

# A study on the carrying capacity of the available habitat for the *Rhinopithecus bieti* population at Mt. Laojun in Yunnan, China

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## Abstract

**Background, aim, and scope** The Yunnan snub-nosed monkey is one of the most endangered primates in the world. It is experiencing a range of ongoing threats and the persisting effects of past disturbances. The prospects for this species are not very optimistic because habitat corridors are severely damaged by logging, grazing, and mining. Each group of the monkeys in different areas is facing a unique variety of threats. Based on genetic analysis, *Rhinopithecus bieti* should be separated into three management units for conservation, of which the Mt. Laojun management unit involves the most endangered primates. Despite the fact that the vegetation on Mt. Laojun is in a relatively pristine state, only two groups of monkeys, of a total of fewer than 300, survive in the area. With this paper, we aimed to address the capacity of the monkeys' habitat at the study site and the possible reasons for the small populations.

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**Materials and methods** Rapid ecological assessment based on a SPOT 5 image and field survey was used to simulate the vegetation of the whole area based on reference ecological factors of the GIS system. The vegetation map of the site was thus derived from this simulation. Based on the previous studies, the three vegetation types were identified as the suitable habitat of the monkeys. The confusion matrix-based field GPS points were applied to analyze the precision of the habitat map. Based on the map of suitable habitat of the monkeys, the utilization of the habitat and the carrying capacity were analyzed in the GIS. **Results** The confusion matrix-based field GPS points were applied to the habitat analysis process, and it was found that the habitat map was 81.3% precise. Then, with the current habitat map, we found that the mixed forest currently used by the monkeys is only a very small fraction (2.65%) of the overall potential habitat of the population, while the dark conifer forest is 4.09%.

**Discussion** Poaching is the greatest short-term threat to this species, particularly in the southern range where local residents have a strong tradition of hunting. Quite a few individual monkeys are still trapped accidentally due to the high density of traps. These problems are hard to mitigate because it is difficult to enforce laws due to the extremely rugged terrain.

**Conclusions** The results show that there is a great ecological capacity of the area for the monkey's survival and a great potential for an expansion of the monkey population at the site. Based on the current population and its geographical range, it can be estimated that the suitable habitat area defined by this study can support more monkeys, about many times the current population. Thus, at least in the Mt. Laojun Area, poaching pressure is the main factor to be responsible for the low density of Yunnan snub-nosed monkeys instead of habitat alteration.

**Recommendations and perspectives** Based on these results, some suggestions relating to conservation can be made: Focus conservation efforts on the current distribution area of the monkeys and create a 20 km buffer zone; design a long-term plan for the suitable habitat outside the buffer zone to set up a wildlife corridor in the long run; establish an association for the local hunters exploiting, their knowledge on the animals to promote monkey conservation and stop poaching. Also, the map derived from the study helps managers to allocate conservation resources more efficiently and enhances the overall outcomes of conservation measures.

**Keywords** Capacity · Mt. Laojun · Population increase · SPOT5 image · Yunnan snub-nosed monkey

## 1 Background, aim, and scope

Yunnan snub-nosed monkeys (*Rhinopithecus bieti*) have a population of about 1,500 individuals, distributed from Mt. Hongla in Tibet (29°20'N, 98°37'E) to Mt. Longma (26°14'N, 99°15'E) in Yunnan (Long et al. 1996a). The region's physical conditions, e.g., its extremely rugged terrain, make fieldwork challenging. Short-term surveys on distribution and population size, which have been carried out since 1979, showed that Yunnan snub-nosed monkeys lived in 13 isolated groups. About 80% of the population was in northwestern Yunnan and 20% in southeastern Tibet (Long et al. 1996a, b). Based on genetic analysis, *R. bieti* should be separated into three management units for conservation, of which the Laojun Mountain management unit involves the most endangered primates (Liu et al. 2007). The prospects for this species are not very optimistic because habitat corridors are severely damaged by logging, grazing, and mining. The habitat is highly fragmented, which makes it impossible for any genetic exchange between populations (Xiao et al. 2003). Habitat alteration (Zhao 1998), poaching (Bai 1987), and economic activities (Xiang et al. 2007a) were the main threats to the endangered species (Baillie and Groombridge 1996). The current habitat status influences the behavior of the monkey, especially its diet; in the northern part of the range, the monkeys mainly forage at higher elevations in the dark-coniferous forest dominated by fir, and their main diet consists of lichens that grow on these trees (Kirkpatrick et al. 1998), while in the middle and southern range, the monkeys mainly forage in mixed coniferous and broadleaf forest (Xiang et al. 2007b), where the diet is much more diverse.

