with alternate spellings, such as Sangi and Sangir). The geology of volcanic arcs, such as the Hawaiian Islands and the Galapagos Islands, is ideal for producing isolation, endemism, and diversification.

Meyer (1897) included Sangihe and Siau islands in the distribution of *T. sangirensis*, but made no mention of the other islands in the chain, and how tarsiers ever came to these islands is a mystery. The reduced furriness of the tarsus and tail tuft of *T. sangirensis* led Meyer (1897) to state: "*Es liegt hierin also eine insulare Abweichung und Hinneigung zur Philippinen Form*." Hill (1955) classified these animals with *T. spectrum* (= *T. tarsier*), however, and genetic data offer robust support for a *T. tarsier*/*T. sangirensis* clade exclusive of *T. syrichta* (Shekelle 2003).

Myron Shekelle led surveys to Biaro, Tagulandang, and Ruang in 2004, in which no evidence of tarsiers was found, results that accord with Riley (2002). A follow up survey in Siau in 2005 succeeded in locating tarsiers on the first day, culminating in a capture on the fourth day. Thus, the biogeographic evidence from brief surveys presents the surprising irony that tarsiers are present on the more distant Sangihe Islands, but there is no evidence for them on islands that are closer to Sulawesi. Indeed, island biogeography in the Sangihe Island chain is made interestingly complex by the fact that island size happens to be inversely proportional to distance from Sulawesi (i.e., area of Biaro<Tagulandang/Ruang<Siau<Sangihe, and distance from Sulawesi to Biaro<Sulawesi to Tagulandang/Ruang<Sulawesi to Siau<Sulawesi to Sangihe). Thus, tarsier distributions support the prediction from island biogeography theory that larger islands are more likely to support extant populations of emigrants, but conflict with the prediction that nearer islands are more likely to support extant populations of emigrants than are more distant islands.

Conservation

By several measures, the conservation threat on Siau is notably more acute than it is on Sangihe, including: much smaller island size (and thus extent of occurrence); lesser extent of remaining forest; higher human density; and greater volcanism (Shekelle and Salim in press). Sangihe is tiny, about the size of Singapore, yet Siau is barely one-fifth as large. The population density on Siau, 311 people/km^2, is about as great as that of India. This population is further squeezed onto the southern 45% of the island in order to avoid a highly active volcano (Fig. 8). Neither island has any protected areas (Riley 2002; Shekelle and Salim in press), although this fact is obscured because the term *hutan lindung* (literally, "protected forest") is not a protected forest in the normal legal sense, but more akin to a 'green belt/area'. The largest expanse of forest on either island is a 800–900 ha patch of mixed primary/old growth secondary forest on the flank of Mt. Sahendaruman on Sangihe Island (Riley 2002; Whitten 2006).

Riley (2002) argued that hunting pressure is causing local extinctions of some mammal populations in the Sangihe Islands. Shekelle and Salim (in press) report that on Siau, local inhabitants have the unique habit of eating tarsiers for a snack food they call "*tola-tola*". Surveys indicate this habit has extirpated tarsiers over much of the island. They recommended that the Siau Island tarsier be categorized as Critically Endangered, and it was listed as one the "World's 25 Most Endangered Primates 2006–2008" to draw attention to its urgent need for conservation measures (Shekelle and Salim 2007).

The hybrid biogeographic hypothesis for Sulawesi (Shekelle and Leksono 2004) guided the discovery of *T. tumpara* (Brandon-Jones *et al*. 2004) and predicted that 16 or more species of tarsier exist within the population that was classified

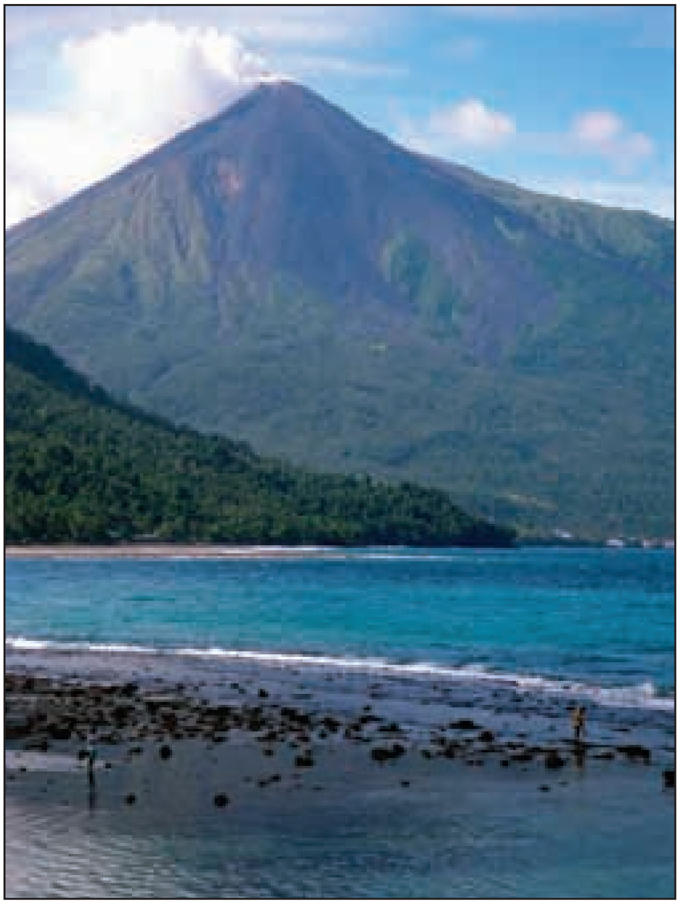

Figure 8. Mt. Karengetang, seen from the southeastern coast, is one of Indonesia's most active and dangerous volcanoes. It dominates the northern half of Siau Island, accounting for approximately 55% of the total land area. The outskirts of the main port of Ulu are barely visible at the water's edge on the far right hand side.

until recently as a single subspecies. With the identification of *T. tumpara*, six of those species have now been recognized, offering increased support for the prediction that biodiversity on Sulawesi may be underestimated by an order of magnitude. Unfortunately, it has taken 27 years, since MacKinnon and MacKinnon (1980) first reported the possibility of numerous cryptic tarsier taxa on Sulawesi, to evaluate and describe just six species; approximately 4.5 years per species. There are at least 10 more populations to assess, while conservation biologists estimate that all of Sulawesi's lowland forests are essentially gone (FWI/GFW 2002) and the tarsiers that remain are largely persisting in degraded habitats outside of protected areas, and are as such highly vulnerable to extinction (Supriatna *et al*. 2001). The bleak situation indicates that some primate species in Sulawesi may go extinct before they have even been identified, leaving scientists with unpleasant and controversial choices for taxonomy and conservation. We foresee increased criticism and controversy down either path: either publishing new species at an increased pace with the heightened chance of error, or not doing so at the risk that primate species are driven to extinction before they have been recognized and named.

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Literature Cited

Brandon-Jones, D., A. A. Eudey, T. Geissmann, C. P. Groves, D. J. Melnick, J. C. Morales, M. Shekelle and C.-B. Stewart. 2004. Asian Primate Classification. *Int. J. Primatol.* 25(1): 97–164.

Feiler, A. 1990. Über die Säugetiere der Sangihe- und Talaud-Inseln – der Beitrag A. B. Meyers für ihre Erforschung (Mammalia). *Zoologische Abhandlungen des Staatlichen Museums für Tierkunde Dresden*, 46: 75–94.

FWI/GFW. 2002. *The State of the Forest: Indonesia*. Report, Forest Watch Indonesia, Bogor, Indonesia, and Global Forest Watch, Washington, DC.

Groves, C. P. 1998. Systematics of tarsiers and lorises. *Primates* 39:13–27.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington DC.

Hill, W. C. O. 1955. *Primates: Comparative Anatomy and Taxonomy. II. Haplorhini: Tarsioidea.* Edinburgh University Press, Edinburgh.

MacKinnon, J. and K. MacKinnon. 1980. The behavior of wild spectral tarsiers. *Int. J. Primatol.* 1(4): 361–379.

Merker, S. and C. P. Groves. 2006. *Tarsius lariang*: A new primate species from western central Sulawesi. *Int. J. Primatol*. 27: 465–485.

Meyer, A. B. 1897. Säugethiere vom Celebes- und Philippinen-Archipel, I. *Abhandlungen und Berichte des Kaiserlich-Zoologische und Anthropologische-Ethnologischen Museums zu Dresden*, 6: I–VIII, 1–36.

Musser,G. G. and M. Dagosto. 1987. The identity of *Tarsius pumilus*, a pygmy species endemic to the montane mossy forests of Central Sulawesi. *Am. Mus. Novit.* (2867): 1–53.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature, Lond.* 403: 853–858.

Niemitz, C. 1984a. Taxonomy and distribution of the genus *Tarsius* Storr, 1780. In: *Biology of Tarsiers*, C. Niemitz (ed.), pp.1–16. Gustav Fischer, Stuttgart.

Niemitz, C. 1984b. Vocal communication of two tarsier species (*Tarsius bancanus* and *Tarsius spectrum*). In: *Biology of Tarsiers*, C. Niemitz (ed.), pp.129–141. Gustav Fischer, Stuttgart.

Niemitz, C. 1985. Der Koboldmaki - Evolutionsforschung an einem Primaten. *Naturwiss Runsch* (38): 43–49.

Niemitz, C., A. Nietsch, S. Warter and Y. Rumpler. 1991. *Tarsius dianae*: a new primate species from central Sulawesi (Indonesia). *Folia Primatol*. 56: 105–116.

Nietsch, A. 1999. Duet vocalizations among different populations of Sulawesi tarsiers. *Int. J. Primatol.* 20: 567–583.

Nietsch, A. and M. L. Kopp. 1998. Role of vocalization in species differentiation of Sulawesi tarsiers. *Folia Primatol*. 69(suppl.1): 371–378.

Nietsch, A. and C. Niemitz. 1993. Diversity of Sulawesi tarsiers. *Deutsche Gesellschaft fur Saugetierkunde* 67: 45–46.

Shekelle, M. 2003. Taxonomy and Biogeography of Eastern Tarsiers. Doctoral thesis, Washington University, St. Louis.

Shekelle, M. and S. M. Leksono. 2004. Rencana konservasi di Pulau Sulawesi: dengan menggunakan Tarsius sebagai flagship spesies. *Biota* 9: 1–10.

Shekelle, M. and A. Salim. 2007. Siau Island tarsier, *Tarsius* sp. In: R. A. Mittermeier *et al.* (compilers), Primates in Peril: The World's 25 Most Endangered Primates 2006–2008, pp.12, 27. *Primate Conserv*. 22: 1–40.

Shekelle, M. and A. Salim, A. In press. An acute conservation threat to two tarsier species in the Sangihe Island chain (North Sulawesi, Indonesia). *Oryx*.

Shekelle, M., S. M. Leksono, L. L. S. Ichwan and Y. Masala. 1997. The natural history of the tarsiers of north and central Sulawesi. *Sulawesi Primate Newsletter* 4(2): 4–11.

Shekelle M., C. P. Groves, S. Gursky and I. Arboleda. In preparation. A method for quantitatively classifying tarsier tail tufts.

Supriatna J., J. Manansang, L. Tumbelaka, N. Andayani, M. Indrawan, L. Darmawan, S. M. Leksono, Djuwantoko, U. Seal and O. Byers. 2001. Conservation Assessment and Management Plan for the Primates of Indonesia: Final Report. IUCN/SSC Conservation Breeding Specialist Group (CBSG), Apple Valley, Minnesota.

Whitten, T. 2006. Cerulean Paradise-Flycatcher not extinct: subject of the first cover lives. *Conserv. Biol*. 20: 918–920.

Whitten, T., S. D. Nash and K. D. Bishop. 1987. One or more extinctions from Sulawesi? *Conserv. Biol*. 1: 42–48.

Wilson, K. A., M. F. McBride, M. Bode and H. P. Possingham. 2006. Biodiversity hotspots for conservation priorities. *Nature, Lond.* 440: 337–340.

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Primates of Bhutan and Observations of Hybrid Langurs

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Abstract: Six, possibly seven, species of non-human primates occur in Bhutan: slow loris (*Nycticebus bengalensis*), Assamese macaque (*Macaca assamensis*), Rhesus macaque (*Macaca mulatta*), Hanuman langur (*Semnopithecus entellus*), golden langur (*Trachypithecus geei*), and capped langur (*Trachypithecus pileatus*). A variant of the Assamese macaque, named *Macaca munzala*, has also been recorded there. Natural hybrids between golden and capped langur occur in an area in south-central Bhutan. The Assamese macaque is the most abundant and widespread primate, while slow loris is the least abundant, with a small range in Bhutan. Primates are not hunted for food in Bhutan, there are large areas of contiguous habitats for primates, and there is, besides, a good network of protected areas in the country. Overall, it would appear that primates have a secure future in Bhutan. The main conservation issues come from development, such as the construction of road networks and hydroelectric projects, grazing by domestic stock in some areas at high elevations, and people living in protected areas.

Key Words: Primates, conservation, *Nycticebus*, *Macaca*, *Semnopithecus*, *Trachypithecus*, *Macaca munzala*, Bhutan

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Introduction

The kingdom of Bhutan in the Himalayan region of the Indian subcontinent is a poorly studied area for non-human primates. Bounded by India on three sides and China (Tibet) along the north and north-west, this mountainous country is known for its conservation of wildlife, strongly influenced by religious beliefs and codes. To date, six, possibly seven, species of non-human primates have been recorded there: the slow loris *Nycticebus bengalensis* (Lacépède, 1800) (formerly *coucang*); Assamese macaque *Macaca assamensis* McClelland, 1840; Rhesus macaque *Macaca mulatta* (Zimmermann, 1780); Hanuman langur *Semnopithecus entellus* (Dufresne, 1797); golden langur *Trachypithecus geei* (Khajuria, 1956); and capped langur *Trachypithecus pileatus* (Blyth, 1843). *Macaca munzala* Sinha *et al*., 2005, a variant of the Assamese macaque and described as a new species, also occurs in Bhutan.

The first report on the primates of Bhutan was published by Choudhury (1990), and further information is available in Choudhury (1992a, 1992b), Wangchuk (1996), Wangchuk *et al*. (2001, 2003, 2004), and Kawamoto *et al*. (2006). There are also a number of synoptic works on primates or wildlife in general covering the sub-continent, which include or mention Bhutan, for example, Pocock (1939, 1941), Prater (1948), Choudhury (1988, 1989, 1997), Corbet and Hill (1992), and Groves (2001, 2005). Here I discuss the distribution, habitat status, and conservation of the primates in Bhutan.

Study Area

The Himalayan kingdom of Bhutan (26°42'–28°20'N 88°45'–92°08'E; 46,500 km² in area) (Fig. 1) is hilly and mountainous. There are small montane valleys in north and middle Bhutan, such as Paro, Thimphu, and Phobjikha, and narrow strips of plains in the south along its border with India. Elevations vary from 100–7,500 m above sea level. Towards the north is the Great Himalayan range. Mt. Kula Kangri (7,554 m above sea level) is the highest peak in Bhutan. The ranges of Lesser Himalaya cover the middle part of the country. The lowest areas are in the south, along India-Bhutan border, especially along the rivers (100 m above sea level.). The main rivers (= *chu*) are the Manas (Dangme *Chu*), Sankosh, Mangde *Chu*, Khulong *Chu*, Kuri *Chu*, Torsa *Chu* and Wang *Chu*. All these ultimately drain into the Brahmaputra River. The Manas (Dangme *Chu*) and one of its tributaries, the Kuri *Chu* are trans-Himalayan rivers, having originated in Tibet (China).

The natural vegetation ranges from tropical wet evergreen and semi-evergreen in the southern foothills to subtropical and temperate forests in the north. Farther north there is the subalpine and alpine vegetation with snow on the high peaks. The climate is tropical monsoon in the south, and montane with a hot and wet summer and a cool and drier winter. The annual rainfall is 2,300–3,800 mm. The temperature ranges from below freezing to 35°C (occasionally to 37°C). The peaks of the Great Himalayan range remain snow-capped for the greater part of the year, while some of the high areas of the Lesser Himalaya, such as the Black Mountains, also experience snowfall in winter. The country is divided into 20 *dzongkhags* or districts.

I have made occasional visits to parts of southern Bhutan since October 1985, and took part in a trip to north-western Bhutan in January 2001, from September 2004 to June 2007. I was able to make frequent visits as part of my official obligations as Deputy Commissioner of Baksa district in Assam, on the border with Bhutan. During these visits, I had many opportunities to observe the primates, along existing paths and roads but also while traveling by boat on the Manas River.

The Primates in Bhutan

Slow loris *Nycticebus bengalensis* (formerly *coucang*)

The slow loris has been recorded in four of the 20 *dzongkhags* of Bhutan (Fig. 2), not to date by direct sightings in the wild, but by more than 11 live animals (the number in each *dzongkhag* shown in parenthesis) obtained by woodcutters and hunters from Pema Gatshel (4), Samdrup Jongkar (3), Sarpang (3) and Zemgang (1) since 1990. I have seen three of these live animals. All were released back to the wild or escaped back into the wild. In 2001, a hunter/woodcutter told me that he saw a loris in the forest towards the south-west of Nganglam in Pema Gatshel *dzongkhag*. During heavy monsoon showers, lorises are occasionally washed down on logs to the plains of Assam. One such was rescued in Tamulpur area of Baksa district on 14 June 2001. From these records it is possible to presume that lorises are present in the Royal Manas National Park, Phibsoo Wildlife Sanctuary and Khaling Wildlife Sanctuary. All the capture sites reported were below 300 m above sea level. The first record for the country was a loris seen near Mathanguri in the 1980s (H. P. Phukan, pers. comm.). Wangchuk *et al*. (2004) wrote that lorises also occur in Chukha and Samchi districts, but did not say on what evidence. To date, we have no records of lorises from the Indian side of these two districts in northern West Bengal (Choudhury 2001). The existing records indicate that the Sankosh River is the western limit for the species in Bhutan as well as Assam. Loris habitat in Bhutan is mostly tropical evergreen and semi-evergreen forests in the foothills. The approximate known 'area of occupancy' (as defined by IUCN 2001) in the country is about 2,500 km².

Assamese macaque *Macaca assamensis*, including *munzala*

The Assamese macaque is the most abundant primate in Bhutan. It occurs from 100 to above 2,900 m above sea level and is the only primate that has been recorded in all the 20 *dzongkhags* (Fig. 3). I have seen it in the *dzongkhags* of Bumthang, Chukha, Mongar, Pema Gatshel, Punakha, Samdrup Jongkar, Sarpang, Thimphu, Trashigang, Trashi Yangshi, Trongsa, Tsirang, Wangdue Phodrang and Zhemgang, and in the Royal Manas National Park, Thrumshingla National Park, Bumdeling Wildlife Sanctuary, Phibsoo Wildlife Sanctuary and Khaling Wildlife Sanctuary. They occur in all of Bhutan's protected areas (Sherub and Sharap pers. comm.). Groups that I have seen (20 of them) ranged in size from two and 40, but they can be as large as 50. Lone individuals were also seen.

The Arunachal macaque, *Macaca munzala*, which I consider to be a variant of *M. assamensis*, was observed only in the *dzongkhags* of Trashi Yangshi and Trashigang (northern parts). In January 2006, I saw two groups, of >10 and >15 macaques, near the Gomukora Monastery and between the Gomukora Monastery and the town of Trashigang, at elevations of 900–1,000 m; much lower than mentioned by Sinha *et. al.* (2005). Sinha *et al.* (2005) informed that the highest elevation for these macaques in Arunachal Pradesh, India was 3,500 m. I saw them at 3,100 m near Geshela, Tawang district in Arunachal Pradesh in 2001, and believed them to be merely a 'dark variant of *assamensis*' (for details on variation in pelage color in *assamensis*, see discussion and Choudhury [2004]).

The habitat of *assamensis* is mostly tropical wet evergreen and semi-evergreen forests in the foothills, subtropical and temperate broadleaf forests in the higher hills and mountains, as well as rocky cliffs with sparse vegetation. Occasionally, they may be seen in subtropical and temperate conifer forests, and rarely in the sub-alpine zone (in the summer). The known 'area of occupancy' in the country is about 20,000 km². *Macaca munzala* occurs in mostly subtropical and temperate broadleaf forests (occasionally coniferous forests) in the higher hills and mountains, as well as rocky cliffs with thin vegetation. The known 'area of occupancy' in the country is about 3,000 km².

Rhesus macaque *Macaca mulatta*

This species has been recorded in six of the 20 *dzongkhags* of Bhutan (Fig. 3). It is confined largely to the southern region of foothills near the India-Bhutan border, at elevations of 100 to 300 m. I have observed groups in the *dzongkhags* of Samchi, Chukha, Pema Gatshel, Samdrup Jongkar, Sarpang and Zhemgang and in the Royal Manas National Park, Phibsoo Wildlife Sanctuary and the Khaling Wildlife Sanctuary. Group sizes ranged from two to 25, but are known to be larger. Their habitats in Bhutan are mostly tropical wet evergreen and semi-evergreen forests, including degraded forests in the foothills. The known 'area of occupancy' in the country is about 4,000 km².

Hanuman langur *Semnopithecus entellus*

The Hanuman langur occurs in western Bhutan, in 10 of its 20 *dzongkhags* (Fig. 4). I have seen it at elevations ranging from 100 to above 2500 m, and Wangchuk *et al.* (2004) reported it from Dochu-la at 3,600 m. I have seen Hanuman langurs in the *dzongkhags* of Chukha, Punakha, Thimphu and Wangdue Phodrang, and they are reported from Samchi, Ha, Paro, Gasa, Daga and the western part of Sarpang. I have never seen them in any protected areas, but they are reported from the Jigme Dorji National Park and Torsa Strict Nature Reserve (Sherub and Sharap, pers. comm.). I did see groups outside protected areas between Dochu-la and Punakha in the *dzongkhag* of Thimphu and south of the township of Wangdue Phodrang in the *dzongkhag* of Wangdue Phodrang in December 2005. In the *dzongkhags* of Sarpang and Daga, these langurs are confined to the west of the River Sankosh; but in Wangdue Phodrang it also occurs east of the river up to Pele-la. The sizes of the Hanuman langur groups that have been seen ranged from 8 to 11. Their habitat is mostly tropical wet evergreen and semi-evergreen forests in the foothills, and subtropical and temperate broadleaf in the higher hills and mountains. They also frequent subtropical and temperate conifer forests and can occasionally be found in the subalpine zone in the summer. The known ‘area of occupancy’ in the country is about 6,000 km².

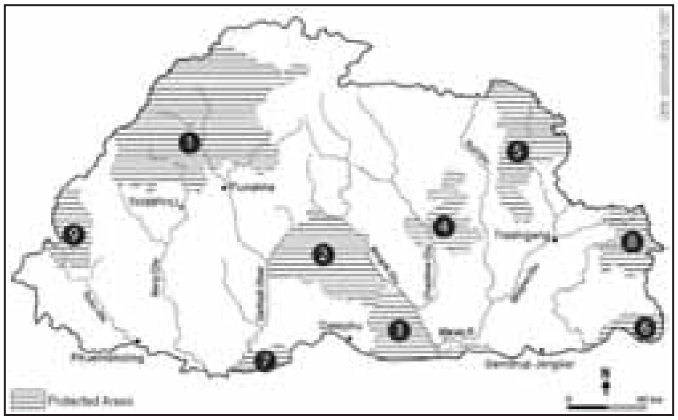

Figure 1. Map of Bhutan showing the general features and the Protected Areas. 1. Jigme Dorji National Park; 2. Jigme Singye Wangchuk National Park; 3. Royal Manas National Park; 4. Thrumshingla National Park; 5. Bumdeling Wildlife Sanctuary; 6. Khaling Wildlife Sanctuary; 7. Phibsoo Wildlife Sanctuary; 8. Sakteng Wildlife Sanctuary; 9. Torsa Strict Nature Reserve. For details, see Table 1. Map by Anwaruddin Choudhury.

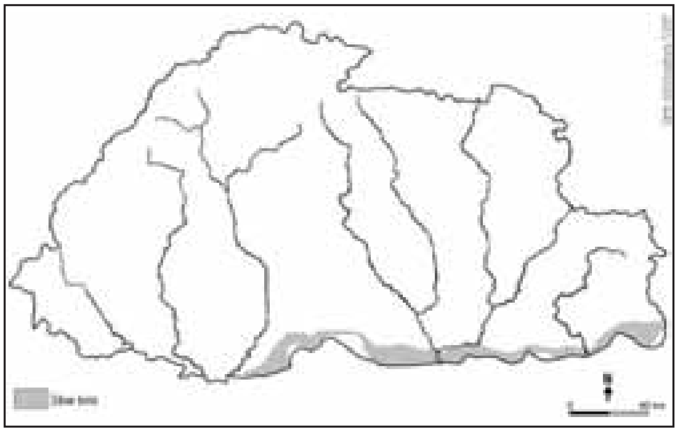

Figure 2. Distribution of slow loris in Bhutan. Map by Anwaruddin Choudhury.

Golden langur *Trachypithecus geei*

The golden langur has been recorded in five of the 20 *dzongkhags* of Bhutan (Fig. 4). One of the more abundant primates of south-central Bhutan, it occurs from 100 to above 2,600 m above sea level, between the Sankosh River and a high mountain ridge (running across Pele-la) in the west, and Manas River, Mangde *Chu* and the high mountain ridge west of Chamkhar *Chu* in the east. I have seen golden langurs in the *dzongkhags* of Mongar, Sarpang, Trongsa, Tsirang, and Zhemgang, and in the Royal Manas National Park, Jigme Singye Wangchuk (Black Mountains) National Park and Phibsoo Wildlife Sanctuary. Group size ranges from 7 to 12, and lone langurs can also be seen.

I saw hybrids of *T. geei* and *Trachypithecus pileatus* in the *dzongkhag* of Zhemgang. These hybrids have features resembling more *geei* than *pileata* (see also the discussion). Four groups were observed around the town of Zhemgang and between Zhemgang and Buli in April 2005. The group size of these hybrid langurs ranged from 9 to 12, and three lone individuals were also seen.

The habitat of golden langur is mostly tropical wet evergreen and semi-evergreen forests in the foothills, and

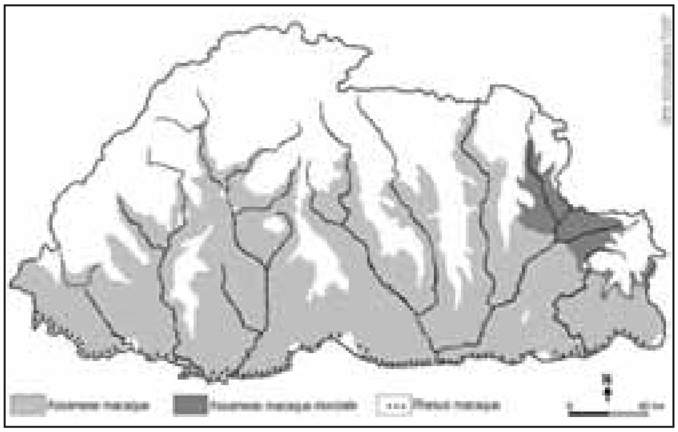

Figure 3. Distribution of macaques in Bhutan. Map by Anwaruddin Choudhury.

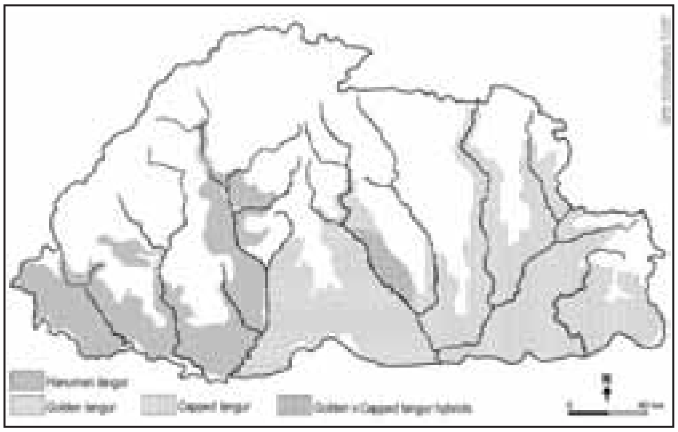

Figure 4. Distribution of langurs in Bhutan. Map by Anwaruddin Choudhury.

Table 1. Protected areas in Bhutan with known primate populations.

Name	Dzongkhag	Area (ha)	Primate species found
Jigme Dorji National Park	Gasa, Punakha, Thimphu and Paro	434,900	Assamese macaque, Hanuman langur
Jigme Singye Wangchuk (Black Mountains) National Park	Zhemgang, Trongsa, Sarpang, Wangdue Phodrang and Chirang	173,000	Assamese macaque, Golden langur
Royal Manas National Park	Zhemgang and Sarpang	102,300	Slow loris, Assamese macaque, Rhesus macaque, Golden langur
Thrumshingla National Park	Bumthang, Lhuentse and Mongar	88,900	Assamese macaque, Capped langur
Bumdeling Wildlife Sanctuary	Trashi Yangtse, Lhuentse and Mongar	148,600	Assamese macaque, Assamese macaque (*munzala*), Capped langur
Khaling Wildlife Sanctuary	Samdrup Jongkar	33,400	Slow loris, Assamese macaque, Rhesus macaque, Capped langur
Phibsoo Wildlife Sanctuary	Sarpang	26,600	Slow loris, Assamese macaque, Rhesus macaque, Golden langur
Sakteng Wildlife Sanctuary	Trashigang	75,500	Assamese macaque, Assamese macaque (*munzala*), Capped langur
Torsa Strict Nature Reserve	Ha and Samchi	65,100	Assamese macaque, Hanuman langur

subtropical and temperate broadleaf in the higher hills and mountains. Occasionally, they can be seen in subtropical and temperate conifer forests. Contiguity with the forests in India was partially lost due to the construction of Sarpang-Gelephu road and the subsequent development of human settlements along it (Choudhury 2002). The known 'area of occupancy' in the country is about 3,000 km². The hybrid langurs occur in subtropical and temperate broadleaf forests between 800 and 2,600 m. Their known 'area of occupancy' in the country is about 600 km².

Capped langur *Trachypithecus pileatus*

The capped langur has been recorded in eight of the 20 *dzongkhags* of Bhutan (Fig. 4). A common primate of eastern Bhutan, I recorded it between 100 and a little more than 2,600 m above sea level. Its western limit is the Manas River, Mangde *Chu* and the high mountain ridge west of Chamkhar *Chu*. Groups were observed in the *dzongkhags* of Bumthang, Mongar, Pema Gatshel, Samdrup Jongkar, Trashigang, Trashi Yangshi and Zhemgang. It also occurs widely in Lhuentse, almost up to the Bhutan-China border along the Kuri *Chu.* I have seen capped langurs in the Royal Manas National Park, Thrumshingla National Park, Bumdeling Wildlife Sanctuary and Khaling Wildlife Sanctuary. Group size ranged from 9 to 13, and individuals can sometimes be seen alone. The habitat of capped langur is mostly tropical wet evergreen and semi-evergreen forests in the foothills, and subtropical and temperate broadleaf forests in the higher hills and mountains, as well as rocky cliffs with sparse vegetation. It can occasionally be found in subtropical and temperate conifer forests. The known 'area of occupancy' in the country is about 7,000 km².

Conservation Issues

Habitat destruction and fragmentation

Forest destruction through tree felling and human encroachment is not a serious problem in Bhutan as a whole. In the border areas, in the *dzongkhags* of Samchi, Chukha, Sarpang, Pema Gatshel and Samdrup Jonkar, for example, illegal immigrant loggers are a matter of concern. This, along with road development and expanding settlements could put the slow loris in some trouble through the fragmentation of its habitat. For the other species of primates, the existing level of harvesting of forest resources is unlikely to be of any serious concern, although Wangchuk *et al.* (2004) reported that commercial logging in eastern Bhutan is a threat to capped langur habitat.

Grazing of domestic stock, with seasonal movements of large herds from summer hill pastures and back to the lowlands in the winter (transhumance), are a serious concern for protected areas at the higher elevations. The pastures for yaks (*Bos grunniens*), cross breeds between yak and cattle, and between mithun (the domesticated gayal, *Bos frontalis*) and cattle, are increasing in the area at the cost of natural habitats. In winter, forest fires, mostly set by accident, also damage forests, especially conifers.

Poaching and trade

There is no organized poaching or trade of any primate inside Bhutan. The illegal woodcutters and loggers from across the border occasionally take slow loris or young golden langur when they catch them opportunistically. These are either kept as pets or eventually released. The hunters from India are occasional visitors, unlike woodcutters who are regulars. These occasional hunters do not do much damage to wildlife as a whole; they hunt otters (the skin is in high demand in Tibet), and sometimes small game (deer, wild pig) but not primates.

Other problems

Other conservation issues include the rapid development occurring in some parts of the country, and a number of proposed hydroelectric projects. The construction of some bridges has been given as the cause of hybridization of langurs in some places (Wangchuk *et al.* 2004; Brandon-Jones 2005; also see discussion). Power lines passing through forests represent a potential threat to primates due to electrocution (no such cases have been reported from Bhutan, there have been instances of this in nearby Assam). Lastly, there are villages inside the protected areas, which may not be of any immediate conservation concern, but could be major issues in future management.

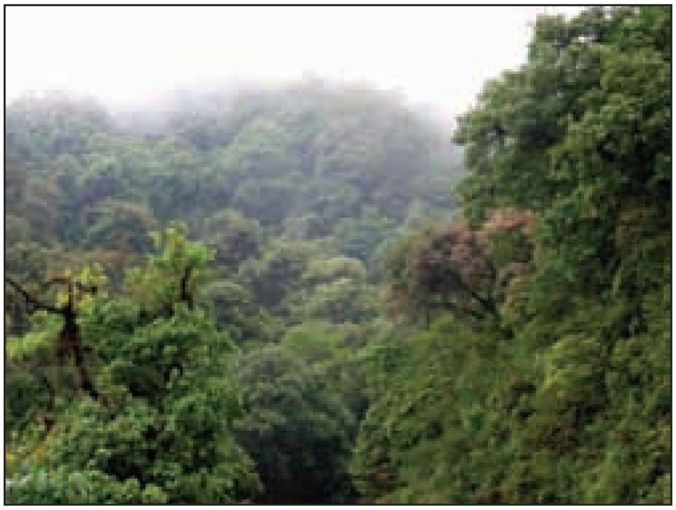

Figure 5. Subtropical broadleaf forests in eastern Bhutan: a key habitat for capped langur and Assamese macaque. Photo by Anwaruddin Choudhury.

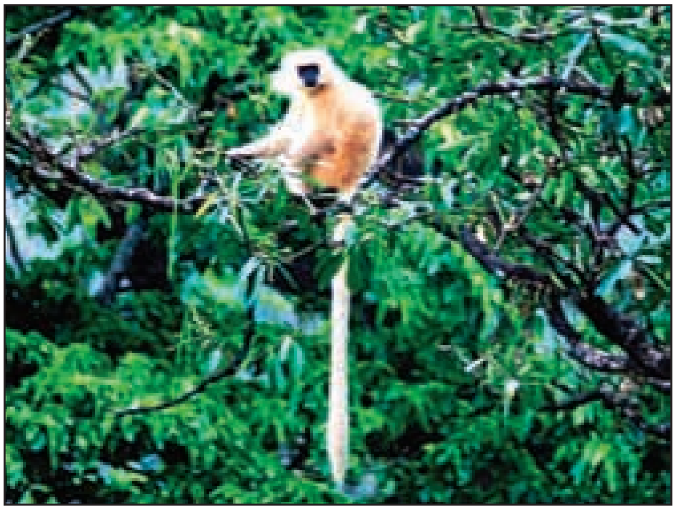

Figure 6. A golden langur at 100 m elevation in Royal Manas National Park. Photo by Anwaruddin Choudhury.

Figure 7. The tropical forests of Royal Manas National Park are major habitat of slow loris and golden langur. Photo by Anwaruddin Choudhury.

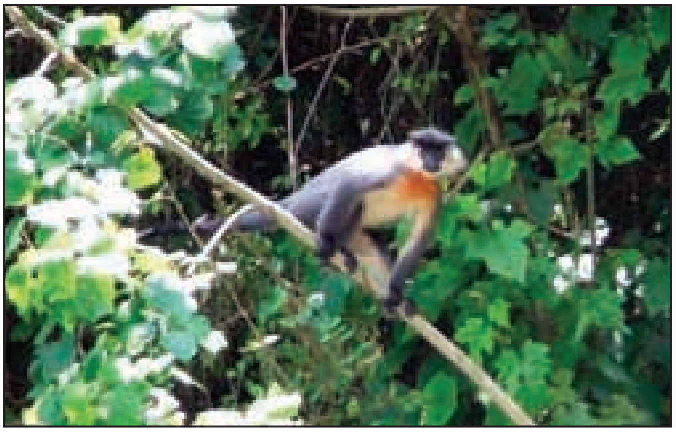

Figure 8. A capped langur at 1,100 m elevation above Deothang in eastern Bhutan. Photo by Anwaruddin Choudhury.

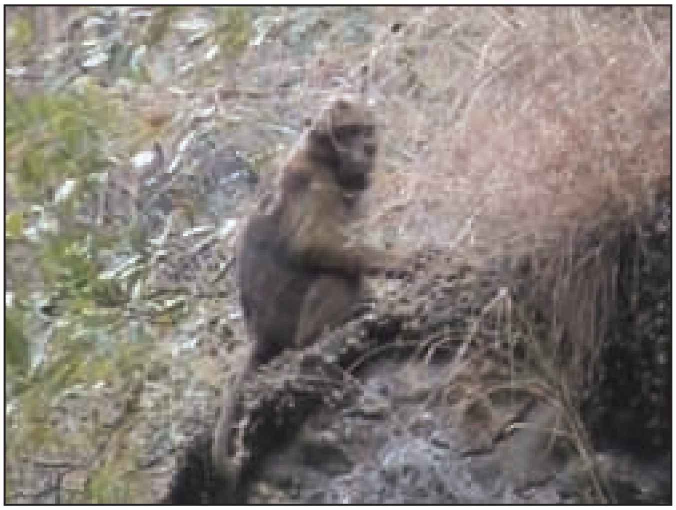

Figure 9. The variant Assamese macaque, *munzala* from Trashi Yangshi district at 900 m elevation. Note the small but clear 'hair tuft' and longer muzzle in the above photo and white on buttock area in the photo on the right. Photo by Anwaruddin Choudhury.

Figure 10. The variant Assamese macaque, *munzala* from Trashi Yangshi district at 900 m elevation. Note the white on buttock area in the above photo and the small but clear 'hair tuft' and longer muzzle in the photo on the left. Photo by Anwaruddin Choudhury.

Figure 11. A male hybrid langur in Zhemgang. Note its almost golden langur-like coat except for two blackish 'horn' like tufts. Photo by Anwaruddin Choudhury.

Figure 13. Another adult hybrid langur in Zhemgang. Note its entirely grey arms, thighs and tail. Photo by Anwaruddin Choudhury.

Figure 14. A sub-adult of the same group looking like a light-colored capped langur with a lighter grey cap. Photo by Anwaruddin Choudhury.

Figure 12. Another male hybrid langur in Zhemgang. Note its grey forearms, thighs and tail and two blackish 'horn' like tufts. Photo by Anwaruddin Choudhury.

Figure 15. A group of young *Lamas* at a monastery in eastern Bhutan. The influence of Buddhism has played the key role in successful wildlife preservation including those of the primates in Bhutan. Photo by Anwaruddin Choudhury.

Conservation Measures

The golden langur is protected under Schedule 1 of the Forest and Nature Conservation Act 1995. There are nine protected areas (four national parks, four wildlife sanctuaries and a strict nature reserve) in Bhutan, but only five of them are operational (Bhutan, Ministry of Agriculture 2002). Some of the protected areas are fairly large and contain significant primate habitat (see Table 1). IUCN (2007) lists the golden and capped langurs as 'Endangered', the Assamese macaque as 'Vulnerable', the Rhesus macaque and Hanuman langur as 'Lower Risk', and the slow loris as 'Data Deficient' (see also Molur *et al*. 2003).

Discussion

Bhutan offers a rare opportunity for long-term conservation of these different species of primates, as well as other wildlife, because 72.5% of its land area is under forest cover (Bhutan, Ministry of Agriculture 2002). An added advantage is its predominantly Buddhist population, most of which do not hunt animals. There are nine protected areas in Bhutan covering a significant 26.23% of the country's geographical area (Bhutan, Ministry of Agriculture 2002). There would appear to be no threat from poaching for any of the primates, but with the country undergoing rapid development in a number of regions, there could be some threat from habitat loss, alteration and fragmentation in the years to come. Except for some specialized species, such as the nocturnal slow loris in a limited part of the southern low hills, however, other primates are unlikely to be significantly affected.

The Assamese macaque in Bhutan is sympatric with all the other five primates, except perhaps for the form *munzala*, in the east. The range of the Rhesus macaque, although much smaller than that of the Assamese species, is also shared by all the other species in some part or other. The three langur species on the other hand are strictly allopatric, with major rivers and high mountain ridges being zoogeographic barriers.

An interesting feature of the primates of Bhutan is the occurrence of 'natural' hybrids between the capped and golden langurs in the *dzongkhag* of Zhemgang. The hybrid langurs observed near the town of Zhemgang resemble golden langurs from a distance (indicating the dominance of the characteristics of this species), but the various shades of grey become evident on closer inspection. There is no uniform pattern. I have seen in the same group, what would seem to be an almost pure golden langur phenotype, one with a gray back, another with gray flanks, and another looking like a capped langur but with lighter gray. Most had gray on their arms, and two blackish 'hornlike' tufts on their heads. I had suspected such hybridization in the zones of overlap (Choudhury 1992b) in the upper reaches of the rivers, where they narrow and often have natural bridges of fallen trees due to landslides or flash floods. The langurs can also cross the streams because of the boulders. However, Wangchuk *et al* (2004) surmised that the probable cause of such hybrids was the construction of four bridges over Chamkhar *Chu* in the *dzongkhag* of Zhemgang. The hybrid langurs extend over large parts of the *dzongkhag,* north and east of Mangde *Chu*, and it is possible that such hybridization had been going on well before the construction of the bridges. The capped langur occurs on both banks of the Chamkhar *Chu.*

Wangchuk (2003) and Wangchuk *et al* (2003, 2004) mentioned a new subspecies of golden langur in Bhutan they named *Trachypithecus geei bhutanensis*. Brandon-Jones (2005) noted that under the stricter criteria of availability introduced in the 4th edition of the *International Code of Zoological Nomenclature* (ICZN 1999), Article 16.1 insists that every new name published after 1999 must explicitly be indicated as intentionally new. Wangchuk *et al*. (2003) failed to satisfy this requirement as they treated the subspecific name as available from an unpublished report (Wangchuk 2003), and *T. g. bhutanensis* is as such a *nomen nudum*. Be that as it may, the validity of this subpecies requires further analysis, as the characters mentioned, such as grey limbs and tail, could have been due to past instances of hybridization. The hybrid langurs are found in the same general area (see also Brandon-Jones 2005).

