

ORIGINAL ARTICLE

Distribution of sleeping sites of the Yunnan snub-nosed monkey (*Rhinopithecus bieti*) in the Samage Forest, China

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Abstract

Sleeping site locations are important to free-ranging primate groups. Sites are strategically selected by primates so as to optimize security, comfort and foraging efficiency. Data were collected on the distribution of sleeping sites of the Yunnan snub-nosed monkey (*Rhinopithecus bieti*) between Sep 2005 and Sep 2006 at Gehuaqing in Baimaxueshan Nature Reserve, China. We identified 54 sleeping sites, which were used 137 times during the study period. These sleeping sites were distributed throughout the monkey group's total home range. *R. bieti* preferred certain sleeping sites over others: 63% of the sleeping sites were used 2 or more times in 13 months. Groups reused locations in an unpredictable long-term pattern, but avoided using the same sleeping site on consecutive nights. To reduce the time and energetic costs of travel, monkeys preferred sleeping near commonly used feeding sites. We recorded 124 feeding sites in the home range, which were used 174 times. A total of 27 sleeping sites were also feeding sites, and all remaining sleeping sites were close to feeding sites. There was a positive correlation between the intensity of use of sleeping sites and feeding sites. The present study suggests that the availability and the location of immediate sources of food is a key factor in the choice of sleeping sites.

Key words: feeding site, home range, *Rhinopithecus bieti*, sleeping site

INTRODUCTION

The choice of sleeping sites is crucial for the survival of diurnal primates (Anderson 1998). Numerous factors have been suggested to explain sleeping site use in primates, including predator avoidance (Heymann 1995; Kappeler 1998; Reichard 1998), proximity to food sources (Chapman *et al.* 1989; von Hippel 1998; Zhou *et al.* 2009), comfort (Liu & Zhao 2004),

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thermoregulation (Dawson 1979; Li *et al.* 2006), range or resource defense (Tilson & Tenaza 1982; Day & Elwood 1999) and reducing parasite infestation (Heymann 1995; Kappeler 1998). Although these factors are not mutually exclusive in influencing observed patterns, certain requirements may take priority over others in choosing a sleeping site.

Territory defense plays an important role in the choice of sleeping site (Heymann 1995; Zhou *et al.* 2009). The occurrence of range guarding behavior predicts that sleeping sites will be distributed either in a core zone of exclusive use or near a contested boundary of the home range (Ramirez 1989). Most primates occupy an almost stationary home range of a certain size (Clutton-Brock & Harvey 1977). Sleeping sites are often concentrated in the area most intensively used or defended by a group, termed the core area or territory (Anderson 1984). For example, according to Kappeler (1981), the sleeping sites of silvery gibbons [*Hylobates moloch* (Audebert, 1798)] were concentrated in a small region of the home range, almost never appearing in the periphery. However, distribution of sleeping sites in the home range is different across primates (Day & Elwood 1999). Sleeping sites in certain primates are found throughout the home range area (Chivers 1974; Raemaekers 1977). Reichard (1998) recorded sleeping site occurrence in nearly all home range areas for the wild white-handed gibbon [*Hylobates lar* (Linnaeus, 1771)], including those that overlapped with neighbors. These examples indicate that range defense never impacts sleeping site choice.

Proximity to food sources has been argued to exert a major influence on sleeping site selection (Chapman *et al.* 1989; von Hippel 1998; Pontes & Soares 2005; Xiang *et al.* 2010). Spider monkeys (*Ateles geoffroyi* Kuhl, 1820) choose the sleeping sites closest to the current feeding region (Chapman *et al.* 1989). Hamadryas baboons [*Papio hamadryas* (Linnaeus, 1758)] change their sleeping locations in connection with shifts in their foraging area (Sigg & Stolba 1981). The choice of sleeping sites of common marmosets [*Callithrix jacchus* (Linnaeus, 1758)] in defaunated urban forest fragments maximizes food intake (Pontes & Soares 2005). These cases suggest that sleeping site location strongly depends on economizing foraging activity.

The Yunnan snub-nosed monkey [*Rhinopithecus bieti* (Milne-Edwards, 1897)] is a highly endangered primate endemic to northwest Yunnan and southeast Tibet,

where they inhabit subalpine forests (Long *et al.* 1994). *R. bieti* is a diurnal colobine primate with a diet based on tree lichens, leaves and the fruits of angiosperm plants (Kirkpatrick *et al.* 1998; Grueter 2009). This primate species lives in a multilevel social system (Grueter & Zinner 2004), whereby one-male/multi-female units reside and travel together in a large, rather cohesive band. *R. bieti* is regarded as partially terrestrial during the day (Xiang *et al.* 2009), but they spend the night in tree crowns (Li *et al.* 2010).