Each group of the monkeys in different areas is facing a unique variety of threats. Despite the fact that the vegetation on Mt. Laojun is in a relatively pristine state, only two groups of monkeys, of a total of fewer than 300,

survive in the area. With this paper, we aimed to address several questions relating to the species' conservation: (1) What is the capacity of the monkeys' habitat at the study site? (2) What are the possible reasons for the small populations? (3) How can resource management of the region improve the conservation of the species?

## 2 Materials and methods

### 2.1 Study area

Mt. Laojun is a very important habitat in the center of the species' geographical range and, if properly restored, can serve as a "corridor" between populations. The study area is inhabited by two of the 13 groups of species. A SPOT 5 image (code: 254–296) that covers the distribution area of one group of monkeys named Jinsichang was selected in the Mt. Laojun area (Fig. 1). Toward the south, the mountains decrease in elevation, while temperature, precipitation, and diversity of the vegetation increase.

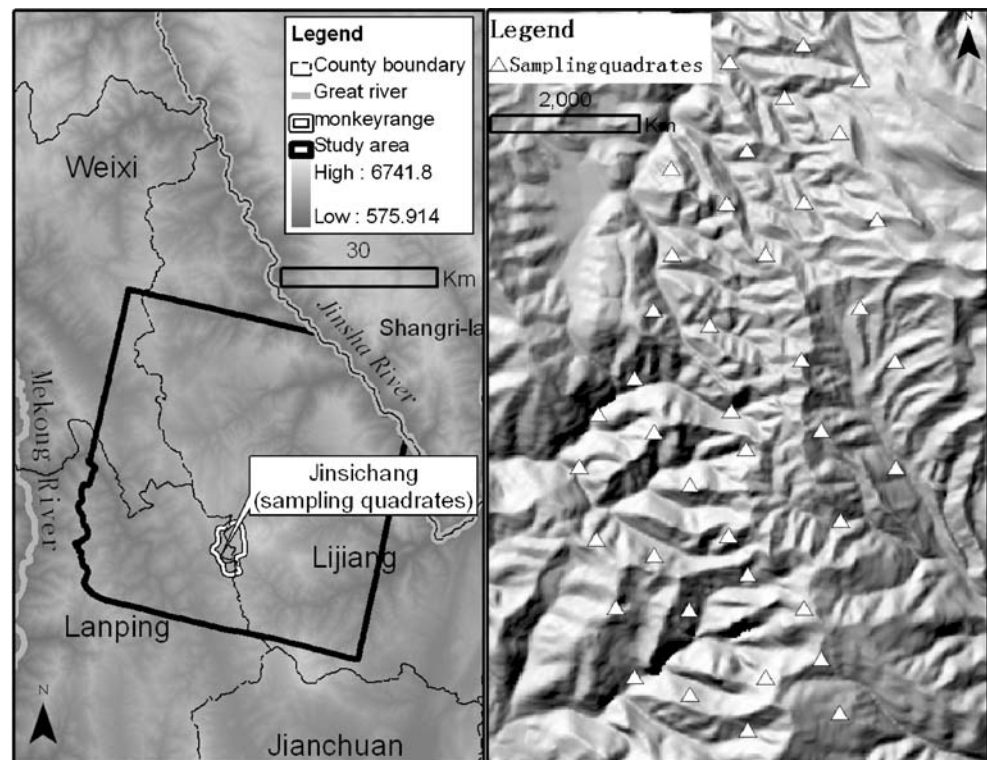
The vegetation on the mountains can be categorized into three types in order of descending elevation: (1) dark-coniferous forest (fir, *Abies georgei*); (2) mixed coniferous and broadleaf forests; (3) Yunnan pine (*Pinus yunnanensis*) forest. What are the suitable and unsuitable habitats? Several research projects show that habitat use of this monkey is determined by its forage plants and covert places, so type 1 and 2 can be defined as suitable habitats (Kirkpatrick et al. 1998; Xiao et al. 2003).