The presence of the variant Assamese macaque *munzala* is the first confirmed record for Bhutan, although it was expected due to the close proximity with its range in Arunachal Pradesh. The first sighting of this macaque was in 1997 in western Arunachal Pradesh when it was tentatively identified as *Macaca thibetana* (see Choudhury 1998). Groves (2001) felt that the macaque photo in Choudhury (1998) was of *thibetana*. In 1998, at least seven groups were observed in the Tawang district at elevations as high as 2,900 m, which looked different from those reported in 1997, but were treated as a variant of the Assamese macaque. An adult male *munzala* was photographed at Brokser in the eastern part of the district of Tawang in 1998 (by Rupin Dang, a cinematographer; see Choudhury 2004). Whether this is a new species will need further study. Chakraborty *et al.* (2007) made molecular analyses which indicated its distinct identity, but the significant variation that can be found among *assamensis* in Eastern Himalaya needs a detailed review (see Fooden 2003; Choudhury 2004). The *assamensis* found in the high elevation areas of Bhutan and Arunachal Pradesh do look quite different from *M. assamensis pelops* found in the lower hills of Bhutan, adjacent areas of Assam and northern Bengal, and *M. assamensis assamensis* found widely towards the south and east of the Brahmaputra River.

Recommendations

The protected areas that are not operational, should be made so. Those on the international border, such as Khaling, Manas and Phibsoo should have adequate enforcement with increased staff and regular patrolling in view of trans-border tree-felling and poaching. The development projects should have realistic environmental impact assessments so that the damage to natural habitats is minimal. Livestock grazing in the protected areas may have to be regulated in the future. Awareness campaigns and programs for the regular monitoring of the primate populations are recommended.

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Literature Cited

Bhutan, Ministry of Agriculture. 2002. *Forestry in Bhutan: Facts and Figures*. Department of Forestry Services, Ministry of Agriculture, Royal Government of Bhutan, Thimphu.

Brandon-Jones, D. 2005. Recent developments in South Asian primate taxonomy. Paper presented at the Indo-US International Workshop for Indian Primates, Jodhpur, India, 12–14 September, 2005.

Chakraborty, D., U. Ramakrishnan, J. Panor, C. Mishra and A. Sinha. 2007. Phylogenetic relationships and morphometric affinities of the Arunachal macaque, *Macaca munzala*, a newly-described primate from Arunachal Pradesh, northeastern India. *Molec. Phylogenet. Evol.* DOI:10.1016/j.ympev.2007.04.007.

Choudhury, A. U. 1988. Priority ratings for conservation of Indian primates. *Oryx* 22: 89–94.

Choudhury, A. U. 1989. Primates of Assam: Their distribution, Habitat and Status. PhD thesis, Gauhati University, Guwahati.

Choudhury, A. U. 1990. Primates in Bhutan. *Oryx* 24: 125.

Choudhury, A. U. 1992a. Golden langur — distribution confusion. *Oryx* 26: 172–173.

Choudhury, A. U. 1992b. On probable sympatric distribution of *Presbytis geei* and *P. pileata* in Bhutan. *J. Ecol. Soc.* 3: 49–51.

Choudhury, A. U. 1997. Mammals of Namcha Barwa, Tibet. *Oryx* 31: 91–92.

Choudhury, A. U. 1998. Pere David's macaque discovered in India. *The Rhino Foundation for Nature in NE India Newsl.* 2: 7.

Choudhury, A. U. 2001. Primates in NE India: an overview of their distribution and conservation status. *ENVIS Bulletin: Wildlife and Protected Areas* 1(1): 92–101.

Choudhury, A. U. 2002. Golden langur *Trachypithecus geei* threatened by habitat fragmentation. *Zoo's Print Journal* 17(2): 699–703.

Choudhury, A. U. 2004. The mystery macaques of Arunachal Pradesh. *The Rhino Foundation for Nature in NE India Newsl.* 6: 21–25.

Corbet, G. B. and J. E. Hill. 1992. *The Mammals of the Indomalayan Region: A Systematic Review*. Oxford University Press, Oxford.

Fooden, J. 2003. Tail length in enigmatic north-east Indian macaques and probable relatives. *J. Bombay Nat. Hist. Soc.* 100: 285–290.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.

Groves, C. P. 2005. Order Primates. In: *Mammal Species of the World: A Taxonomic and Geographic Reference*, 3rd Edition, Vol. 1, D. E. Wilson and D. M. Reeder (eds.), pp.111–184. Johns Hopkins University Press, Baltimore.

ICZN. 1999. *International Code of Zoological Nomenclature*. 4th Edition. International Commission on Zoological Nomenclature (ICZN), c/o The Natural History Museum, London. Website: <http://www.iczn.org/>.

IUCN. 2001. *2001 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland.

IUCN. 2007. *The IUCN Red List of Threatened Species*. IUCN – The World Conservation Union, Species Survival Commission (SSC), Gland, Switzerland, and Cambridge, UK. Website: <http://www.iucnredlist.org/>. Accessed: 24 September 2007.

Kawamoto, Y., M. Aimi, T. Wangchuk and Sherub. 2006. Distribution of Assamese macaques (*Macaca assamensis*) in the Inner Himalayan region of Bhutan and their mtDNA diversity. *Primates* 47: 388–392.

Molur, S., D. Brandon-Jones, W. Dittus, A. A. Eudey, A. Kumar, M. Singh, M. M. Feeroz, M. Chalise, P. Priya and S. Walker (eds.). 2003. *Status of South Asian Primates: Conservation Assessment and Management Plan (C.A.M.P.) Workshop Report*. Zoo Outreach Organization and Conservation Breeding Specialist Group (CBSG) – South Asia, Coimbatore, India.

Pocock, R. I. 1939. 1941. *The Fauna of British India: Mammalia. Primates and Carnivora.* Taylor and Francis, London.

Prater, S. H. 1948. *The Book of Indian Animals.* 4th edition 1980. Bombay Natural History Society, Bombay (Mumbai).

Sinha, A., A. Datta, M. D. Madhusudan and C. Mishra. 2005. *Macaca munzala*: a new species from western Arunachal Pradesh, northeastern *India. Int. J. Primatol.* 26: 977–989.

Wangchuk, T. 1996. A census and biogeography of golden langurs in Bhutan. *Tigerpaper* 22(3): 1–6.

Wangchuk, T. 2003. Report on the status and distribution of the golden langur (*Trachypithecus geei*) in Bhutan based on surveys between 1994–2000. Report, Nature Conservation Division, Royal Government of Bhutan, Thimphu.

Wangchuk, T., Y. Kawamoto and M. Aimi. 2001. Discovery of a contact zone between the golden langurs (*Trachypithecus geei*) and capped langurs (*Trachypithecus pileata*) in Bhutan. *Am. J. Primatol.* 54 (suppl. 1): 40.

Wangchuk, T., D. Inouye and M. Hare. 2003. A new subspecies of golden langur (*Trachypithecus geei*) from Bhutan. *Folia Primatol.* 74(2): 104–108.

Wangchuk, T., P. Thinley, K. Tshering, C. Thsering and D. Yonten. 2004. *A Field Guide to the Mammals of Bhutan*. Department of Forestry, Ministry of Agriculture, Royal Government of Bhutan, Thimphu.

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The Time is Now: Survival of the Douc Langurs of Son Tra, Vietnam

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Abstract: Red-shanked douc langur (*Pygathrix nemaeus*) groups were located in the Son Tra Nature Reserve, Da Nang, Vietnam, and two preliminary censuses were undertaken in December 2006 and April 2007. Several teams located and counted Douc Langur groups by direct observation. Large numbers of groups with multiple members were located at various sites in the nature reserve. These findings are highly significant because reports over the last several years have recorded low numbers of Douc groups, and some have predicted an entire loss of doucs in Son Tra Nature Reserve. The numbers of Douc groups and individuals is also very significant since they may represent at least 60% of all of the living red shank Douc Langurs in Vietnam.

Key words: Douc Langur, Vietnam, endangered primate, survey

Introduction

Red-shanked douc langur (*Pygathrix nemaeus*) groups were observed and counted by direct observation during two field seasons in 2006 and 2007 in Son Tra Nature Reserve, Da Nang, Vietnam. The red-shanked douc is the northern variant of douc langur and is characterized by red lower legs, a light yellow face, and white forearms. In Vietnam, the present range of the red-shanked douc langur occurs between 18°29'N and 14°21'N (Lippold 1977, 1995, 1998; Lippold and Vu 1996, in prep.). By any and all measures, this monkey is rare and considered endangered by all international conservation organizations. It is listed as Endangered on the IUCN Red List (IUCN 2007) and is also on Appendix 1 of CITES and in Vietnam's Red Data Book (Anon. 2000). Recent research has revealed that the red-shanked douc is now locally extinct in areas where it was reported just 10 years ago (Lippold and Vu in prep.).

Son Tra Nature Reserve (Fig. 1) is on the Son Tra peninsula (16°06'–16°09'N, 108°13'–108°21'E). It is 10 km from the center of Da Nang City, the third largest city in Vietnam. Da Nang was the location of a major American presence during the Vietnam war. During that time, Son Tra (elevation 696 m) was called Monkey Mountain on military maps and was the location of a primary radar installation. The red-shanked douc langur was first recorded on Son Tra during those years by American service personnel (Van Peenan 1969; Van Peenan *et al.* 1971; Gotchfield 1974), and were the subject of a short study there by the first author in 1974 (Lippold 1977). After the war, intermittent reports (MacKinnon and MacKinnon 1986; A. Eudey pers comm. 1988) indicated that the doucs of Son Tra were extinct. However, more recent studies on Son Tra during the 1990s carried out by Nhat (1993), Lippold (1995, 1998) and Anh (1997) reported that small numbers of red-shanked douc langurs groups could still be found on Son Tra.

The Son Tra Nature Reserve (Fig. 1) was established in 1977 by decision number 41 by the Prime Minister and then upgraded from a cultural and historical site to a Nature Reserve in 1992 by the Ministry of Agriculture and Rural Development because of the presence of the red-shanked douc langur. The nature reserve has a total of 4,439 ha, of which 4,190 are forested. Some of the forest is considered primary, while in other areas it is secondary. Reforestation projects are underway over 249 ha where the forest has been cleared or highly modified (T. D. Phan pers. comm. 2007). Studies by Van Peenan *et al*. (1971) and Lippold (1977) during the Vietnam war, and later Lippold (1995, 1998) and Anh (1997), revealed a rich and varied fauna and flora, with records of at least 985 plants of 143 families, 36 mammals of 18 families, 106 birds of 34 families, 23 reptiles of 12 families, 9 amphibians of 4 families, and 113 insects of 26 families.

Recent reports of a precipitous decline or complete extinction of the douc langur population in Son Tra Nature

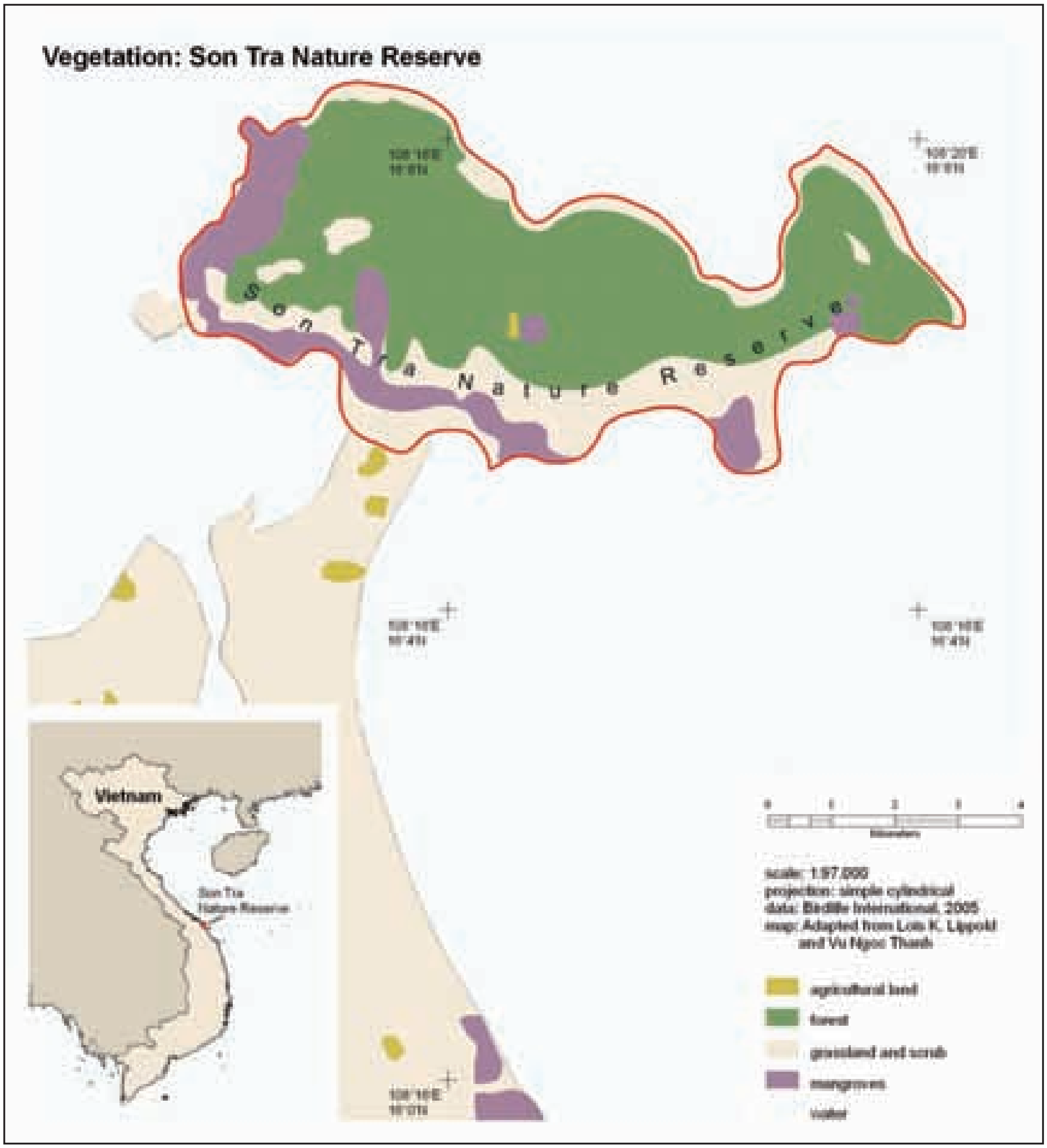

Figure 1. Location of Son Tra Nature Reserve in relation to Vietnam and differentiation of vegetation types (from Birdlife International 2005). Map Conservation International – Leanne Miller.

Reserve (D. T. Phan and M. V. Nguyen pers. comm. 2006), coupled with the recent intensification all kinds of development approaching, and potentially engulfing, the Son Tra peninsula, prompted two surveys to substantiate the permanence of doucs there and assess their conservation status.

Methods

Members of the reserve staff provided specific and accurate information concerning the best survey locations to observe douc groups as well as other primates such as macaques and lorises. Local guides, who had previously been hunters on Son Tra, along with members of the reserve staff accompanied our teams. Due to time and financial constraints this was not a random survey. Field surveys took place over two one-week periods (22–29 December 2006 and 10–17 April 2007) in specific forested areas of Son Tra Nature Reserve, based on locations identified by reserve staff and local guides. Three separate areas were surveyed by teams made up of a guide, one or two researchers, and at least one reserve staff member. Existing trails were used. Once located, the doucs were watched, counted, and differentiated by sex and age. Age and sex of doucs was based on criteria outlined by Lippold (1977). Daylight surveys started around 07:00 and finished at 18:00. Field results were compared each night. During field surveys doucs were identified, their location recorded using GPS receivers, and the locations were mapped. Photographs were taken when possible.

Results

Twelve groups of red-shanked douc langurs were located and observed in a number of locations (Table 1). Groups did not immediately flee as they usually do in areas where they are heavily hunted; instead they remained resting or feeding half an hour or more, allowing us to obtain information on the age-sex composition (Lippold 1977). Most groups contained very small infants and we observed one group with an infant that appeared to have been born during the preceding night. The infant slept in its mother's lap for more than half an hour while she watched us attentively. Ten of the twelve groups had infants and juveniles; a very hopeful indication of population maintenance and growth. The twelve douc groups identified contained at least 171 individuals (Table 1). The smallest group contained six individuals and the largest 24. Since these animals were observed for relatively short periods, it is quite probable that group sizes were underestimated. The ratio of males to females is about 1:2.

Based on these preliminary counts and the area of Son Tra, it is evident that the density of douc langurs is high. In fact, they appear to be the most abundant primate in the nature reserve. The total population of doucs that we were able to record would probably be larger if we had been able to survey the entire area. However, this survey was preliminary, and as a result of the very significant findings; further surveys have been scheduled to assess the douc population more thoroughly throughout the reserve.

Table 1. Son Tra red-shanked douc langurs (*Pygathrix nemaeus*): group sizes, age and sex composition.

Group	No. of individuals	Males	Females	Juveniles	Infants
1	11	3	6	1	1
2	11	2	7	1	1
3	6	3	3	0	0
4	12	4	5	2	1
5	14	4	7	1	2
6	6	2	4	0	0
7	24	7	14	1	2
8	19	5	11	2	1
9	12	3	6	1	2
10	21	6	12	2	1
11	16	5	9	1	1
12	19	6	9	2	2

Doucs were seen most frequently in the tall trees of the high canopy of Son Tra's primary forest. These forests contain tall 40-meter emergents such as *Parashorea stellata*, *Polyalthia* sp. and *Syzgium* sp. and cover approximately one-third of the Son Tra peninsula. Many other primates were seen in the reserve, including the rhesus macaque (*Macaca mulatta*), the stump-tailed macaque (*Macaca arctoides*), long-tailed or crab-eating macaque (*Macaca fascicularis*), and the pygmy loris (*Nycticebus pygmaeus*). Traps and snares of various kinds were observed in all parts of the reserve. Many traps were constructed along the trails, but they were also set at the base of the douc langur's fruit-feeding trees. Doucs were seen to come to the ground to gather fruit and might have been trapped in these snares if they had not been removed. We disassembled and broke all the snares and traps that we found. Any animals alive in the traps were released. One infant rhesus macaque was found alive in a trap with a wire noose around its neck. Its mother was close by and calling to the infant. The infant was photographed and immediately released to its mother. She bravely came from her hiding place, scooped up the infant and ran into the trees.

Discussion

The good news is that this was a very successful set of surveys. They substantiated not only the presence of red shanked douc langurs at Son Tra Nature Reserve but also that large numbers of groups with multiple members were present in several areas. The population appeared to be healthy with some groups numbering over twenty members. We are certain that several more groups will be located in future surveys. In these two short surveys we found more animals than had been seen in several months of surveys in other locations (Lippold and Vu in prep.); suggestive of a very high density of doucs in the fairly restricted area of Son Tra Nature Reserve.

One of the historical problems for Son Tra has been its status as a military installation. Because of this, many animals were shot by the military in target practice. Certainly this was the case during the American presence. This situation apparently continued after the war when the Vietnamese military took over the radar installation. However, this practice has been curtailed, if not entirely stopped, as a result of the active management of the forest by ranger staff of Son Tra Nature Reserve. Son Tra was demarcated as special-use forest in 1977, and was then elevated to nature reserve status in 1992. At that time, a small reserve staff was installed in a headquarters at the base of Mt. Son Tra on the only road leading up to the military installation on the southwestern side of the peninsula.

According to the director and rangers of the nature reserve, illegal hunting and trapping is currently the major threat to all of the animals of Son Tra. The number of guns has been reduced over the years by governmental decree and recent confiscations of firearms from local residents of Da Nang. However, traps of every type were found along the trails, at the base of trees, along streams and in all areas of the reserve. We found large numbers of noose snares set for terrestrial mammals, such as deer, muntjac, porcupine and wild pig, but some were also built and placed to catch primates. Several traps were found at the base of fruiting and flowering trees where doucs were observed to come to the ground to gather fruits. Certainly primates coming to the ground to collect the fruit would be caught. In some areas it was impossible to move around without walking into a snare. All of this activity is illegal, but the duties of the small staff do not allow time for them to search for and dismantle traps. This is certainly one area where additional funding for a snare collection patrol could directly influence the survival of many of the forest animals, including doucs.

Collection of firewood for production of charcoal and non-timber forest products such as resins, palm leaves, cycad, and rattan are common activities in the reserve. Resin is collected from one of the doucs' favorite feeding trees, *Parashorea*. Large holes are gouged in the bark at the base of the tree causing the tree to bleed resin. Over time this activity supports the destructive activity of termites and weakens the trees so that they eventually succumb to strong winds and the occasional typhoons that are characteristic of Son Tra. A strong typhoon in 2007 (D. T. Phan pers. comm. 2007) devastated the eastern side of Son Tra and destroyed large numbers of trees that had been weakened by resin collecting.

Compounding the many challenges for Son Tra is the fact that it has been slated for development by the People's Committee of Da Nang expressly because of its beautiful beaches and its potential for tourism. A massive construction program is underway that will link the reserve to Da Nang City by way of a huge new bridge. At least eight new roads are being built, most leading to the beaches and all of which cut forested areas, producing isolated fragments. Characteristic of road building in Vietnam, the construction crews live along the road they are building. They utilize the adjacent forests; hunting for meat to supplement their rice diets. There is no question that many of Son Tra's animals have been lost due to this type of hunting activity.

Roads are built to entice resort construction on Son Tra's spectacular beaches. One hotel and several small restaurants have already sprung up on the southern shore of Son Tra which joins China Beach, a famous R&R (rest and relaxation) area during the Vietnam War, and prime beach area for both local and foreign tourism. This is not a good sign since it is common at other parks in Vietnam for endangered animals of the nearby forest to appear on the menu of restaurants of resorts and hotels that are in close proximity or within buffer zones of national parks (T. N. Vu pers.obs.; U. Streicher and T. Nadler pers. comm. 2007). Future development plans also include villas and holiday homes in prime locations overlooking the beach. Development plans even include a rescue center for primates with eventual release of rehabilitated primates onto Son Tra (T. Nadler pers. comm. 2007).

The policy of Vietnam is for tourist companies to purchase rights to bring tourists to a specific location. The People's Committee, the governing body of all cities or towns, grants the right for purchase to the tourist company. The proceeds from tourism are then divided between the tourist company and the People's Committee of Da Nang. No money from tourism goes to the Forest Protection Department at either city or reserve level, yet the Forest Protection Department is mandated to protect the forest. The more tourists that come to the nature reserve, the more money there is to divide, so it is in the best interests of the tourist companies to bring as many tourists as possible. The problems of unregulated tourism are many. At the moment, tourist companies can take tourists to the reserve from 07:00 until 22:30, with no supervision of the tourists' behavior. Tourist vans speed up and down roads directly affecting wildlife that might attempt to cross from one isolated forest area to another. Tourists are allowed to hike inside the forest completely unsupervised. They picnic along the streams leaving all their garbage, and often fouling the streams. Tourists leave human waste all over the forest and they chase and sometimes capture and kill wildlife. There have even been some reports of prostitution in this relatively secluded area (D. T. Phan pers. comm. 2007).

The situation and problems of Son Tra are not unique to Vietnam. Beautiful places with nice beaches and wild places always seem to be "discovered" then turned into high density "wild places" with tourist accommodation owned or administered by foreign corporations and priced completely out of the reach of the local residents. There are many examples world wide such as Montezuma in Costa Rica, The Grand Tetons, and Yellowstone National Park, Wyoming, USA (Lippold, field notes). It is always the wildlife that suffers — confined to smaller and smaller habitats so that human development can prosper from the wild. In Vietnam, the traditional method of enjoying the wild consists of bringing a group to the forest, having a picnic or staying for a weekend, staying up late, playing a boom box at top volume and leaving trash and garbage everywhere.

In Vietnam, wild animals are food, and on most occasions Vietnamese talking to the survey members would not ask about the doucs' behavior or characteristics in the wild but how they taste or how to cook them. Visitors understand why we would want to collect animals to eat but not why we would observe, count and conserve these beautiful primates. Primates are hunted for food or medicinal purposes and it is a common occurrence to find them in bottles in alcohol, not as zoological specimens but as tonics for their medicinal value or for sipping as monkey wine. Restaurants in the area often display many bottles containing various animals prepared with alcohol as wine, to be consumed after the meal, as a tonic for a medical condition or as an all purpose tonic.

Son Tra presents a microcosm of the challenges facing conservation in Vietnam today. Competing interests must be balanced for the benefit of both humans and wildlife. On Son Tra, the continued existence of the douc langur, a spectacular primate that has survived subsistence hunting, wars, defoliation and development, hangs in the balance. Whether they survive to be appreciated by future generations of Vietnamese and the world depends on our ability to balance these competing interests… now.

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Literature Cited

Anh, D. T. 1997. Studies on Fauna, Flora and Impact Factors in Son Tra Nature Reserve with Recommendations of Rational Conservation Solutions. Final Report, Da Nang University, Da Nang, Vietnam.

Anonymous. 2000. *Red Data Book of Vietnam. 2000: Animals*. Science and Technical Publishing, Hanoi.

Birdlife International. 2005. *Source Book for Protected Areas of Vietnam*. Hanoi.

Gochfield, M. 1974. Douc Langurs. *Nature, Lond.* 247: 177.

Lippold, L. K. 1977. The douc langur: a time for conservation. In: *Primate Conservation*, H.S.H. Prince Rainier and G. H. Bourne (eds.), pp.513–538. Academic Press, New York.

Lippold, L. K. 1995. Distribution and conservation status of douc langurs in Vietnam. *Asian Primates* 4: 4–6.

Lippold, L. K. 1998. Natural history of douc langurs. In: *The Natural History of the Doucs and Snub-nosed Monkeys*, N. G. Jablonski (ed.), pp.191–206. World Scientific Publishing, Singapore.

Lippold, L.K. and T. N. Vu. 1996. Douc langur variety in the Central Highlands of Vietnam. *Asian Primates* 10: 7–11.

Lippold, L. K. and T. N. Vu. 2004. Density of douc langurs (*Pygathrix* spp.) in Vietnam. Abstract. XX Congress of the International Primatological Society (IPS), August 22–28, Torino, Italy. *Folia Primatol.* 75 (suppl. 1): 295.

Lippold, L. K. and T. N. Vu. In prep. *Douc Langurs of Vietnam: Distribution and Conservation Update.*

MacKinnon, J. and K. MacKinnon. 1986. *Reviews of the Protected Areas System in the Indo-Malayan Realm*. International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland.

Pham, N. 1993. The distribution and status of the douc langur (*Pygathrix nemaeus*) in Vietnam. *Asian Primates* 3(1–2): 2–3.

Phan, D. T. 2005. Study on Biodiversity Values and Impact Factors to Recommend Solutions for Biodiversity Conservation in Son Tra Nature Reserve, Da Nang City Vietnam. Project Report, Son Tra Nature Reserve, Forest Protection Department, Da Nang City, Vietnam.

Van Peenan, P. F. D. 1969. *Preliminary Identification Manual for Mammals of South Vietnam*. United States National Museum, Smithsonian Institution, Washington, DC.

Van Peenan, P. F. D., R. H. Light and J. F. Duncan. 1971. Observations on mammals of Mt. Sontra, S. Vietnam. *Mammalia* 35(1): 126–143.

Vu, T. N., L. V. Khoi *et al*. 2007. Survey Results for Red Shanked Douc Langur in Son Tra Nature Reserve, Da Nang City, Central Vietnam. Technical Report, Hanoi University of Science, Hanoi.

Lois K. Lippold, Douc Langur Foundation, PO Box 23912, San Diego, CA 92193, USA. E-mail: <doucproject@yahoo.com>.
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Diurnal Primates in Sri Lanka and People's Perception of Them

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Abstract: Five species of non-human primates occur in Sri Lanka — the toque macaque (*Macaca sinica*), purple-faced langur (*Trachypithecus vetulus*), slender lorises (*Loris tardigradus* and *Loris lydekkarianus*) and the gray langur (*Semnopithecus priam thersites*). The primates of Sri Lanka are endemic and considered to be Critically Endangered or Endangered. Here we report on some observations, information from interviews with local people regarding primate-human interactions, and also morphological differences in the subspecies we observed during field visits in 2004, 2005, and 2007. When asked, most people stated that they believed that primate populations had increased over the years, and many consider them to be agricultural pests due to the damage they inflict on crops. Due to religious beliefs, hunting and killing of primates were reported in low frequency, but some eat the meat of purple-faced langur for medicinal purposes. The most common methods people use to prevent monkeys from damaging crops are throwing stones, and the use of firecrackers or any other way of producing loud noises. The major threat that these primates face is the destruction of their habitat due to deforestation, human population growth and the expansion of various rural development projects. Public awareness programs for schools and through the media are needed to encourage the protection of these animals and their habitats.

Key words: Toque macaque, purple-faced leaf langur, gray langur, human-primate conflict

Introduction

Sri Lanka is an island, situated between 79°39' and 81°53'E, and 05°54' and 09°52'N, in the Indian Ocean, off the southeastern tip of India. Although small (65,000 km²), Sri Lanka has many endemic species in its fauna and flora (Gunethilleke and Gunethilleke 1983; Erdelen 1988), including five primate species (Table 1) all of which are threatened (Dela 2007; Rudran 2007). The western purple-faced langur (*Trachypithecus vetulus nestor*) and the Horton Plains slender loris (*Loris tardigradus nycticeboides*) are Critically Endangered (IUCN 2008) and have been listed amongst the World's 25 Most Endangered Primates (Dela and Rowe 2006; Nekaris 2006). The toque macaques (three subspecies), the gray-handed crested langur (*Semnopithecus priam thersites*), the remaining three subspecies of the purple-faced langur, and the Sri Lankan subspecies of the lorises, *L. tardigradus* and *L. lydekkerianus*, are all Endangered (IUCN 2008).

The forest cover of Sri Lanka has been declining at a steady rate over the past few decades due to agricultural and irrigational developmental projects and to human settlements (Erdelen 1988; Wickramagamage 1998). Recent developments in the industrial and agricultural sectors and the growing human population have been particularly damaging to the country's remaining forests, and a greater awareness of their plight and measures for their protection are paramount for the survival of these primates. The total closed-canopy forest cover decreased from about 84% of the total land area in 1881 to about 30% in 2005. Rudran (2007) estimated that 81% of the habitat of the Critically Endangered western purple-faced langur is in deforested areas with dense human populations, and only two natural forest patches of about 21 km² remaining around two reservoirs. Owing to the expansion of the plantation industry, forest cover in the hill country has been reduced to isolated patches on hill tops and a handful of reserves above the 1,524 m contour (Wickramagamage 1998), posing a serious threat for the survival of the Endangered slender loris, *L. t. nycticeboides* (Mittermeier *et al*. 2007).

Most of the forests in wet zone and dry zone areas have been fragmented. As a result, primates tend to frequent farms and agricultural plots in search of food. This inevitably creates conflict, as has been reported in many parts of Sri Lanka

Table 1. Primate species and subspecies in Sri Lanka.

	Common name[1]	Reference
Macaca sinica sinica (Linnaeus, 1771)	Common toque macaque	Dittus (1975)
Macaca sinica aurifrons Pocock, 1931	Pale-fronted toque macaque	Dittus (1975)
Macaca sinica opisthomelas Hill, 1942	Hill zone toque macaque	Dittus (1975)
Trachypithecus vetulus vetulus (Erxleben, 1777)[2]	Southern purple-faced langur	Molur *et al.* (2003)
Trachypithecus vetulus monticola (Kelaart, 1850)[2]	Highland purple-faced langur	Molur *et al.* (2003)
Trachypithecus vetulus philbricki (Phillips, 1927)[2]	Northern purple-faced langur	Molur *et al.* (2003)
Trachypithecus vetulus nestor Bennett, 1833[2]	Western purple-faced langur	Molur *et al.* (2003)
Semnopithecus priam thersites (Blyth, 1847)[3]	Grey-handed crested langur	Molur *et al.* (2003)
Loris tardigradus tardigradus (Linnaeus, 1758)	Red slender loris	Nekaris & Jayawardene (2003, 2004)
Loris tardigradus nycticeboides Hill, 1942	Horton Plains slender loris	Nekaris & Jayawardene (2003, 2004)
Loris lydekkerianus grandis Hill & Phillips, 1932	Highland slender loris	Nekaris & Jayawardene (2003, 2004)
Loris lydekkerianus nordicus Hill, 1933	Northern Ceylonese slender loris	Nekaris & Jayawardene (2003, 2004)

[1] Common names follow Brandon-Jones *et al*. (2004).

[2] Brandon-Jones *et al*. (2004) and Dela (2007) consider that the purple-faced langur is a member of the genus *Semnopithecus*. Groves (2001, 2005), Molur *et al*. (2003), and Rudran (2007), on the other hand, place it in the genus *Trachypithecus*.

[3] Groves (2005) considers *Semnopithecus priam thersites* to be a junior synonym of *S. p. priam* (Blyth, 1844).

(McDougal 1987; Sukumar 1989; Nowell and Jackson 1996; Katugaha *et al*. 1999; Santiapillai and Jayawardene 2004). Many of the Sri Lankan primates are found near Buddhist and Hindu temples. The priests are more tolerant, and the constant supply of food received from large numbers of pilgrims (for example, Kataragama, Sellakataragama and Vadasitikanda) keep them around the temple grounds. Primates are otherwise generally restricted to certain National Parks, sanctuaries and remaining forest patches, and only the toque macaque is widespread.

In order to implement effective conservation strategies, it is important to know the current distributions of these primates and their remaining forest habitats in each province and district, as well as the threats they face. Our research aims to document the primate species, their group numbers and sizes, in the national parks and temples. Important too is an understanding of the perceptions that the local communities have of the primates, in order to better assess the context for conservation initiatives.

Methods

To date we have carried out three field trips in Sri Lanka; 2004, 2005 and 2007. Even though subspecies differences among these primates have been clearly described (Dittus 1975; Molur *et al*. 2003), there are no published photographs which effectively illustrate them. We collected photographic records of the toque macaques, purple-faced langurs and gray langurs for this purpose.

In 2004, we spent one week in the Anuradhapura and the Kandy-Udawattakele forest area; in 2005, two weeks traveling to Sinharaja and Polonnaruwa; and in 2007, the Wildlife Department provided permits to survey the primate populations of Bundala, Yala, Udawalawe and Horton Plains national parks. Our surveys, 5–20 February (16 days), consisted of walking the existing trails, accompanied by a guide, and recording all groups seen and their sizes. On our way to these national parks we also collected information on primates in Rumassala, around Kataragama, Badulla, Dambulla and Kandy (for further details of places visited see Table 2). We have also observed primates living in the suburbs of Colombo (Wijerama — around the University of Sri Jayawardenepura, Boralasgamuwa, Navinna).

In 2007, we interviewed people during the field trip using a questionnaire, accompanied by images of each primate species with their common names in Sinhalese, Tamil and English. The questionnaire included 28 questions on such topics as the primates that could be seen in the area, the approximate number of groups and their group size, whether they damage crops, whether measures are taken to prevent crop damage, about the extent of hunting and eating primates, land use, and about peoples' opinions of primates.

Results

External morphological subspecies traits

Characteristic external morphological differences of some of the different subspecies observed are shown in Figures 1–3 (see Table 1 for subspecies listings). The toque macaque of the wet zone (*Macaca sinica aurifrons*) has the darkest pelage color of the three subspecies. The dry zone subspecies (*M. s. sinica*) has the lightest pelage and is the smallest. It has the shortest crown hair length, while the highland subspecies (*M. s. opisthomelas*) has the longest, and *M. s. aurifrons* is intermediate (Fig. 1).

Among the four purple-faced langurs (*Trachypithecus vetulus*), the southern subspecies *(T. v. vetulus*) has the darkest pelage color and their white rump patch is more apparent than in the western (*T. v. nestor*) and northern (*T. v. philbricki*) subspecies. The montane *T. v. monticola* lacks a rump patch, is the largest of the four, and has the longest cheek hairs (Fig. 2). During our surveys, we found that gray langurs (*Semnopithecus priam*) in the southern dry zone are generally lighter in pelage color than in the north (Fig. 3).

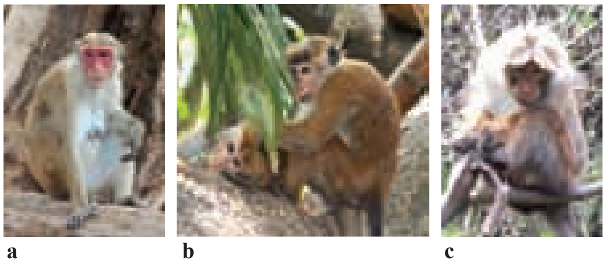

Figure 1. The three macaque subspecies found in Sri Lanka; **a.** *Macaca sinica sinica* – (Sellakataragama); **b.** *Macaca sinica aurifrons* – (Kandy: Peradeniya Gardens) and **c.** *Macaca sinica opisthomelas* – (Ohiya). Photographs by Charmalie Nahallage.

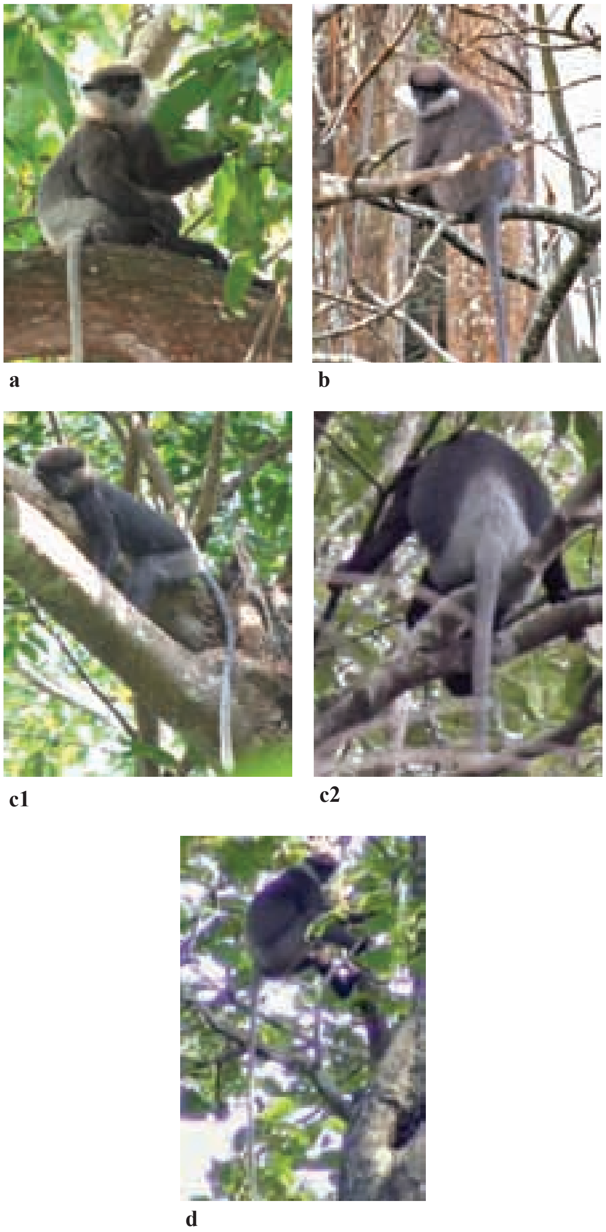

Figure 2. The four purple-faced langur subspecies found in Sri Lanka; **a.** *Trachypithecus vetulus nestor* – (Wijerama: Colombo); **b.** *Trachypithecus vetulus monticola* – (Pattipola); **c.** *Trachypithecus vetulus vetulus* – (**c1**. Rumassala, **c2**. Sinharaja); and **d.** *Trachypithecus vetulus philbricki* – (Polonnaruwa). Photographs by Charmalie Nahallage.

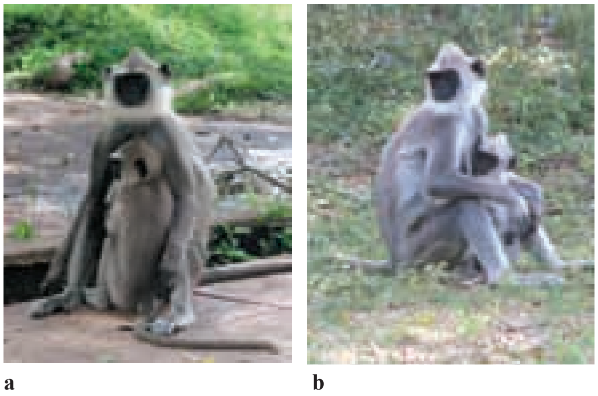

Figure 3. The gray langur *Semnopithecus priam thersites* found in Sri Lanka; **a.** north central dry zone (Anuradhapura) (photograph by Michael Huffman); and **b.** southern dry zone (Bundala National Park) (photograph by Charmalie Nahallage).

Distributions of primate species in National Parks and surrounding areas

We observed only two primate species in the three southern national parks of Bundala, Yala and Udawalawe: the toque macaque and the gray langur. The gray langur was the most commonly seen. We saw more groups of gray langurs than macaques, and they were larger (Table 2). The gray langurs in the parks were more habituated to humans and easier to observe. The situation was similar outside the parks. In the Kataragama area (Southern province), grey langurs were seen mostly in Buddhist and Hindu temples, where they were partially provisioned by devotees and priests, and were quite tame. Few macaque groups were observed around these temples, and their groups were smaller (Table 2).

In Horton Plains National Park we recorded four purple-faced langur groups and one macaque group. The langur groups were relatively small and very shy. The macaque group we saw was quite tame, commonly begging for food from people along the road. Outside the park, in the areas of Ohiya and Pattipola, we observed one macaque group and one langur troop (Table 2). The langurs were again quite shy compared to the macaques.

The macaque groups we encountered in the Kandy-Peradeniya Botanical Gardens and in Dambulla were small, except for one we saw in Udawattakale (Table 2). They were quite habituated and commonly begged or stole food from local residents and tourists.

Results of the Questionnaires

We interviewed 39 people in 2007: 14 women and 25 men, 20 to 85 years old. Twelve were small-scale fruit or vegetable vendors, whose livelihoods were affected by primate activities. Housewives and government officers each accounted for six. Wildlife officers and guides working in the park accounted for four each, retired government officers, teachers, traditional doctors, a justice of the peace, fisherman,

Table 2. Number of places visited and primate species observed.