Several researchers have published descriptive accounts of sleeping sites and individual sleeping trees for this species (Liu & Zhao 2004; Cui & Xiao 2006; Li *et al.* 2006). Such information gathered from different sites is of utmost importance when it comes to evaluating the value of certain forest types and tree species from the animals' perspective. However, no conclusive evidence has been garnered as to what the main determinant of sleeping site selection is for *R. bieti*. Authors of prior studies have tried to explain sleeping site selection ecologically, the majority suggesting that predators have a critical influence on the choice of site (Liu & Zhao 2004; Cui & Xiao 2006). Given that top predators have become rare or been extirpated from many sites (no dangerous predators were observed in the Samage Forest from 2004 to 2010 (D. Li, unpubl. data), this consideration alone is unlikely to account for the habits thus far observed in *R. bieti*.

In this study, we present detailed information on the distribution of sleeping sites and the relationship between sleeping site and feeding area utilization in a free-ranging group of *R. bieti* living in the Samage Forest. We attempt to answer whether the choice of sleeping sites supports the territory defense hypothesis and the proximity to feeding sites hypothesis.

MATERIALS AND METHODS

This study was carried out at Gehuaqing (27°34'N, 99°17'E), which is located in the temperate Samage Forest in Baimaxueshan Nature Reserve, Yunnan, southwest China (Grueter *et al.* 2008). Observations were collected from Sep 2005 to Sep 2006. The main study area is approximately 40 km² in area, consisting of subtropical to temperate primary forest interspersed with some cattle pasture. Altitude at the site ranges between 2600 and 4000 m. The study site is characterized by marked seasonality in day length, rainfall and temperature (Li *et al.* 2008). During the study period, annual

precipitation in the study area was 1004 mm but there was a prolonged dry period with almost no precipitation from Oct 2005 to Feb 2006. The mean annual temperature at Gehuaqing was 14.3 °C (2480 m asl). In winter, temperatures can drop to as low as -3.8 °C or even lower within the monkeys' habitat. A group of *R. bieti* composed of approximately 410 members inhabits the study area (Grueter 2009). The study group had become fairly well habituated to human contact after years of monitoring by reserve staff, so we were able to conduct full-day group follows some of the time (Grueter 2009).

The map grid quadrat where the group spent the night was defined as a sleeping site. We could also identify sleeping sites based on high concentrations of fresh scat droppings on the forest floor and occasionally urine (Liu & Zhao 2004; Li *et al.* 2006). We did not accurately measure the spread of sleeping sites, but they seemed to stretch over an area of roughly $3 \times 10^4 \text{ m}^2$ (Li *et al.* 2006). A feeding site was defined when most members of the group were feeding simultaneously for more than 30 min. The spread of the individuals during feeding was often wide enough to cover an entire $250 \times 250 \text{ m}$ map grid cell. Accordingly, $250 \times 250 \text{ m}$ grid cells were designated for both sleeping sites and feeding sites. If several global positioning system (GPS) positions were located in 1 grid cell, we marked it as only 1 sleeping site or feeding site. The distance between 2 sites was defined as the line measure between the centroids of the grid cells.

We followed the monkey group until they stopped to rest for the night. The locations of the monkey group were recorded every 30 min with the aid of a GPS receiver. These sites were later marked on the map of the study area (1:50 000). We used the grid cell method for the calculation of the total home range. We chose $250 \times 250 \text{ m}$ grid cells because we found the usual spread of the band to be around 200 m. We measured and corrected home range sizes using the following formula:

$$A = (\text{number of cells entered}) \times 0.0625 / \cos(40^\circ) ,$$

where $\cos(40^\circ)$ represents the approximate average angle of slope (Grueter *et al.* 2008). The grid cell was based both on sightings of the group itself and secondary signs of its presence, such as fresh feces. Isolated grid cells were linked via the minimum number of intervening cells of suitable habitat (Grueter *et al.* 2009). We took the number of times a particular cell was used as a sleeping or feeding site to be the utilization intensity

of these locations. The intensities of quadrats used for sleeping sites and feeding sites were represented as the percentage of group location records in each quadrat among total group location records. To compare the utilization intensity of sleeping sites in the home range, we used an enlarged dataset as compared to Li *et al.* (2006). Li *et al.* (2006) deal with physical properties of sleeping trees, while here we focus on their distribution and relation to feeding sites.

We performed all statistical tests in SPSS 12.0. Statistical analyses were 2-tailed and the default significance level was set at $\alpha = 0.05$. We used χ^2 -tests to determine whether the monkey group showed a preference for certain sleeping sites according to their expected use based on frequency in each sleeping site. To compare the different intensity of use of sleeping sites between the border area and the core zone in the home range, we used Mann–Whitney *U*-tests. Periphery area is defined as 1 or more edges of the cell grids at the boundary of the home range. If cell grids' edges are not adjacent to the boundary of the home range, they are recorded as within the core zone. We employed nonparametric correlation analysis for the relationship between the intensity of use of sleeping sites and the amount of feeding site use close to sleeping sites. Mann–Whitney *U*-tests were used to examine whether there were significant differences in the intensity of use for the different vegetation types of sleeping sites. Descriptive statistics were used to examine the intensity of use of sleeping sites.