### 2.2 Field survey

The geographical points of the study monkey group were collected from 17 December 2003 to 22 October 2004 by radio collars (Ren et al. 2008, 2009). On the basis of analyzing the geographical points of the group monkey in the study site, we investigated vegetation in the home range of the group from 17 September 2006 to 24 November 2006.

Within the range of monkey distribution, we collected data from 40 sampling quadrates (see Fig. 1). In each sampling quadrate of 20×20m, we recorded plant species, coverage, diameter at breast height, and other environmental characteristics. The sampling quadrates were selected based on the data collected on monkey distribution from radio collars placed on an individual, so that these sampling quadrates truly reflect the habitat use of the group. Outside the range of monkey distribution, we recorded vegetation types at more than 200 GPS points. The suitable habitat types were further divided into subdivisions based on dominant species (Table 1). In the laboratory, we combined these data with the Rapid Ecological Assessment to simulate the vegetation of the whole area based on reference ecological

**Fig. 1** The geographic location and the distribution of sampling quadrates (20 m×20 m)



factors of the GIS system (Li and Yang 2000; Roger et al. 2000), which resulted in a habitat map of the monkeys showing the distribution of the three vegetation types and, thus, the suitable habitat of the monkeys. The field survey showed that about 232 individuals occupied 33 km<sup>2</sup> of habitat and 1,023 km<sup>2</sup> of inactive habitat. Based on the map of suitable habitat of the monkeys, the area of suitable habitat was computed in GIS. The carrying capacity of the habitat was also analyzed based on the number of individuals per square meter in the active habitat.

### 3 Results

Two hundred GPS points from the field survey were randomly selected and used for precision analysis using the confusion matrix method. The results show that the precision of this study reached 81.3%.

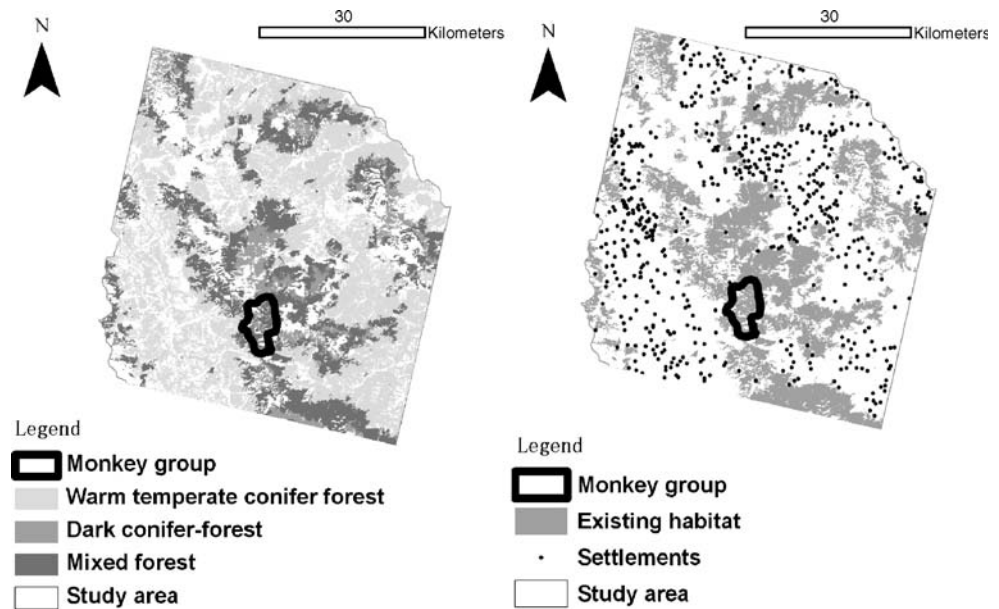
According to these results, a habitat map of the monkeys was generated showing the distribution of the two vegetation types that represent the suitable habitat of the monkeys (Fig. 2). The results show that the area of mixed forest