Province District	Location	Species	*T. vetulus* No. of groups (size)	*S. priam* No. of groups (size)	*M. sinica* No. of groups (size)
Western					
Colombo	Wijerama	*T. v. nestor*	3 (6 ± 1.5)	—	—
	Navinna		1 (5)		
	Boralasgamuwa		1 (7)		
Sabaragamuwa					
Ratnapura	Sinharaja Forest	*T. v. vetulus*	1 (8)	—	1(5)
		M. s. aurifrons			
Ratnapura	Udawalawa National Park	*S. p. thersites*		3 (22 ± 27)	1 (20–25)
		M. s. sinica			
Southern					
Galle	Rumassala	*T. v. vetulus*	2 (8 ± 0.7)		
		M. s. aurifrons			
Hambantota	Bundala National Park	*S. p. thersites*		3 (22 ± 17)	2 (13 ± 10)
		M. s. sinica			
Hambantota	Vadasitikanda	*S. p. thersites*		3 (8 ± 6)	2 (8 ± 3)
	Kataragama	*M. s. sinica*		3 (27 ± 12)	1 (9)
	Sellakataragama			2 (5 ± 0.7)	1 (8)
	Katagamuwa			1 (7)	1 (10)
	Sithulpahuwa			1 (31)	1 (26)
	Yala National Park			7 (13 ± 9)	
Uva					
Moneragala	Wellawaya	*M. s. aurifrons*			1 (6)
Badulla	Rawana Ella	*T. v. monticola*			1 (15)
	Ohiya	*M. s. opisthomelas*	1 (20)		1 (10)
Central					
Nuwaraeliya	Horton Plains National Park	*T. v. monticola*	4 (7 ± 3)		1 (15)
	Pattipola	*M. s. opisthomelas*	1(6)		
Kandy	Peradeniya Gardens	*M. s. aurifrons*			
	Udawattakele				1*
	Victoria Reservoir				1*
Matale	Dambulla	*M. s. sinica*			3 (8 ± 5)
North Central					
Anuradhapura	Anuradhapura	*M. s. sinica*		*	*
Polonnaruwa	Polonnaruwa	*M. s. sinica*	*	*	*
North Western					
Kurunegala	Kurunegala	*M. s. sinica*?			*

* Observed but could not determine the number of groups nor their size.

priests and a postmaster accounted for one each. In 2007, we spent the most time in the Southern and Uva provinces, so the results of the questionnaire strongly reflect conditions there rather than in the other provinces we visited. Sixty-one percent of the questionnaires were from the Southern Province, 21% from Uva Province, 10% from the Central Province and 8% were from the Western Province.

When asked about primate numbers, 82% of the people believed that numbers had increased over the years, and 95% informed us that the primates raid crops. All primates except for the lorises were considered pests in all the provinces we visited. Of the people we interviewed, 67% considered them to be pests, 13% did not, and 20% failed to comment. Fifty-one percent said that people do not hunt or kill monkeys, 38% said that some people in their area were known to kill monkeys (all from the Southern and Uva provinces), and 10% made no comment or were unsure.

The most common cause of primate deaths was reported as predation by dogs (26%), leopards (18%), crocodiles (8%) and pythons (8%). Twenty-one percent of the interviewees indicated that there were no natural predators of monkeys in their areas. Other factors reported to be responsible for deaths were electrocution from power lines (13%), hunting (8%) and road kill (3%).

People use a number of methods to prevent monkeys from raiding their crops and gardens. The most common was to use firecrackers (37%) to chase them away. Other frequently used methods were throwing stones (16%) or making loud noises (8%). Others reported using catapults/sling shots (5%) and dogs (3%). Less frequently used were electric barriers, covering fruit trees with nets, hanging red flags or mirrors on crop plants or in the vicinity, and scarecrows. Mostly, these methods were effective and harmless. Only in a few areas did people shoot them (6%) or use traps (2%).

Discussion

The majority of people we interviewed told us that monkey populations and the incidence of crop-raiding had increased over the years. Macaques (*Macaca*), baboons (*Papio*) and guenons (*Cercopithecus*) are the principal crop-raiding monkeys in Asia and Africa (Else 1991; Hill 1997; Naughton-Treves 2001; Osbern and Hill 2005; Riley 2007). This is partly due to their complex social organization, adaptable and intimidating behavior, ability to travel on the ground and in the trees, and their reliance on unspecialized and omnivorous diets (Frothman-Quick 1986; Else 1991; Hill 2000; Webber *et al*. 2007). We have no information on primate population sizes in the past, and so it is difficult to determine whether the perceived increase in numbers is real or due to changes in behavior or forest loss (increased, and forced, proximity to humans). We believe that the last of the three possibilities is the most likely.

Threats to each of the primate species differ in different parts of the country and depend in part on the presence of other primates and the socio-economic status of the area. For example, the purple-faced langurs are the most common primate in the Western Province, and there they are considered pests, damaging houses and raiding garden crops (Dela 2007; Rudran 2007). In Nuweraeliya district (Central Province) they co-exist with macaques, which people consider to be the more troublesome, being more present in human settlements, and stealing food from houses and raiding crops more often than langurs, which are more shy and tend to avoid human habitations. The more terrestrial and omnivorous lifestyle of macaques, compared to the arboreal leaf-eating langurs, brings them closer to humans, and they are considered as pests in many areas. In a similar study around Kibale National Park in Uganda, Hill (2000) found that red-tailed guenons (*Cercopithecus ascanius*) and L'Hoest's guenons (*C. lhoesti*) were more frequent visitors to farms than olive baboons (*Papio anubis*), but the baboons caused more damage to the crops. In the Western Province, langurs can be mostly found in gardens and they eat fruits grown for household consumption but not crops grown for commercial use. In these parts, primates were considered to be more of a nuisance than crop raiding pests, and people were quite tolerant of them. In the Southern and Central provinces, however, macaques and langurs raid commercial crops with more serious consequences. People have a harsher opinion of them as pests. Macaques are considered pests in the districts of Anuradhapura, Polonnaruwa, Kandy and Matale. Gray langurs were considered to be more serious pests than macaques in the areas of Bundala, Kataragama, Sellakataragama, Vadesitikanda and Sithulpahuwa due to their large group sizes and their habit of stealing food from shops as well as damaging crops. More systematic long-term data collection is planned to verify these trends.

In Sri Lanka, people are generally tolerant toward animals due to religious beliefs, and the major threat to their survival is more likely to be the loss of their forest habitats. The few reports we received of killings were all secret operations and on a small-scale since primates are protected by law. Hunting primates for food was not a common practice in most of these areas since most of the people are Buddhists and against the killing of any animal. In some areas, however, especially in the Southern Province, people believe that monkey meat can cure certain illnesses and some use especially the purple-faced langur for medicinal purposes. In the Southern Province it is a common belief that the meat of the purple-faced langur is good for asthma or that it can cure sight defects. Of course, none of this has been medically proven. Another interesting belief of people in the south is that monkey organs (heart and lungs) are being used in the cities for organ transplants in humans due to their close similarity to humans. Some believe that the monkey's right leg contains human flesh, and even if they eat the meat they usually avoid eating this part. When we inquired about the macaques, many reported that they would not eat them because they are smaller and have too little meat — only the meat of the larger langurs was eaten. Consumption of monkey meat can be fatal if it is not prepared properly. Lamabadusuriya (1992) reported an outbreak of salmonella following consumption of monkey meat in the Southern Province (the species eaten was not reported). The author believed that the meat was probably contaminated because the monkey was already dead when the people found it.

Although most farmers believe that primates cause more damage to their crops than other species, some researchers have systematically quantified the crop damage caused by primates and other animals and shown that the damage is far less than the farmers believe (Siex and Struhsaker 1999; Riley 2007). The larger size and large group sizes of primates can give people the wrong impression as to the extent of crop damage. In Sri Lanka too, it is necessary to systematically quantify the damage caused by primates and inform farmers of these results. Together with their help, it will be possible to implement methods to control crop damage, benefiting both primates and farmers alike. Public awareness programs for schools and through the media are needed to encourage the protection of these animals and their habitats.

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Literature Cited

Brandon-Jones, D., A. A. Eudey, T. Geissmann, C. P. Groves, D. J. Melnick, J. C. Morales, M. Shekelle and C.-B. Stewart. 2004. Asian primate classification. *Int. J. Primatol*. 25(1): 97–164.

Dela, J. 2007. Seasonal food use strategies of *Semnopithecus vetulus nestor*, at Panadura and Piliyandala, Sri Lanka. *Int. J. Primatol.* 28: 607–626.

Dela, J. and N. Rowe. 2006. Western purple faced langur *Semnopithecus vetulus nestor* Bennett, 1833. In: R. A. Mittermeier, C. Valladares-Padua, A. B. Rylands, A. A. Eudey, T. M. Butynski, J. U. Ganzhorn, R. Kormos, J. M. Aguiar and S. Walker. 2006. Primates in peril: The world's 25 most endangered primates, 2004–2006, pp.12–13, 24. *Primate Conserv.* (20): 1–28.

Dittus, W. P. J. 1975. Population dynamics of the toque monkey, *Macaca sinica*. In: *Socioecology and Psychology of Primates,* R. H. Tuttle (ed.), pp.125–151. Mouton Publishers, The Hague.

Erdelen, W. 1988. Forest ecosystems and nature conservation in Sri Lanka. *Biol. Conserv.* 43: 115–135.

Else, J. G. 1991. Non-human primates as pests. In: *Primate Responses to Environmental Change*, H. O. Box (ed.), pp.155–165. Chapman and Hall, London.

Frothman-Quick, D. L. 1986. Activity budgets and the consumption of human foods in two troops of baboons (*Papio anubis*) at Gilgil Kenya. In: *Primate Ecology and Conservation*, J. G. Else and P. C. Lee (eds.), pp.221–228. Cambridge University Press, Cambridge.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.

Groves, C. P. 2005. Order Primates. In: *Mammal Species of the World: A Taxonomic and Geographic Reference*, 3rd Edition, Volume 1, D. E. Wilson and D. M. Reeder (eds.), pp.111–184. Johns Hopkins University Press, Baltimore.

Gunathilleke, C. V. S. and I. A. U. N. Gunathilleke. 1983. A forestry case study of the Sinharaja rainforest in Sri Lanka. In: *Forest and Freshwater Development and Conservation in Asia and the Pacific*, L. S. Hamilton (ed.), pp.289–357. Westview Press, Colorado.

Hill, C. M. 2001. Conflict of interest between people and baboons: Crop raiding in Uganda. *Int. J. Primatol.* 21: 299–315.

Hill, C. M. 1997. Crop-raiding by wild vertebrates: the farmer's perspective in an agricultural community in western Uganda. *Int. J. Pest Mgmt.* 43: 77–84.

IUCN. 2008. *2008 IUCN Red List of Threatened Species.* International Union for Conservation of Nature and Natural Resources (IUCN), Species Survival Commission (SSC), Gland, Switzerland, and Cambridge, UK. Available at: <http://www.iucnredlist.org>. Accessed on 15 October 2008.

Katugaha, H. I. E., M. de Silva and C. Santiapillai. 1999. A long-term study on the dynamics of the elephant (*Elephas maximus*) population in Ruhuna National Park, Sri Lanka. *Biol. Conserv.* 89: 51–59.

Lamabadusuriya, S. P., C. Perera, I. V. Devasiri, U. K. Jayantha and N. Chandrasiri. 1992. An outbreak of salmonellosis following consumption of monkey meat. *J. Trop. Med. Hyg.* 95: 292–295.

McDougal, C. 1987. The man-eating tiger in geographic and historical perspective. In: *Tigers of the World: The Biology, Biopolitics, Management and Conservation of Endangered Species*, R. L. Tilson and U. S. Seal (eds.), pp.435–448. Noyes Publications, Park Ridge, NJ.

Mittermeier, R. A., J. Ratsimbazafy, A. B. Rylands, L. Williamson, J. F. Oates, D. Mbora, J. U. Ganzhorn, E. Rodriguez-Luna, E. Palacios, E. W. Heymann, M. C. M. Kierulff, L. Yongcheng, J. Supriatna, C. Roos, S. Walker and J. M. Aguiar. 2007. Primates in Peril: The World's 25 Most Endangered Primates, 2006–2008. *Primate Conserv.* (22): 1–40.

Molur, S., D. Brandon-Jones, W. Dittus, A. Eudey, A. Kumar, M. Singh, M. M. Feeroz, M. Chalise, P. Priya and S. Walker. 2003. *Status of South Asian Primates: Conservation Assessment and Management Plan (C.A.M.P.) Workshop Report, 2003*. Zoo Outreach Organization (ZOO) and CBSG–South Asia, Coimbatore, India.

Naughton-Treves, L. 2001. Farmers, wildlife and the forest fringe. In: *African Rain Forest Ecology and Conservation; An Interdisciplinary Perspective*, A. D. Weber., L. J. T. White, A. Vedder and L. Naughton-Treves (eds.), pp.369–384. Yale University Press, New Haven.

Nekaris, K. A. I. 2006. Horton Plains slender loris, Ceylon mountain slender loris *Loris tardigradus nycticeboides* (Hill, 1942). In: R. A. Mittermeier, C. Valladares-Padua, A. B. Rylands, A. A. Eudey, T. M. Butynski, J. U. Ganzhorn, R. Kormos, J. M. Aguiar and S. Walker. 2006. Primates in Peril: The World's 25 Most Endangered Primates, 2004–2006, pp.10–11, 23. *Primate Conserv.* (20): 1–28.

Nekaris, K. A. I. and J. Jayawardene. 2003. Pilot study and conservation status of the slender loris (*Loris tardigradus* and *L. lydekkerianus*) in Sri Lanka. *Primate Conserv*. (19): 83–90.

Nekaris, K. A. I. and J. Jayawardene. 2004. Survey of the slender loris (Primates, Lorisidae Gray, 1821: *Loris tardigradus* Linnaeus, 1758 and *Loris lydekkerianus* Cabrera, 1908) in Sri Lanka. *J. Zool. Soc., Lond.* 262: 327–338.

Nowell, K. and P. Jackson (eds.). 1996. *Wild Cats: Status Survey and Action Plan*. IUCN, Gland, Switzerland.

Osborn, F. V. and C. M. Hill. 2005. Techniques to reduce crop loss: Human and technical dimensions in Africa. In: *People and Wildlife: Conflict or Coexistence*? R. Woodroffe, S. Thirgood and A. Rabinowitz (eds.), pp.72–85. Cambridge University Press, Cambridge, UK.

Patterson, J. D. and J. Wallis. 2005. *Commensalism and Conflict: The Primate-Human Interface*. American Society of Primatologists, Norman, Oklahoma.

Riley, E. P. 2007. The human-macaque interface: Conservation implications of current and future overlap and conflict in Lindu National Park, Sulawesi, Indonesia. *Am. Anthropol.* 109: 473–484.

Rudran, R. 2007. A survey of Sri Lanka's endangered and endemic western purple-faced langur (*Trachypithecus vetulus nestor*). *Primate Conserv.* (22): 139–144.

Santiapillai, C. and R. Jayawardene. 2004. Conservation of the leopard and other carnivores in Sri Lanka. *Current Sci.* 86: 1063–1064.

Siex, K. S. and T. T. Struhsaker. 1999. Colobus monkeys and coconuts: A study of perceived human-wildlife conflicts. *J. Appl. Ecol.* 36: 1009–1020.

Sukumar, R. 1989. *The Asian Elephant: Ecology and Management*. Cambridge University Press, UK.

Webber, A. D., C. M. Hill and V. Reynolds. 2007. Assessing the failure of a community-based human-wildlife conflict mitigation project in Budongo Forest Reserve, Uganda. *Oryx* 41: 177–184.

Wickramagamage, P. 1998. Large-scale deforestation for plantation agriculture in the Hill country of Sri Lanka and its impacts. *Hydrol. Process* 12: 2015–2028.

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A Review of the Distribution of Grey Slender Loris (*Loris lydekkerianus*) in Sri Lanka

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Abstract: *Loris lydekkerianus* is known to be the most widespread among two currently recognized species of slender loris in Sri Lanka. Here I review the distribution of *L. lydekkerianus* in the island, based on recent literature and data collected over fifty years ago by W. C. Osman Hill and William W. A. Phillips. According to the early literature, *L. l. nordicus* was distributed in the lowland dry zone of north and east Sri Lanka, while *L. l. grandis* was found in hills in the Central Province. Information gathered in this review along with an observation by the author, extends the distribution of *L. lydekkerianus nordicus* towards the southeastern coastal belt of Sri Lanka, and suggests that the actual range of the species could be larger than previously known. Recent observations raise a number of questions on the range, abundance, variation and the biogeography of the hitherto known and possibly unknown forms of slender loris, stressing the need for further studies on these little known taxa.

Key words: Grey slender loris, *Loris lydekkerianus*, Lorisidae, distribution, Sri Lanka

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Introduction

Slender lorises are small, nocturnal primates of the family Lorisidae. There are two species, *Loris tardigradus* Linnaeus, 1758 and *Loris lydekkerianus* Cabrera, 1908, and six subspecies endemic to India and Sri Lanka. Their taxonomy has been revised through museum specimens based on morphology (Groves 1998, 2001). These have been confirmed with behavioral and morphological evidence from wild populations (Coultas 2002; Nekaris 2002; Nekaris and Jayewardene 2002, 2003) and verified by phylogenetic studies of museum specimens (Nekaris *et al*. 2006).

The slender loris in Sri Lanka was formerly regarded as a single species, *Loris tardigradus*, comprising four subspecies: *L. t. tardigradus* (Western Ceylon slender loris); *L. t. nycticeboides* (Ceylon mountain slender loris), *L. t. grandis* (Highland Ceylon slender loris) and *L. t. nordicus* (Northern Ceylon slender loris) (Hill and Phillips 1932; Hill 1933, 1942, 1953; Phillips 1935). Recent studies, however, have revealed that the Sri Lankan races in fact belong to both species of slender loris. *Loris tardigradus* (Sri Lanka red slender loris), endemic to the island, has two recognized subspecies: *L. t. tardigradus* (Linnaeus 1758) and *L. t. nycticeboides* Hill, 1942. *Loris lydekkerianus* (the grey slender loris) is represented in Sri Lanka with two subspecies endemic to the island: *L. l. grandis* Hill and Phillips, 1932 and *L. l. nordicus* Hill, 1933 (Groves 2001; Nekaris and Jayewardene 2002, 2003, 2004; Weerakoon and Goonatilake 2006; Bernede and Gamage 2006; Gamage *et al.* 2006). All four taxa have been assessed as Endangered (IUCN 2008).

Loris t. tardigradus is distributed in the southwestern wet zone of Sri Lanka, while *L. t. nycticeboides* is found in the upper montane cloud forests. *Loris l. grandis* and *L. l. nordicus*, which occur in the hill country and dry zone, respectively, are considered by Groves (1998, p.22; 2001, p.98) to be synonyms — he "could not distinguish *grandis* from *nordicus* externally, though the single skull examined of the former is but marginally distinguishable." Although the form *nycticeboides* was described as a subspecies of *L. lydekkerianus* by Groves (2001) based mainly on its size, it has now been accepted as a subspecies of *L. tardigradus* (Roos 2003; IUCN 2008), as verified by phylogenetic studies of museum specimens; morphology and molecular genetic data (Nekaris *et al.* 2006). The main reasons underpinning such taxonomic confusions are undoubtedly the lack of specimens, especially in rarer forms, and the lack of information on their range boundaries (where one taxon intergrades with another).

Literature on the Distribution of *Loris lydekkerianus* in Sri Lanka

There is a fair amount of recent literature available on the distribution of *Loris lydekkerianus* in Sri Lanka (Hladik and Petter 1970; Petter and Hladik 1970; Eisenberg and Lockhart 1972; Jenkins 1987; Dharmasena 1989; Meier 1989; Bambaradeniya 1996; Nekaris 2003a, 2003b; Walker and Molur 2003; de Silva and de Silva 2004; Nekaris and Jayewardene 2004; Perera *et al*. 2005; Schulze 2005; Bernede and Gamage 2006; Gamage *et al*. 2006), and a considerable amount of data was collected over fifty years ago by W. C. Osman Hill and William W. A. Phillips (Phillips 1926, 1931, 1935; Hill and Phillips 1932; Hill 1933, 1953).

Although its taxonomic status is still being researched, the form we refer to as *Loris lydekkerianus* is known to be the most widespread species in Sri Lanka (Nekaris and Jayewardene 2003, 2004; Bernede and Gamage 2006; Gamage *et al.* 2006). The exact geographic ranges of the two endemic subspecies, *grandis* and *nordicus*, however, have yet to be determined. Here I review the distribution of *L. lydekkerianus* on the island of Sri Lanka based on literature listed above as a step towards an attempt to determine the range of two subspecies.

Historical Distribution of *Loris lydekkerianus* (More Than 50 Years Ago)

According to early literature, *L. l. nordicus* was distributed in the lowland dry zone of north and east Sri Lanka, including the Jaffna peninsula (Hill 1953). *L. l. grandis* was found in hills in the eastern Matale District of the Central Province at altitudes between 330 m and 1,050 m (Hill and Phillips 1932). Hill (1953) found that the range merged with *tardigradus* at lower altitudes, but did not meet the range of *nycticeboides*. Phillips (1980) suggested that the range of *grandis* may have been contiguous with *nycticeboides* before montane forests were felled for cultivation.

Loris lydekkerianus grandis in historical records

The type locality of *Loris l. grandis* is Mousakanda, Gammaduwa in the East Matale Hills or the Knuckles Range (Hill and Phillips 1932). Phillips (1935) argued, however, that "it is possible that this race occurs also throughout the lower foot hills of the mountain cluster of the Central and Uva Provinces" (p.35). It has also been recorded from Opalgalla, on the other side of the ridge where Mousakanda is located (Hill and Phillips 1932), while reports of large lorises from Badulla and Bandarawela were also suspected to be *grandis* (W. W. A. Phillips, quoted by Hill 1933). A specimen of *grandis* from Namunukula was deposited in the British Museum of Natural History (Jenkins 1987).

Loris lydekkerianus nordicus in historical records

The type locality of *L. l. nordicus* is Talawa (Hill 1933). It has also been recorded from Mannar, Jaffna, Anuradhapura, Tammannewa, Wilachchiya, Chavakachcheri, Kekirawa, Sigiriya and Cheddikulam (Phillips 1935; Hill 1933, 1953). Four specimens collected from Anuradhapura, Wilachchiya, Chavakachcheri, and Monaragala in, respectively, 1913, 1914, 1933 and 1939, and a fifth from Point Pedro in Jaffna (date of collection unknown) are deposited in the British Museum of Natural History (Jenkins 1987). Phillips (1935, p.37) also reported that "Although specimens have been obtained from the northern part of the island only, there are persistent rumours of lorises being present in the dry zone jungles of the eastern and south-eastern districts." He also mentioned that *nordicus* occurs throughout the dry zone, but is not common anywhere in its range.

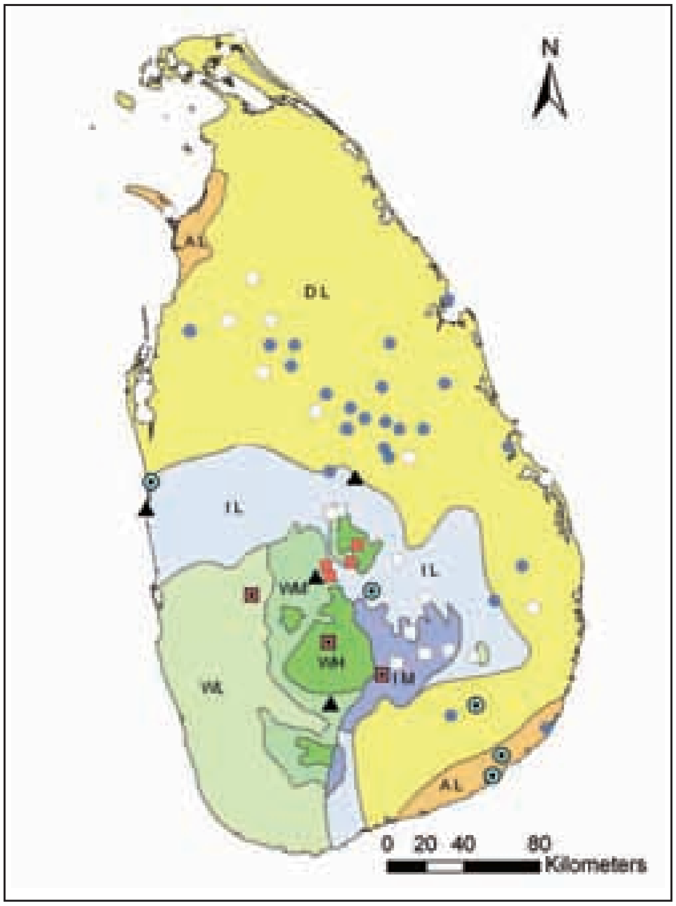

Figure 1. Distribution of grey slender loris, *Loris lydekkerianus*, in Sri Lanka: *L. l. grandis* (squares), *L. l. nordicus* (circles), and intermediate forms (triangles); shaded — recorded within last 50 years; shaded with a central dot — recorded within last 50 years and subspecies suspected; clear — recorded more than 50 years ago and no recent records. **WL** = Wet Lowlands, **IL** = Intermediate Lowlands, **DL** = Dry Lowlands, **AL** = Arid Lowlands, **WM** = Wet Midlands, **IM** = Intermediate Midlands, **WH** = Wet Highlands. Map courtesy of GIS laboratory, Faculty of Geomatics, Sabaragamuwa University.

Lorises have also been recorded from several other sites without positive confirmation of the subspecies, but within the suspected range of *nordicus*. These records include oral reports (quoted by Hill 1933) from localities such as Batticaloa, Tamankaduwa, and Monaragala, wider areas named as Wellassa District, and Bintenna District, as well as two old specimens in the British Museum of Natural History (date

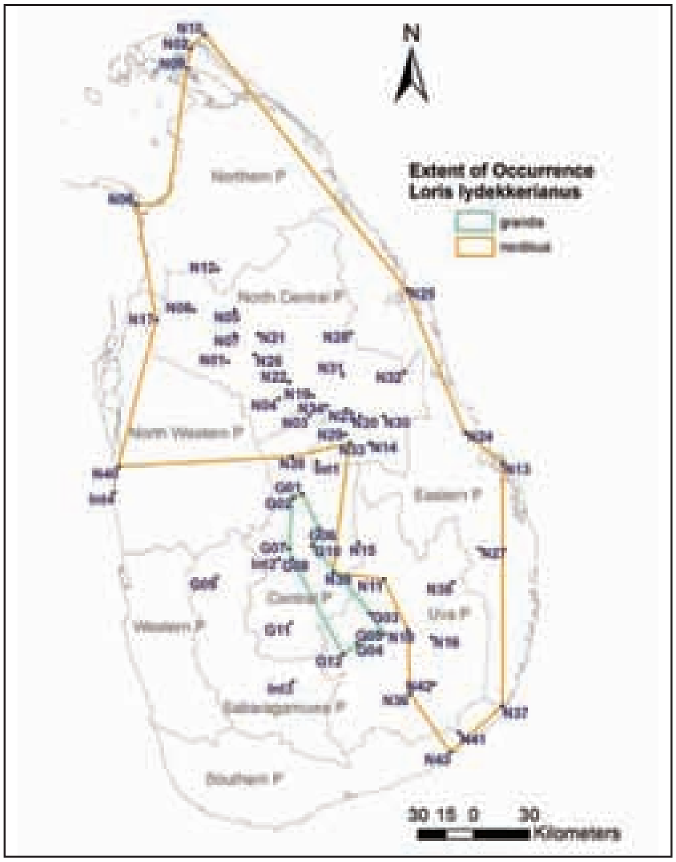

Figure 2. Extent of occurrence of *Loris lydekkerianus grandis* and *Loris lydekkerianus nordicus* shown on a map of administrative provinces of Sri Lanka (**P** = Province). See Table 1 for details of localities depicted by codes: **G** = grandis, **N** = nordicus and **Int** = intermediate forms. The localities of G09 and G11 are exempted from the extent of occurrence of *L. l. grandis*, as further clarification is needed as to which of the subspecies they belong. Map courtesy of GIS laboratory, Faculty of Geomatics, Sabaragamuwa University.

Figure 3. A young *Loris lydekkerianus nordicus* from Wilpattu National Park, Sri Lanka. Photograph by M. S. J. Perera.

of collection unknown), from Monaragala and Badalkumbura (Jenkins 1987). During early surveys, Phillips recorded the strange, shrill cry of a loris without a confirmed sighting in Marai villlu of Wilpattu National Park (Phillips 1933).

Intermediate forms in historical records

An intermediate of *L. l. nordicus* and *L. l. grandis* was recorded from Elahera (Hill 1933). Intermediate forms between *L. tardigradus* and *L. lydekkerianus* have also been recorded from three other localities as follows: intermediates between *L. l. grandis* and *L. t. tardigradus* were recorded from Peradeniya and Balangoda (Phillips 1926, 1935; Hill 1933); and an intermediate between *L. l. nordicus* and *L. t. tardigradus* from Chilaw — the oldest known locality of a loris from Sri Lanka (Tannent 1861; Hill and Phillips 1932; Hill 1933).

Recent Records of *Loris lydekkerianus* (Within the Last 50 years)

Loris lydekkerianus grandis in recent records

Specimens of *Loris l. grandis* in the Field Museum of Natural History, Chicago, were collected by E. C. Fernando from Pindeniya and Digana, in 1961 and 1966, respectively (Schulze 2005). *Loris l. grandis* has recently been recorded from Udawattekele Sanctuary (Petter and Hladik 1970; Dharmasena 1989; Nekaris and Jayewardene 2004), Kandyan Home Gardens (Petter and Hladik 1970) and the Knuckles Range — the type locality (Walker and Molur 2003; Nekaris and Jayewardene 2004).

The specimen from Pindeniya needs to be re-examined and its locality checked, as it lies in the wet lowlands of Sri Lanka, which is otherwise inhabited by *L. t. tardigradus*. Lorises considered to be *L. l. grandis* from Talawakele (Dharmasena 1989), also need a reconfirmation, as this location shows a discontinuity of the geographic range, and is within the wet highlands above the usual altitudinal range of the taxon that could have been inhabited by *L. t. nycticeboides*.

Walker and Molur (2003), in their report of the Conservation Assessment and Management Plan Workshop on Status of South Asian Primates, reported the presence of lorises in Thangamalai Sanctuary, in addition to the Knuckles Range.

Loris lydekkerianus nordicus in recent records

There are a number of opportunistic records of *L. l. nordicus* after 1965: a specimen from Habarana, collected by E. C. Fernando in 1965, deposited in the Field Museum of Natural History, Chicago (Schulze 2005); Polonnaruwa (Hladik and Petter 1970; Petter and Hladik 1970); and Wilpattu National Park (Eisenberg and Lockhart 1972; M. S. J. Perera pers. obs. 2005). The record of a loris from Victoria-Randenigala-Rantambe Sanctuary (Bambaradeniya 1996) is also suspected to be *nordicus* (see Walker and Molur 2003). Walker and Molur (2003) reported the presence of *L. l. nordicus* in Mihintale Sanctuary, Giritale Nature Reserve, Sigiriya Sanctuary, Ampara Sanctuary, Kanthale Forest Reserve,

Table 1. Sources of information for the distribution of grey slender loris, *Loris lydekkerianus*, in Sri Lanka (see Fig. 2).

Code	Locality	Source(s) of Information
G01	Mousakanda, Gammaduwa – Knuckles Range (type locality of *grandis*)	Phillips (1931); Hill & Phillips (1932); Hill (1933); Specimen at British Museum of Natural History, date of collection unknown (Jenkins 1987); Phillips (1935)
G02	Opalgalla	Hill & Phillips (1932)
G03	Badulla	Phillips quoted by Hill (1933)
G04	Bandarawela	Phillips quoted by Hill (1933)
G05	Namunukula (Tonacombe Estate)	Specimen at British Museum of Natural History, date of collection unknown (Jenkins 1987)
G06	Knuckles range	Walker & Molur (2003); Nekaris & Jayewardene (2004)
G07	Udawattekele Forest Reserve	Petter & Hladik (1970); Dharmasena (1989); Nekaris & Jayewardene (2004)
G08	Kandy	Petter & Hladik (1970); Walker & Molur (2003)
G09	Pindeniya	Specimen in the Field Museum of Natural History, Chicago, collected by E. C. Fernando in 1961 (Schulze 2005)
G10	Digana	Specimen in the Field Museum of Natural History, Chicago, collected by E. C. Fernando in 1966 (Schulze 2005)
G11	Talawakele	Dharmasena (1989)
G12	Thangamalai Sanctuary	Walker & Molur (2003)
N01	Talawa (type locality of *nordicus*)	Hill (1933); Phillips (1935)
N02	Jaffna	Hill (1933); Phillips (1935)
N03	Sigiriya Sanctuary	Hill (1933); Phillips (1935); Walker & Molur (2003)
N04	Kekirawa	Hill (1933); Phillips (1935)
N05	Tammannewa	Mayor, quoted by Hill (1933); Phillips (1935)
N06	Mannar	Mayor, quoted by Hill (1933); Phillips (1935)
N07	Anuradhapura	Mayor, quoted by Hill (1933); Phillips (1935); specimen at British Museum of Natural History, collected in 1913 (Jenkins 1987); Nekaris & Jayewardene (2004)
N08	Wilachchiya	Mayor, quoted by Hill (1933); Phillips (1935); specimen at British Museum of Natural History, collected in 1914 (Jenkins 1987)
N09	Chavakachcheri	Specimen at British Museum of Natural History, collected in 1933 (Jenkins, 1987)
N10	Point Pedro	Specimen at British Museum of Natural History, date of collection unknown (Jenkins 1987)
N11	Monaragala, Uva	Specimen at British Museum of Natural History, collected in 1939 (Jenkins 1987)
N12	Cheddikulam	Hill (1953)
N13	Batticaloa	Oral reports quoted by Hill (1933)
N14	Tamankaduwa	Oral reports quoted by Hill (1933)
N15	Bintenna district (Mahiyanganaya)	Oral reports quoted by Hill (1933)
N16	Monaragala and Wellassa district	Oral reports quoted by Hill (1933)
N17	Wilpattu National Park	Phillips (1933); Eisenberg & Lockhart (1972); B. Meier in 1972 and Verner-Carlsson in 1984 quoted by Schulze (2005); Walker & Molur (2003); M. S. J. Perera (pers. obs. 2005)
N18	Badalkumbura	Specimen at British Museum of Natural History, collected in 1955 (Jenkins 1987)
N19	Habarana	Specimen in the Field Museum of Natural History, Chicago, collected by Fernando, E.C. in 1965 (Schulze 2005)
N20	Polonnaruwa Sanctuary	Hladik & Petter (1970); Petter & Hladik (1970); Meier in 1980 (1989); Walker & Molur 2003; Nekaris & Jayewardene 2004
N21	Mihintale Sanctuary	Walker & Molur (2003); Nekaris & Jayewardene (2004)
N22	Ritigala Strict Nature Reserve	Nekaris & Jayewardene (2004)
N23	Giritale Nature Reserve	Walker & Molur (2003); Nekaris & Jayewardene (2004)
N24	Maduru Oya National Park	Nekaris & Jayewardene (2004)
N25	Trincomalee	Nekaris & Jayewardene (2004)
N26	Forests around Nachchaduwa and Turuwila Tanks	R. Jayewardene pers. comm. quoted by Nekaris & Jayewardene (2004)
N27	Ampara Sanctuary	Walker & Molur (2003)
N28	Kanthale Forest Reserve	Walker & Molur (2003)
N29	Angammedilla National Park	Walker & Molur (2003)
N30	Flood Plains National Park	Walker & Molur (2003)
N31	Kaudulla National Park	Walker & Molur (2003)
N32	Somawathie National Park	Walker & Molur (2003)
N33	Wasgomuwa National Park	Walker & Molur (2003)
N34	Minneriya National Park	Walker & Molur (2003)
N35	Menikdena Forest Reserve	Walker & Molur (2003)

continued on next page

Table 1. *continued from previous page*

Code	Locality	Source(s) of Information
N36	Demodara, north-western boundary of Ruhunu National Park	S. Gamage (pers. comm. 2006); Bernede and Gamage (2006)
N37	Kumana National Park	Bernede and Gamage (2006)
N38	Galoya National Park	Bernede and Gamage (2006)
N39	Victoria-Randenigala-Rantambe Sanctuary	Bambaradeniya (1996); Walker & Molur (2003)
N40	Anawilundawa Sanctuary	Perera *et al.* (2005)
N41	Thalgasmankada, Ruhunu National Park	Photographed in 1970s (S. Gunasekara pers. comm. 2007)
N42	Block IV, Ruhunu National Park	de Silva & de Silva (2004)
N43	Block I, Ruhunu National Park	M. S. J. Perera (pers. obs. 2004); Perera *et al.* (in press)
Int1	Intermediate between *nordicus and grandis* – Elahera	Hill (1933)
Int2	Intermediate between *grandis and tardigradus* – Peradeniya	Phillips (1926); Specimen at British Museum of Natural History, date of collection unknown (Jenkins 1987); Phillips (1935)
Int3	Intermediate between *grandis and tardigradus* – Balangoda	Phillips (1926); Hill (1933)
Int4	Intermediate between *nordicus and tardigradus* – Chilaw	Tannent (1861); Hill & Phillips (1932); Hill (1933)

Angammedilla National Park, Flood Plains National Park, Kaudulla National Park, Somawathie National Park, Minneriya National Park and Wasgomuwa National Park, in addition to the sites mentioned earlier.

The reconnaissance survey for slender loris of Nekaris and Jayewardene (2004) included 31 sites in all the bioclimatic zones of the island: 10 of them in the known range of *L. l. nordicus***.** It was recorded from only seven sites, namely Polonnaruwa Smithsonian Primate Research Camp, Anuradhapura, Mihintale Sanctuary, Ritigala Strict Nature Reserve, Minneriya Giritale Nature Reserve (earlier referred to as Minneriya Giritale Sanctuary), Maduru Oya National Park, and Trincomalee. Lorises have also been detected from forests around Nachchaduwa and Turuwila Tanks (R. Jayewardene pers. comm. in Nekaris and Jayewardene 2004).

Loris specimens observed by the author in Anawilundawa Sanctuary (Perera *et al.* 2005) were identified as *L. l. nordicus* based on their general appearance. Some of their coats were reddish rather than grey, suggesting they may have been intermediate forms between *L. t. tardigradus* and *L. l. nordicus* (M. S. J. Perera pers. obs. 2005). Anawilundawa is only about 10 km north of Chilaw from where Tannent (1861) recorded a red slender loris, later also suspected to be an intermediate between *tardigradus* and *nordicus* (Hill and Phillips 1932; Hill 1933). The specimen could, however, have been a juvenile *nordicus* with the reddish color typical of immature animals (Hill and Phillips 1932).

Lorises were not recorded from Wilgamuwa scrub jungle in Matale District, within the known range of *L. l. nordicus*, nor at Elahera and Udawalawe National Park, where Nekaris and Jayewardene (2004) suspected the occurrence of intermediate forms of *nordicus* with other races. Nekaris and Jayewardene (2004) were unable to record lorises from six other sites in southeastern Sri Lanka where they suspected the occurrence of *L. l. nordicus*: Wellawaya (Rosbery Estate and Buttala road), forests around Handapangala tank and Pelwatta, Yala (Ruhunu) National Park, Bundala National Park, Kataragama forest patches, and Nimalawa sanctuary. They noted that "the probability is high that lorises are indeed absent from these areas, have migrated for the time being, or that their densities are low" (Nekaris and Jayewardene 2004, p.329).

Even though historical records and the broad reconnaissance survey conducted by Nekaris and Jayewardene (2004) do not include the southeastern dry zone in the range of *L. l. nordicus,* a few recent records reveal its presence in Ruhunu National Park and adjacent areas. A slender loris, most probably *nordicus*, was recorded in the early 1970s from Thalgasmankada, in Ruhunu National Park more than 5 km inland from the southeast coast (S. Gunasekara pers. comm. 2007). De Silva and de Silva (2004) recorded *L. lydekkerianus* (suspected to be *nordicus*) from block IV of the Ruhunu National Park, more than 20 km inland from the coast. Recent surveys conducted by S. N. Gamage have recorded *nordicus* from several locations in southeast Sri Lanka (unpubl. data). They include Galoya and Kumana (Yala East) National parks and the Demodara area on the northwestern boundary of Ruhunu National Park (S. N. Gamage pers. comm. 2006; Bernede and Gamage 2006). An observation, made by the author on the night of 8 October 2004, extends the range of *L. lydekkerianus* to block I of the Ruhunu National Park, nearly 1 km from the southeastern coast of the island. The animal could not be identified to subspecies level but it is most likely to be *L. l. nordicus* (Perera *et al*. in press).

Concluding Remarks

Even though *L. l. nordicus* has recently been recorded from many new localities, it is interesting to note that they include only three sites with historical records, namely Anuradhapuara, Wilpattu National Park and Sigiriya Sanctuary. This does not necessarily mean the disappearance of lorises from other localities, but the lack of recent surveys covering its historical range. *L. l. grandis* has been recorded only from the Knuckles Range, within its historically known distribution. All other recent records of this race are from areas around Kandy plateau, along with some other localities with records which have not been confirmed as *grandis*. There are many sites from which both above races are recorded historically, where no attempt been made to confirm their presence today. While there is less emphasis on *grandis* in recent studies, there is an urgent need for a detailed distribution study on both subspecies. It should also be noted that only three of 12 localities of *grandis* and 23 of 43 localities of *nordicus* are within the existing protected area network managed by the Department of Wildlife Conservation and the Forest Department of Sri Lanka.

The distribution map (Fig. 1) shows the ranges of the two subspecies of *L. lydekkerianus* in the different bioregions of Sri Lanka (Sri Lanka, Ministry of Forestry and Environment 1999). *L. lydekkerianus* has never been recorded from the wet lowlands with characteristic tropical lowland evergreen (rain) forest and annual rainfall of 2,500 to 5,000 mm.

Loris l. nordicus is found only in the dry arid and intermediate lowlands and not farther up in the hills. Dry lowlands are characterized by dry mixed-evergreen (monsoon) forest and secondary scrub forest ranging in altitude from 0 to 500 m, and receiving an annual rainfall of 1,250–1,900 mm. The annual rainfall is between 1,900 and 2,500 mm in the intermediate lowlands, ranging in elevation from 0 to 1,000 m, with characteristic tropical moist evergreen forest. Arid lowlands receive a rainfall of less than 1,250 mm annually and are characterized by tropical thorn scrub with isolated trees.

Loris l. grandis is found in wet and intermediate midlands ranging in altitude from 1,000 to 1,500 m, and seems to prefer the intermediate climate over the wet. Wet midlands are characterized by tropical sub-montane evergreen forest, with rainfall of 2,500 to 5,000 mm per year, while intermediate midlands are characterized by dry patana grassland and associated moist evergreen forest with 1,900 to 2,500 mm annual rainfall. They do not ascend into the wet highland areas in the central mountain massif (1,500–2,500 m above sea level) with wet patana grassland and tropical montane (cloud) forest, which are inhabited by *L. t. nycticeboides*.

Figure 2 shows the extent of occurrence (IUCN 1994) of *L. l. nordicus* and *L. l. grandis* with codes for their localities that refer to the location names and sources of information given in Table 1.

Information gathered in this review along with an observation by the author, extends the distribution of *L. lydekkerianus* towards the southeastern coastal belt of Sri Lanka, and suggests that the actual range of the species could be larger than previously known. It confirms that even though they are not as abundant as in the northern parts of the island *L. lydekkerianus* is still present in the south. Whether the southern population belongs to the race *nordicus* or to a different race needs to be addressed in future through detailed surveys in the area.

Recent observations raise a number of questions on the range, abundance, variation and the biogeography of the hitherto known and possibly unknown forms of slender loris, stressing the need for further studies on these little known taxa. The 2007 Red List of Threatened Fauna and Flora of Sri Lanka (IUCN-Sri Lanka and the Ministry of Environment and Natural Resources 2007) recorded that *Loris tardigradus* has already been subject to local extinctions, mainly as a result of habitat loss. Researchers have recommended that *Loris lydekkerianus* and *Loris tardigradus* be considered as distinct species for conservation measures (Groves 1998, 2001; Nekaris and Jayewardene 2003). Hence, identification of threats and conservation opportunities within their exact ranges is of vital importance for their survival.

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Literature Cited

Bambaradeniya, C. N. B. 1996. The Victoria-Randenigala-Rantambe Sanctuary. *Loris* XXI(1): 2–4.

Bernede, L. and S. Gamage. 2006. *A Guide to the Slender Lorises of Sri Lanka*. Primate Conservation Society of Sri Lanka, Galle, Sri Lanka.

Coultas, D. S. 2002. Bioacoustic Analysis of the Loud Call of Two Species of Slender Loris (*Loris tardigradus* and *Loris lydekkerianus nordicus*) from Sri Lanka. Master's thesis, Oxford Brookes University, Oxford.

De Silva, M. and P. K. de Silva 2004. *The Yala Wildlife Reserves: Biodiversity and Ecology*. WHT Publications (Private) Limited, Colombo, Sri Lanka.

Dharmasena, C. 1989. The highland Ceylon slender loris. *Loris* XVIII (3): 141–142.

Eisenberg, J. F. and M. Lockhart. 1972. An ecological reconnaissance of Wilpattu National Park, Ceylon. *Smithson. Contrib. Zool.* 101: 1–119.

Gamage, S. N., D. K. Weerakoon and A. Gunawardena. 2006. Current distribution and abundance of slender lorises (*Loris tardigradus* and *L. lydekkerianus*) in Sri Lanka. In: *Abstracts of the 11th International Forestry and Environment Symposium*, p.74. Department of Forestry and Environmental Science, University of Sri Jayawardenapura, Sri Lanka.

Groves, C. P. 1998. Systematics of tarsiers and lorises. *Primates* 39(1): 13–27.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.

Hill, W. C. O. 1933. A monograph on the genus *Loris* with an account of the external, cranial and dental characters of the genus; a revision of the known forms; and the description of a new form from Northern Ceylon. *Ceylon J. Sci. (Spolia Zeylanica)* XVIII(1): 89–132.

Hill, W. C. O. 1942. The slender loris of the Horton Plains, Ceylon, *Loris tardigradus nycticeboides* subsp. nov. *J. Bombay Nat. Hist. Soc.* 43: 73–78.

Hill, W. C. O. 1953. *Primates: Comparative Anatomy and Taxonomy. Vol. I, Strepsirhini*. Edinburgh University Press, Edinburgh.

Hill, W. C. O. and W. W. A. Phillips. 1932. A new race of slender loris from the highlands of Ceylon. *Ceylon J. Sci. (Spolia Zeylanica)* XVII(2): 109–122.

Hladik, C. M. and J. J. Petter. 1970. Le loris tardigrade. Observations de terrains effectuées à Ceylan. *Science et Nature* 101pp.

IUCN 1994. *IUCN Red List Categories*. IUCN – The World Conservation Union, Species Survival Commission (SSC), Gland, Switzerland.

IUCN 2008. *2008 IUCN Red List of Threatened Species.* International Union for Conservation of Nature and Natural Resources (IUCN), Species Survival Commission (SSC), Gland, Switzerland, and Cambridge, UK. Available at: <http://www.iucnredlist.org>. Accessed on 10 October 2008.

IUCN-Sri Lanka and the Ministry of Environment and Natural Resources. 2007. *The 2007 Red List of Threatened Fauna and Flora of Sri Lanka*. Colombo, Sri Lanka.

Jenkins, P. D. 1987. *Catalogue of Primates in the British Museum (Natural History) Part IV: Suborder Strepsirrhini*. British Museum (Natural History), London, UK.

Meier, B. 1989. Genetic management of captive prosimian populations: a report of experience with *Loris tardigradus*. *Hum. Evol*. 4(2–3): 223–229.

Nekaris, K. A. I. 2002. Slender in the night. *Nat. Hist.* 20(2): 54–59.

Nekaris, K. A. I. 2003a. Observations on mating, birthing and parental care in three taxa of slender loris in India and Sri Lanka (*Loris tardigradus* and *Loris lydekkerianus*). *Folia Primatol.* 74(suppl.): 312–336.

Nekaris, K. A. I. 2003b. Rediscovery of the slender loris in Horton Plains National Park, Sri Lanka. *Asian Primates* 8(03):1–7.

Nekaris, K. A. I. and J. Jayewardene. 2002. Status survey and pilot study of the slender loris in Sri Lanka. In: *Caring for Primates*. *Abstracts of the XIXth Congress of the International Primatological Society*, p.340. Mammalogical Society of China, Beijing.

Nekaris, K. A. I. and J. Jayewardene. 2003. Pilot study and conservation status of the slender loris (*Loris tardigradus* and *Loris lydekkerianus*) in Sri Lanka. *Primate Conserv.* (19): 83–90.

Nekaris, K. A. I. and J. Jayawardene. 2004. Survey of slender loris (Primates, Lorisidae Grey, 1821): *Loris tardigradus* (Linnaeus, 1758) and *Loris lydekkerianus* Cabrera, 1908 in Sri Lanka. *J. Zool., Lond.* 262: 327–338.

Nekaris, K. A. I., C. Roos, E. R. Pimley and H. Schulze. 2006. Diversity slowly coming to light: reconsidering the taxonomy of pottos and lorises. *Int. J. Primatol.* 27 (suppl. 1): 441. (Abstract)

Perera, M. S. J., W. P. N. Perera, R. K. Rodrigo, S. P. Ekanayake, C. N. B. Bambaradeniya, V. A. P. Samarawickrema and L. J. M. Wickramasinghe. 2005. *A Biodiversity Status Profile of Anawilundawa Sanctuary – A Ramsar Wetland in the Western Dry Zone of Sri Lanka. Occ. Pap. IUCN Sri Lanka* (9): 48pp. Colombo, Sri Lanka.

Perera, M. S. J., R. K. Rodrigo, W. P. N. Perera, V. A. P. Samarawickrema, M. D. C. Asela, D. C. Perera and P. G. D. R. Perera. In press. Extension of range of the grey slender loris (*Loris lydekkerianus*) towards southeastern Sri Lanka. *Loris*.

Petter, J. J. and C. M. Hladik. 1970. Observations sur le domaine vital et la densité de population de *Loris tardigradus* dans les forêts de Ceylan. *Mammalia* 34: 394–409.

Phillips, W. W. A. 1926. A guide to the mammals of Ceylon. Part IV – The Monkeys. *Ceylon J. Sci. (Spolia Zeylanica)* XIII(3): 261–283.

Phillips, W. W. A. 1931. The food of the Ceylon slender loris (*Loris tardigradus*) in captivity. *Ceylon J. Sci. (Spolia Zeylanica)* XVI(2): 205–208.

Phillips, W. W. A. 1933. Survey of the distribution of mammals in Ceylon (Report 10). *Ceylon J. Sci. (Spolia Zeylanica)* XVIII(1): 133–142.

Phillips, W. W. A. 1935. *Manual of the Mammals of Ceylon. Ceylon J. Sci.* pp.30–36. Dulau and Company, London.

Phillips, W. W. A. 1980. *Manual of the Mammals of Sri Lanka.* 2nd Revised Edition, pp. 117–127. Wildlife and Nature Protection Society of Sri Lanka, Colombo, Sri Lanka.

Roos, C. 2003. Molekulare Phylogenie der Halbaffen, Schlankaffen, und Gibbons. PhD thesis, Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung, Umwelt der Technischen Universität München, München.

Schulze, H. (compiler). 2005. Conservation database for lorises (*Loris*, *Nycticebus*) and pottos (*Arctocebus*, *Perodicticus*), prosimian primates. Last updated 18 July 2005. Available at: <http://www.loris-conservation.org>. Accessed 10 December 2007.

Sri Lanka, Ministry of Forestry and Environment. 1999. *Biodiversity Conservation in Sri Lanka: A Framework for Action*. Battaramulla, Sri Lanka.

Tennent, Sir J. E. 1861. *Sketches of the Natural History of Ceylon*. Spottiswoode and Co., London.

Walker, S. and S. Molur (compilers). 2003. *Summary of the Status of South Asian Primates.* Extracted from the CAMP 2003 Report. Zoo Outreach Organisation, CBSG-South Asia and WILD, Coimbatore, India.

Weerakoon, D. K. and W. L. D. P. T. S. de A. Goonatilake. 2006. Taxonomic status of the mammals of Sri Lanka. In: *Fauna of Sri Lanka: Status of Taxonomy, Research and Conservation*, C. N. B. Bambaradeniya (ed.), pp. 216–231. IUCN – The World Conservation Union, and Government of Sri Lanka, Colombo.

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Population Status and Conservation of Capped Langurs (*Trachypithecus pileatus*) in and around Pakke Wildlife Sanctuary, Arunachal Pradesh, India

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Abstract: A survey of the distribution and population status of the capped langur (*Trachypithecus pileatus*) was conducted in and around the Pakke Wildlife Sanctuary in Arunachal Pradesh, India. From 2001–2003, we surveyed ten selected localities, recording 26 groups and a total of 195 individuals. The data was obtained using line transect surveys and total count methods. Capped langurs were found in a number of different habitats: tropical semi-evergreen forest and moist deciduous forests. Of the 195 individuals registered, 14% were adult males, 52% adult females, 2% unidentified adults, 7% sub-adults, 11% juveniles and 15% infants. The smallest group numbered 3, and the largest 13, with an average group size of 7.5 individuals. The male-female ratio was 1:3.6. The most common size class of the group was of 7–9 individuals.

Key words: Capped langur, population status, sex ratio, group size class, Pakke Wildlife Sanctuary, conservation

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Introduction

The capped langur occurs in northeastern India, Bangladesh, northwestern Myanmar, Bhutan and southern China (Zhang *et al.* 1981; Blower 1985; Stanford 1991; Ahsan 1994; Srivastava and Mohnot 2001). It lives in small groups, mostly single-male, multi-female, but occasionally with more than one male (Mukherjee 1978; Green 1981; Stanford 1991; Mukherjee *et al*. 1995). The species occupies a number of different habitats within its range including stands of bamboo, and plantations in northeast India (Choudhury 1989, 1996; Raman *et al.* 1995). Populations have been declining mainly due to habitat loss and degradation (Srivastava *et al*. 2001a, 2001b) and hunting (for food, medicinal purposes, and artifacts for socio-cultural practices and religious and cult ceremonies [Solanki 2002; Kumar and Solanki 2004]). Here we document the status, distribution, and group size and composition of capped langurs in and around the Pakke Wildlife Sanctuary, Arunachal Pradesh, India. We also report on human impacts on the species and their habitats in the sanctuary so that effective conservation measures can be formulated for the species in the region and particularly for the study area.

Methods

Study area

The Pakke Wildlife Sanctuary (PWLS) (formerly known as Pakhui Wildlife Sanctuary) is located between 92°35' to 93°09'E and 26°55' to 27°15'N, and covers 861.95 km²; 20% of the East Kameng district of Arunachal Pradesh (Fig. 1). It is bordered by Bhoreli River (or Kameng River) in the north and west, by Pakke River in the east, and by the Nameri National Park and Nauduar Reserve Forest of Assam in the south. The sanctuary is well drained by tributaries of the Bhareli and Pakke rivers. The topography is undulating-hilly and the altitude ranges from 200 to 2,040 m above sea level. The climate is tropical and subtropical; cold weather prevails from November to February. Average annual rainfall is 2,599 mm, and the annual mean (± se) maximum temperature is 31 ± 1.1°C, and the mean minimum temperature is 18 ± 1.2°C. There are four primates in the Pakke Wildlife Sanctuary — the rhesus macaque (*Macaca mulatta*), Assamese macaque (*M. assamensis*), the capped langur (*Trachypithecus pileatus*), and the Bengal or northern slow loris (*Nycticebus bengalensis*). The vegetation is Assam Valley type (2B/C1); tropical semi-evergreen with a high density and diversity of trees, woody lianas and climbers (Champion and Seth 1968). Tropical, semi-evergreen forests dominate the lower plains

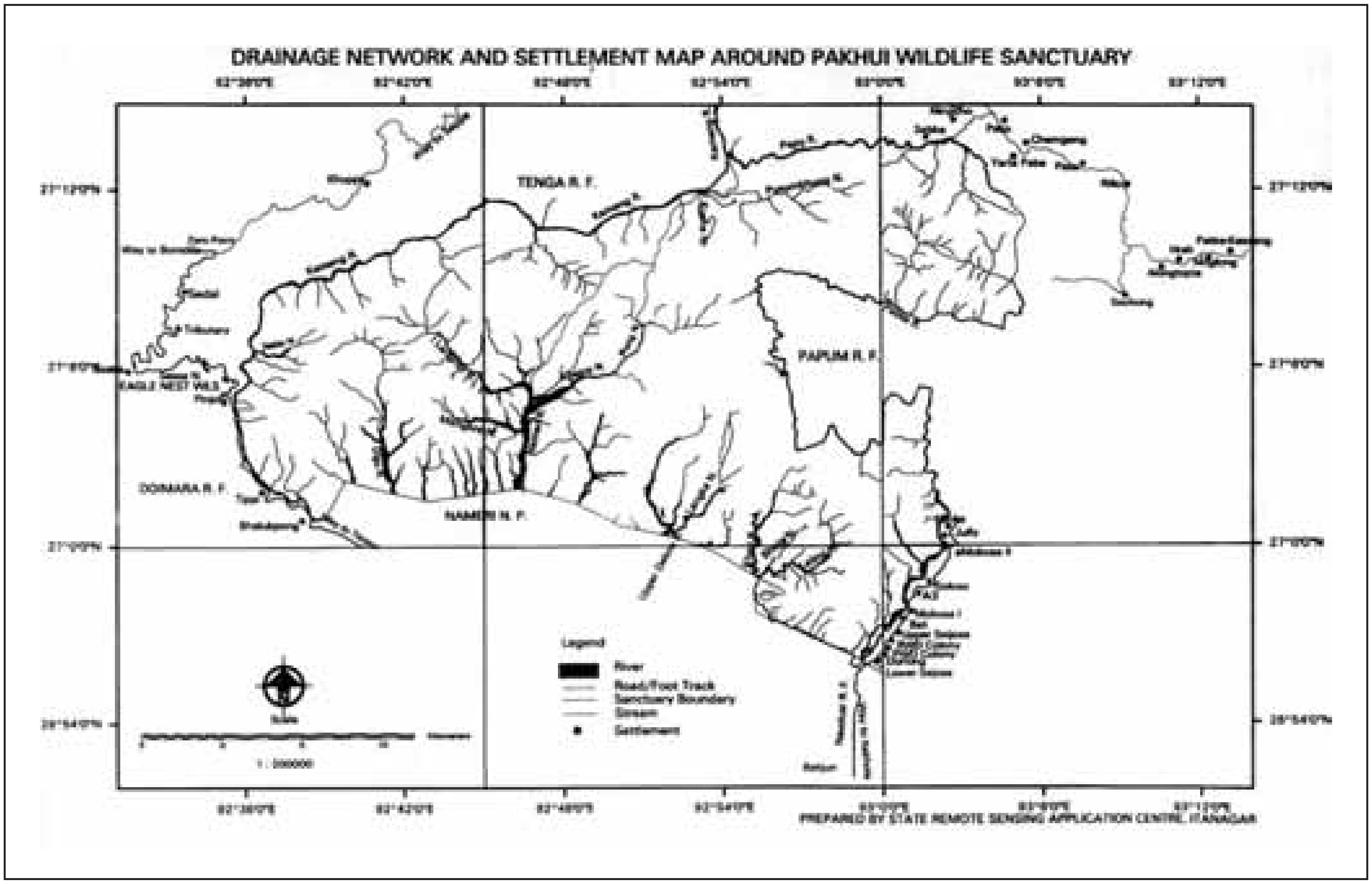

Figure 1. The location of villages around the Pakke Wildlife Sanctuary, Arunachal Pradesh, India.

and foothills, while subtropical, broadleaved, evergreen and dense forests occur at elevations of 900 to 1,800 m above sea level. The Nyishi tribe lives around the sanctuary, one of the major elements of the human population living in the region, which also includes Nepalies, Kuli-bengalies and Bodo tribes.

Methods

A population survey was carried out at selected sites in and around the sanctuary over three years (2001–2003). We interviewed the sanctuary patrols, the range officer and the residents of peripheral villages for information as to the occurrence of capped langur groups in the area. A line-transect method was used to cover all areas in the sanctuary (Brockelman and Ali 1987). Total-count sampling was used in the areas of undulating terrain (NRC 1981). Repeat surveys were conducted on foot, recording group size and structure, sex ratio, vegetation type and any disturbances due to human activities such as settlements, grazing, logging, agriculture, hunting and poaching. Surveys were carried out by one researcher and two local guides from 06:00 to 11:00 and 14:00 to 18:00 or sunset. The langurs were classified into four age categories; adult, sub-adult, juvenile and infant based on the morphological differences described by Stanford (1991).

Results

Population distribution

The surveys covered 201 km of transect in ten different locations (Table 1). Most of the groups sighted were at altitudes of around 800 m (26 groups), and mostly in tropical semi-evergreen forest and moist deciduous forests. Of the 26 groups, 20 were in the sanctuary and six were on the periphery. The maximum number of groups (4) and individuals (38) were recorded at Bhola Nallah Pung (Table 1). Groups ranged in size from 2 individuals to 13, with an average of 7.5 individuals per group.

Group composition

The group structure and composition of capped langurs is shown in Figure 2. Nearly 90% of the population was recorded in one male–multi female social system. The male-female sex-ratio for identified adults was 1:3.6. A group size of 7–9 individuals was most commonly sighted.

Demography of the villages and the livestock

Demographic information on the villages and livestock around the sanctuary, and who are dependent on the sanctuary for their daily needs, is shown in Table 2. We counted 37 villages, totaling 815 houses, 4,787 people in the

Table 1. Numbers and average size of the groups and population density of capped langur.

Location	Distance (km)	No. of groups	No. of individuals	Relative abundance (groups/10 km)	Average group size
Khari	28	3	23	1.07	7.7
Upper Dekorai	25	2	13	0.80	6.5
Bhola Nallah Pung	16	4	38	2.50	9.5
Lalung Nallah Pung	18	2	11	1.10	5.5
Mahauth Palti Nallah	06	2	17	3.30	8.5
West Bank	25	2	14	0.80	7.0
Dichu	28	2	15	0.71	7.5
Tipi (Mithun Nallah)	32	3	25	0.94	8.3
Hatiputi	15	4	24	2.70	6.0
Nameri	08	2	15	2.50	7.5
Total	**201**	**26**	**195**		
Average			**7.5/group**	**1.29**	

surrounding area of PWLS. No human habitation was recorded inside the sanctuary. The number of cattle was 1,967, which generally use the buffer zone of sanctuary for grazing.

Threats

Illegal hunting and the depletion of food plants important to the langurs due to the collection of non-timber forest produce (NTFP) were found to be the most serious threats (Fig. 3). Five capped langur groups totaling 37 individuals were recorded in December 2001 next to the eastern boundary of the sanctuary in Hatiputi area, which comes under the jurisdiction of Nauduar RF, Assam, but by the end of December 2002, the number had dropped to 13; twenty-four lost within a year (Kumar and Solanki 2004). Of these, four died due to accidents (two electrocutions, one bitten by a domestic dog and one fell out of a tree during ground foraging and social playing respectively) and the remaining individuals were hunted by tribal groups for bushmeat, ethno-medicine and socio-cultural practices (Table 3). They are also traded in local and external markets.

Extraction of plant resources

The plants exploited by the local people are shown in Table 4. A number of them are also important foods for the langurs. We recorded 37 plant species of 29 families being used by local people inhabiting the surrounding area of the sanctuary (Table 4). Of these, 21 were also used by the capped langur and other primate species in their diet (Kumar and Solanki 2003; Kumar 2006).

Discussion

Capped langurs occupy all types of habitat inside and outside the sanctuary, but the tropical evergreen and semi-evergreen, deciduous forests with such trees as *Ficus bengalensis, Ficus glomerata*, *Bombax ceiba, Altinga excelsa, Gmelina arborea, Morus levigata* have been found to be important for the distribution of capped langurs in the region (Kumar 2006), and the availability of food trees may be a limiting factor (Joseph and Ramachandran 2003). Most of the langur groups

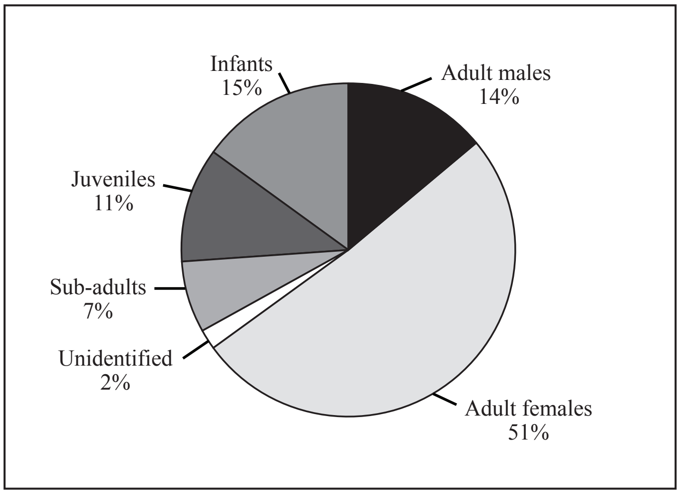

Figure 2. Group composition (%) of capped langur (*Trachypithecus pileatus*).

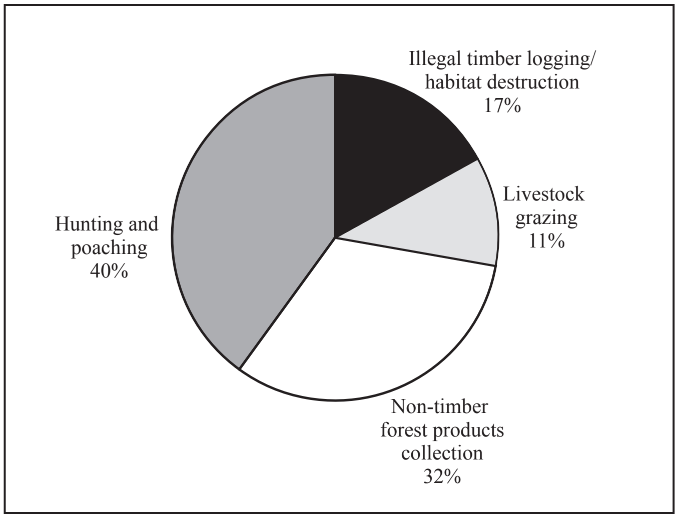

Figure 3. Categories of threats to species and their habitats in the Pakke Wildlife Sanctuary, Arunachal Pradesh.

Table 2. Demographics of human and cattle's population around the Pakke Wildlife Sanctuary, Arunachal Pradesh, India.

	Village	No. of households	Total human population	Total cattle population	Distance (km) from the sanctuary boundary (approx.)
Eastern border					
1.	Murgaso	8	44	43	7.0
2.	Mabusa II	9	44	71	3.0
3.	Lanka	10	55	18	1.5
4.	Jolly	18	122	156	1.0
5.	Goloso	22	116	225	0.5
6.	A3	5	44	79	0.4
7.	Mabusa I /A2	29	148	174	0.4
8.	Upper Bali	18	87	74	0.3
9.	Lower Bali	13	88	94	0.3
10.	Upper Seijosa	120	800	133	0.4
11.	RWD Colony	15	45	25	0.3
12.	Dorlong	53	323	178	0.3
13.	Lower Seijosa	55	350	90	0.4
14.	West Dekorai	20	56	32	0.2
15.	Lomta	5	33	4	2.0
16.	Yayak	6	36	9	3.0
17.	Sochang	9	30	11	3.0
18.	Longpung	6	22	3	3.5
19.	Alongtopte	11	34	20	5.0
20.	Hrah	7	39	18	6.0
21.	Moglong	7	40	10	7.0
22.	Pakke Kessang	65	500	209	9.0
North-eastern border					
23.	Sebba	7	34	12	1.0
24.	Ningcho	8	40	10	4.0
25.	Pako	9	44	0	5.0
26.	Yarte Pabe	11	51	12	3.0
27.	Chemgeng	8	38	3	6.0
28.	Pasa	10	34	12	8.0
Western border					
29.	Balukpong	150	900	156	2.5
30.	Tipi	45	325	56	0.5
31.	Pinjoli	7	40	6	0.5
32.	Sessa	6	32	4	12.0
33.	Tributary	6	36	3	11.0
34.	Sedal	8	42	8	10.0
Northern border					
35.	Kuppi	11	40	3	10.0
36.	Kimi	8	36	2	1.5
37.	Sakchakchum	10	39	4	2.2
Total		**815**	**4,787**	**1,967**	

Table 3. Ethnozoological uses and trading of body parts of capped langur (*Trachypithecus pileatus*).

Body part	Use	Market value (Rs)
Skin with fur (body)	Making children's clothing and small bags	500–800/piece
Skin with fur (tail)	Used for wrapping around the Dao (a big knife)	400–500/piece
Meat	Food	10–115/kg
Dry liver	Eaten by women for safe and easy childbirth	400–450/item
Bones	Headache and cure for rheumatism	-
Teeth	Ornamentation (men, women and children)	-
Skull	Home decoration and used in some cult and religious practices	-
Dry gall bladder	Treatment of malaria, typhoid and other kinds of fever	-
Skin of forehead	An amulet for curing undiagnosed prolonged disease	-

recorded were between 400 m and 1,500 m above sea level. The largest numbers were recorded in the south-eastern part of the sanctuary, from Dichu to west of Tipi. Harwich (1972) argued that evergreen forest is necessary and is always present in the home ranges of this arboreal species.

The size and composition of social groups varies geographically (Chivers and Raemakers 1980) because of habitat structure and food availability. Mukherjee (1978) recorded a group size of 7–13 for this species in the Manas Wildlife Sanctuary, Assam, and 5–16 in Tripura (Mukherjee 1982). In the Tinsukia district of Assam, Choudhury (1995/1996) recorded group sizes of 5–15 individuals. Disturbance, especially hunting, in the Pakke Wildlife Sanctuary may have been the cause of slightly smaller group sizes (2 to 15 individuals). Gupta (1994) recorded smaller groups, averaging of 5.7 individuals, in Gumati Wildlife Sanctuary, Tripura, and similar or slightly larger average group sizes have been recorded elsewhere in northeast India (9.7 — Mukherjee 1978; 10.0 — Choudhury 1995/1996) and Bangladesh (6.4 — Islam and Husain 1982; 7.0 — Green 1978; and 7–9 — Stanford 1987, 1989). The average group size of capped langur is small when compared to other Indian colobine monkeys such as *Trachypithecus. geei*, *T. obscura*, *T. johnii*, *T. phayrei*, *T. senex*, *T. vetulus*, *P. melalophos*, *Semnopithecus entellus*, *Presbytis thomasi,* and *Presbytis rubicunda* (Table 5). Variation in group size in different habitats may be due to the difference in the distribution, abundance and quality of the food resources in the habitat and the population density.

The Pakke Wildlife Sanctuary is also a tiger reserve; hence the core area is mostly free of biotic pressures except for the occasional organized hunting and poaching trips, as informed by the local hunters. Hunting, poaching and habitat destruction, is frequent in the adjacent forest areas of PWLS such as Hatiputi, Nauduar, Charduar reserve forests and Nameri National Park in the Sonitpur District of Assam (Choudhury 1996; Kumar and Solanki 2004; Kushwaha and Hazarika 2004).

Table 4. Plants used by local people and included in the diet of the capped langur (*Trachypithecus pileatus*).

No.	Scientific name	Family	Habit	Commercial/ subsistence use
1.	*Spondias axillaries*[1]	Anacardiaceae	Tree	Edible fruits, bark is chewed as substitute for betel nut
2.	*Mangifera sylvatica*[1]	Anacardiaceae	Tree	Edible fruits
3.	*Spondias pinnata*	Anacardiaceae	Tree	Edible fruits, firewood
4.	*Livistona jenkinsiana*	Arecaceae	Shrub	Leaves for thatch roofing, fruits/seeds edible
5.	*Horsfieldia kingii*	Arecaceae	Tree	Seeds used as betel nut
6.	*Calotropis procera*	Asclepiadaceae	Tree	Edible seeds
7.	*Oroxylum indicum*	Bignonaceae	Tree	Medicinal value of seeds
8.	*Bomabx ceiba*[1]	Bombacaceae	Tree	Cotton from pods
9.	*Canarium bengalense*	Burseraceae	Tree	Resin used as insect repellent
10.	*Bauhinia variegate*[1]	Caesalpiniacea	Tree	Flowers used as vegetable
11.	*Terminalia chebula*[1]	Combretaceae	Tree	Medicinal value of fruits/seeds
12.	*Terminalia bellerica*	Combretaceae	Tree	Medicinal value of fruits/seeds
13.	*Dillenia indica*[1]	Dilleniaceae	Tree	Fruit used as souring agent in food
14.	*Elaeocarpus floribundus*[1]	Elaeocarpaceae	Tree	Seeds used as rosary beads
15.	*Turpinia pomifera*[1]	Staphyleaceae	Shrub	Firewood, bark is used for making fine rope
16.	*Gynocecardia odorata*	Flacourtiaceae	Tree	Bark is used as fish poison
17.	*Gmelina arborea*[1]	Verbenaceae	Tree	Important timber and fodder species
18.	*Talauma hodgsonii*	Magnoliaceae	Tree	Low-grade timber, firewood
19.	*Polyalthia simiarum*	Anonaceae	Tree	Firewood, bark is used for making coarse rope
20.	*Chisocheton paniculates*[1]	Miliaceae	Tree	Low-grade timber, firewood
21.	*Baccaurea ramiflora*[1]	Averriiaceae	Tree	Edible fruits
22.	*Bridelia retusa*[1]	Euphorbiaceae	Tree	Firewood
23.	*Artocarpus chaplasha*[1]	Moraceae	Tree	Timber
24.	*Garcinia cowa*[1]	Clusiaceae	Tree	Edible fruits
25.	*Castanopsis* sp.	Fagaceae	Tree	Timber
26.	*Altingia excelsa*[1]	Hamamelidaceae	Tree	Edible fruits
27.	*Kydia calliciana*[1]	Malvaceae	Tree	Firewood
28.	*Dendrocalamus hamiltonii*[1]	Poaceae	Bamboo	Young tender shoots
29.	*Sterculia villosa*[1]	Sterculiaceae	Tree	Flowers used as vegetable
30.	*Anthocephalus Kadamba*[1]	Rubiaceae	Tree	Flowers used as vegetable
31.	*Aquilaria agallocha*	Thymelaeaceae	Tree	Resin
32.	*Musa* spp.	Musaceae	Tall herb	Young leaves, stem, root has medicinal value
34.	*Syzygium formosum*[1]	Myrtaceae	Tree	Edible fruits
35.	*Paederia foetida*	Rubiaceae	Climber	Medicinal uses, body pain, kidney trouble
36.	*Vengueria spinosa*[1]	Rubiaceae	Tree	Edible fruits, medicinal value
37.	*Mikania micrantha*[1]	Moraceae	Climber	Leaves used for clotting of blood

[1] Plant species included in the capped langur diet.

Table 5. Summary of different colobine monkey social systems.

Species	Average group size	Group type	Study area	Source
Trachypithecus pileatus	7.50	1 or 2-male	Pakke Wildlife Sanctuary, Arunachal Pradesh, India	Present study
T. pileatus	9.70	1 or 2-male	Assam	Mukherjee 1978
T. pileatus	6.40	1 or 2-male	Madhupur National Park, Bangladesh	Islam and Husain 1982
T. pileatus	7.00	1 or 2-male	Madhupur National Park, Bangladesh	Stanford 1987
T. pileatus	9.00	1-male	Madhupur National Park, Bangladesh	Stanford 1989
T. pileatus	5.70	1 or 2-male	Gumati Wildlife Sanctuary, India	Gupta 1994
T. geei	8.20	1-male	Western Assam, India	Srivastava et al. 2001
T. obscura	17.00	1 or 2 male	Krau Game Reserve	Curtin 1980
T. obscura	10.30	1 or 2 male	Krau Game Reserve	MacKinnon and MacKinnon 1980
T. johnii	17.00	1 or 2 male	Ootacumnd Area Nilgiri Hill	Poirier 1970
T. johnii	18.50	1 male	Mundanthurai Plateau	Sunderraj 2001
T. johnii	5.89	1-male/multi-male	Silent Valley National Park, India	Joseph and Ramachandran 2003
T. phayrei	15.00	1 or 2 male	Gumati Wildlife Sanctuary, India	Gupta and Kumar 1994
T. phayrei	11.00	1 or 2 male	Bangladesh	Ahsan 1994
T. phayrei	8.80	1 or 2 male	Rajkandi Reserve Forest, Bangladesh	Stanford 1988
T. senex	11.00	1-male	—	Rudran 1973
T. vetulus	8.40	—	Polonnaruwa	Rudran 1973
T. vetulus	8.90	—	Horton Plains	Rudran 1973
P. melalophos	15.00	1-male	Krau W. Malaysia	Bennett 1983
Semnopithecus entellus	11.00	Multi-male	—	Curtin 1975
S. entellus	5–100 (range)	1-male/multi-male	North India	Jay 1965
S. entellus	22.00	1-male (most)	—	Hladik 1977
Presbytis thomasi	1.00	1-male	—	Gurmaya 1986
Presbytis rubicunda	7.00	1-male	—	Davies 1984
Presbytis aygula	7.00	1-male	—	Ruhiyat 1983
Procolobus badlus	20.00	multi-male	—	Struhsaker 1975
Presbytis cristata	15.00	1-male	—	Wolf and Fleagle 1977
Colobus satanus	15.00	two-male	Douala-Edea, Cameroon	Mckey and waterman 1982
Colobus guereza	12.00	1-male/multi-male	Kibale, Uganda	Oates 1974
Colobus guereza	7.00	1-male/multi-male	—	Dunbar 1987
Nasalis larvatus	12.00	1-male	—	Yeager 1989

Habitat destruction for agricultural activities, permanent settlement, fuel and fodder, and for minor forest produce is also a threat to the sanctuary, and has been since the mid 1990s. There has been an unprecedented number of encroachments by the Bodo tribe, involving clear felling of mature forests for agriculture and settlements in the area bordering the Nameri National Park (Assam) and Pakke Wildlife Sanctuary. Choudhury (2002) reported that reserved forested areas close to the sanctuary and Nameri National Park had been fully converted into agricultural lands and permanent settlements by the end of 2000. The macaques adapted, occupying nearby tea gardens and village woodlands, but the capped langur is now restricted to a few fragmented forests. Crop raiding began following this loss of habitat, as was also reported by Das (1998) in Tripura. The villages close to the sanctuary are using it for grazing; regularly sending large numbers of cattle into the forest there. Grazing pressure is highest from September to November in the sanctuary when agricultural fields are sown with paddy and others crops.

Capped langur, one of the most threatened primates of India due to hunting for their fur and Bushmeat, requires special attention for its long-term survival. The species is declining due to habitat loss and fragmentation and hunting in the entire distribution range of northeast India (Srivastava 2001a, 2001b; Kumar and Solanki 2004) and particularly in Arunachal Pradesh (Solanki and Chutia 2004; Kumar 2006). Preventing hunting and habitat destruction in these protected and non-protected areas is vital for protecting and conserving the species from extinction.

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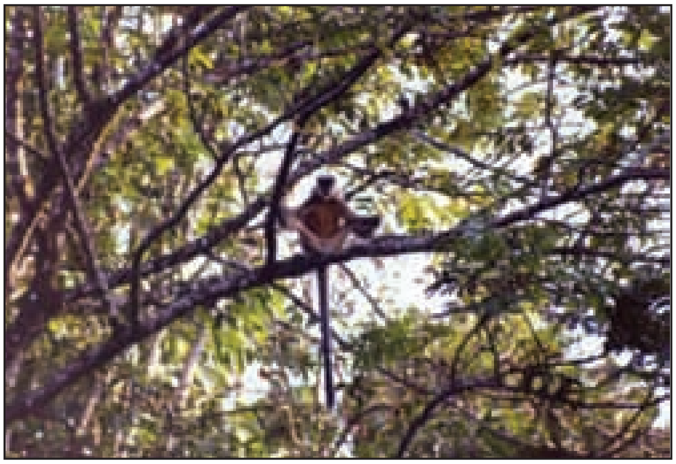
Social group of capped langur (*Trachypithecus pileatus*) at Pakke Wildlife Sanctuary, Arunachal Pradesh, India. Photograph by Awadhesh Kumar.



Adult capped langur male presenting sexual solicitation during the mating season to attract the female. Photograph by Awadhesh Kumar.

Fur of capped langur is used to decorate the sheath of a traditional Dao (a big knife). Photograph by Awadhesh Kumar.

A group of local people carrying the traditional Dao in sheaths decorated with capped langur fur. Photograph by Awadhesh Kumar.

Pregnant female capped langur (*Trachypithecus pileatus*). Photograph by Awadhesh Kumar.

Deforestation around the Pakke Wildlife Sanctuary, Arunachal Pradesh. Photograph by Awadhesh Kumar.

Literature Cited

Ahsan, M. F. 1994. Feeding ecology of the primates of Bangladesh. In: *Current Primatology Volume 1. Ecology and Evolution*, B. Thierry, J. R. Anderson, J. J. Roeder and N. Herrenschmidt (eds.), pp.79–86. Université Louis Pasteur, Strasbourg.

Bennett, E. L. 1983. The Banded Langur: Ecology of a Colobine in a West Malaysian Rain Forest. PhD thesis, University of Cambridge, Cambridge, UK.

Blower, J. G. 1985. Millipedes. Keys and notes for the identification of the species. Synopses of the British Fauna, No. 35. E. J. Brill, Leiden.

Brockelman, W. Y. and R. Ali. 1987. Methods of surveying and sampling forest primate populations. In: *Primate Conservation in the Tropical Forest*, C. W. Marsh and R. A. Mittermeier (eds.), pp.23–62. Alan R. Liss, New York.

Champion, H. G. and S. K. Seth. 1968. *A Revised Survey of the Forest Types of India*. The Manager of Publications, New Delhi.

Chivers, D. J. and Raemaekers, J. J. 1980. Long-term changes in behaviour. In: *Malayan forest Primates: Ten years' Study in Tropical Rain Forest*, D. J. Chivers (ed.), pp.209–260. Plenum Press, New York.

Choudhury, A. 1989. Ecology of the capped langur (*Presbytis pileatus*) in Assam, India. *Folia Primatol.* 52: 88–92.

Choudhury, A. 1995/1996. Primates in Bherjan, Borajan, and Podumoni Reserved Forests of Assam, India. *Asian Primates* 5(3–4): 10–11.

Choudhury, A. 1996. Primates in Assam—status and conservation. *TigerPaper* 23(3): 14–17.

Choudhury, A. 2002. Massive habitat loss for primates in Assam's Sonitpur district. *Asian Primates* 8(1–2): 18–20.

Curtin, R. 1975. Socioecology of the Common Langur (*Presbytis entellus*) in Nepal, Himalaya, PhD thesis, University of California, Berkeley.

Curtin, S. H. 1980. Dusky and banded leaf monkeys. In: *Malayan Forest Primates*: *Ten Years' Study in Tropical Rain Forest*, D. J. Chivers (ed.), pp.107–146. Plenum Press, New York.

Das, S. 1998. Depredations on crops by langurs in Tripura. *Tiger Paper* 25(4):29–31.

Davies, A. G. 1984. An Ecological Study of the Red Leaf Monkey (*Presbytis rubicunda*) in the Dipterocarp Forest of Sabah, Northern Borneo. PhD thesis, University of Cambridge, Cambridge, UK.

Dunbar, R. I. M. 1987. Habitat quality, population dynamics, and group composition in colobus monkeys (*Colobus guereza*). *Int. J. Primatol.* 8(4): 299–329.

Green, K. M. 1978. Primates of Bangladesh: a preliminary survey of population and habitat. *Biol. Conserv.* 13(2): 141–160.

Green, K. M. 1981. Preliminary observations on the ecology and behavior of the capped langur, *Presbytis pileatus* in the Madhupur Forest of Bangladesh. *Int. J. Primatol*. 2(2): 131–151.

Gupta, A. K. and A. Kumar. 1994. Feeding ecology and conservation of Phayre's leaf monkey *Presbytis phayrei* in northeast India. *Biol. Conserv.* 69: 301–306.

Gupta, A. K. 1994. Status and conservation of non-human primates in Tripura, India. In: *Current Primatology Volume 1: Ecology and Evolution*, B. Thierry, J. R. Anderson, J. J. Roeder, and N. Herrenschmidt (eds.), pp.101–111. Université Louis Pasteur, Strasbourg.

Gurmaya, K. J. 1986. Ecology and behavior of *Presbytis thomasi* in northern Sumatra. *Primates* 27: 151–172.

Hladik, C. M. 1977. A comparative study of the feeding strategies of two sympatric species of leaf monkeys: *Presbytis senex* and *Presbytis entellus*. In: *Primate Ecology,* T. H. Clutton-Brock (ed.), pp.323–353. Academic Press, London.