**Table 1** Primary vegetation types and the potential food selection of the monkey in the study site

Forest type	Main species of forest type	Potential food type		
		Lichen	Leaves	Insects
Warm coniferous forest	<i>Pinus yunnanensis</i> forest alliance			
Dark-coniferous forests <sup>a</sup>	<i>Abies georgei</i> forest alliance	√	√	√
	<i>Larix potaninii</i> forest alliance	√		√
Mixed forest <sup>a</sup>	<i>Tsuga dumosa</i> forest alliance	√	√	√
	<i>Quercus pannosa</i> forest alliance	√		√
	<i>Rhododendron trailliamum</i> shrub alliance	√		√
	<i>Rhododendron phaeochrysum</i> shrub alliance	√		√
	<i>Rhododendron telmateium</i> dwarf shrub alliance	√		√
	Perennial forest vegetation			√
Sparse vegetation				√

<sup>a</sup> Used habitat

**Fig. 2** The current habitats at the study site



currently used by the monkeys is only a very small fraction (2.65%) of the overall potential habitat of the population, while it is 4.09% for the dark conifer forest (Table 2). This means that there is a great ecological capacity of the area for the monkey’s survival and a great potential for an expansion of the population.

**4 Discussion**

From previous studies (Bai 1987; Long et al. 1996b; Zhao 1996; Xiang et al. 2007a), poaching is seen to be the greatest short-term threat to this species, particularly in the southern range where local residents have a strong tradition of hunting. All the local mountainous residents within the range of the Yunnan snub-nosed monkey (including Yi, Lisu, Tibetan, Pumi, Naxi, Bai, Molimosuo, and Han) have a long hunting history. Although the government’s Wildlife Protection Law was enacted in 1987, the law was not fully enforced, and poaching is a key threat for the species in this area. The long hunting history has resulted in extinctions and the endangerment of many wildlife species in this area. About 4 years ago, Yunnan enacted a hunting ban in the province and confiscated almost all guns in the area. This move has greatly relieved the hunting pressure on wildlife species. However, traps and

snares are still quite common. It is estimated that over 10,000 traps and snares are set in the Mt. Laojun area (Long YC., per.com.). Although the traps are not set specifically for the Yunnan snub-nosed monkey, quite a few individuals are still trapped accidentally due to the high density of traps. This problem is hard to mitigate because it is difficult to catch such criminals and to enforce laws due to the extremely rugged terrain. The Yunnan snub-nosed monkey has a very low reproductive rate (Kirkpatrick 1996; Cui 2006).

**5 Conclusions**

Based on the surveyed population density, it can be estimated that the suitable habitat area defined by this study can support more monkeys, about many times that of the current population. From the results, we assume there is a great ecological capacity for the monkeys’ survival and a great potential for an expansion of the population.

**6 Recommendations and perspectives**

The Yunnan snub-nosed monkey was on the list of “The World’s Top 25 Most Endangered Primates”, jointly released by

**Table 2** Comparison of suitable and usual habitat of the three vegetation types

Vegetation types	Suitable habitat (SH)		Used habitat (UH)		UH/SH (%)
	Area (km <sup>2</sup> )	% in study area	Area (km <sup>2</sup> )	% in used habitat	
Warm conifer forest	847.33	26	0	0	0
Mixed forest	739.79	22.7	19.61	47	2.65
Dark- conifer forest	316.15	9.7	12.94	31	4.09

the Conservation International and World Conservation Union's (IUCN) Species Survival Commission-Primate Specialist Group in January 2000. Based on the IUCN's Red List of vulnerable species in the world, the Yunnan snub-nosed monkey belongs to the endangered class.

The maps from this study show that much of the SH was found outside of the monkey's existing distribution range, and a large number of human settlements can be found within this area (see Fig. 2). The monkey population has probably been forced to reduce its distribution by increasing pressure from human disturbances.

Based on these results, some suggestions relating to conservation can be made: (1) Focus conservation efforts on the current distribution area of the monkeys and create a 20 km buffer zone, decrease human disturbances by village relocation, suppressing pasturing and hunting, and through environmental education; and (2) to design a long-term plan for the SH outside the buffer zone, including environmentally considerate regional development, forest restoration, etc. for more efficient protection of the monkey's potential habitat and to set up a wildlife corridor in the long run. (3) To establish an association for the local hunters, through education and cooperation, make them the guardians of the Yunnan snub-nosed monkeys. The aim is to exploit their knowledge on the animals to promote monkey conservation and stop poaching.

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