Horwich, R. H. 1972. Home range and food habits of the Nilgiri langur *Presbytis johnii*. *J. Bombay Nat. Hist. Soc.* 69(2): 255–267.

Islam, M. A. and K. Z. Husain. 1982. A preliminary study on the ecology of the capped langur. *Folia Primatol.* 39: 145–159.

Jay, P. 1965. The common langur of North India. In: *Primate Behavior: Field Studies of Monkeys and Apes*, I. DeVore (ed.), pp.197–249. Holt, Rinehart, and Winston, New York.

Joseph, G. K. and K. K. Ramachandran. 2003. Distribution and demography of the Nilgiri langur (*Trachypithecus johnii*) in Silent Valley National Park and adjacent areas, Kerala, India. *Primate Conserv.* (19): 78–82.

Kumar, A. 2006. Studies on Ecological and Behavioural Aspects of Capped Langur, *Trachypithecus pileatus* (Blyth 1843) in Pakhui Wildlife Sanctuary, Arunachal Pradesh, India. PhD thesis, North Eastern Hill University, Meghalaya, India.

Kumar, A. and G. S. Solanki. 2003. Food preference of rhesus monkey *Macaca mulatta* during the pre-monsoon and monsoon season, Pakhui Wildlife Sanctuary, Arunachal Pradesh. *Zoos's Print Journal* 18(8): 1172–1174.

Kumar, A. and G. S. Solanki. 2004. Ethno-sociological impact on capped langur (*Trachypithecus pileatus*), and suggestions for conservation: a case study of Reserve Forest in Assam, India. *J. Nat. Conserv.* 16(1): 107–113.

Kushwaha S. P. S. and R. Hazarika. 2004. Assessment of habitat loss in Kameng and Sonitpur Elephant Reserve, *Current Science* 87(10):1447–1453.

MacKinnon, J. R. and K. S. MacKinnon. 1980. Niche differentiation in a primate community. In: *Malayan Forest Primates*: *Ten Years' Study in Tropical Rain Forest*, D. J. Chivers (ed.), pp.167–190. Plenum Press, New York.

McKey, D. B. and P. G. Waterman. 1982. Ranging behavior of a group of black colobus (*Colobus satanas*) in the Douala Edea Reserve, Cameroon. *Folia Primatol*. 39: 264–304.

Mukherjee, R. P. 1982. Survey of non-human primates of Tripura, *J. Zool. Soc. India* 34: 70–81.

Mukherjee, R. P., S. Chaudhuri and A. Murmu. 1995. Population survey of South-Asian non-human primates in and around Darjeeling. *Prim. Rep.* 41: 23–32.

Mukherjee, R. P. 1978. Further observations on the golden langur (*Presbytis geei* Khajuria, 1959) with a note to capped langur (*Presbytis pileatus* Blyth, 1843) of Assam. *Primates* 19(4): 737–747.

NRC. 1981. *Techniques for the Study of Primate Population Ecology*. National Research Council (ed.), National Academy Press, Washington, DC.

Oates, J. F. 1974. The Ecology and Behaviour of the Black and White Colobus Monkey (*Colobus guereza* Ruppell) in East Africa. PhD thesis, University of London, UK.

Poirier, F. E. 1970. The Nilgiri langur (*Presbytis johnii*) of south India. In: *Primate Behavior: Developments in Field and Laboratory Researches*, Rosenblum, L.A. (ed.), pp. 254–383. Academic Press, New York.

Raman, T. R. S., C. Mishra and A. J. T. Johnsingh. 1995. Survey of primates in Mizoram, north-east, India. *Primate Conserv.* (16): 59–62.

Rudran, R. 1973. Adult male replacement in one-male troops of purple-faced langurs (*Presbytis senex senex*) and its effect on population structure. *Folia Primatol.* 19: 166–192.

Ruhiyat, Y. 1983. Socio-ecological study of *Presbytis aygula* in West Java. *Primates* 24: 344–359.

Solanki, G. S. 2002. Socio-cultural and faunal diversity of Arunachal Pradesh. *Himalayan J. Environ. Zool.* 16(2): 159–170.

Solanki, G. S. and Chutia, P. 2004. Ethno-zoological and socio-cultural aspects of Monpas of Arunachal Pradesh. *J. Hum. Ecol.*, 15(4): 251–254.

Srivastava, A. and M. S. Mohnot. 2001. Distribution, conservation status and priorities for primates in northeast India. *Envis Bulletin: Wildlife and Protected Areas* 1(1): 102–108.

Srivastava, A., D. Chetry, P. Bujarbarua, J. Das and P. Sarkar. 2001a. Status of primates in the Gibbon Wildlife Sanctuary, Assam, India. *Biosphere Conserv.* 4(1): 43–49.

Srivastava, A., J. Das, J. Biswas, P. Bujarbarua, P. Sarkar, I. S. Bernstein and S. M. Mohnot. 2001b. Primate population decline in response to habitat loss: Borajan Reserve Forest of Assam, India. *Primates* 42(4): 401–406.

Stanford, C. B. 1987. Ecology of the capped langur (*Presbytis pileata*) in Bangladesh. *Am. J. Primatol.* 12: 373. Abstract.

Stanford, C. B. 1988. Ecology of the capped langur and Phayre's leaf monkey in Bangladesh. *Primate Conserv.* (9): 125–128.

Stanford, C. B. 1989. Predation on capped langurs (*Presbytis pileata*) by cooperatively hunting jackals (*Canis aureus*). *Am. J. Primatol.* 19: 53–56.

Stanford, C. B. 1991. The capped langur in Bangladesh: behavioral ecology and reproductive tactics. *Contrib. Primatol*. 26: 1–179.

Struhsaker, T. T. 1975. *The Red Colobus Monkeys*. University of Chicago Press, Chicago.

Sunderraj, S. F. W. 2001. Ecology and conservation of Nilgiri langur (*Trachypithecus johnii*). *Envis Bulletin: Wildlife and Protected Areas* 1(1): 49–59.

Wolf, K. and J. G. Fleagle. 1977. Adult male replacement in a group of silvered leaf-monkeys (*Presbytis cristata*) at Kuala Selangor, Malaysia. *Primates* 18: 949–955.

Yeager, C. P. 1989. Feeding ecology of the proboscis monkey (*Nasalis larvatus*). *Int. J. Primatol*. 10: 497–530.

Zhang, Y. Z., S. Wang and G. Q. Quan. 1981. On the geographical distribution of primates in China. *J. Hum. Evol.* 10: 215–226.

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Status and Conservation of Proboscis Monkeys (*Nasalis larvatus*) in Sabah, East Malaysia

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Abstract: The proboscis monkey (*Nasalis larvatus*) was surveyed in the East Malaysian state of Sabah to establish its population status and to assess threats to its survival. It was found to be more widespread and abundant than previously thought, with a minimum population size of *c.* 5,907 individuals found along major coastal river systems in Sabah. The distribution of proboscis monkeys appeared highly fragmented, with only five major centers of continuous distribution and numerous small isolated populations. Existing proboscis monkey habitats are increasingly threatened by human activities. Of particular concern is the clearing and conversion of important riparian and coastal mangrove habitats to plantations and human habitation, which result in fragmentation of otherwise continuous populations along rivers, and local extinction of remnant populations trapped in small forest fragments. Only 15.3% of the population estimated in this study was found within protected forest reserves, with much of the species' diminishing range habitats exposed to further conversion, extraction and disturbance. Urgent mitigating strategies are necessary to ensure the long-term survival of proboscis monkeys in Sabah. Immediate actions are needed to prevent small isolated populations from local extinction, and long-term efforts must be undertaken to protect important proboscis monkey habitats and re-establish connectivity between fragmented populations.

Key words: Proboscis monkey, *Nasalis larvatus*, Sabah, status, conservation

Introduction

Proboscis monkeys (*Nasalis larvatus*) are endemic to the island of Borneo. They are classified as Endangered on the *IUCN Red List of Threatened Species* (IUCN 2008) and listed under Appendix I of CITES (UNEP-WCMC 2007). Proboscis monkeys have a flexible social structure with one-male multi-female groups as the basic social unit, peripheral males sometimes forming all-male groups (Bennett and Sebastian 1988; Yeager 1990; Boonratana 2002) and a secondary level of association with fission-fusion of stable one-male groups within bands (Yeager 1991, 1992). They are largely restricted to coastal lowland mangrove, riparian, and swamp forests (Kawabe and Mano 1972; Wolfheim 1983; Salter *et al.* 1985, Boonratana 1993; Bernard 1995) up to 750 km inland, but usually less than 55 km from the coast, and at altitudes below 350 m above sea level (Medway 1977; Salter and Mackenzie 1985; Bennett and Sebastian 1988; Meijaard and Nijman 2000). Proboscis monkeys are closely associated with waterways, traveling inland to forage (generally up to 1 km) and returning to their sleeping sites along the river edge every evening (Bennett 1988; Bennett and Sebastian 1988; Yeager 1989; Boonratana 2000; Matsuda 2008).

Populations of proboscis monkeys are known to exist mainly in the fresh water wetlands around Dewurst Bay, along the Kinabatangan, Segama and Sugut rivers in the eastern deltas and in the Klias Peninsula on the west coast (Davies and Payne 1982). Previous estimates of the species in Sabah put the total population at *c.* 3,000 (IUCN 1978) or *c.* 2,000 (Davies and Payne 1982). In the last decade, independent observers have suspected these earlier projections to be underestimates. Goossens *et al.* (2002) found a population of 3,430 in the Kinabatangan floodplains alone, albeit estimated by extrapolation, while Boonratana (1993) indicated a minimum population of 832 and an actual population size likely to double this figure (R. Boonratana pers. comm.). Bernard and Zulhazman (2006) estimated a population of 569 in Klias Peninsula, and Rajanathan (1995) indicated a population of at least 1,056 in Segama.

Comparisons of proboscis monkey abundance from different studies are fraught with difficulties, due mainly to time lag, and differences in methodologies and sampling effort.

Few studies have focused on their population status, and those reported were mainly conducted in a small number of known localities of important populations. While there are indications that proboscis populations have been declining over the past decades (e.g., Chapman and Peres 2001; Fuller *et al*. 2004), the lack of holistic and updated information on their current population status has frustrated any attempt at a successful systematic evaluation of the conservation status of the species. A Population and Habitat Viability Assessment (Manansang *et al*. 2005) originally planned to cover the species' entire range concluded that the basic data needed to draw up accurate range maps and estimate population numbers were insufficient, particularly for Malaysian Borneo. In this study, we aim to address this information gap that is crucial to an assessment of the current conservation status of the proboscis monkey, to understand the threats the species is facing, and to allow for the identification of key areas and strategies for their protection in Sabah.

Methods

Study area

The Malaysian state of Sabah (76,000 km²) is situated between latitudes 4°8' and 7°22' north of the equator on the northeastern tip of Borneo. The western and eastern regions are divided by the Crocker Range, which runs almost parallel to the west coast, extending from the southern end of Marudu Bay in the north and southwards along the western part of the state to the Sarawak border. Like most parts of Borneo, human activities have had a considerable impact on Sabah's vegetation in recent decades, with the inevitable increase in agricultural crop cultivation, logging and expansion of human habitation (Primack and Hall 1992). The narrow western lowland plains contain areas of low, flat ground that is densely populated, while eastern Sabah is characterized by low dissected hills, gentle slopes and poorly drained flatland and low lying swampy zones that have been extensively logged and converted to permanent agriculture where soil and terrain is suitable (Payne 1988).

Forest type classification

The main forest and land use type classification for Sabah was defined according to Fox (1978) and the Sabah Forestry Department (1989). Two different classification maps were used to illustrate forest type and land use: (1) a 1997 vegetation cover map of Sabah, rectified and updated with a mosaic of Landsat ETM+ ranging from 1999 to 2002 in MrSID format (ERDAS Imagine 8.6 and ArcGIS 8.3); and (2) a SPOT-Vegetation satellite image of coarse spatial resolution (1 km) generated from satellite images acquired for the period 1998 to 2000 (Stibig *et al.* 2002). We classified habitats as suitable and unsuitable according to known occurrence of proboscis monkeys in habitat types. Suitable proboscis monkey habitats include mangrove and nipah forest, riverine forest or mixed lowland dipterocarp forest along rivers, and swamp forests that consist of freshwater swamp, peat swamp and swampy grassland, a unique habitat comprising mostly of herbaceous scrubs and swampy grasses found only in the Klias Peninsula. In total, mangrove, freshwater swamp, and undisturbed mixed dipterocarp forests account for 7,467.3 km² or about 9.8% of the total land area (Sabah Forestry Department 2002). Unsuitable habitats are characterized by montane and highland dipterocarp forest, developed land and permanent agriculture (mostly coconut, oil palm and rubber), thickets, shrubs and dry grassland.

Forest reserve classification

Forest reserves in Sabah (Forests Amendment Enactment 1984) total 35,940 km² or 48.8% of the total land area (Sabah State Government 1998), and are divided into seven classes. Class I Protection Forest, Class VI Virgin Jungle Forest and Class VII Wildlife Reserve total about 8% of the land area, and consist of protected forests conserved for the protection of watersheds and the maintenance of the stability of essential climatic and other environmental factors, as well as research on and protection of wildlife. Logging is strictly prohibited in these areas. Class II Commercial Forest, Class III Domestic Forest, Class IV Amenity Forest, and Class V Mangrove Forest total about 41.8% of the land area, and consist of various forests allocated for logging, consumption by local communities, provision of amenities, and recreation for local inhabitants, as well as to guarantee a supply of mangrove, timber and other produce to meet general trade demands.

River surveys

Preliminary information about possible locations of proboscis monkeys and about threats and other historical and current data were collected through questionnaire interviews of selected respondents knowledgeable about their areas. They included wildlife officers and local residents. River surveys using boats were conducted in areas identified through the information obtained, along with other literature sources, to census proboscis monkeys from sunrise to about 08:30 and about 16:30 to sunset with slight variations according to local conditions. Survey routes were largely random and dictated by logistical or environmental constraints such as the course of the river, low water levels due to tide timings, or blocked river passages. The short survey timings available each day (just after dawn before monkeys move into the forest and before dusk, after they return to sleeping sites) made it impossible to complete large areas in one survey, particularly in some areas that have long rivers. Due to the time and budget needed for the large survey effort, a single boat census with no replicates was used whereby as much river as possible was covered in one survey and continued in the next survey at the point where the previous survey left off. Rivers and tributaries that were close to each other were preferentially covered in one session or on consecutive days to reduce the probability of replicate counts. Each survey consisted of at least one boatman and one assistant to assist in spotting. As soon as a monkey group or individual was sighted, the boat engine was switched off and paddled to near the group to record the number of individuals, their age-class and sex. Ecological and other habitat variables, including weather condition and habitat type, were also noted. Groups were defined by their close proximity to sleeping sites and coordination of movement within a group (Bennett and Sebastian 1988; Yeager 1991, 1995) and distinguished from separate groups by the presence of a prominent dominant male (in harem groups) and a distance criterion of at least 50–100 m between them (Kern 1964; Kawabe and Mano 1972; Macdonald 1982; Salter *et al.* 1985). Exact locations of sightings and transect routes traversed were recorded using a Differential Geographic Positioning System, DGPS (Trimble™ XRS) and Trimble™ Recon Data Logger. Spatial and attribute data were overlayed on georeferenced vegetation and land use maps for analysis using a Geographic Information System, GIS (ESRI® ArcGIS™ 8.3, Environmental Systems Research Institute, USA).

We used Analysis of Covariance (ANCOVA) to test for a relationship between proboscis monkey abundance and the major habitat types they were found in, while controlling statistically for survey distance. All analyses were done using the Statistical Package for the Social Sciences version 13.0 (SPSS Inc., Chicago, Illinois). Statistical significance was set at $p<0.05$.

Results

Eighty-two boat surveys, covering a distance of 1220.6 km, were conducted over 98 field days during 6 months from June to November 2005. The mean (±SD) distance covered per boat survey was 13.27±3.42 km (range 5.4 to 20.2 km). The mean number of groups sighted per survey was 5.81±3.84 (range 0 to 18). Groups were found at localities from 0 to 110 km inland with 2.0% of group sightings along the coast, 79.2% less than 50 km from coast, 17% between 50 to 100 km, and 1.8% at distances greater than 100 km. A total of 5,907 individuals in 477 sightings was recorded in this survey (mean group size 12.38±4.82; range 1 to 28) and made up of 435 harem groups, 31 all-male groups, and 12 single-male sightings.

The distribution of the proboscis monkey is shown in Figure 1 and referenced in Table 1. On the west coast, populations of proboscis monkeys were found in the Klias Peninsula (five sub-populations of 818 individuals in 75 groups) [1-5]. On the east coast, populations were found at Tangkarason and Paitan (90 individuals in eight groups) [6,7]; Sugut River (787 individuals in 58 groups) [8]; Beluran (317 in 30 groups) [9]; Sandakan (three sub-populations of 326 in

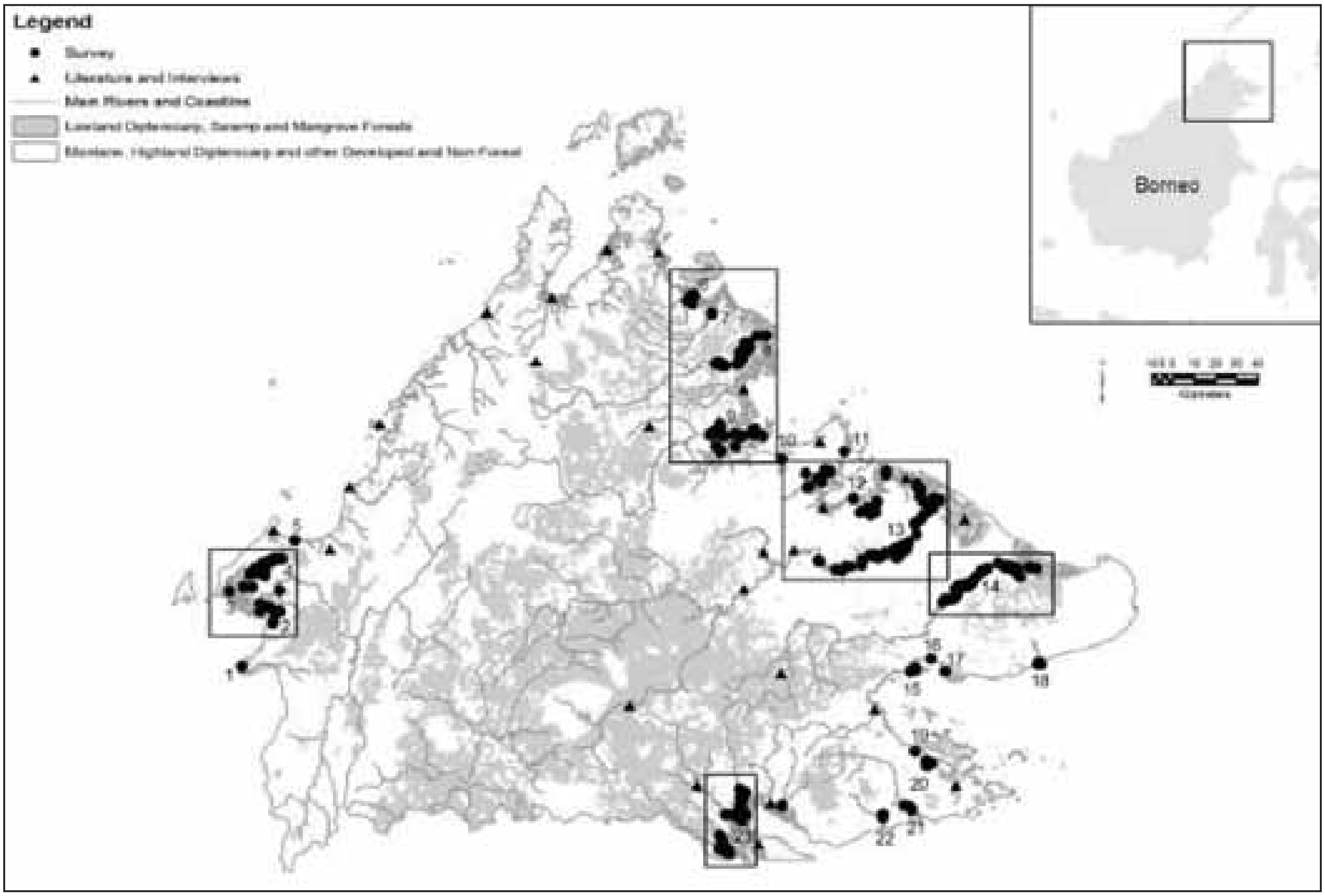

Figure 1. Distribution of proboscis monkeys in Sabah. "Survey" indicates locations of sightings from this study, "Literature and interviews" indicate sightings from literature, interviews and other sources that were not verified in this study. "Boxed" areas are identified major centers of continuous distribution.

28 groups) [10-12]; Kinabatangan River (1,454 individuals in 101 groups) [13]; Segama River (1040 individuals in 83 groups) [14]; Lahad Datu (four sub-populations of 188 individuals in 16 groups) [15-18]; Semporna Peninsula (four sub-populations of 169 individuals in 16 groups) [19-22]; and Tawau Bay (718 individuals in 63 groups) [23] on the east coast. The range limits of proboscis monkeys are likely to extend much further inland as far as Danum Valley (Marsh 1995) *c.* 170 km and Maliau Basin (Bennett and Gombek 1993) *c.* 200 km. There are also recent inland records in the vicinity of Serinsim near Marak Parak in Kota Marudu (Shultz and Beck 1999); and in Ulu Tungud Forest Reserve and Deramakot Forest Reserve (Sabah Wildlife Department 2003). Locations where proboscis monkeys are likely to be still present but not directly verified in this study include: on the west coast — Bongawan (Bernard and Zulhazman 2006), Tempurong, Rampayan, Pulau Gaya, Rampayan; north coast — Pitas, Marudu Bay; and east coast — Bongaya, Labuk Bay, Gum Gum, Sekong Bay, Mumiang, Lokan (Goossens *et al.* 2002), Dewhurst Bay (Davies and Payne 1982), Kulamba FR (T.S. Liew pers. comm.), Tinkayu, Silam, Pulau Sebatik (Bennett & Gombek 1993) and Kalabakan FR (Malim *et al.* 1999).

Table 1. Locations of proboscis monkey sightings in this survey, corresponding population sizes, sighting frequency, forest type, reserve classification, threats and local extinction risk.

Name of Locality		**Reference (Fig. 1)**	**No. Groups/ Sighting frequency per km**		**No. Individuals/ Sighting frequency per km**		**Forest Type[1]**	**% groups in forest reserves (Forest reserve type classification) /% protected[2]**	**Threats[3]**	**Local Extinction Risk[4]**
Klias Peninsula	Menggalong	1	3	**75/0.41**	33	**818/4.47**	Mangrove and Nipah	59.2% (Class I, IV, V) / 1.3%	HLFA, HLFF, HLFH, H, T	Very high
	Weston	2	12		114		Mangrove and Nipah, Freshwater and Peat Swamp			Low
	Menumbok	3	6		73		Mangrove and Nipah			Low
	Garama and Kota Klias	4	53		578		Mangrove and Nipah, Riverine, Swampy Grassland			Low
	Binsulok	5	1		20					Very high
Tangkarason and Paitan		6,7		**8/0.17**		**90/1.9**	Mangrove and Nipah	87.5% (Class V) / 0%	HLFA, HLFF, HLFL, H	High
Sugut		8		**58/0.61**		**787/8.28**	Mangrove and Nipah, Riverine	5.2% (Class II, V) / 0%	HLFA, HLFF, HLFL	Low
Beluran		9		**30/0.31**		**317/3.23**	Mangrove and Nipah, Riverine, Freshwater and Peat Swamp	76.7% (Class II, V) / 0%	HLFA	Low
Sandakan	Samawang	10	1	**28/0.16**	18	**326/1.92**	Mangrove and Nipah	75% (Class V, VI) / 14.3%	HLFA, HLFL, HLFH	Very high
	Sibuga	11	1		14					Very high
	Sandakan Bay	12	26		294					Low
Kinabatangan		13		**101/0.55**		**1454/7.89**	Mangrove and Nipah, Riverine	75.2% (Class V, VI) / 62.4%	HLFA, T	Low
Segama		14		**83/0.57**		**1040/7.15**	Mangrove and Nipah, Riverine	12.0 (Class V, VI) / 7.2%	HLFA, HLFL	Low
Lahad Datu	Sakar	15	65	**16/0.21**	6	**188/2.41**	Mangrove and Nipah	36.1% (Class V) / 0%	HLFA, HLFL, HLFH, H	High
	Bikang	16	22		1					Very high
	Silabukan	17	7		1					High
	Tungku	18	94		8					Very high
Semporna	Sipit	19	1	**15/0.28**	12	**169/3.15**	Mangrove and Nipah	100% (Class V) / 0%	HLFA, HLFL, HLFH, H	Very high
	Balung	20	4		57					High
	Kalumpang	21	4		51					High
	Sapang	22	6		49					Very high
Tawau		23		**63/0.37**		**718/4.91**	Mangrove and Nipah	96.8% (Class V) / 0%	HLFA, HLFH	Low

[1] Forest type classification according to Fox (1978) and SFD (1989), verified from SPOT-Vegetation satellite image (Stigbig *et al.* 2002) and Landsat ETM+ vegetation cover map of Sabah (1999–2002).

[2] Percentage in forest reserves. Classification according to Forests Amendment Enactment (1984). Class I, VI, VII are considered strictly protected.

[3] Threats classified as: (HLFA) Habitat loss and/or fragmentation due to agriculture/aquaculture; (HLFF) Habitat loss and/or fragmentation due to fire; (HLFL) Habitat loss and/or fragmentation due to logging; (HLFH) Habitat loss and/or fragmentation due to human habitation; (H) Hunting; (T) Tourism.

[4] Local Extinction Risk classified as: *Very high:* with small isolated populations that are very likely to go locally extinct; *High*: with larger populations in bigger habitat fragments but sufficiently small and isolated to be at risk in the near future; *Low:* with large continuous populations with a broad geographic distribution.

Mean sighting frequency of proboscis monkeys was 0.39 groups/km and 4.84 individuals/km, and was highest for the Sugut River followed by Kinabatangan River and Segama River. Highest numbers of proboscis monkeys were found in riparian forest (48.0%), followed by mangrove and nipah forest (44.9%) and swamp forest (7.1%). Sighting frequency was, however, higher in swamp forests (0.86 groups/km and 10.86 individuals/km), followed by riparian forest (0.64 group/km and 8.43 individuals/km), and lowest in mangrove and nipah forest (0.26 group/km and 2.98 group/km). Irrespective of more groups and individuals recorded with increasing survey distance covered (ANCOVA: groups – $R^2 = 0.793$; $p = 0.000$; individuals – $R^2 = 0.743$; $p = 0.001$), group and individual abundance in riparian forest was significantly higher than in mangrove forest (ANCOVA: groups – df = 3,12; $F = 5.626$; $p = 0.012$; individuals – df = 3,12; $F = 5.215$; $p = 0.016$).

Discussion

Status of proboscis monkeys in Sabah

Proboscis monkey populations were found along most coastal river systems throughout Sabah where suitable habitats still exist. The estimate of *c.* 5,907 individuals in this study is a minimum population estimate for Sabah, bearing in mind that not all areas of possible proboscis monkey occurrence were completely surveyed, in particular, large tracts of mangrove forests in the Bongaya, Mumiang, Dewhurst Bay, Marudu Bay and Muara Kalabakan areas, and farther inland along long rivers such as the Kinabatangan and Segama. Other inland records from literature showed that remnant populations are still present and may represent the actual distribution range limits of proboscis monkeys in Sabah. This is not unlikely as the proboscis monkey range from the coast can be greater than 300 km and as far as 750 km along the courses of major rivers (Meijaard and Nijman 2000), and there are morphological and biogeographical indications that proboscis monkeys are well adapted as an inland species (Brandon-Jones 1996). It is, however, not expected that large populations persist in those areas, and may be limited by historical fragmentation leaving small inland populations isolated from major populations nearer the coast.

Although the estimate in this study is much higher than the previous estimates of 2,000 (Davies and Payne 1982) and 3,000 individuals (IUCN 1978), it should not be taken that the population has actually increased, but rather is a result of a more comprehensive review of the baseline population size that is corroborated with the higher abundances reported by independent researchers at various localities in recent years. We cannot conclude whether the population has increased or decreased over the last 20 years. However, there is strong evidence that the extant population is highly fragmented, with only five major centers of continuous distribution and numerous small isolated populations. The Klias Peninsula population is the only major center of proboscis monkey distribution on the west coast and is separated from the east coast populations by the highland areas of the Crocker Range. On the east coast, populations in Tangkarason, Paitan, Sugut and Beluran appeared connected by coastal mangroves from the west of Pitas up to the Samawang area in Sandakan. Populations in Sandakan Bay and Kinabatangan are likely continuous along narrow coastal mangrove strips. The population along the Segama River is probably completely isolated. Satellite image data showed extensive habitat loss in Kulamba Forest Reserve, which would otherwise provide an important corridor between major populations in Kinabatangan and Segama. Tawau Bay has a continuous population along the extensive mangrove habitat, which is possibly connected with the major population of the delta of the Sesayap, Sembakung and Sebuku rivers in Kalimantan identified by Meijaard and Nijman (2000).

Relative abundances in different habitat types indicated that densities may be comparatively much higher in riparian forest compared to mangrove forest, and can be even higher in swamp forest. This finding agrees with those of other studies (for example, Salter *et al.* 1985; Salter and Mackenzie 1985; Yeager and Blondal 1992; Rajanathan 1991; Boonratana 1993). However, high densities can also be an artifact of habitat fragmentation, forcing proboscis monkey populations into smaller areas of suitable habitat. In Garama and various other localities, for example, large numbers of proboscis monkeys were found in narrow strips of forest that are at times less than 20 m in width. In Kalimantan, E. Meijaard (pers. comm.) indicated that the Mahakam Delta, which had extensive mangroves and tidal swamps up until the early 1990s, presently has only a few forest fragments left which are now invariably overpopulated with proboscis monkeys.

Threats

Habitat loss and fragmentation is identified as the major threat to proboscis monkey populations in Sabah. Loss of habitat due to expansion of human settlements is most marked in the coastal mangrove areas of Sandakan, Lahad Datu and Semporna (Appendix A). Proboscis monkeys have been recorded in disturbed habitats of secondary growth near human settlements; in remnant tidal forest close to agricultural land, in selectively felled forest (Kawabe and Mano 1972; Jeffrey 1982; Salter and Mackenzie 1985; Salter *et al.* 1985); in a rubber plantation (Soendjoto 2003); and we have seen them in coconut plantations (feeding on the inflorescences). This indicates a certain degree of dietary plasticity and habitat adaptability, but they are not known to use many habitats, in particular, farmland and permanent cultivations such as oil palm. The local extinction of proboscis monkey populations as a result of habitat loss has been recorded in Papar (Davies and Payne 1982) and in Kunak (Anon. 2003). This is likely to be only the tip of the iceberg with many other populations disappearing unrecorded.

Habitat fragmentation and degradation due to logging and conversion of important riparian habitats to agriculture/aquaculture is highly evident along major rivers such as the Kinabatangan and Segama (Appendix B), where an intervening matrix of cultivated land, human settlement or grassland areas, between fragments may impede movement, dispersal and social activities of groups at important resting sites. Forests near or along rivers that are converted to oil palm or other cultivated crops significantly reduce the quality of the habitat for proboscis monkeys, and may increase inter-specific resource competition, which favors more omnivorous species such as the macaques. Pig-tailed and long-tailed macaques were more abundant in disturbed secondary habitats, and pig-tailed macaques were particularly common along the river in the upper reaches of Segama River in forests converted to oil palm with the consequent reduction or complete displacement of proboscis monkeys in these areas. In Kinabatangan, proboscis monkeys were observed to alter their normal ranging patterns up to 500 m inland during an extended flood season due to hydrological changes probably induced by extensive planting of oil palm near river banks (I. Matsuda pers. comm.). Other short-term impacts of fragmentation include increasing encroachment activities such as hunting by plantation workers with easy accessibility to proboscis monkeys trapped in forest fragments.

During the *El Niño* event of 1997–1998 almost 30,000 km² forest was lost in Kalimantan (Fuller *et al.* 2004), and riparian forest was particularly heavily affected, causing the proboscis monkeys to lose a greater percentage of its remaining habitat than any primate species in Borneo (Yeager and Frederiksson 1998). Fires that resulted in habitat loss and degradation in Sabah are evident in Klias, Sugut, Tangkarason and Paitan (Appendix C). Proboscis monkeys do not use areas of extensively burnt dryland forest but may use secondary growth on burnt swamp forests, as indicated by the population in the swampy grasslands of Garama. However, these sub-optimal habitats may not be able to support populations in the long term, and the detrimental effects of habitat loss may only be evident over a longer period of time.

Hunting of proboscis monkeys appears less common in Sabah where existing populations are found mainly in predominantly Moslem areas but, as in Kalimantan (Meijaard and Nijman 2000), it may have historically exterminated populations in some areas of otherwise suitable habitat. Although locals do not usually hunt, they often facilitate this activity by renting boats and imparting knowledge about the location of proboscis monkeys to others. There is anecdotal evidence of hunting by police or army personnel and recreational sport hunters in areas such as Sebatik Island, Sandakan Bay, Tangkarason and Brontian. Proboscis monkey meat is rumored to be sold for food in Kota Marudu and Sandakan. One account told of a proboscis monkey used as crocodile bait in the Klias Peninsula (J. Augustine pers. comm.), and a proboscis monkey we saw being kept as a pet may have been a result of hunting.

Tourism presents an indirect threat in accessible areas of large, easily sighted populations. In Garama (Klias Peninsula) and Sukau (Kinabatangan), there has been a proliferation of large- and small-scale tourist establishments over the last 5 to 10 years to cater to the increasing tourist volume. Although community-based ecotourism can bring significant benefits (for example, income for local communities and incentives for policy makers to protect the species), lack of proper evaluation and control mechanisms often lead to unethical and irresponsible mass tourism activities by profit-oriented establishments. Increasing proximity of humans to proboscis monkeys may result in disturbance and altered behaviors that are detrimental to the long-term conservation of this sensitive species.

Conservation recommendations: Translocation of populations at risk of local extinction

Increasing loss of suitable habitats for proboscis monkeys is resulting in many remnant populations facing local extinction. Clearing of the remaining forest habitat of the Kunak population in 2003 resulted in the displacement of 30 or so monkeys and the death of an infant, and the Labuk Bay Proboscis Monkey Sanctuary population was almost exterminated by forest clearance for oil palm plantations. Translocation in this case may be the only recourse, even though there are risks. Translocation of sensitive species remains highly controversial due to associated high mortality rates, introduction of diseases or parasites, and the disruption of food resources and their social structure (Yeager and Silver 1999; Fisher and Lindameyer 2000). An example can be found in the difficulties that were encountered during the translocation scheme of the Pulau Kaget Nature Reserve population (Meijaard and Nijman 1999). However, for highly isolated proboscis monkey populations that are facing displacement or extermination, translocation would be the only logical step, at least on compassionate grounds.

Conservation recommendations: Protecting important proboscis monkey habitats

The natural forest cover in Sabah was reduced from an estimated 86% in 1953 (Fox 1978) to 57.4% by 2001 (FAO 2002). Immediate action is required to halt the decline of existing habitats. Although an estimated 9.8% of suitable habitat is still found throughout Sabah, the majority of proboscis monkeys are found near coastal areas and rivers, where available habitat is decreasing rapidly. The largest population in Kinabatangan — about 25% of the total population — is surviving in only an estimated 0.7% of the total forested area. The current network of forest reserves in Sabah harbors 57.2% of the proboscis monkeys recorded in this survey (Table 1). If only strictly protected reserves are considered, only 15.3% of the total population qualifies, with major populations in the Segama, Sugut and Garama area in Klias not within forest reserves land (Appendix D). Riparian habitats in particular are not sufficiently protected, compounded by the fact that most human settlements are closely associated with river systems. Although the strip of 20 m of riparian forest perpendicular to the river is legally protected (Water Resources Enactment 1998), this is insufficient for proboscis monkeys. They can range up to 1 km from the riverbank to forage in just a day. It is imperative that land use planning take into account the urgent need to protect the habitats of the proboscis monkeys, especially those that are severely under-represented in the existing forest reserve system. Bernard *et al*. (2006) provided a framework for a system of reserve networks in the Klias Peninsula through extension of protection to small but important proboscis monkey habitat areas between existing forest reserves. An extension conservation area linking three small reserves within the Klias Peninsula was successfully gazetted as the Bukau-Api Api Protection Forest Reserve under a United Nations Development Programme/Global Environment Facility (UNDP/GEF) funded peat swamp forest project. More important populations and habitats need to be protected and ideally conferred strict protection such as national parks or wildlife sanctuaries. It is also important to ensure the integrity and effectiveness of existing protected areas through increased enforcement and local community participation.

Conservation recommendations: Re-establishment of forest and river corridors

The current distribution of proboscis monkeys in Sabah is fragmented, with many isolated populations and large populations that are themselves fragmented into sub-populations by various forms of land conversion. Fragmentation of river systems is most severe along the Kinabatangan, Segama and Sugut rivers, where the remaining large populations exist. The strategic plan for forest resource development of the Sabah Forestry Department (Forestry Department 1998) recognized that extensive reforestation is now necessary as a result of overexploitation of natural forests. It is also encouraging that there is renewed impetus by the State Government to identify the severity of the problem of riparian reserve encroachment along state rivers by planters, and establish plans to rehabilitate forest along rivers that have been converted to oil palm plantations (Anon. 2006). Greater efforts must be dedicated to restoring remnant habitat patches as well as re-establishing corridors along fragmented river systems, preferably linking major populations through a protected area network, as part of a conservation strategy that extends beyond borders for the protection of the species across its range.

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Literature cited

Anonymous. 2003. Proboscis at risk: Call for urgency as abandoned baby becomes first victim. *New Sabah Times*, 23 January 2003.

Anonymous. 2006. River bank encroachers to face stern action: CM. *The Borneo Post*, 4 May 2006.

Bernard, H. and H. Zulhazman. 2006. Population size and distribution of the proboscis monkey (*Nasalis larvatus*) in the Klias Peninsula, Sabah, Malaysia. *Malayan Nature Journal* 59(2): 153–163.

Bennett, E. L. 1986. Proboscis monkeys in Sarawak: their ecology, status, conservation and management. Report, World Wildlife Fund (WWF) Kuala Lumpur, Malaysia.

Bennett, E. L. 1988. Proboscis monkeys and their swamp forests in Sarawak. *Oryx* 22(2): 69–74.

Bennett, E. L. and A. C. Sebastian. 1988. Social organisation and ecology of proboscis monkey (*Nasalis larvatus*) in mixed coastal forest in Sarawak. *Int. J. Primatol.* 9: 233–255.

Bennett, E. L. and F. Gombek. 1993. *Proboscis Monkeys of Borneo.* Natural History Publications (Borneo) Snd. Bhd, Kota Kinabalu.

Bernard, H. 1995. A study on the distribution and abundance of proboscis monkey (*Nasalis larvatus*) in the Klias Peninsula, Sabah, North Borneo. *J. Wildl. Manag and Res. Sabah* 1: 1–72.

Bernard, H., I. M. Said and C.M. Sha. 2006. Proboscis monkey protection plan for Klias Forest Reserve and its surrounding southern ecotones. Report, Conservation and Sustainable Use of Tropical Peat Swamp Forests and Associated Wetland Ecosystems, United Nations Development Programme/Global Environment Facility (UNDP/GEF) funded project MAL/99/G31.

Boonratana, R. 1993. The Ecology and Behaviour of the Proboscis Monkey (*Nasalis larvatus*) in the Lower Kinabatangan, Sabah. PhD Thesis, Faculty of Graduate Studies, Mahidol University, Thailand.

Boonratana, R. 2000. Ranging behaviour of proboscis monkeys (*Nasalis larvatus*) in the Lower Kinabatangan, Northern Borneo. *Int. J. Primatol.* 21: 497–518.

Boonratana, R. 2002. Social organisation of proboscis monkeys (*Nasalis larvatus*) in the Lower Kinabatangan, Sabah, Malaysia. *Malayan Nature Journal* 56(1): 57–75.

Brandon-Jones, D. 1996. The Asian colobinae (Mammalia: Cercopithecidae) as indicators of Quaternary climatic change. *Biol. J. Linn. Soc.* 59: 327–350.

Chapman, C. A. and C. A. Peres. 2001. Primate conservation in the new millennium: The role of scientists. *Evol. Anthropol.* 10: 16–33.

Davies, G. and J. Payne. 1982. A faunal survey of Sabah. Report, IUCN/WWF Project No.1692, Kuala Lumpur: WWF–Malaysia.

Fischer, J. and D. B. Lindenmayer. 2000. An assessment of the published results of animal relocations. *Biol. Conserv.* 96: 1–11.

Food and Agriculture Organisation. 2002. An overview of forest products statistics in South and Southeast Asia. EC-FAO Partnership Programme (2000–2002), Tropical Forestry Budget Line, B7-6201/1B/98/0531, Project No. GCP/RAS/173/EC.

Fox, J. E. D. 1978. The natural vegetation of Sabah, Malaysia: the physical environment and classification. *Trop. Ecol.* 19: 218–239.

Fuller, D. O., T. C. Jessup and A. Salim. 2004. Loss of forest cover in Kalimantan, Indonesia, since the 1997–1998 El Niño. *Conserv. Biol.* 18(1): 249–254.

Goossens, B., J. M. Setchell, D. M. A. Abulani, F. Jalil, S. S. James, S. H. Aris, M. H. Lakim, A. D. Seventri, S. S. Sariningsih and M. Ancrenaz. 2002. A boat survey of primates in the Lower Kinabatangan Wildlife Sanctuary. In: *Lower Kinabatangan Scientific Expedition*, M. Maryati, A. B. Takano, B. Goossens and R. Indran (eds.), pp.37–45. Universiti Malaysia, Sabah.

IUCN 1978. Proboscis or long-nosed monkey. Draft data sheet for *Red Data Book*. International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland.

IUCN 2008. *2008 IUCN Red List of Threatened Species*. International Union for Conservation of Nature and Natural Resources (IUCN), Species Survival Commission (SSC), Gland, Switzerland, and Cambridge, UK. Website: <http://www.iucnredlist.org>. Accessed 18 September 2008.

Jeffrey, S. M. 1982. Threats to the proboscis monkeys. *Oryx* 16(4): 337–339.

Kawabe, M. and T. Mano. 1972. Ecology and behaviour of the wild proboscis monkey, *Nasalis larvatus* (Wurmb) in Sabah, Malaysia. *Primates* 13: 213–228.

Kern, J. A. 1964. Observations on the habits of the proboscis monkey, *Nasalis larvatus* (Wurmb), made in the Brunei Bay area, Borneo. *Zoologica*, *New York Zool. Soc.* 49(11): 183–191.

Macdonald, D. W. 1982. Notes on the size and composition of groups of proboscis monkey, *Nasalis larvatus*. *Folia Primatol.* 37(1-2): 95–98.

Malim, T. P., M. Andau and L. Ambu. 1999. A faunal survey of the Kalabakan Forest Reserve of Tawau, Sabah and its potential management implications. Report, Sabah Wildlife Department, Sabah.

Manansang, J., K. Traylor-Holzer, D. Reed and K. Leus (eds.). 2005. Indonesian Proboscis Monkey Population and Habitat Viability Assessment: Final Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Marsh, C. W. 1995. Danum Valley Conservation Area, Sabah, Malaysia. Management Plan 1995–2000. Yayasan Sabah/Innoprise Corporation Sdn. Bhd., Kota Kinabalu. 144pp.

Matsuda, I. 2008. Feeding and Ranging Behaviors of Proboscis Monkey *Nasalis larvatus* in Sabah, Malaysia. PhD thesis, Graduate School of Environmental Earth Science, Hokkaido University, Japan.

Medway, Lord. 1977. Mammals of Borneo. Field keys and annotated checklist. *Monograph. Malayan Branch Royal Asiatic Society* No. 7.

Meijaard, E. and V. Nijman. 1999. The local extinction of the proboscis monkey *Nasalis larvatus* in Pulau Kaget Nature Reserve, Indonesia. *Oryx* 34(1): 66–70.

Meijaard, E. and V. Nijman. 2000. Distribution and conservation of the proboscis monkey (*Nasalis larvatus*) in Kalimantan, Indonesia. *Biol. Conserv.* 92: 15–24.

Payne, J. 1988. Orang-utan conservation in Sabah. WWF Malaysia Project No. 96/86, WWF International Project No. 3759.

Primack, R. B. and P. Hall. 1992. Biodiversity and forest change in Malaysian Borneo. *BioScience* 42(11): 829–837.

Rajanathan, R. and E. L. Bennett. 1990. Notes on the social behaviour of wild proboscis monkey (*Nasalis larvatus*). *Malayan Nature Journal* 44: 35–44.

Rajanathan, R. 1991. Differential Habitat Use by Primates in Samunsam Wildlife Sanctuary, Sarawak, and Its Application to Conservation Management. MSc Thesis, University of Florida., Gainesville.

Rajanathan, R. 1995. A mammal and bird survey in the Lower Segama Region, Sabah, with emphasis on the proboscis monkey. Report, Sabah Wildlife Department and World Wildlife Fund, Malaysia.

Salter, R. E. and N. A. Mackenzie. 1985. Conservation status of the proboscis monkey in Sarawak. *Biol. Conserv.* 33: 119–132.

Salter, R. E., N. A. Mackenzie, K. M. Aken and P. K. Chai. 1985. Habitat use, ranging behaviour, food habits of the proboscis monkey, *Nasalis larvatus* (van Wurmb), in Sarawak. *Primates* 26(4): 436–451.

Sabah Forestry Department. 1989. *Forestry in Sabah*. Sabah Malaysia.

Sabah Forestry Department. 1998. *Annual Report, 1997*. Sabah, Malaysia.

Sabah Forestry Department. 2002. *Production and Export Statistics of Forest Products, 2001*. Sabah, Malaysia.

Sabah State Government 1998. *Forestry in Sabah—Status, Policy and Actions*. Government Printers, Sabah, Malaysia.

Sabah Wildlife Department 2003. Faunal survey. Report, Sabah Wildlife Department, Sabah, Malaysia.

Schultz, C. H. and J. Beck. 1999. A record of proboscis monkey (*Nasalis larvatus*) (Mammalia, Primates, Cercopithecidae) from Kinabalu Park, Sabah, Malaysia. *Sabah Park Nat. Journal* 2: 23–26.

Soendjoto, M. A. 2003. Adaptasi bekantan (*Nasalis larvatus*) terhadap hutan karet: Studi kasus di Kabupaten Tabalong, Kalimantan Selatan. Usulan Penelitian. Program Pasca Sarjana, Institut Pertanian Bogor.

Stibig, H.-J., R. Beuchle and P. Janvier. 2002. Forest cover map of insular Southeast Asia at 1:5500000. *Derived from Spot-vegetation Satellite Images. TREES. Tropical Ecosystem Environmental Observations by Satellites.* TREES Publications Series D: Thematic outputs nº 3. Publications of the European Communities, EUR 20129 EN, European Commission, Luxembourg.

UNEP-WCMC 2003. UNEP-WCMC Species Database: CITES-Listed Species. United Nations Environment Programme (UNEP) – World Conservation Monitoring Centre (WCMC). Website: <http://sea.unep-wcmc.org>. Accessed: 12 August 2007.

Wolfheim, J. H. 1983. *Primates of the World: Distribution, Abundance and Conservation*. University of Washington Press, Seattle.

Yeager, C. P. 1989. Feeding ecology of the proboscis monkey. *Int. J. Primatol.* 10(6): 497–530.

Yeager, C. P. 1990. Proboscis monkey (*Nasalis larvatus*) social organization: group structure. *Am. J. Primatol.* 20(2): 95–106.

Yeager, C. P. 1991. Proboscis monkey (*Nasalis larvatus*) social organization: intergroup patterns of association. *Am. J. Primatol.* 23: 73–86.

Yeager, C. P. 1992. Proboscis monkey (*Nasalis larvatus*) social organization: the nature and possible functions of intergroup patterns of association. *Am. J. Primatol*. 26: 133–137.

Yeager, C. P. 1995. Does Intraspecific variation in social systems explain reported differences in the social structure of the proboscis monkey (*Nasalis larvatus*)? *Primates* 36(4): 575–582.

Yeager, C. P. and T. K. Blondal. 1992. Conservation status of the proboscis monkeys (*Nasalis larvatus*) at Tanjung Putting National Park, Kalimantan Tengah, Indonesia. In: *Forest Biology and Conservation in Borneo*, G. Ismail, M. Mohamed and S. Omar (eds.), pp.220–228. Yayasan Sabah Center for Borneo Studies, Publication No. 2. Kota Kinabalu, Sabah.

Yeager, C. P. and G. Frederiksson. 1998. Fire impacts on primates and other wildlife in Kalimantan, Indonesia, during 1997/1998. Report, WWF Indonesia Jakarta.

Yeager, C. P. and S. C. Silver. 1999. Translocation and rehabilitation as primate conservation tools: are they worth the cost? In: *The Non-human Primates*, P. Dolhinow and A. Fuentes (eds.), pp.164–169. Mayfield, Mountain View, CA.

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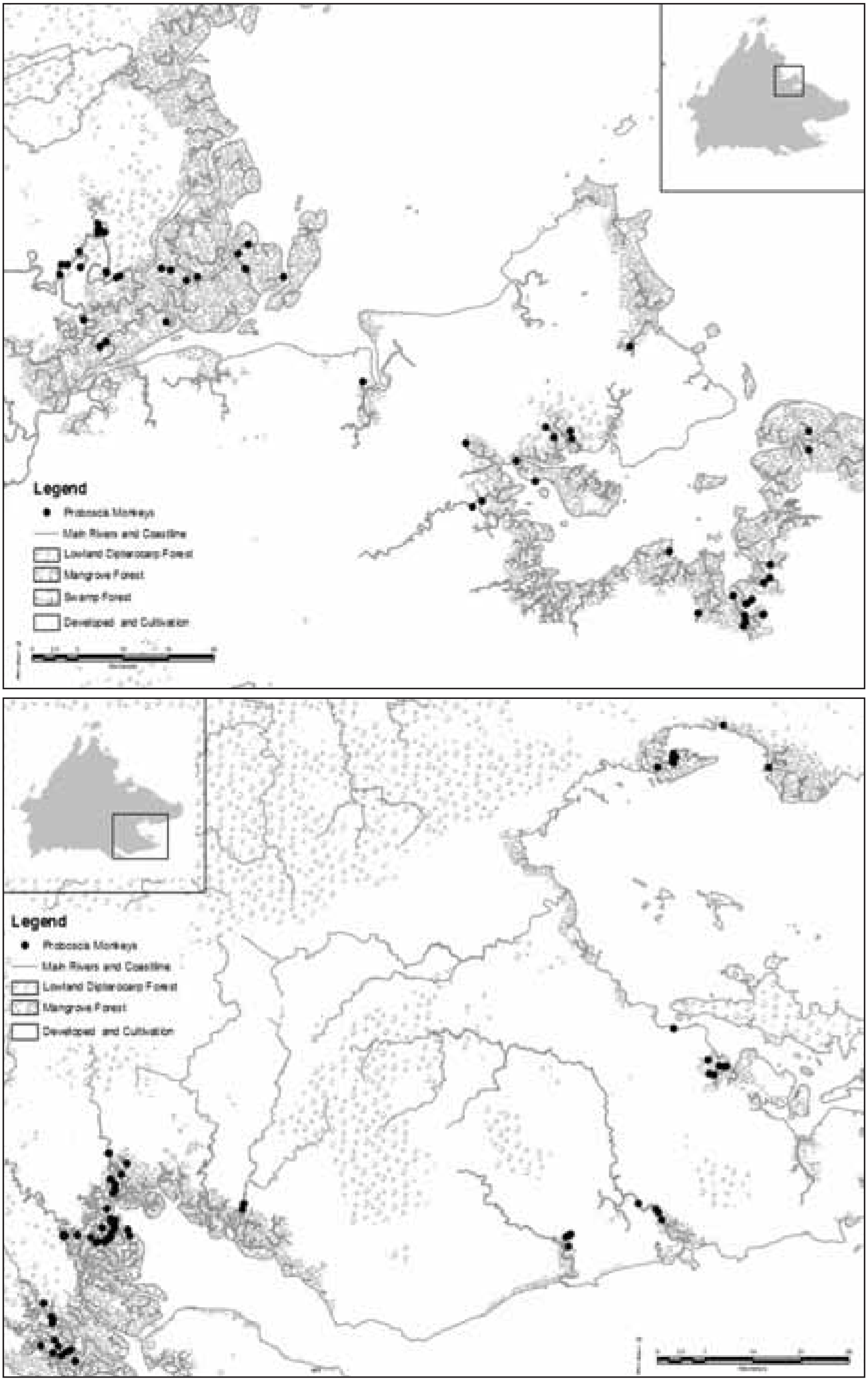
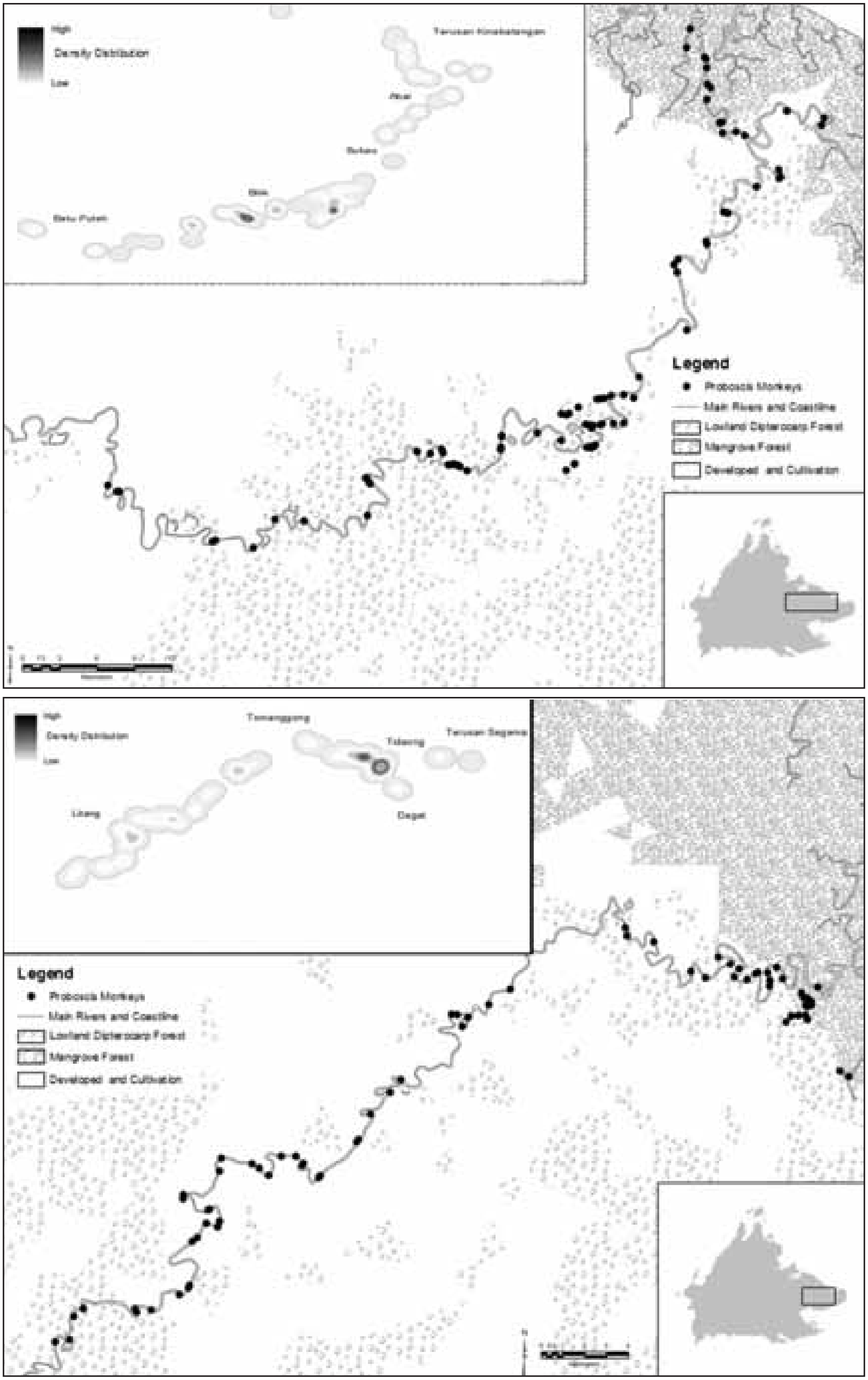
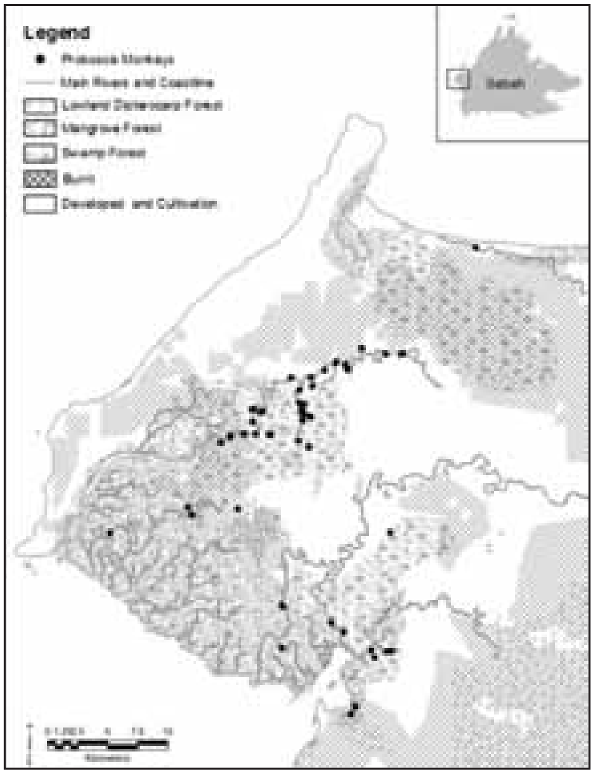
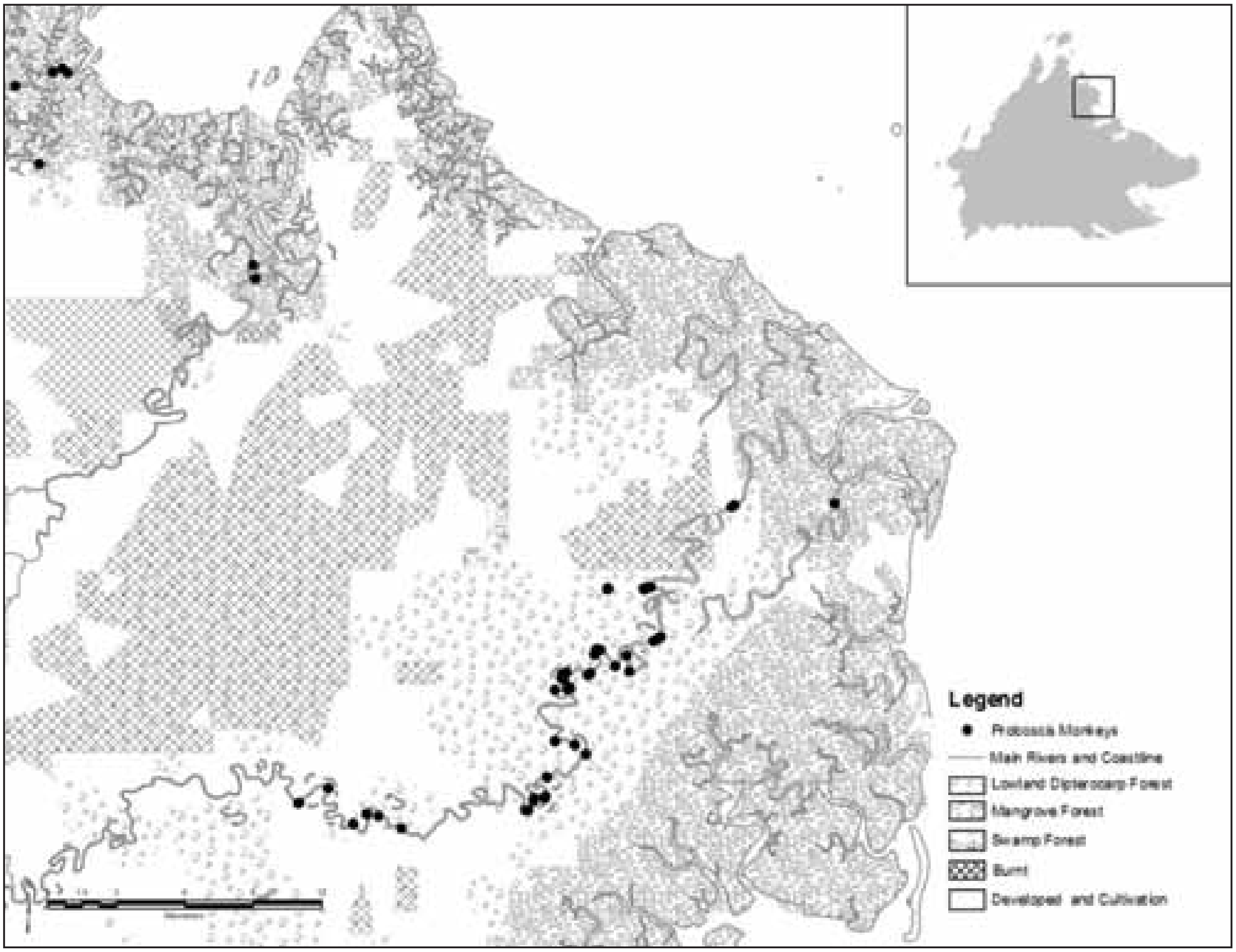


Appendix A. Loss and fragmentation of coastal habitats in Sandakan (top) and Semporna Peninsula (bottom).

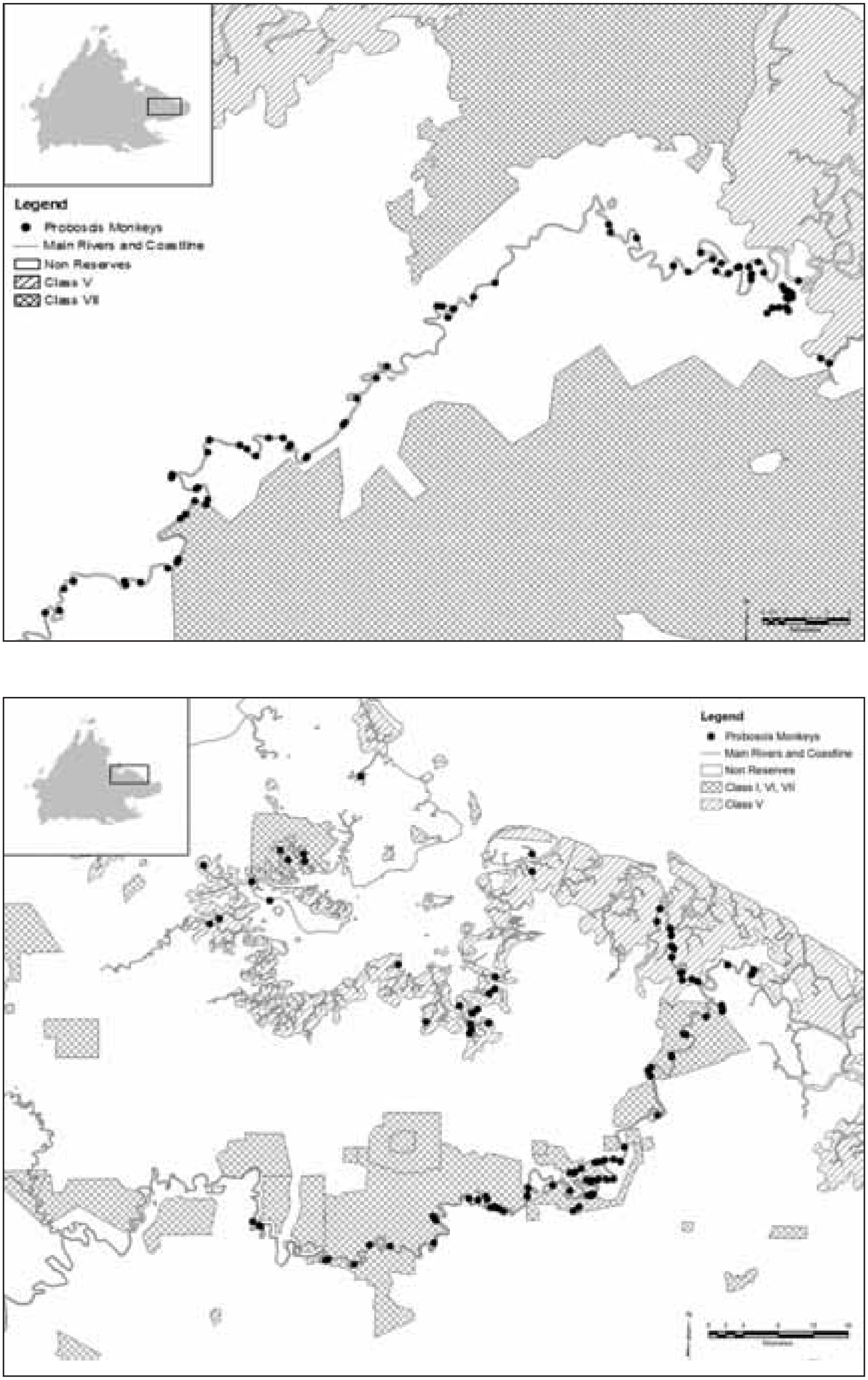


Appendix B. Fragmentation along Kinabatangan (top) and Segama (bottom).

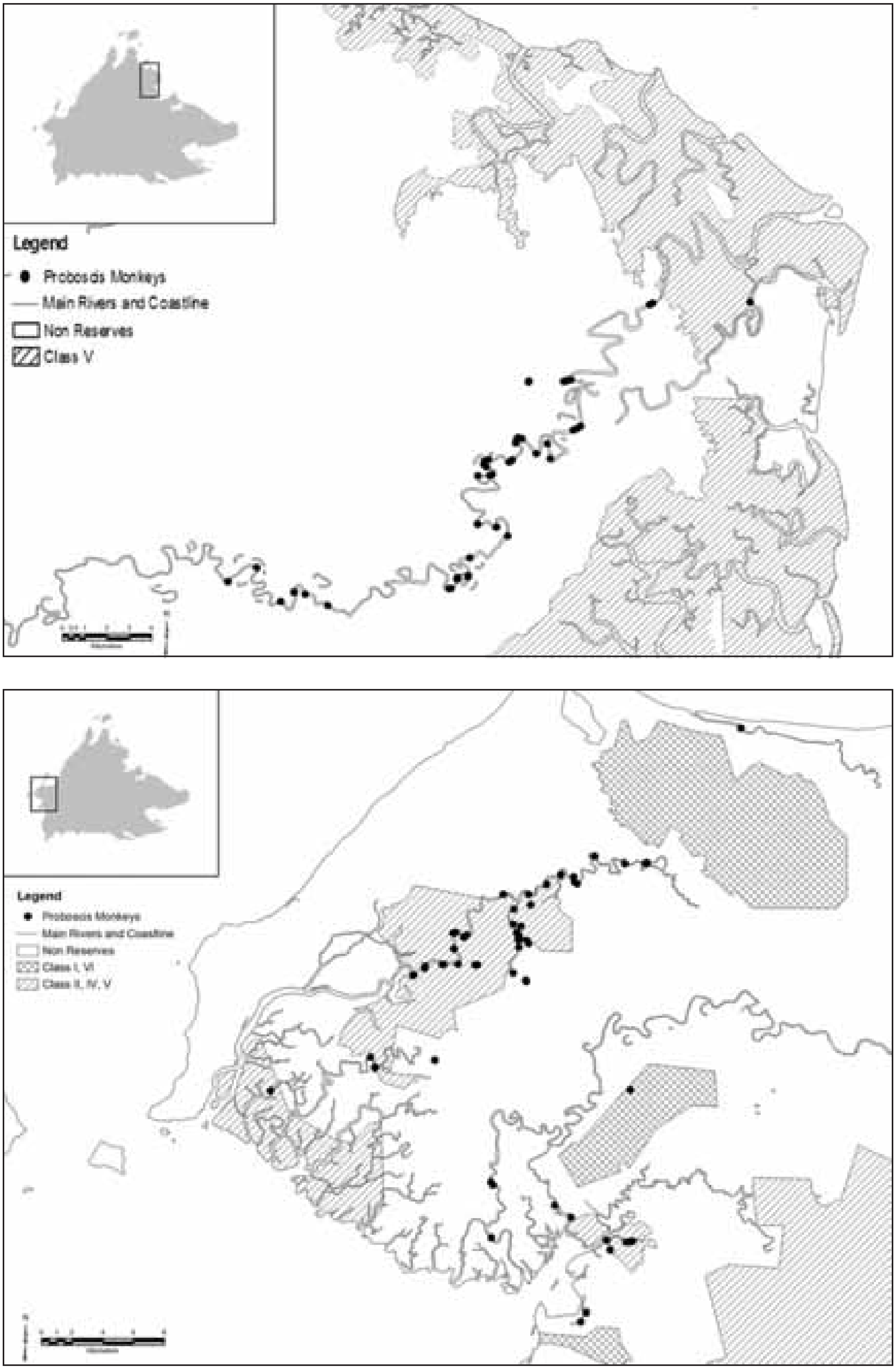




Appendix C. Areas affected by forest fires in Klias Peninsula (top) and Sugut, Tangkarason, Paitan (bottom).



Appendix D. Proboscis monkey distribution in forest reserves. Segama (top) and Kinabatangan (bottom). Sugut and Klias Peninsula).



Appendix D. Proboscis monkey distribution in forest reserves. Sugut (top) and Klias Peninsula (bottom).

Primate Conservation 2008 (23): 121–124

The History and Mystery of the Mountain Tarsier, *Tarsius pumilus*

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Abstract: *Tarsius pumilus* is one of two tarsier taxa listed as Data Deficient. Known by only three museum specimens collected over the course of the past ninety years, it is one of the most mysterious primate species. Inferences drawn from these specimens are that it is a small tarsier adapted for life in the mossy montane forests of Sulawesi at elevations of 1,800–2,200 m. To this I add the further inference from unsuccessful field surveys that is unlikely that this species duets as do other tarsiers from Sulawesi. This raises the possibility that it is not closely-related to other Sulawesian tarsiers, all of which duet, and the phylogenetic position of this species becomes highly interesting. Fossil and biogeographic evidence are consistent with the hypothesis that *T. pumilus* is the sister-taxon to all other extant tarsier species. If this is verified, then the small size of *T. pumilus* is likely to be primitive, and other extant tarsiers, small as they are, might be island giants. I argue that "mountain tarsier" is a more apt common name than "pygmy tarsier".

Key words: Conservation, biogeography, tarsier, *Tarsius*, montane endemic, primate evolution

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Wright (2003) identified the need to remedy the categorization of Data Deficient (DD), then attributed to all the species of tarsiers, as a critical step for their conservation. Subsequent to the Global Mammal Assessment workshop in the Philippines (Puerto Princesa City, Palawan, Philippines, April 2006) and the Asian Primates Red List Workshop held in Cambodia (Phnom Penh, Cambodia, September 2006), the DD status has been removed from all but two of the tarsier taxa: the recently described Palu tarsier *Tarsius lariang* Merker and Groves, 2006, and the pygmy or mountain tarsier *Tarsius pumilus* Miller and Hollister, 1921, one of the world's most mysterious primates. Is *Tarsius pumilus* a developmental aberration unworthy of taxonomic separation, or is it perhaps the grandfather of all extant tarsiers, a sort of Rosetta stone that will unlock the mysteries of the historical biogeography of extant tarsiers? This paper focuses on what we know and what can be inferred about this mysterious primate, and what mysteries may yet be revealed.

Of more than 240 taxa of primates in *The Pictorial Guide to the Living Primates* (Rowe 1996) *Tarsius pumilus* is unique in that, not only has this animal never been photographed, there is no evidence that it has even been seen alive by a scientist who recognized it for what it was. Until the new millennium, this species was known by only two specimens, one collected on New Year's Eve 1917 by American Henry Raven, and the second collected on 17 June 1930 by German Dr. G. Heinrich (Musser and Dagosto 1987). After a gap of nearly seventy years, a third specimen was found in May 2000.

The history of work on *T. pumilus* contains some complexities that warrant clarification. It was described as a small, or pygmy, tarsier based on one of three tarsier specimens collected in 1917 from central Sulawesi by Raven (Miller and Hollister 1921): one was from Rano Rano and the other two from Gimpu. Subsequent analysis of dental eruption revealed that the specimens from Gimpu were juveniles of the ordinary lowland tarsier (Musser and Dagosto 1987), and this population was subsequently taxonomically separated from *T. tarsier* and named *Tarsius lariang* Merker and Groves 2006. The third specimen, the holotype, was an adult, however, and it showed some peculiarities for tarsiers.

First, the collection locality, Rano Rano, was listed as 1,800 m above sea level. Very few other tarsier specimens, from Sulawesi or elsewhere, have been collected above 1,100 m (Gorog and Sinaga 2008). Tarsiers in museum collections from Sulawesi go from sea level up to 1,100 m (the highest of these being a series of tarsiers in the American Museum of Natural History (AMNH) from Lombasang, on the southwest peninsula, east of Makasar). There is a skin in the AMNH from Wawo, on the southeastern peninsula of Sulawesi, from 1,500 m above sea level. MacKinnon and MacKinnon (1980) reported hearing tarsier duet calls in Tangkoko Nature Reserve, on the extreme northern tip of Sulawesi, from sea level to the top of the mountain, an elevation of 1,149 m. Prior to 2000, the only tarsier specimens collected above 1,500 m were the holotype of *T. pumilus*, and the specimen mentioned earlier that was collected by Heinrich in 1930, which was at 2,200 m on the flanks of Mount Rantemario, at the junction where the southwestern peninsula meets the central core of Sulawesi.

Musser and Dagosto (1987) noted several morphological peculiarities shared by the specimens from Rano Rano and from Rantemario. Most obviously, both specimens were quite small, although clearly adult. Linear measurements averaged about 75% of those seen in other Eastern tarsiers (those from the Sulawesi biogeographic region). Other oddities included the keeled, claw-like nails on the fingers and toes, very long and extending beyond the digital pad. The central lower incisors were relatively long, and scanning electron microscopy revealed fine striations, consistent with their having been used to comb their fur. The mountain tarsiers from Rano Rano and Rantemario were different from all others in having rather longer, silkier fur. Additionally, both exhibited enlarged auditory bullae.

The montane habitat of Sulawesi at 1,800–2,200 m above sea level is characterized by cool moss forests. Musser and Dagosto (1987) interpreted the distinctive morphology of the Rano Rano and Rantemario specimens as adaptations for this habitat: the long fur was an adaptation for the colder climate; the elongated incisors helped to groom the fur, as evidenced by the wear pattern seen in the microscopy; the claws were valuable for gripping surfaces in the moss forest, the forest at this elevation being virtually bereft of the smooth surfaces that necessitated the disk-like gripping pads on the digits of lowland tarsiers; and the enlarged bullae reflected auditory adaptations, as this mossy covering deadens sound. Thus, by conducting a detailed morphometric analysis of numerous museum specimens, Musser and Dagosto (1987) were able to identify *T. pumilus* as a montane endemic tarsier adapted to the unique characteristics of the moss forest.

Virtually every tarsier biologist who has worked on Sulawesi has attempted to locate this tarsier, but without success, particularly subsequent to Musser and Dagosto's seminal work on the species. Niemitz (1984) searched near Gimpu, photographing and making field recordings of tarsiers there that he understandably assumed were *T. pumilus*, but which, as was mentioned above, were tarsiers of the *T. tarsier*-complex and are currently classified as *T. lariang*. Mike Tremble and Yopie Muskita (Y. Muskita pers. comm.) spent a month near the type locality, Rano Rano, in the early 1990s before giving up and focusing, instead, on what was then a newly described species, *Tarsius dianae*, which Niemitz *et al*. (1991) had described from Kamarora, a village at about 600–700 m above sea level that lies some 20–30 km west of Rano Rano (see Tremble *et al.* 1993). Subsequently, evidence from the distribution of duet calls that were diagnostic of *T. dianae* indicated that it was a junior synonym of *T. dentatus* Miller and Hollister 1921 (Brandon-Jones *et al*. 2004). Alexandra Nietsch, Stefan Merker, and myself made unsuccessful attempts to locate *T. pumilus* in the highlands around Kamarora in the 1990s (A. Nietsch and S. Merker pers. comm.). During the same period Sharon Gursky searched unsuccessfully for *T. pumilus* in the highlands of Morowali National Park (pers. comm.). In no instance was the tell-tale sign of the Eastern tarsier's duet call encountered, leading some field biologists to privately speculate that the two museum specimens were either aberrant individuals of the *T. tarsier*-complex that develop differently in cold high-altitude environments, or, perhaps, that *T. pumilus* had gone extinct. This second hypothesis seemed particularly unlikely since the montane forests of Sulawesi were little disturbed relative to the lowland forests, where large populations of tarsiers of the *T. tarsier*-complex persist. If anything, the mystery of the mountain tarsier had deepened during the 1990s.

With the dawn of the new millennium new light was suddenly and unexpectedly shed on this mystery. In May 2000, a field assistant working for a small mammal survey of Lore Lindu National Park sponsored by The Nature Conservancy inadvertently trapped and killed the third known specimen of *T. pumilus* in a "Victor"-style snap trap at 2,200 m above sea level on the flank of Mt. Rorekatimbu (Maryanto and Yani 2004). The great irony of this capture is that it occurred very close to areas that were independently surveyed by Nietsch, Merker, and myself. Indeed, both Merker and myself returned to the very site of the third capture and, again, failed to locate definitive evidence of tarsiers. The facts that *T. pumilus* was proven to exist in an area where a number of experienced tarsier field biologists had failed to locate tarsiers, and that experienced tarsier field biologists could not locate tarsiers at a site proven to have them, provided a hint that, perhaps, *T. pumilus* exhibited marked behavioral differences from other Eastern tarsiers. Specifically, it seemed possible that *T. pumilus* did not duet, or produce other vocalizations that are common to Eastern tarsiers and that are well-known to tarsier field biologists experienced in Sulawesi.

Thus, one of the most fundamental questions about *Tarsius pumilus* — does it even exist? — has been answered conclusively with the discovery of the third specimen. The montane habitat of *T. pumilus* is relatively less disturbed compared with its lowland relatives, and from this we can predict that populations of *T. pumilus* should be under relatively less threat of extinction.

Is *T. pumilus* simply an aberrant lowland tarsier, and will we find tarsiers that share this suite of traits wherever lowland tarsiers are pushed into montane habitats? This seems less likely, although a definitive answer to this question will probably require more information, such as observations in the wild or genetic data. But this raises the question about the phylogenetic relationship of *T. pumilus* with other tarsiers: is *T. pumilus* the sister-taxon of some lowland tarsier population (i.e., nested within other Eastern tarsiers), or the sister taxon of all other Eastern tarsiers, or, perhaps, the sister taxon of all other tarsiers? This intriguing possibility — that *T. pumilus* could be the primitive sister-species of all extant tarsiers — is not mere speculation.

While the polarity of character states among tarsiers is not clearly understood, assuming global polarity, *T. pumilus* is primitive in having the furriest tail (Shekelle *et al.* 2008, unpubl. data) and, presumably, no duet call. Furthermore, the small size of *T. pumilus* may well be primitive, as all known fossils of the family Tarsiidae are smaller than extant lowland tarsiers, including *Tarsius eocaenus* and *Xanthorhysis tabrumi* from the Eocene of China (Beard *et al.* 1994; Beard 1998), the disputed *Afrotarsius chatrathi* from the Oligocene of Africa (Simons and Bown 1985), and the last known fossil tarsier, *Tarsius thailandicus*, from Miocene deposits in Thailand (Ginsburg and Mein 1987; see Simons 2003 for a review of the fossil history of tarsiers). This last fossil is very well-placed in space and time to facilitate the dispersal of tarsiers from mainland Asia to Sulawesi in the middle Miocene, according to models of geologic and genetic evolution (Shekelle 2008). Finally, biological evidence indicates that Sulawesi has experienced multiple waves of immigration dating back to the early or middle Miocene, with dispersal from Thailand in the middle Miocene being considered the most likely route (Hall 2001). Although these immigration events are not yet thoroughly understood, one pattern that has emerged from the rodents is that the oldest immigrants are today distributed as montane endemics (J. C. Morales pers. comm.). A small tissue sample suitable for analysis of mitochondrial DNA should be able to answer this question definitively. Unfortunately, the third specimen was placed in formalin before a tissue sample was taken, and subsequent attempts to sequence the formalin-preserved tissue have been unsuccessful (unpubl. data).

The phylogenetic position of *T. pumilus* bears directly on one more assumption about its nature: that it is a pygmy tarsier. If it turns out that *T. pumilus* is, indeed, the sister-species of other extant tarsiers, then being small is quite likely the primitive state (see Beard 2001). Furthermore, if small size is the primitive state for tarsiers, and if *T. pumilus* retains the primitive state, then all other extant tarsiers, small as they are, are actually island giants, following Foster's "island rule" (Foster 1964; MacArthur and Wilson 1967). Thus, an answer to the question of the phylogenetic relationships of *T. pumilus* could have great impact on our understanding of the historical biogeography of extant tarsiers.

As a postscript, given that we are now reasonably certain that *T. pumilus* is a montane tarsier with a known distribution of 1,800–2,200 m above sea level, and given that its status as a pygmy form is unresolved, perhaps it is more apt to think of this animal as the mountain tarsier, and refer to it by that name.

Acknowledgments

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Literature cited

Beard, K. C., T. Qi, M. R. Dawson, B. Wang and C. Li. 1994. A diverse new primate fauna from middle Eocene fissure-fillings in southeastern China. *Nature, Lond.* 368: 604–609.

Beard, K. C. 1998. A new genus of Tarsiidae (Mammalia: Primates) from the middle Eocene of Shanxi Province, China, with notes on the historical biogeography of tarsiers. *Bull. Carnegie Mus. Nat. Hist.* 34: 260–277.

Beard, K. C. 2001. The fossil record and the evolutionary history of tarsiid primates. In: *Abstracts and Programme. The XVIII Congress of the International Primatological Society "Primates in the New Millennium"*, p.225. 7–12 January 2001, Adelaide, Australia. Abstract.

Brandon-Jones, D., A. A. Eudey, T. Geissmann, C. P. Groves, D. J. Melnick, J. C. Morales, M. Shekelle and C.-B. Stewart. 2004. Asian primate classification. *Int. J. Primatol.* 25: 97–164.

Foster, J. B. 1964. Evolution of mammals on islands. *Nature, Lond*. 202: 234–235.

Ginsburg, L. and P. Mein. 1987. *Tarsius thailandica* nov. sp., Tarsiidae (Primates, Mammalia) fossile d'Asie. *C. R. Academie of Science (Paris)* t.304, ser. II, (19): 1213–1215.

Gorog, A. J. and M. H. Sinaga. 2008. A tarsier capture in upper montane forest on Borneo. In: *Primates of the Oriental Night*, M. Shekelle, I. Maryanto, C. Groves, H. Schulze and H. Fitch-Snyder (eds.), pp.29–33. Indonesian Institute of Sciences. Cibinong, Indonesia.

Hall, R. 2001. Cenozoic reconstructions of SE Asia and the SW Pacific: changing patterns of land and sea. In: *Faunal and Floral Migrations and Evolution in Southeast Asia – Australia*, I. Metcalf, J. Smith, M. Morwood, and I. Davidson (eds.), pp. 35–56. Swets and Zeitlinger, Lisse, The Netherlands.

MacArthur, R. H. and E. O. Wilson. 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton, NJ.

MacKinnon J. and K. MacKinnon. 1980. The behavior of wild spectral tarsiers. *Int. J. Primatol.* 1(4):361–379.

Maryanto, I. and M. Yani. 2004. The third record of pygmy tarsier (*Tarsius pumilus*) from Lore Lindu National Park, Central Sulawesi, Indonesia. *Trop. Biodiv.* 8(2) 79–85.

Merker, S. and C. P. Groves. 2006. *Tarsius lariang*: a new primate species from western central Sulawesi. *Int. J. Primatol.* 27: 465–485.

Miller Jr., G. S. and N. Hollister. 1921. Twenty new mammals collected by H. C. Raven in Celebes. *Proc. Biol. Soc. Wash.* 34: 93–104.

Musser, G. G. and M. Dagosto. 1987. The identity of *Tarsius pumilus*, a pygmy species endemic to the montane mossy forests of Central Sulawesi. *Am. Mus. Nov.* (2867): 1–53.

Niemitz, C. 1984. Vocal communication of two tarsier species (*Tarsius bancanus* and *Tarsius spectrum*). In: *Biology of Tarsiers*, C. Niemitz (ed.), pp.129–142. Gustav Fischer Verlag, New York.

Niemitz, C., A. Nietsch, S. Warter and Y. Rumpler. 1991. *Tarsius dianae*: a new primate species from Central Sulawesi (Indonesia). *Folia Primatol.* 56: 105–116.

Rowe, N. 1996. *The Pictorial Guide to the Living Primates*. Pogonias Press, East Hampton, NY.

Shekelle, M. 2008. Distribution and biogeography of tarsiers. In: *Primates of the Oriental Night*, M. Shekelle, I. Maryanto, C. P. Groves, H. Schulze and H. Fitch-Snyder (eds.), pp.13–28. Indonesian Institute of Sciences. Cibinong, Indonesia.

Shekelle, M., C. P. Groves, S. Gursky, I. Neri-Arboleda and A. Nietsch. 2008. A method for multivariate analysis and classification of tarsier tail tufts. In: *Primates of the Oriental Night*, M. Shekelle, I. Maryanto, C. P. Groves, H. Schulze and H. Fitch-Snyder (eds.), pp.71–84. Indonesian Institute of Sciences. Cibinong, Indonesia.

Simons, E. L. and T. M. Bown. 1985. *Afrotarsius chatrathi*, first tarsiiform primate (? Tarsiidae) from Africa. *Nature, Lond*. 313: 475–477.

Simons, E. L. 2003. The fossil record of tarsier evolution. In: *Tarsiers: Past, Present, and Future*, P. C. Wright, E. L. Simons and S. Gursky (eds.), pp.9–34. Rutgers University Press, New Brunswick.

Tremble, M., Y. Muskita and J. Supriatna. 1993. Field observations of *Tarsius dianae* at Lore Lindu National Park, Central Sulawesi, Indonesia. *Trop. Biodiv.* 1(2): 67–76.

Wright, P. C. 2003. Are tarsiers silently leaping into extinction? In: *Tarsiers: Past, Present, and Future*, P. C. Wright, E. L. Simons and S. Gursky (eds.), pp.296–308. Rutgers University Press, New Brunswick.

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Editor's Note: As this article was being finalized for online publication, MSNBC reported that *Tarsius pumilus* had been rediscovered. According to the report, *T. pumilus* does not duet, as was predicted in this article.

Boyle. A. 2008. [Science editor msnbc.com]. Real-life Furbys rediscovered: Some experts feared that Indonesia's pygmy tarsier was extinct. Website: <http://www.msnbc.msn.com/id/27786771/from/ET>. Posted 2:01 p.m. ET, 18 November 2008. Accessed 18 November 2008.

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New Distribution Records for *Hoolock leuconedys* in India

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Abstract: The western hoolock gibbon (*Hoolock hoolock*) occurs in India (south of the southern bank of the River Dibang-Brahmaputra in the seven northeastern states), Bangladesh and Myanmar. The eastern hoolock gibbon (*Hoolock leuconedys*) is restricted to the state of Arunachal Pradesh in northeast India, and occurs also in Myanmar and China. Here we report new information that extends the known range of the eastern hoolock gibbon in India. *Hoolock leuconedys* was found in Koraonu circle in the lower Dibang Valley district beyond its previously known range in the Lohit district.

Key words: Hoolock gibbon, *Hoolock hoolock, Hoolock leuconedys*, distribution, Dibang, Lohit, Arunachal Pradesh, India

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Gibbons are found in South and Southeast Asia. There are 16 species belonging to four genera. The genus *Hoolock* is characterized by a diploid chromosome number of 38 and has two species: the western hoolock gibbon (*Hoolock hoolock*) and the eastern hoolock gibbon (*Hoolock leuconedys*). In the past, *leuconedys* was considered to be a subspecies of *Hoolock hoolock* (see Groves 1967). The generic name *Hoolock* was assigned to the species only recently by Mootnick and Groves in 2005: the two gibbons were previously placed in the genus *Hylobates* and, later, *Bunopithecus*. The two gibbons are considered to be distinct species due to features in their fur coloration as described by Groves (1967, 1972).

The western (*H. hoolock*) and eastern hoolock gibbons (*H. leuconedys*) are found in India. The former also occurs in the neighboring countries of Bangladesh (Anderson 1878), Myanmar (Tickell 1864) and China (Anderson 1878). Until 2006, however, it was believed that the eastern hoolock gibbon occurred only to the east of the River Chindwin to the River Salween in Myanmar and southwestern Yunnan Province in China (Groves 1971). Das *et al*. (2006) provided the first report of its occurrence in India, between the River Lohit in the north and the high mountains of the Dafa Bum in the south. Here we provide further information on the range of *H. leuconedys* in India.

The species was sighted during a field study (2006–2007) in the area between the rivers Dibang and Lohit in the lower Dibang valley district of Arunachal Pradesh, specifically in the area known as the Koronu circle (see Table 1; Fig. 1).

Table 1. Records (sightings) of eastern hoolock gibbons, *Hoolock leuconedys*, in Koronu circle area, Arunachal Pradesh, India.

	Group size	Group composition					Coordinates		Altitude (m)
		AM	AF	SA	J	I			
1	2	1	1				28°06'04.8N	95°54'29.2E	500
2	1	1					28°06'25.4N	95°55'04.9E	750
3	4	1	1	-	1	1	28°03'40.1N	95°56'00.0E	310
4	3	1	1			1	28°03'93.3N	95°56'49.3E	357
5	1	1					28°03'93.7N	95°56'50.6E	348
6	1	1					28°04'39.7N	95°58'19.0E	430
7	3	1	1		1		Dello Village		
8	3	1	1		1		Dello Village		
9	3	1	1			1	Dello Village		
10	3	1	1		1		Dello Village		

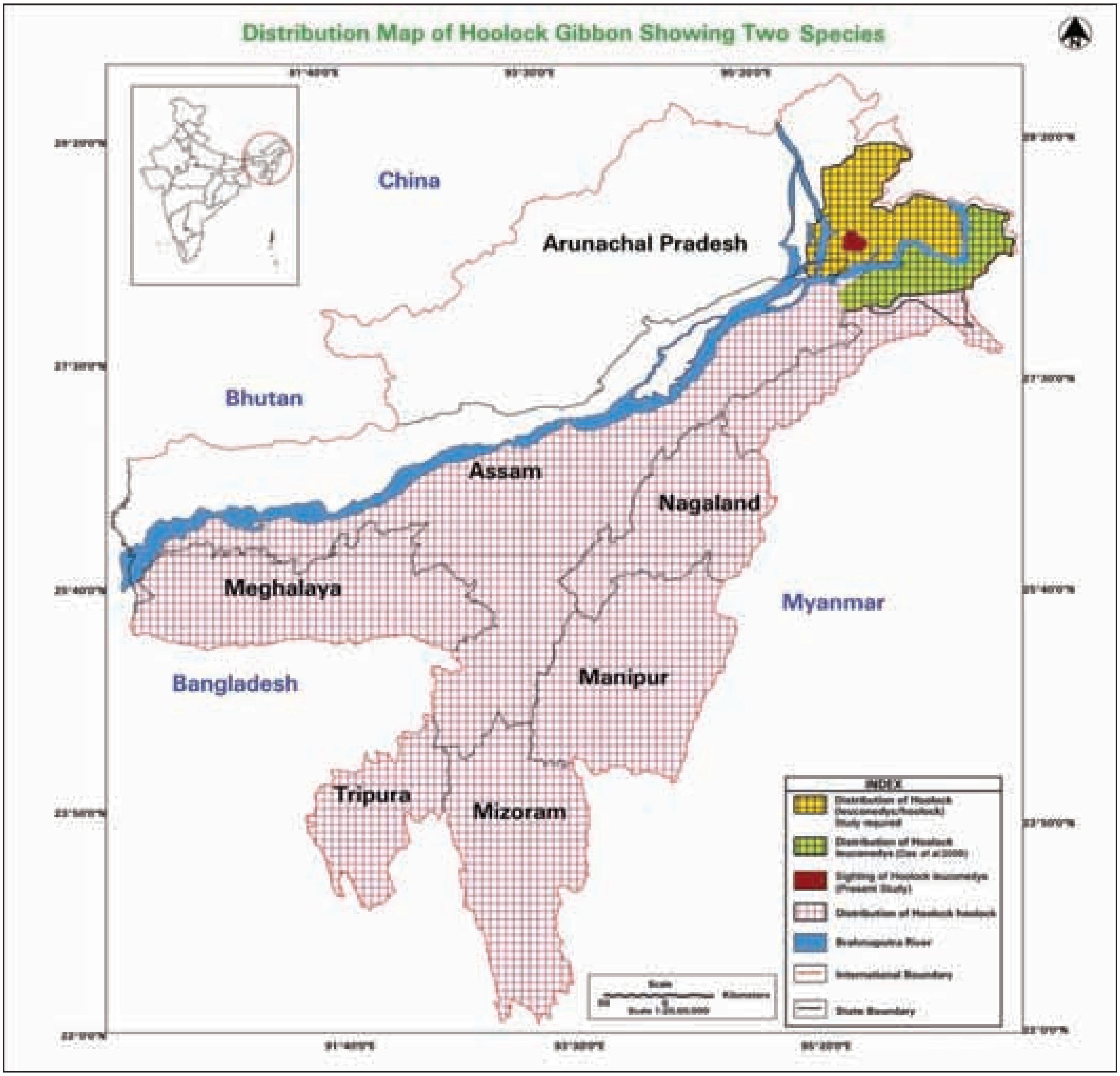

Figure 1. The distributions of the western hoolock gibbon (*Hoolock hoolock*) and the eastern hoolock gibbon (*H. leuconedys*) in northeastern India. The patch in red marks the occurrence of *H. leuconedys* reported here; between the rivers Dibang and Lohit.

The pelage color differences that distinguish it from the western hoolock gibbon were confirmed through binoculars and photographs. Their identity was further confirmed through a review of recent literature (Groves 1972, 2001, 2007; Mootnick and Groves 2005) and through personal correspondence with Colin P. Groves and Warren Brockelman. We sent them color photographs, and both confirmed the species as eastern hoolock gibbon (*H. leuconedys*).

This range extension lies between the rivers Dibang and Lohit. Although further, more detailed, studies are needed, it is evident that forest loss and fragmentation due to expansion of tea gardens, ginger and mustard cultivation, horticulture, *jhum* cultivation, and rice paddies is a major threat to the species in this area. In 2007, a team of forest officers of the Arunachal Pradesh government, under the supervision of Mr. C. Loma of the Deputy Conservator of Forests (DCA) (Director, Biological Park, Itanagar), rescued 12 individuals of eastern hoolock gibbon (in four groups) from the Dello village in the Koronu Circle area in the Lower Dibang valley district. The gibbons had been trapped in a very small remnant forest with very few trees left standing. The rescued gibbons are now in the Zoological Park at Itanagar, the capital of Arunachal Pradesh. The Koronu Circle area on the fringe of the Mehao Wildlife Sanctuary and Turung Reserve Forest

Figure 2. Adult male eastern hoolock gibbon (*Hoolock leuconedys*) showing the genital tuft.

Figure 3. Adult female eastern hoolock gibbon (*Hoolock leuconedys*).

in Lohit district are the best sites for observing this species (Chetry *et al*. 2007). A detailed systematic study is needed to evaluate the population status of the eastern hoolock gibbons between the Dibang River and the Lohit River in particular and India in general.

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Literature Cited

Anderson, J. 1878. *Anatomical and Zoological Researches Comprising an Account of the Zoological Results of the Two Expeditions to Western Yunnan in 1868 and 1875*. Quaritch, London.

Chetry, D., R. Chetry and P. C. Bhattacharjee. 2007. *Hoolock: The Ape of India.* Gibbon Conservation Centre, Gibbon Wildlife Sanctuary, Mariani, Assam, India. 133pp.

Das, J., J. Biswas, P. C. Bhattacharjee and S. M. Mohnot. 2006. First distribution records of the eastern hoolock gibbon *Hoolock hoolock leuconedys* from India. *Zoo's Print J.* 21(7): 2316–2320.

Groves, C. P. 1967. Geographic variation in the hoolock or white browed gibbon *Hylobates hoolock* (Harlan, 1834). *Folia Primatol.* 7: 276–283.

Groves, C. P. 1971. Geographic and individual variation in Bornean gibbons, with remarks on the systematics of the subgenus *Hylobates*. *Folia Primatol.* 14: 139–53.

Groves, C. P. 1972. Systematics and phylogeny of gibbons, In: *Gibbons and Siamang*, Vol. 1, D. M. Rumbaugh, (ed.), pp.1–89. S. Karger, Basel.

Groves, C. P. 2001. *Primate Taxonomy*. Smithsonian Institution Press, Washington, DC.

Groves, C. P. 2007. The two species of hoolock gibbon (*Hoolock* Mootnick & Groves, 2005). *Zoo's Print J.* in press.

Mootnick, A. R. and C. P. Groves 2005. A new generic name for the hoolock gibbon (Hylobatidae). *Int. J. Primatol*. 26(4): 971–976.

Tickell, S. R. 1864. Notes on the gibbon of Tenasserim, *Hylobates lar*. *J. Asiatic Soc. Bengal* 33:196–199.

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The Crab-eating Macaque (*Macaca fascicularis*): Widespread and Rapidly Declining

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Abstract: The crab-eating or long-tailed macaque (*Macaca fascicularis*) of tropical Southeast Asia is a widespread but rapidly declining species. The threats to the species are manifold and include habitat loss and degradation that increasingly result in conflict with expanding human populations in both rural and urban landscapes, as well as trapping and trade for pharmaceutical testing, research, and development. The greatest threat from the trade is in the Indochinese region, especially Cambodia where in 2003–2004 macaques began to be harvested from the wild, ostensibly for captive breeding for export to China and to the USA and elsewhere. The lucrative operations, however, may serve to "launder" wild-caught monkeys and appear to have resulted in their disappearance even from legally protected areas. Much of the impetus for this trade appears to be biowarfare research in the USA, the country that is the world's largest user of primates. *Macaca fascicularis* is classified as of "Least Concern" in the *IUCN/SSC 2008 Red List of Threatened Species.* It is imperative that the conservation status of the species be reassessed and that the impact of trade on the species be assessed by the CITES Secretariat.

Key Words: *Macaca fascicularis*, crab-eating macaque, trafficking, Pharma, Indochinese region, Cambodia

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Introduction

During an open meeting at the 2008 Congress of the International Primatological Society (IPS) in Edinburgh, UK, to review the biennial listing of the "World's 25 Most Endangered Primates", a joint endeavor of the IUCN/SSC Primate Specialist Group, Conservation International and IPS, I raised the issue of how one should address the status of a species, in this instance *Macaca fascicularis*, that is widespread and, therefore, apparently numerous, but shares threats with Critically Endangered and Endangered species, as well as suffering from growing exploitation of wild populations for biomedical research/industrial testing. It is categorized as of "Least Concern" in the IUCN/SSC *2008 Red List of Threatened Species* (IUCN 2008).

I brought up this issue more than 20 years ago at the 1986 IPS Congress in Göttingen, Germany (Eudey 1986), and subsequently recognized it in the *Action Plan for Asian Primate Conservation: 1987–91* (Eudey 1987). At the 2008 IPS Congress, Holger Preuschoft, twice president of IPS, had questioned the wisdom of focusing attention just on precariously small populations, many of which are relict (my term). I likened *Macaca fascicularis* to the North American passenger pigeon (*Ectopistes migratorius*), which was considered to be the most abundant bird on Earth until it was hunted to extinction in 1900 (Weisman, 2007). Russell A. Mittermeier, as convenor of the 2008 meeting on the "World's 25 Most Endangered Primates" (Mittermeier *et al*. 2008), responded knowledgeably to my inquiry (see below), and *M. fascicularis* became recognized as the first "widespread and rapidly declining" species. Justification for this is presented below.

Geographic Distribution and Threats

Macaca fascicularis (Raffles, 1821), commonly known as the crab-eating or long-tailed macaque, is widely distributed in tropical mainland and insular Southeast Asia (Fooden 1995). The species' natural range extends southward and eastward from India (the three southernmost Nicobar Islands), into southernmost Bangladesh, where the population has been completely decimated by shrimp cultivation and shipbuilding (Molur *et al.* 2003) and southern Burma (also known as Myanmar), where habitat area and quality have been significantly reduced by human activity, including logging, agriculture and shrimp farming (Molur *et al.* 2003). Its range also includes the southern part of the Indochinese Peninsula (Thailand, Cambodia, Laos and Vietnam, south of 17°N), the Isthmus of Kra, the Malay Peninsula (including Singapore), Sumatra, Borneo, Java and the Lesser Sunda Islands (including Bali and Timor), and the Philippines.

The species is found most commonly at low elevations, where it prefers seashore and mangrove forest, river banks, and swamp forest (Fooden 1995), much of which is highly vulnerable to the effects of global warming. According to a recent United Nations Environment Programme (UNEP) report (Nelleman 2007), up to 98% of forest habitat in Sumatra and Borneo — a significant part of the crab-eating macaques' core area — may be destroyed by 2022 through conversion to oil palm plantations, poaching of high-grade timber and clearing land for farming.

The genus *Macaca* appears to be the most successful of all nonhuman primates in human landscapes (Muroyama and Eudey 2004). In contrast to many other Asian primates, crab-eating macaques thrive in secondary forest and in commensal relationships with humans, who have been introducing them onto islands for at least 4,000–5,000 years (Fooden 1995). Economic growth and a rapidly expanding human population have resulted in increasingly widespread encroachment on forest habitat, resulting in burgeoning human/nonhuman primate conflict due to crop-raiding by the macaques and, more recently, pest behavior in urban environments as they exploit garbage and other human food sources (Twigg 2008). The reluctance of people to stop deliberately feeding the macaques and to take recognized measures to secure garbage has exacerbated the problem in many urban settings. Besides forest loss and increasing urbanization in their range, trade in wild-caught macaques for human consumption and, increasingly, for research and development and testing by the pharmaceutical industry (Pharma) is having a negative impact on their populations.

In 2007, the government of Peninsular Malaysia, amid accusations of corruption, temporarily lifted a 23-year-old ban on the export of macaques in a purported, but successfully contested, effort to control urban macaques by allowing for trade for research and human consumption to China and elsewhere. A six-month program of culling and translocation based on questionably high numbers of urban and forest crab-eating macaques is reported to have been initiated during the latter half of 2008, so as to reduce the urban populations (Twigg 2008).

Trafficking in the Indochinese Region

The Indochinese region, especially Cambodia, is where *Macaca fascicularis* faces the greatest threats from trade, specifically for toxicology studies and pharmaceutical research and development. Imports to the United States (the largest user of primates in experimentation and testing) and elsewhere began to increase in 1974–1978 during the worldwide reduction and subsequent ban of *Macaca mulatta* (rhesus macaque) exports from India. Malaysia, the Philippines, and Indonesia became the primary suppliers of crab-eating macaques (Mack and Eudey 1984). In the late 1980s, *M. fascicularis* was introduced into China, where it is not native, for captive breeding (Fan and Song 2003; Hsu and Jia 2003), although acquisition of wildlife for human consumption (food and traditional medicine) by affluent Chinese appears to have been the force driving the trade (CRES undated). China had already begun captive breeding of native rhesus macaques in 1978 and was exporting them by 1984 (Fan and Song 2003; Hsu and Jia 2003). Initially, unregulated border trade appears to have occurred between China and government-owned companies (NAFORIMEX) and government agencies in Vietnam. In the 1990s, however, some four commercial monkey farms, operated by entrepreneurs from Hong Kong and China, began to export wild-caught macaques as captive-bred in these countries, probably for transshipment. Early on, the macaques may have sold for US$50–60, and monkeys smuggled from Cambodia and Laos appear to have figured in all these transactions (CRES undated).

In 2002–2003, the Cambodian Ministry of Agriculture, Forestry and Fisheries (MAFF) granted harvest permits to five monkey farms to breed *Macaca fascicularis* for export (Cambodian CITES Management Authority pers. comm. 2007). Ostensibly the farms are joint ventures, but they are owned and operated by Chinese and Hong Kong entrepreneurs, including some already operating in Vietnam. Collecting of monkeys began to accelerate in 2004 as farms (and holding areas) were established adjacent to protected areas, where macaques, along with other wildlife, are protected. Farm staff enlisted the aid of, and instructed, local villagers in the trapping of monkeys, which involves isolating groups in trees by felling the surrounding forest: a practice that exacerbates the already serious threat of forest loss through logging. The monkeys caught are worth the equivalent of US$20–80, depending on weight and condition (Cambodian CITES Management Authority pers. comm. 2007).

Observers from non-governmental organizations (NGOs) question whether the breeding farms are illegally buying and selling macaques, as numbers of monkeys show extreme fluctuations and the numbers of infants may exceed adults. Although "factory farming" of infant macaques (that is, removing the infant from its mother at birth to accelerate her resuming ovulation) now may occur, export of wild-caught monkeys still is suspected; and new breeding farms continue to obtain monkeys from the wild rather than purchasing captive-bred ones from existing farms (Cambodian CITES Management Authority pers. comm. 2007). At the same time, there is growing suspicion that crab-eating macaques caught in Cambodia with forged CITES permits from Laos are being smuggled into Vietnam by a large and sophisticated trans-border wildlife trafficking network (see, for example, Hoang Quoc Dong 2008). Three monkey colonies also have been identified in Laos. They appear to be obtaining macaques from Cambodia and from Thailand (where trafficking in "temple monkeys" to Cambodia may have existed for years; K. Bauers pers. comm. 2008), and transshipping them to Hong Kong and China for further export (Y. Hamada pers. comm. 2008).

As a consequence of the wildlife trafficking described above, *Macaca fascicularis* may no longer be found in protected areas in Cambodia even where rare and more endangered species occur (R. A. Mittermeier pers. comm. 2008). During a month-long study of open wildlife (bushmeat) trade in the northeastern Cambodian province of Ratanakiri in 2008, Lee (2008) found no crab-eating macaques for sale; dead or alive. None of four farmer-hunters interviewed by him reported harvesting macaques in recent times, but one recalled hunting them and other primates with guns in the 1980's. Lee (2008) reports a general consensus that all wildlife has declined drastically in the past 5–10 years. Trappers and NGOs alike have expressed concern that at the present rate of exploitation crab-eating macaques will be extirpated in Cambodia within one or two years.

Importations into the United States

Data compiled by the US Fish and Wildlife Service (Law Enforcement Management Service) indicate a significant increase in imports of *Macaca fascicularis* into the United States, the world's greatest user of primates. Numbers rose from 17,214 in 2004 to more than 24,000 annually during 2005–2007 (Anon. 2007; my analysis of 2007 data). Imports from Cambodia, all of which were claimed to be captive-bred, went from zero in 2004 to 240 in 2005, to 2,532 in 2006, and then may have declined to 720 in 2007 (McGreal 2007; my analysis). (At a 2008 conference entitled *Animal Research in a Global Environment: Meeting the Challenges*, organized by the U.S. Institute for Laboratory Animal Research [ILAR], discussion indicated a lack of agreement on exact numbers but suggested that during 2007 total imports of *M. fascicularis* and imports from Cambodia might be higher.)

According to the Cambodian CITES Management Authority (pers. comm. 2007), the country exported 23,000 crab-eating macaques to China during 2004–2006 and more than 17,000 as of November 2007. In turn, China was responsible for more than half of all monkeys imported into the United States in 2006 and 2007 (Anon. 2007; my analysis). A contract negotiated for a drug development services company indicates that US buyers have paid US$1,475 (cost and freight) per monkey to Cambodian macaque suppliers (plus an additional US$100 to the transfer agent for each monkey that completes quarantine). The initial impetus for this trade would appear to be "Project Bioshield", which was signed into US law in 2004, to encourage, with a budget of $5.6 billion, the development of vaccines or other products to counter biowarfare (see Dudley and McFee 2005). A more recent development is outsourcing of experimentation and testing on primates to China and the associated growth of joint ventures. A press release on the company's website, for example, reports that on 24 June 2008 Covance Inc., headquartered in Princeton, New Jersey, and considered to be one of the world's largest and most comprehensive drug development services companies, had entered into a Memorandum of Understanding with WuXi Pharma Tech of Shanghai to create a 50-50 joint venture "to provide world-class preclinical contract research services in China."

Conclusions

Macaques frequently are considered as well known or common: as a consequence, data on the present status of populations such as numbers, distribution and population trends are deficient for most species, especially those that are widespread geographically, such as *Macaca fascicularis* (see Muroyama and Eudey 2004). It is imperative that the conservation status of *M. fascicularis* be reassessed, particularly taking into account the impact of trade on the species, requiring as such a careful assessment by the CITES Secretariat.

Literature Cited

Anonymous. 2007. U.S. primate imports spike. *IPPL News* 3(1): 8–10.

CRES. Undated. Final report on Vietnam Wildlife Trade Monitoring Project. Report, Centre for Natural Resources Management and Environmental Studies (CRES), University of Hanoi, Vietnam.

Dudley, G. and R. B. McFee. 2005. Preparedness for biological terrorism in the United States: Project BioShield and beyond. *J. Am. Osteopathic Assoc.* 105:417–424.

Eudey, A. A. 1986. Rethinking the theoretical base for primate conservation. XI Congress of the International Primatological Society, Göttingen, Germany. *Primate Rep.* 14: 196. Abstract.

Eudey, A. A. (compiler). 1987. *Action Plan for Asian Primate Conservation: 1987–91.* IUCN/SSC Primate Specialist Group, Gland, Switzerland.

Fan, Z. and Y. Song. 2003. Chinese primate status and primate captive breeding for biomedical research in China. In: *International Perspectives: The Future of Nonhuman Primate Resources, Proceedings of the Workshop Held April 17–19, 2002*, National Research Council (ed.), pp.36–45. National Academic Press, Washington, DC.

Fooden, J. 1995. Systematic review of Southeast Asian longtail macaques, *Macaca fascicularis* (Raffles, [1821]). *Fieldiana Zool., new series* (81): 1–206.

Hoang Quoc Dung. 2008. A trans-border wildlife trade network unmasked, in 4 parts. *Tien Phong Newspaper*, Hanoi, Vietnam. Unofficial translation, Earth Journalism Network. Website: <http://www.earthjournalism.org/ejn_info.htm>. Accessed 24 October 2008.

Hsu, C. K. and R. Jia. 2003. Chinese macaques — East meets West. In: *International Perspectives: The Future of Nonhuman Primate Resources, Proceedings of the Workshop Held April 17–19, 2002*, National Research Council (eds.), pp. 197–199. National Academic Press, Washington, DC.

Lee, B. P. Y. H. 2008. A possible decline in populations of the long-tailed macaque (*Macaca fascicularis*) in northeastern Cambodia. Unpublished report, Programme in International Wildlife Trade & Conservation, Durrell Institute of Conservation & Ecology, University of Kent, Canterbury, UK.

Mack, D. and A. Eudey. 1984. A review of the U.S. primate trade. In: *The International Primate Trade. Volume 1, Legislation, Trade and Captive Breeding*, D. Mack and R. A. Mittermeier (eds.), pp.91–136. TRAFFIC (USA), Washington, DC.

Mittermeier, R. A., A. B. Rylands and E. A. Williamson. 2008. The world's 25 most endangered primates: 2008–2010. In: *Abstracts: XXII Congress of the International Primatological Society, August 3–8 2008, Edinburgh, UK. Primate Eye (96) Special Issue*: 241–242. Abstract.

McGreal, S. 2007. The sad fate of Cambodia's monkeys. *IPPL News* 3(1):4–7.

Molur, S., D. Brandon-Jones, W. Dittus, A. Eudey, A. Kumar, M. Singh, M. M. Feeroz, M. Chalise, P. Priya and S. Walker (eds.). 2003. *Status of South Asian Primates: Conservation and Management Plan (C.A.M.P.) Workshop Report.* Zoo Outreach Organisation/CBSG-South Asia, Coimbatore, India.

Muroyama, Y. and A. A. Eudey. 2004. Do macaque species have a future? In: *Macaque Societies: A Model for the Study of Social Organization*, B. Thiery, M. Singh, and W. Kaumanns (eds.), pp.328–332. Cambridge University Press, Cambridge, UK.

Nelleman, C., L. Miles, B. P. Kaltenborn, M. Virtue and H. Alenius. 2007. *The Last Stand of the Orangutan — State of Emergency: Illegal Logging, Fire and Palm Oil in Indonesia's National Parks.* United Nations Environment Programme (UNEP), Nairobi, with the Department for Environment, Food and Rural Affairs (DEFRA), the Great Ape Survival Project (GRASP), and the United Nations Educational, Scientific and Cultural Organisation (UNESCO).

Twigg, I. 2008. A warning of the possible decline in long-tailed macaques (*Macaca fascicularis*) in Peninsular Malaysia due to a programme of indiscriminate culling. Unpublished report, Primate Conservation, Oxford Brookes University, Oxford, UK.

Weisman, A. 2007. *The World Without Us.* Thomas Dunne Books, St. Martin's Press, New York.

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Karst Habitat Fragmentation and the Conservation of the White-headed Langur (*Trachypithecus leucocephalus*) in China

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Abstract: The white-headed langur survives in just four karst forest fragments in China: one in the Longgang National Nature Reserve on the border of the counties of Longzhou and Ningming (NS habitat); a second in Chongzuo Banli Provincial Nature Reserve, Chongzuo County (CZ habitat); and two in Fusui Papen Provincial Nature Reserve, Fushui County (F1 habitat and F2 habitat), all in the southwest of Guangxi Province. The population is fewer than 700. We used GIS of Mapinfo Professional 7.0 and Arcview 3.2 to study karst landscape features (forest fragmentation and patchiness of natural formations and those resulting from or affected by human activities) in the known range of the white-headed langur. Results indicated that the NS fragment was the best conserved regarding the presence of natural karst hill system forest and the connectivity of forest habitat, and having the least agriculture. F1 and F2 ranked the second and the third in these aspects, while the CZ forest was the most fragmented and degraded by human activities. Most of the plains in F1, F2 and CZ were cultivated, given over to sugarcane plantations — the most widespread cash crop in the southwest of Guangxi province. The four karst habitats and their populations of white-headed langurs are facing similar problems, most marked in F1, F2 and CZ. Foremost are cultivation and human interference, then firewood collection and illegal hunting. Fortunately, the government has initiated some measures to mitigate the affects of human activities, including clamping down on illegal hunting.

Key Words: Conservation, fragmentation, karst habitat, white-headed langur, *Trachypithecus leucocephalus*

Introduction

Habitat fragmentation is one of the main factors causing decreases in animal populations in the wild (Caro 1998). The forests of the karst fengcong (peak cluster) depression provide a very special type of habitat (Jiang 1996). They are naturally isolated from other peak clusters, but they are now suffering intense fragmentation, reduction and degradation of the forests within the clusters due to intensive agricultural activities in the flat lowlands (Jiang 1996; Huang 2002; see Fig. 1). The white-headed langur, *Trachypithecus leucocephalus*, occurs only in these forests, but their fragmentation and degradation, along with illegal hunting, is driving them to extinction. It is one of the world's most endangered primates (Konstant *et al.* 2002–2003).

The white-headed langur is one of a few primates endemic to Asian karst forests, one of the so-called limestone langurs (Huang 2002; Groves 2004; Nadler 2006). It is found only in the karst hills of four counties (Longzhou, Ningming, Chongzuo and Fushui) in southern Guangxi province, China, between 107°46' and 108°03'E and 22º25' and 22°31'N (Li *et al*. 2003). These langurs are well adapted to this environment, skillfully climbing up and down the cliffs to reach the caves where they sleep at night (Huang *et al*. 2003a; Huang and Li 2005). The most recent surveys have indicated that many groups have been lost from the smaller karst forests, and that white-headed langurs now remain in just these four forest habitats of the larger region (Huang *et al.* 2002; Huang *et al.* 2003b). The so-called NS habitat is in Longgang National Nature Reserve at the border between the counties of Longzhou and Ningming. The CZ habitat is in Chongzuo Banli Provincial Nature Reserve, in Chongzuo County. The F1 and F2 habitats are in Fusui Papen Provincial Nature Reserve in Fushui County (Fig. 2).

White-headed langurs typically form groups containing an adult male with a number of adult females and their offspring. Group size ranges from 3–16 (Huang *et al.* 2003a; Li and Rogers 2004). Similar to François' langur (*Trachypithecus françoisi*), another primate that occurs in the karst fengcong depressions in Fusui County (Hu *et al.,* 2004), the white-headed langur suffers from illegal hunting and habitat deterioration. We carried out this study to collect information on vegetation cover, fragmentation, landscapes, and human activities in order to better understand the threatened status of the white-headed langur and evaluate options for conservation measures.

Study Area

The study was carried out in three nature reserves: Longgang National Nature Reserve on the borders of the counties of Longzhou and Ningming; Chongzuo Banli Provincial Nature Reserve in Chongzuo County; and Fusui Papen Provincial Nature Reserve in Fushui County in the southern Guangxi Province (Fig. 2). This covers the entire known range of the wild population of the white-headed langur. Average annual precipitation in the region is 1,022 mm, with an average daily temperature of 22.1°C (Huang 2002). The four areas consist of karst hills and flat lands in the valleys (Fig. 1) in the triangular region between north Mingjiang River, south Zuojiang River, and west of the Shiwan Mountains in parts of the four counties (Fig. 2).

Figure 1. The topography and fragmentation of karst hills in habitat of white-headed langur.

The dominant trees of the forests in these areas are *Ulmus tonkinensis, Semiliquidambar cathayensis*, and *Parashorea chinensis*, and endemic plant species include *Camellia nitidissima*, *Camellia longggangensis*, *Cathaya argyrophylla*, and *Cyathea spinulosa* (Guangxi Forestry Department 1993; Huang 2002).

Methodology and Data Analysis

We used Landsat 7 Thematic Mapper (TM) satellite imagery (resolution of 30 m per pixel) and relief maps (1:10,000) to The TM images were rectified to the Geographic Transverse Mercator coordinate system based on 1:10,000 scale relief maps, and were re-sampled using the nearest neighbor algorithm with a pixel size of 30 by 30 m for all bands. The resultant RMSE was found to be less than 0.5 pixel.

Using the TM imagery, we set 561 sampling points for ground-truthing the vegetation in the four habitats: 65 in NS; 155 in CZ; and 341 in F1 and F2 in order to collect sufficient information about the landscape categories. The location of each sampling point was recorded using a GPS (MAGELLAN 315). There were fewer sample points in the NS habitat because of the difficult terrain.

Using manual interpretation we achieved an overall accuracy of about 91%. We used the following landscape categories: Forest (karst hills covered with natural arboreal

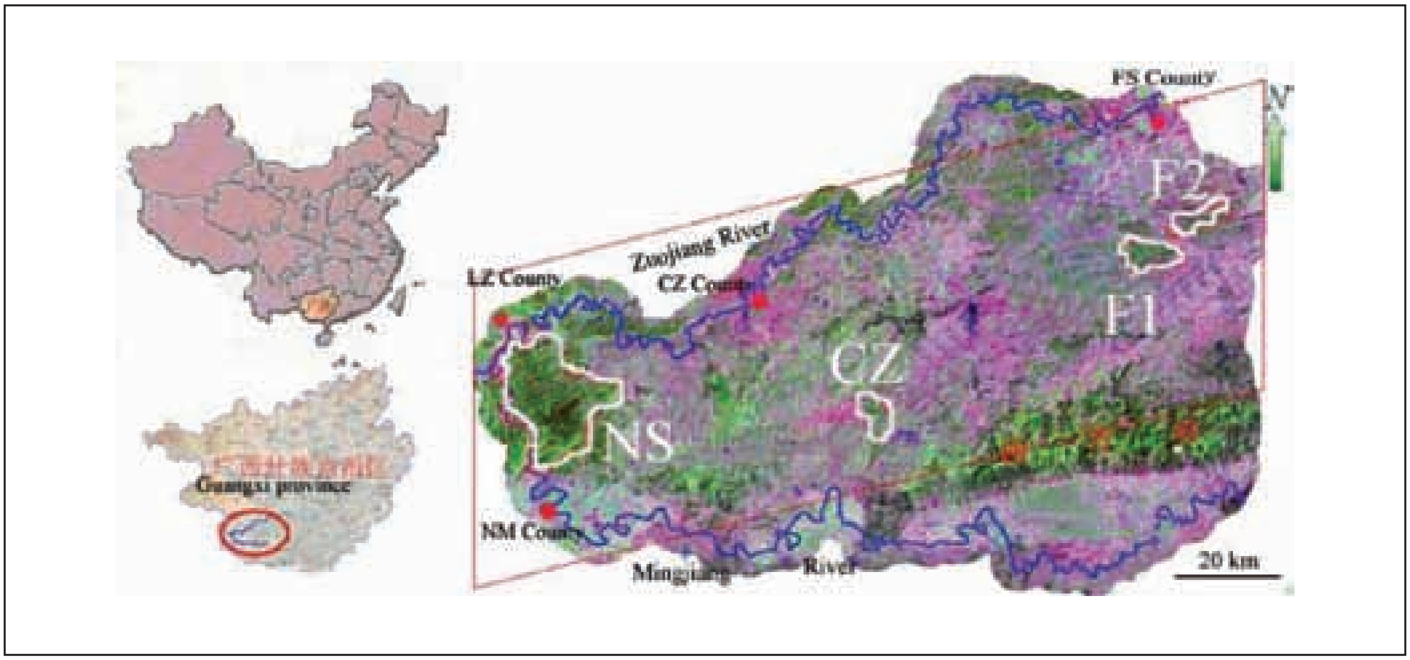

Figure 2. Location of the four karst habitats where the white-headed langur, *Trachypithecus leucocephalus*, survives. NS is in Longgang National Nature Reserve at the border between the counties of Longzhou and Ningming. CZ is in Chongzuo Banli Provincial Nature Reserve, in Chongzuo County. F1 and F2 fragments are in Fusui Papen Provincial Nature Reserve in Fushui County.

vegetation, shrubs and vines); meadows (plains of native grass); farmland (cultivated plains); villages and urban areas; bare rock (karst hills lacking vegetation); and water bodies (permanent pools and rivers near the habitat).

We used ARCGIS 8.0 (ERSI Inc., Redlands, CA) to create shape files of the results of the classification and relief maps. We then calculated the area and perimeter of each patch of each category, and the number of patches. We calculated indices of landscape pattern and habitat fragmentation with Fragstats 3.3 (Table 1).

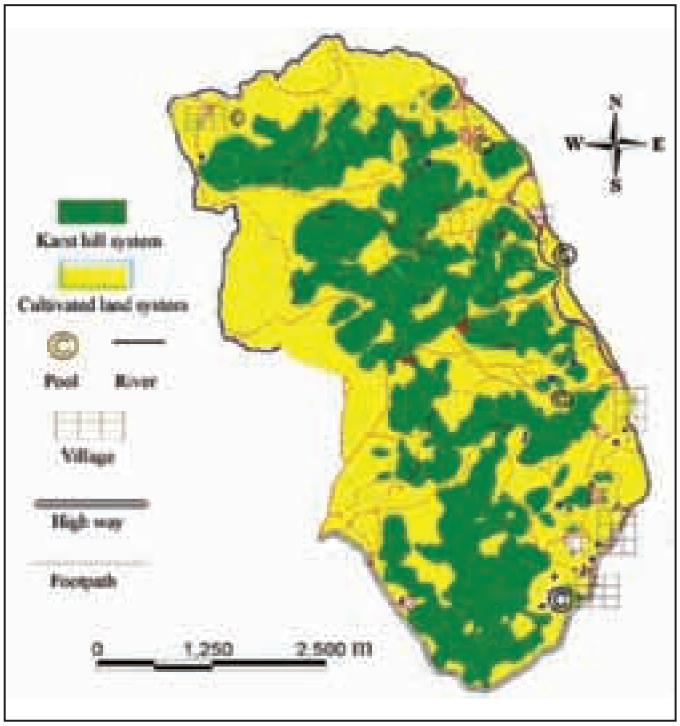

Figure 3. Composition of white-headed langur, *Trachypithecus leucocephalus*, habitat in CZ habitat, Chongzuo Banli Provincial Nature Reserve, Chongzuo County, Guangxi Province, China.

Results

Habitat composition

Each of the four karst fragments were completely isolated from each other (Fig. 2). The distances between fragments ranged from 2 km (the edge of F1 to F2) to 100 km (edge of F1 to NS). Even between F1 and F2, the closest fragments, it was still difficult for the langurs to cross the large expanses of cultivation, rivers and villages because of a lack of natural vegetation to serve as a corridor. All four habitats consisted of karst hill systems, areas of agriculture, and water bodies, and all had roads passing through their core areas. There were people living around the habitats, using the core areas of the karst fragments to cultivate the plains and collect firewood — most particularly in CZ, F1 and F2 (Fig. 3).

The karst hill system is composed of karst hills and plains, the latter being cultivated by nearby villages in some areas. Of the four habitats, NS (20,167 ha) had the highest percentage of karst hill system (70.7%) and the least area given over to agriculture (24.5%), while CZ (2,084 ha) had the smallest area of karst hill system (43.3%) and highest given over to agriculture (56.2%) (Table 2).

Vegetation composition and coverage in karst habitat

Sugarcane (*Calamus thysanolepis*) is the most important cash crop in the southern counties of Guangxi Province. It has been planted over large areas of the plains in the core areas of the fragments CZ, F1 (2,935 ha) and F2 (2,338 ha). We detected two categories with eleven subcategories of landscape in the fragments. Water bodies, forest, grass, shrub and bare rocks were the natural categories, while areas denuded of vegetation, dry land cultivation, rice fields (wet cultivation), sugarcane and houses were artificial landscape subcategories. Combining the TM imagery and field samples indicated that the natural landscape cover was highest (41%) in NS and the lowest in CZ (28%), while the reverse was true in terms of the areas of human activities. NS had the most forest cover (34%) and CZ the lowest (4%) (Table 3). The factors indicate that

Table 1. The calculation of indices for fragmentation analysis of the habitats of the white-headed langur, *Trachypithecus leucocephalus*, in China.

Index name	Formulation	Specification
Total area	$A_{sum} = \sum_{i=1}^{n} A_i$	n is the number of patches, A_i is the area of patch i.
Patchiness	$PT = \frac{1}{Nb}\sum_{i=1}^{F}\sum_{j=1}^{F} EE(i,j)DD(i,j)$	Nb is total length of all patches, EE(i,j) is shared length of neighboring patches i and j; DD(i,j) is unshared length of patches i and j (Liu and Zhang 2004).
Fragmentation index	$F=(NF-1)/MPS$	NF is the number of certain landscape types, MPS is the average area of patches (Liu and Zhang 2004).
Patches fragmentation index (FN_1\\FN_2)	$FN_1 = (Np-1)/Nc$ $FN_2 = MPS(Nf-1)/Nc$	Np is the number of patch type, Nc is the whole area of landscape(×10^5km²), MPS is the average area of patches (×10^5km²), Nf is the number of karst hill patch (Liu and Zhang 2004).
Human disturbance index	$H_{DI}=A_h/A_n$	A_h the area of artificial landscape, A_n is the area of natural landscape (Liu and Zhang 2004).

NS provided the best quality habitat, followed by F1, F2 and then CZ (Table 2).

Fragmentation and human disturbance

Three landscape categories were defined in Forman's system (Forman and Gordon 1986) and (Liu and Zhang 2004). The "patch" is one of the basic landscape units, the other two are "corridors" and "matrices". We used patch units for the habitat analysis. In NS there were 203 patches of hills, cultivated land and water bodies, with a total patch density of 100.34/ha. NS had the lowest indices of patchiness and patch fragments compared with other fragments, indicating that, in these aspects, it is the best habitat for white-headed langurs. CZ, F1 and F2 had patch densities of 311.82, 258.96, and 265.19, respectively (Table 2).

Human disturbance (communities around the reserves, agricultural land, and roads inside and around the protected areas) constitutes a threat to the white-headed langur in these fragments. NS had the lowest density of people, roads, and cultivated land, and therefore the lowest index of human disturbance (0.323), while the CZ fragment had the highest (1.28) (Table 2).

Discussion

The white-headed langur and other Indochinese limestone langurs (see Groves 2004) are endemic to karst hill forests, and their survival is, as such, closely linked to the preservation of these habitats (Huang *et al.* 1997; Huang and Li 2005; Nadler 2006). Deng (1987) divided the karst hills into peak cluster depressions and peak cluster valleys according to the densities of the hills. Peak cluster depressions are in karst hill ranges with more than 20 hills per km², with more hills and less flat land, which is less fragmented and suffers less human interference, while peak cluster valleys have less than 20 hills per km² with large areas of plains where agricultural activities are predominant. The NS area in Longgang National Nature Reserve fits the pattern of peak cluster depression (33.6 ± 19.2/km²), while the karst hills in CZ, F1 and F2 (19 ± 6.3/km²) are classified as peak cluster valleys. The two types have distinct characteristics in terms of their geology and the human activities that are degrading and destroying them. In NS, karst hills are dense, concentrated, and less fragmented; it has a higher percentage of karst hills, more extensive vegetation cover, and less fragmentation and human interference. It is possible to protect this area with just the one reserve (Longgang) created in 1980. The other two provincial nature reserves (Chongzuo Banli and Fusui Papen) consist of several widely separated fragments. The borders of these fragments were unclear, and the ownership of the land was also confused at the time the reserves were created. As it turns out, people living around the fragments have the right to access the land and to cultivate areas in and around the fragments. They also take firewood from the hills in the nature reserves: the reserve staffs have authority only to protect the animals. CZ, F1 and F2 have, therefore, a lower percentage of karst hills, less forest, and higher indices of fragmentation and human interference (Tables 2 and 3).

The forest and the karst hills are very important to the white-headed langurs. The hills have four distinct zones: the flat plains, the lower, middle slopes and the hill tops. All except for the plains in CZ, F1 and F2 are covered with forest. The valleys in CZ, F1 and F2 are cultivated. Our studies have indicated that the white-headed langurs spent 65.25% of their time on lower slopes, 22.25% on the middle cliffs and steep slopes, and 12.5% on the hill tops (Huang 2002). They do not use the valley bottoms due to the heavy human disturbance.

Large areas of the plains and valleys are planted with sugarcane and other cash crops. Agricultural activity reaches a peak during planting and harvesting seasons in Spring and Autumn when hundreds of people and dozens of trucks enter the core areas of CZ, F1 and F2, seriously affecting the activities of the white-headed langurs (Huang 2002; Li and Rogers 2004). Over the long-term it will be necessary to greatly reduce the levels of human activity for cultivation by developing alternative sources of income that will not only reduce disturbance to the langurs but improve the well-being of the local communities there. This could include eco-tourism (Huang *et al.* 2003b; Bleisch *et al.* 2006).

Table 2. Composition, fragmentation indices, and human disturbance in karst habitats of the white-headed langur, *Trachypithecus leucocephalus*, in China.

Name of habitat	NS	CZ	F1	F2
Total area (ha)	20167	2084	2935	2338
Hill system (ha)/(%)	14272/(70.7)	903/(43.3)	1613/(54.95)	1204/(51.49)
Agricultural system (ha)/(%)	4936/(24.5)	1171/(56.2)	1276/(43.5)	1119/(47.86)
Water system (ha)/(%)	1023/(5.1)	100/(0.5)	46/(1.6)	140/(0.59)
No. of patches	203	65	76	62
Patch density (/ha)	100.34	311.82	258.96	265.19
Patchiness index	0.472	0.737	0.713	0.773
Fragment (F) index	0.9289	0.9733	0.9665	0.9675
Patch fragment (FN1/FN2) index	0.0998/0.1133	0.3070/0.2923	0.2555/0.1974	0.2609/0.1935
Density of residents (person/ha)	0.74	5.8	5.0	3.5
Density of cultivated land (patch/ha)	0.41	0.83	0.49	0.59
Density of roads (km/km²)	0.244	0.562	0.434	0.479
Index of human disturbance	0.323	1.28	0.769	0.919

Firewood collection is an even greater threat than agriculture to the white-headed langurs in these areas. It not only interferes with their normal activities, but also destroys the vegetation and reduces their food sources. Most local households are poor and rely on firewood for energy: about 2.5 tons is used annually by each household. As the local population grows, the demand becomes more and more serious. Fortunately, local and provincial governments have initiated measures for the provision of methane gas as an alternative, with priority being given to families in the immediate vicinities of the nature reserves. To date about one-third of the households are already benefiting from this program (Huang *et al.* 2003b).

Local people have traditionally hunted the langurs, shooting them in order to make 'langur wine'; a concoction said to be effective in curing rheumatism. The white-headed langur was protected in 1980 (Lin 1980; Huang *et al.* 2002), and the government now seriously punishes illegal hunting, but there are still occasional incidents.

White-headed langur populations in each fragmented habitat are completely isolated from each other at distances of two to 100 km. This prevents the exchange of individuals and will predictably cause inbreeding depression to occur sooner or later. A fragmented population is the most dangerous of the metapopulation patterns that cause reduced gene flow (Frankham *et al.* 2003). The white-headed langur is believed to have originated in Southeast Asia, dispersing north to reside in the triangle between Zuojiang River and Mingjiang River two million years ago. It gradually occupied many karst fragments and there was undoubtedly frequent exchange of individuals between the fragments (Shen and Li 1981; Lu and Li 1991). However, hunting prior to the creation of the nature reserves extirpated the white-headed langurs from many of the smaller forests, and the increasing distance between populations has evidently reduced their capacity for recolonization (Lin 1982; Huang *et al.* 2003a).

The four isolated karst habitats in the southwestern Guangxi Province comprise the last refuge of the white-headed langur. In assessing the size, composition, vegetation cover, indices of fragmentation, and human interference, we find that NS has the best and largest habitat, followed by F1 and F2, and CZ has the worst and smallest (Tables 2 and 3). However, a recent survey showed that F1 and F2 in Fusui Nature Reserve together have the largest population (319 individuals in 42 groups), while CZ was in second place with 211 individuals in 21 groups). NS had the lowest population, with an estimated 86 individuals in eight groups (Huang *et al,* 2003b). Wang *et al*. (2004) considered the white-headed langur population of NS to be near extinction due to hunting from 1990 to 1998.

A number of white-headed langur surveys in the early 1980s indicated that NS had a population of about 240 individuals (Shen and Li 1981; Wu 1983). This would indicate that the population could increase considerably if the langurs were properly protected by the Nature Reserve Authority. However, it would seem that the population has remained low, at about 80 individuals over the last 10 years, despite the improved protection of the region. Z. Y. Li counted 80 individuals in NS in his survey in the mid-1990s (pers. comm.), and Huang *et al.* (2003b), with 30 people surveying the area for two weeks, recorded 86 in 2003. A survey carried out by local rangers of the Longgang National Nature Reserve in 2006 (unpublished), also came up with a total of about 80 individuals. The other populations in apparently in worse situations in CZ, F1 and F2 have, on the other hand, increased.

Studies of karst langurs — white-headed langur, Hatinh langur (*T. laotum hatinhensis*), and François' langur — have shown that they prefer to sleep on cliff faces (Huang 2002; Huang and Li 2005; Huang *et al.* 2004; Li and Rogers 2006; Nguyen 2006), and it may be that the availability of sleeping sites in the cliff faces is affecting population numbers in NS. The density of cliffs is much lower there ($0.5 \pm 0.85/\text{km}^2$), than in SZ ($1.6 \pm 1.8/\text{km}^2$) and F1 and F2 ($4.1 \pm 1.96/\text{km}^2$). The differences are statistically significant ($Z = -3.489$, $p<0.001$) (Huang *et al*. submitted).

There are two possible explanations for this contradictory finding that the smallest population of white-headed langurs is that in the largest and least fragmented forest of NS. One is that the lower population is real because of the lower density of cliffs. Sleeping sites as such being the limiting factor for

Table 3. Coverage of the landscape elements in the four karst habitats — areas of the surviving populations of the white-headed langur, *Trachypithecus leucocephalus*, in China.

NS habitat			CZ habitat			F1 and F2 habitat		
Category	**Subcategory**	**%**	**Category**	**Subcategory**	**%**	**Category**	**Subcategory**	**%**
Natural 41%	Water bodies	2	Natural 28%	Water bodies	3	Natural 32%	Water bodies	5
	Forest	34		Forest	4		Forest	14
	Grass	3		Grass	12		Grass	7
	Shrub	2		Shrub	7		Shrub	6
	Bare rock	0		Bare rock	2		Bare rock	0
Artificial 59%	Bare land	2	Artificial 72%`	Bare land	2	Artificial 68%	Bare land	2
	Dry land	19		Dry land	1		Dry land	3
	Rice field	12		Rice field	10		Rice field	9
	Sugarcane	18		Sugarcane	39		Sugarcane	39
	Fruit tree	2		Fruit tree	10		Fruit tree	11
	Resident	6		Resident	10		Resident	4

population growth; and the survey in the early 1980s consequently had overestimated the population size. Another possibility is that hunting pressure in NS is much higher than in the other, more fragmented, habitats. Resolving which of the two is causing the lower population in NS, requires further study and, besides, more effective measurements to protect the population in NS.

Acknowledgments

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Literature Cited

Bleisch, W., T. Nadler, Y. Y. Zhang and P. Insua-Cao. 2006. Prioritization of conservation action for primates of Indochina and South China. In: *Proceedings of China Fusui International Primatological Symposium*, China, p.1–2.

Caro. T. 1998. *Behavioral Ecology and Conservation Biology*. Oxford University Press, Oxford, UK.

Cowlishaw, G. and R. Dunbar. 2000. *Primate Conservation Biology.* University of Chicago Press, Chicago.

Deng, Z. 1987. Investigation report of karst geology in Longgang Nature Reserve. *J. Guangxi Bot.* 1(suppl): 1–16. In Chinese.

Forman, R..T. and M. Gordon. 1986. *Landscape Ecology*. John Wiley & Sons, New York.

Frankham, R., J. Ballou and D. Briscoe. 2003. *Introduction to Conservation Genetics*. Cambridge University Press, Cambridge, UK.

Groves, C. P. 2004. Taxonomy and biogeography of primates in Vietnam and neighbouring regions. In: *Conservation of Primates in Vietnam*, T. Nadler, U. Streicher and Ha Thang Long (eds.), pp.15–28. Framkfurt Zoological Society, Frankfurt, and Endangered Primates Rescue Center, Cuc Phuong Natinal Park, and Vietnam Primate Conservation Programme, Hanoi.

Guangxi Forestry Department. 1993. *Nature Reserves of Guangxi.* Forestry Publishing House, Beijing, China. In Chinese.

Hu, G., X. Dong, Y. Wei, X. Zhu and X. Duan. 2004. Evidence for a decline of François' langur *Trachypithecus francoisi* in Fusui Nature Reserve, Southwest Guangxi, China. *Oryx* 38(1): 48–54.

Huang, C. M. 2002. *White-headed Langur in China*. Guangxi Normal University Press, Guilin, China. In Chinese.

Huang, C. M. and Y. B. Li. 2005. How does the white-headed langur (*Trachypithecus leucocephalus*) adapt locomotor behavior to its unique limestone habitat? *Primates* 46(4): 261–267.

Huang, C. M., L. R. Lu and C. Y. Li. 1997. The water metabolism of white-headed leaf monkey in cage in summer. *Acta Theriol. Sinica* 17(2): 100–106.

Huang, C. M., F. W. Wei, M. Li, G. Q. Quan and H. H. Li. 2002. Current status and conservation of white-headed langur (*Trachypithecus leucocephalus*) in China. *Biol. Conserv.* 104(2): 221–225.

Huang, C. M., F. W. Wei, M. Li, Y. B. Li and R. Y. Sun. 2003a. Sleeping cave selection, activity pattern and time budget of white-headed langurs. *Int. J. Primatol.* 24(4): 813–824.

Huang, C. M., Y. Q. Zheng and Z. Y. Li. 2003b. The report of nature reserve management plan of Guangxi Zhuang Autonomous Region, People's Republic of China. Report, The T.A/3821-PRC of Asia Development Bank.

Huang, C. M., Y. B. Li, Q. H. Zhou and F. W. Wei. 2004. The preliminary study on behavior of cave-leaving and entering and selection of sleeping cave of François' langur in China. In: *Conservation of Primates in Vietnam*, T. Nadler, U. Streicher and H. T. Long (eds.), pp.137–143. Haki Publishing. Hanoi, Vietnam.

Jiang, Z. C. 1996. An analysis of formation of the karst fengcong depressions in China. *Carsologica Sinica*. 15(1–2): 83–90.

Konstant, W., R. A. Mittermerier, T. M. Butynski, A. A. Eudey and J. U. Ganzhorn. 2002–2003. The World's Top 25 most Endangered Primates – 2002. *Asian Primates* 8(3–4): 29–34.

Li, Z.Y., Y. Wei and E. Rogers. 2003. Food choice of white-headed langurs in Fusui, China. *Int. J. Primatol.* 24(6): 1189–1205.

Li, Z. Y. and E. Rogers. 2004. Social organization of white-headed langurs *Trachypithecus leucocephalus* in Fusui, China. *Folia Primatol.* 75(2): 97–100.

Lin, L.H. 1982. *Medical Animals of Guangxi*. People's Press of Guangxi, Nanning, China.

Liu, M. and M. Zhang. 2004. *Landscape Ecology: Principles and Method*. Chinese Chemical Industry Press. Beijing.

Lu, L. R. and Z. Y. Li. 1991. On taxonomy of white-headed leaf monkey. *J. Guangxi Normal University* 11: 12–16.

Nadler, T. 2006. Why do several langur species occur in karst habitat? In *Proceedings of China Fusui International Primatological Symposium*, p.19. Unpublished.

Nguyen, M. H. 2006. Some observations on the Hatinh langur, *Trachypithecus laotum hatinhensis* (Dao, 1970) in north central Vietnam. *Primate Conserv*. (21): 149–154.

Shen, L. T. and H. H. Li. 1981. White-headed leaf monkey in Guangxi. *J. Guangxi Normal College* 3: 71–80.

Richard, A. 1985. *Primates in Nature.* W. H. Freeman and Company, New York.

Wang. D., W. Ran, T. Jin and W. Pan. 2004. Population census of the white-headed langur (*Trachypithecus leucocephalus*) at Longrui Karst Hills, Guangxi, China. *Primates* 46(3): 219–222.

Wu, M. 1983. Taxonomy of primates in Guangxi and its population estimation. *Acta Theriol. Sinica* 3(1): 16.

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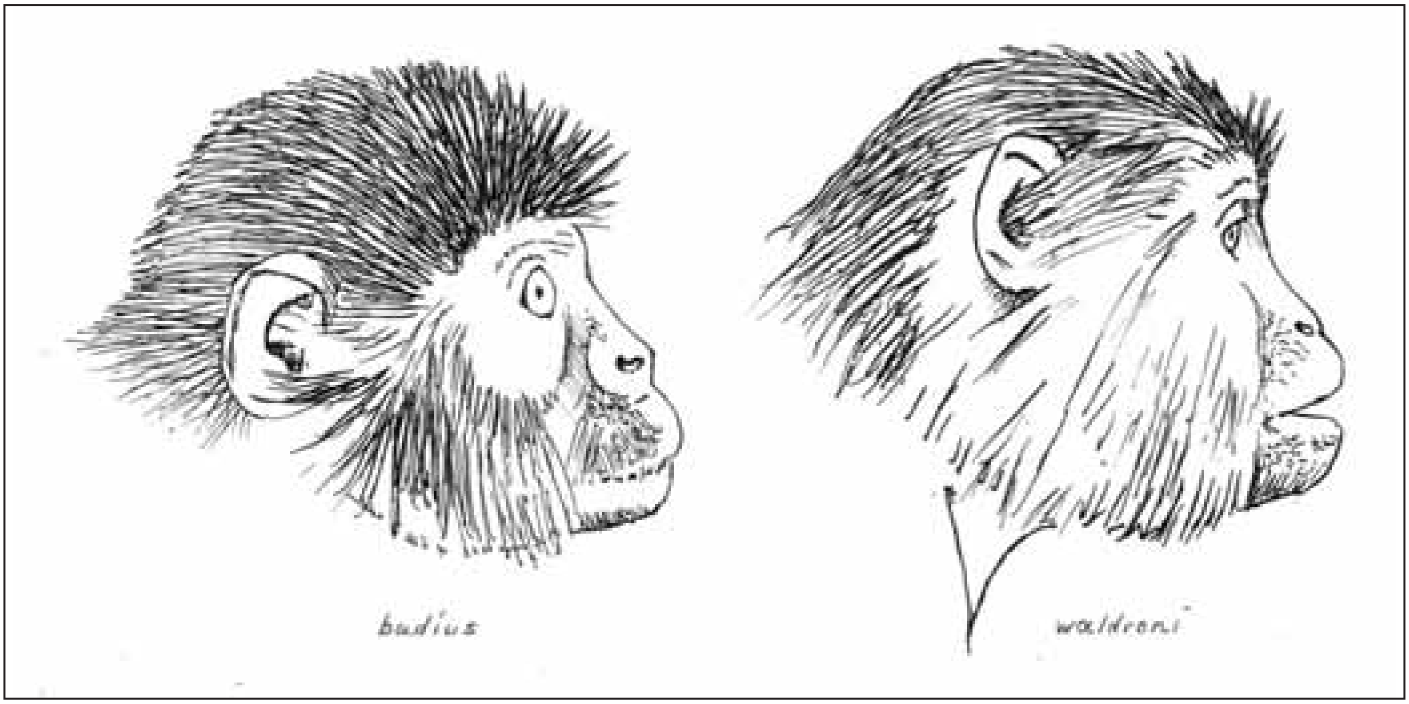
Obituaries

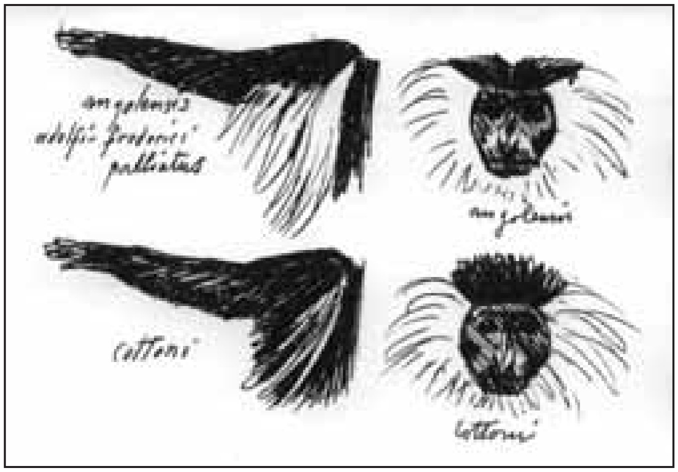
Pierre Dandelot (2007)

Pierre Dandelot, who died in 2007, was a superb painter, sculptor and taxidermist of animals, especially primates. In "A Field Guide to the Larger Mammals of Africa" (1970), his colour paintings and black-and-white drawings, complementing the text by Jean Dorst, established the precedent that beautiful yet accurate artwork can reveal as much or more about an animal as can a photograph — thus starting a tradition which is still today upheld by notable artists such as Stephen Nash. Pierre was enthusiastic about the animals themselves, and even published a few papers on the taxonomy of African monkeys, in which, as an artist, he showed that he was able to detect significant features which had been missed by standard taxonomists: as he put it, "ils n'ont pas l'oeil" ("they do not have the eye").

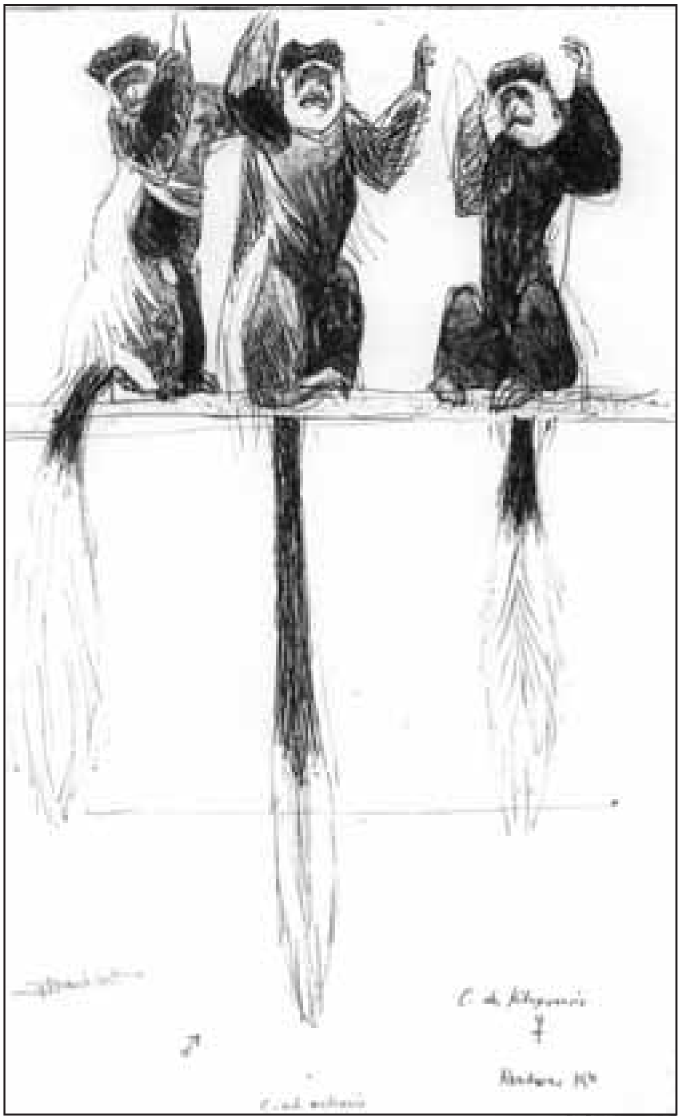
Colin P. Groves, Canberra, Australia



Sketches by Pierre Dandelot. Faces of red colobus monkeys — comparing *badius* and *waldronae*. Original with Colin P. Groves.



Sketches by Pierre Dandelot. Angola colobus, *Colobus angolensis*. *Top left.* Labeled "*angolensis*, *adolfi-frederici* and *palliatus*". The form *adolfi-frederici* is considered a junior synonym of *C. a. ruwenzorii* by Groves (2001, *Primate Taxonomy*, Smithsonian Institution Press, Washington, DC). Groves (2001) lists the form *palliatus* as a subspecies of *Colobus angolensis*. *Top right*. Labeled *angolensis*. *Bottom left and right.* Labeled *cottoni*. Considered a subspecies of *C. angolensis* by Groves (2001). Original with Colin P. Groves.



Sketches by Pierre Dandelot. Three black and white colobus, labeled *C.[olobus] ab.[yssinicus] uelensis* [*sic*] male (center and left) and *C.[olobus] ab.[yssinicus] kikuyuensis* female Aberdares Mts. (right). Groves (2001, *Primate Taxonomy*, Smithsonian Institution Press, Washington, DC) places both as subspecies of *Colobus guereza*; the former, as *uellensis* Matschie, as a junior synonym of *C. g. occidentalis*. Original with Colin P. Groves.

Sketches by Pierre Dandelot. Black-and-white colobus leaping. Original with Colin P. Groves.

Peter Grubb (1942–2006)

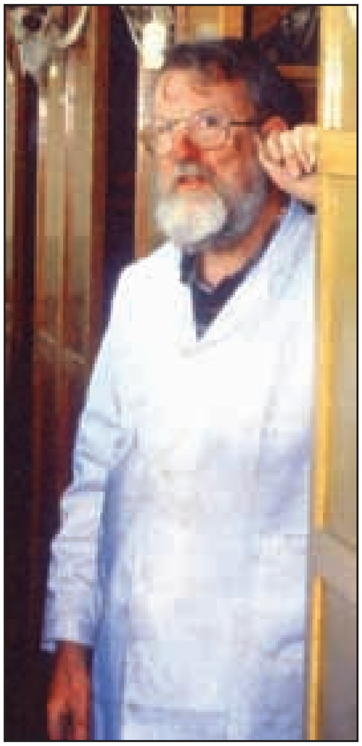
Peter Grubb receiving the Zoological Society of London's Stamford Raffles Award from the President of ZSL, Professor Sir Patrick Bateson FRS, in 2005. The award was for "Contributions to Mammalian Systematics." Photograph kindly provided by Eileen McGrath.

Not only was our science much diminished by Peter Grubb's early death from cancer in December 2006, but I also felt a strong sense of personal loss. I was two years behind Peter as an undergraduate in zoology at University College London, and we each went on to do doctoral research on mammals under Professor Peter Jewell. Each of us developed a strong interest in African mammals, and had special connections with West Africa. Peter's base in the 1970s was Ghana, where he followed in the footsteps of the legendary Angus Booth.

Deteriorating conditions in Ghana led Peter and his wife Eileen back to London in the early 1980s, and Peter took up a job as a school teacher. But his passion for natural history fortunately was not dimmed. I was then in New York, but I kept up a correspondence with him on African primate taxonomy and zoogeography, and when I was able to visit London I quite often joined him in the mammal collection at the South Kensington museum. We ended up collaborating on several projects, and Peter became drawn into an international network of primatologists interested in the application of taxonomy to conservation planning.

In the years that I knew Peter, my respect for him continued to grow. Not only because of the great depth and breadth of his knowledge, his intelligence and his commitment, but also — and very importantly — for the common sense and modesty he brought to his science. In a world that seems ever-more obsessed with self-advancement and materialism, Peter stood out as being interested in science for science's sake. He did not seek celebrity, or regard science as a competition with rivals. This fundamental goodness of Peter's greatly impressed all those who worked with him. He richly deserved the 2005 Stamford Raffles Award from the Zoological Society of London (an award given for distinguished contributions by zoologists outside the scope of their professional activity), and thankfully he was able to receive this award in person in June 2006, before his health seriously deteriorated.

John F. Oates, London, UK



Peter Grubb died in London in December, 2006. He was Britain's leading mammalian taxonomist, and one of the pre-eminent mammalogists worldwide. He was trained initially in animal behaviour, and for his PhD did superb research on Soay sheep (an important feral population of primitive domestic sheep), but gradually turned to taxonomy and biogeography, concentrating mainly on ungulates (especially in Africa) but turning from time to time to primates. These studies led him to formulate the system of African mammal biogeography which has become standard today. Early in his career, he worked in the University of Ghana, returning to Britain at a time when academic positions in zoology had largely been filled, and he took a position as a biology schoolteacher. He derived great satisfaction from this work, even though it meant that he had to conduct his research in his spare time. He was an extremely gentle, self-effacing man, whose humility hid an extraordinary breadth of knowledge and understanding, and simple wisdom. I loved working with him, and learned a lot from our many collaborations. I miss him greatly.

Colin P. Groves, Canberra, Australia

Peter Grubb in the Institute of Zoology, Beijing, April or May 2000. Colin Groves: "I might say that, although the specimens in the collection are Asian, not African, Peter of course knew all about them, and the importance of all the type specimens. He was overwhelmed. Anja [Braun] and I had arrived in Beijing a few days before him, and found a few important specimens already. When he arrived to join us, he spent the first morning walking back and forth along the shelves, looking at the labels we had made, and going "Good Lord... well... Good Lord", and Anja and I kept looking at each other and grinning." Photograph by Colin P. Groves.

I emigrated to Australia three months before Peter Grubb died of head cancer on 23 December 2006, and so was regrettably unable to visit him during his last days. He had been ill for two years but remission enabled him to visit the Natural History Museum, London, the site where our paths usually crossed, even if less frequently than before. It was a shock to discover an operation to alleviate his condition had involved the removal of one ear and part of his jaw. It affected his speech but seemed not to affect his characteristic nonchalant manner nor his fervour for recent zoological developments. Common interests often bring people together at the Natural History Museum. That was how I met Peter. It is not, however, an ideal location for conversations. Generally visitors are on a mission. Peter always seemed to be. Visitors are therefore reluctant to adjourn to a more suitable venue, but also reluctant to forego the conversation. Our conversations usually occurred in the echoing confines of the Mammal Section corridor where Peter was often browsing the library, consulting the accessions registers or simply signing in. Despite concerns about disturbing staff in the adjoining offices, those conversations were one of the great pleasures of visiting the museum, and the museum will not be the same without them.

Peter and I became familiar with one another's research interests through such encounters, but it was not until February 2000 that I came to know Peter better personally when, as members of the IUCN/SSC Primate Specialist Group, we were both invited to participate in the workshop "Primate Taxonomy for the New Millennium", held at the Disney Institute, Orlando, Florida. Being assigned to different groups, he to Africa, me to Asia, we saw little of one another during the sessions but the trip included the bizarre experience of some of the world's leading primate taxonomists travelling (by rail) on an "African wildlife safari" in a vehicle resembling a large jeep at the Animal Kingdom theme park in Disney World. This involved negotiating "a rickety bridge" and detecting "elephant poachers". I wondered whether the "driver" could have delivered his script had he known the credentials of his passengers. Later Peter and I returned side-by-side on a switchback to the age of the dinosaurs! As always, Peter took everything in his stride and seemed to enjoy it well enough. I got to know him better in 2004 when we shared accommodation at the XX Congress of the International Primatological Society, Turin, Italy, where we both presented follow-up papers on the Orlando workshop. We found a small restaurant with pavement tables in a street arcade and spent most evenings enjoying a couple of beers, excellent Italian pizza and convivial conversation.

Peter was not only a primatologist. His expertise on ungulate taxonomy earned him authorship of the Artiodactyla and Perissodactyla sections in Wilson and Reeder's (1993, 2005) *Mammal Species of the World*. He was also self-effacing; maintaining, for instance, that one paper of his on zoogeography came about only because the conference organizers had mistakenly invited him instead of his botanist namesake. The breadth of his knowledge really came home to me when I asked him for pre-submission comments on my taxonomic revision of the Indian langurs. To my surprise and delight he methodically processed the 30,000 words one by one, resulting in substantial textual improvements. Commas, especially those preceding the conjunction "but", were a major casualty. One of his suggestions was that "Anis" should be translated from the French as "coucals or koels". Within days of being asked to write this memoir a common koel turned up in our garden. To my recollection I have never seen one before, not even in captivity. This one further reminded me of Peter by confounding confident identification. According to the field guide, adults have a black cap; juveniles a "rufous" one. Fittingly, on this occasion it was golden.

Douglas Brandon-Jones, Brisbane, Australia

Peter died after two major operations (in January and August 2005) to remove a tumour, probably the result of the radiation treatment that he received after an earlier operation to remove a similar tumour when he was 13. He and I graduated from the same Zoology Department, University College London, and became colleagues in the Zoology Department of the University of Ghana (1968–1980) where I had preceded him in 1960 and followed him to London in 1986. In Ghana he was my valued critic and confidant on African place names as we were both involved with relating taxonomy (of mammals in his case, snakes in mine) to geographic sources and we both mounted expeditions to European and US museums to discover their unrecognised treasures. It is only after his death, as I helped his widow Eileen McGrath sort out his books and papers, that I have learnt something of his family background and how that contributed to the formation of his character.

Peter's father William was unusual in attending Glasgow University at the age of 16 and graduating with a First Class Honours Degree in Chemistry at age 19. William Grubb worked for awhile as a research chemist at ICI, later becoming a science teacher and moving, in 1948, from Scotland, where Peter was born, to Ealing in West London. William had a library of several thousand volumes, catalogued and largely retained after his death by Peter's sister Katrina. Having access to London Zoo and the museums, including the Natural History Museum, provided Peter with opportunities to meet exotic animals and to practice his drawing skills which had been apparent in his mother, Anne Sirutis, a school teacher from Lithuania. His younger sister Katrina is an exhibiting artist, which supports the idea that Peter acquired some graphic skill from his mother. From an early age Peter delighted in the natural world, whether animals or plants, and not only drew but cut out and kept every published picture he came across! He later accumulated a similarly eclectic collection of photographs and specimens.

Peter's first job after graduation was to work as a Research Assistant in the Wellcome Institute of the Zoological Society of London and be posted to St Kilda where his work on Soay Sheep culminated in a PhD, with a Certificate of Commendation for the Thomas Henry Huxley award of the Zoological Society.

His second assignment was as part of the Royal Society Expedition to Aldabra, Indian Ocean, to work particularly on the giant tortoises. With this background it seems strange that in Ghana he did not emulate in the field his eminent predecessor, primatologist Angus Booth (1927–58) but spent more time in foreign museum collections. No doubt he realised, as did I, that much in those institutions remained unpublished or unevaluated until mapped in relation to specimens in other collections. It is easier to study African collections brought together in one place rather than attempt new collecting in Africa itself. Much of Peter's original, unpublished data has been salvaged by Colin Groves and will not be lost through Peter's untimely demise. He leaves behind his widow Eileen and children Elizabeth and Christopher.

Barry Hughes, London, UK

Suzanne Ripley (2008)

Suzanne Ripley relaxing with Freddie, the resident toque macaque at Polonnaruwa

Suzanne Ripley suffered an aortic dissection and died at the age of 72 on February 22, 2008, in Los Angeles, California. She was spending a few months away from her home in Edgecomb, Maine, and planning, according to her journal, "the next quarter century of my life." Sue was one of the early group of anthropology graduate students of Sherry (Sherwood) Washburn who conducted field studies of nonhuman primates in the 1960s. Each collected baseline data on the social organization and ecology of a ground-dwelling primate species as part of Washburn's call for a "new physical anthropology" in which field studies of nonhuman primate behavior provide a key element for understanding the evolution and behavior of humans. Sue Ripley developed a field site in Polonnaruwa in Sri Lanka and her work there on Ceylonese grey langurs formed the basis of much of her later work. She had actually started graduate study in cultural anthropology at UC Berkeley but switched to physical anthropology in her first year. Sue felt equally comfortable on both sides of the human-nonhuman primate continuum. Early in her career, because of her interest in human communication, she was invited to participate in the 1970 Wenner Gren Conference on Interaction Ethology organized by Erving Goffmen and Thomas Sebeok, and in 1965, she worked for a year with Raymond Birdwhistell, the founder of the study of human kinesics, at the Eastern Pennsylvania Psychiatric Institute. Sue earned a PhD in Anthropology from the University of California, Berkeley in 1965. She was a member of the department of anthropology at City College of New York in the early 1970s, and later taught for one year in 1981 as a visiting professor at UCLA.

Sue's primary focus was always the intersection of evolution, ecology and behavior. Probably her most important piece of work was her 1967 paper published in the *American Journal of Physical Anthropology* titled "Leaping of langurs: a problem in the study of locomotor adaptations." In it, she took on the established categories of locomotor patterns in primates in which species were labeled by particular locomotor types, for example, quadruped or brachiator. Sue pointed out that there are several factors besides anatomy involved in how a species moves. She argued that the anatomy of a species evolved through its interaction with a specific configuration of environmental features — trees with particular branch patterns with limbs of particular sizes, to name just one. To understand how and why a species of primate moves as it does and has the anatomy it does, one must get out of the laboratory and watch it move in its natural habitat. Furthermore, the object of study must be a whole group of animals, since anatomy is shaped by natural selection over a reproductive lifespan and individuals of different ages engage the environment differently. Habitats must be described in extremely specific ways so that anatomical features can be seen as the result of movement and postures that interact with the complex environment in which the animals live. In this paper, Sue suggested elements of movement, posture and habitat type that must be defined in order to truly understand the anatomy of a primate species, and hence, its evolution. John Fleagle, Professor of Anthropology at the State University of New York at Stony Brook, says of this paper: "it was one of the most important papers in the history of primatology… (it) inspired a whole generation of researchers and was the impetus behind many careers" (his included). Sue went on to write other papers refining and using her paradigm, expanding it to include ways of studying and understanding feeding behavior as an evolved part of a species' biology. Her last paper was a comparison of infanticide in langur monkeys and humans, arguing that since both species are successful generalists and share a fundamental adaptation to drier seasonal habitats, a comparison of their use of infanticide to limit population could be illuminating.

In 1967, she and Smithsonian biologist John Eisenberg were awarded a Currency Project grant for a multi-year, multidisciplinary project studying primates and elephants at Polonnaruwa, in Sri Lanka. Over the years, this project has included many scientists and graduate students, and Sue was especially proud of the number of Sri Lankan students and field workers who were trained at that site.

In the months since Sue's death, I have been in touch with many colleagues who knew her. I was surprised to learn how widespread her circle was and how much she was admired for her contributions to the field. Dr. Sarah Hrdy, noted anthropologist and fellow langur researcher, wrote: "In terms of the work … (Sue) did in the early years, she was among the very best… As well as a fieldworker, she was a scholar's scholar intent on charting new paths, and also someone determined to find a precise terminology to interpret her ideas. I still smile when I think of Sue's phrase "monopodal arboterrestrial link". It was her term for a tree, and from the perspective of the ecology, locomotion and behavior of a monkey, that's exactly what a tree is."

Sri Lankan primatologist, Rudy Rudran wrote:

"Sue was a modern day pioneer of Primatology in Sri Lanka. She was instrumental in launching the Sri Lanka Primate Project way back in the early 1960s which continues even today with the work of Wolfgang Dittus. And just last year I renewed my work on Sri Lanka's endemic purple-faced langur — I likely would not have re-started this project had I not been part of the team that Sue set up for the Smithsonian Institution at Polonnaruwa. As a young Sri Lankan graduate working on the Smithsonian Project as a Field Assistant, Sue was the first person who introduced me to field research on primates, which was practically unheard of in those days in Sri Lanka. I learnt a great deal from her about the work ethic and the commitment that was required to follow monkeys from dawn to dusk to study their ecology and behavior. This lesson has stayed with me right through my career as a Primatologist during the past forty years, and I am the richer for it. There were many other Sri Lankans who also benefited from Sue's counsel and enthusiasm for primate field investigations. So it is with great sadness that I received the news that Sue is no more. May she rest in peace."

Colleagues all included the words "pioneer" when they spoke of Sue — yes, Sue was out there, and she blazed trails for many of us. She was challenging, exhausting, and always pushing the boundaries. She leaves anthropology a legacy that includes a number of published papers all of which expand our thinking in major new directions, a field site in Sri Lanka that has contributed to our understanding of primate and human evolution for more than 40 years, and for those of us who knew her, a more rigorous and adventurous way to think about the research issues that we are working on.

Naomi Bishop, Portland, Oregon, USA

Regional Newsletters

The IUCN/SSC Primate Specialist Group also produces regional newsletters/journals which publish short articles and notes on general and specific aspects of primate ecology, taxonomy, distributions, behavior and conservation, tropical forest ecology and conservation, forest destruction, and protected areas. Also please send information on projects, research groups, events, recent publications, courses, funding sources, activities of primatological societies and NGOs, and other newsworthy items of interest to primate conservationists, directly to the editors at the addresses below.

Madagascar - *Lemur News*

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Neotropical Region - *Neotropical Primates,* Mesoamerica

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African Region - *African Primates*

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Instructions to Contributors

Articles submitted to Primate Conservation

Manuscript Format

All manuscripts should be typewritten, double spaced with generous margins, and accompanied by the text on diskette in Word format or by e-mail in RTF or as a Word document. Please indicate on a separate cover page the author to which correspondence should be sent, including fax number and e-mail, the month and year the manuscript was completed, up to six key words, and a short running title. Abstracts are not published. Footnotes are to be avoided (except for tables and figures). Subdivision titles, for example, Methods, Conclusions, etc. are not necessary. Please give all measurements in metric units. Please accent all foreign words carefully. The literature cited should be in the following style:

Example – journal article:

Struhsaker, T. T. 1972. Rain-forest conservation in Africa. *Primates* 13: 103–109.

Example – chapter in book:

Goodall, A. G. and C. P. Groves. 1977. The conservation of eastern gorillas. In: *Primate Conservation*, H. S. H. Prince Rainier of Monaco and G. H. Bourne (eds.), pp.599–637. Academic Press, New York.

Example – book:

Soulé, M. E. 1987. *Viable Populations for Conservation*. Cambridge University Press, Cambridge, UK.

Example – dissertation:

Homewood, K. M. 1976. Ecology and Behaviour of the Tana Mangabey (*Cercocebus galeritus galeritus*). PhD thesis, University College, London.

Maps

Maps should always be made as concise as possible and should include an inset showing the location of the area discussed in relation to its home country or continent.

Photographs

Black-and-white prints are ideal. Original color slides from which we can make prints are also acceptable. However, please send only sharply-focused, high quality slides and photographs. Please label each slide or photograph with the photographer credit and number the identifying caption. Captions should be listed on a separate sheet, or after “Literature Cited.” We are always interested in receiving high quality photographs for our covers, especially those of little known and rarely photographed primates, even if they do not accompany an article.

All Figures

Please indicate on all figures the title and author of the manuscript to which they belong and package them carefully to avoid damage in the post. Figures will only be returned at the special request of the author. Electronic high resolution files (300 dpi) of maps, photographs and figures can be sent in any one of the following types of files: EPS, TIF, or JPG. Please, however supply a hard copy of all drawn maps or figures, preferably in the size in which they should be published.

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Back cover: The Siau Island tarsier, *Tarsius tumpara* sp. n. (left, above and below; photos by Geoff Deehan) and the Sangihe tarsier, *Tarsius sangirensis* Meyer, 1897 (right, above and below; photos by Myron Shekelle). See page 55.