RESULTS

Distribution of sleeping sites

Over the course of the study, we recorded 54 different sleeping sites. The number of new sleeping sites did not continue to increase in the last 2 months of the study (Fig. 1), which suggests that we have exhaustively sampled the sleeping sites in the group's home range in the Samage Forest. The 54 sleeping sites were distributed throughout the home range, both in peripheral areas and in the core areas of the home range (Fig. 2). Of the 54 sleeping sites, 20 were located within 250 m of the range boundary, and 34 were distributed in the core areas. We found that the group spent significantly more nights in the core zone than in the periphery of the home range (Mann–Whitney *U*-tests: $Z = -2.420$, $n_1 = 20$, $n_2 = 34$, $P = 0.016$). The distribution of sleeping sites was not homogeneous across the home range; there is a clear preference for particular areas.

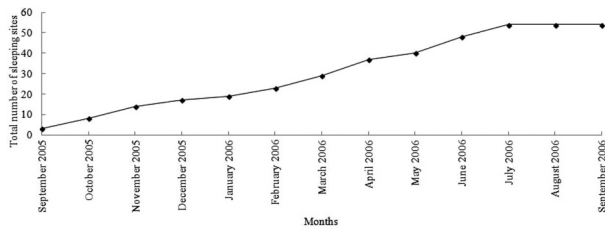


Figure 1 Cumulative increase in sleeping sites of *Rhinopithecus bieti* from Sep 2005 to Sep 2006.

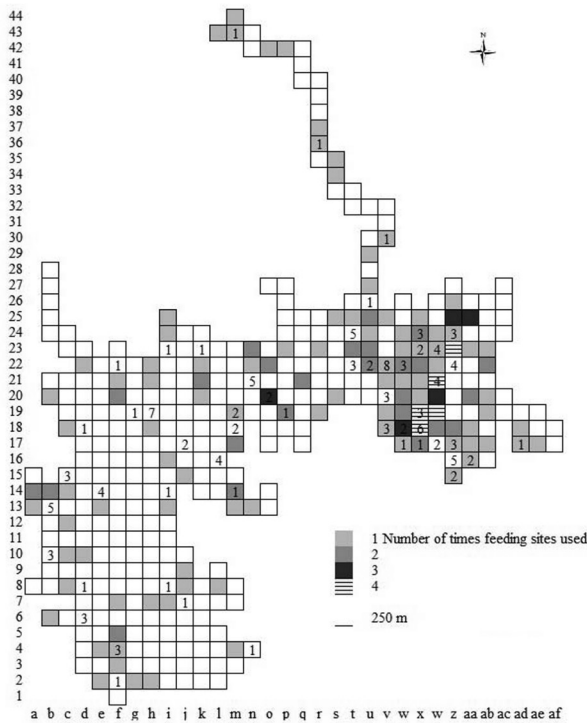


Figure 2 Distribution of feeding sites and sleeping sites of *Rhinopithecus bieti* in the Samage Forest. The numbers in the figure indicate the locations of sleeping sites and the times of use during the study of period.

Use of sleeping sites

The study group used 54 sleeping sites a total of 137 times and 20 of these sleeping sites were used only once. The remaining 34 sleeping sites were used 2 or more times during the course of study. We recorded a maximum site use of 8 nights (Table 1). A significant difference was found between observed and expected frequencies of sleeping site use, indicating preference for particular locations ($\chi^2 = 47.93$, $df = 53$, $P < 0.001$).

The 54 sleeping sites were distributed across 4 vegetation types: 42 occurred in mixed deciduous broadleaf/conifer forest, 5 were in dark conifer forest, 5 were in Yunnan pine forest and the last 2 were in evergreen forest. During the study period, *R. bieti* spent 118 (86.1% of 137 observed nights) nights in mixed deciduous broadleaf/conifer forest (Table 1), indicating their preference for sleeping in mixed deciduous broadleaf/conifer forest (Mann–Whitney *U*-test: $Z = -2.588$, $n_1 = 42$, $n_2 = 12$, $P = 0.010$).

Relation between sleeping sites and feeding sites

We recorded 124 feeding sites that were used 174 times (Fig. 2). The location of sleeping sites was closely associated with the location of feeding sites (Fig. 2). Sleeping sites used frequently are all located within or adjacent to the quadrats used frequently for group feeding. We found 24 sleeping sites situated within the same quadrat as the afternoon group feeding sites or the next morning group feeding sites. The other 31 sleeping sites were distributed in the quadrats neighboring feeding sites (Fig. 2). The intensity of sleeping site use was positively correlated with the intensity of nearby feeding site use (Spearman rank correlation: $r_s = 0.408$, $P = 0.002$, $n = 54$).

DISCUSSION

Territory defense hypothesis

To defend resources or territory, animal sleeping sites are often distributed either in a core zone of exclusive use or on the border of the home range area (Reichard 1998; Day & Elwood 1999). For example, sleeping sites of some primates were distributed only in certain areas of the home range (Kappeler 1981; Anderson 1984; Day & Elwood 1999; Di Bitetti *et al.* 2000; Wang *et al.* 2011). Savage (1990) also reports that 82% of sleeping sites of the cotton-top tamarin [*Saguinus oedipus* (Linnaeus, 1758)] were located in the center of the home range, and that they rarely entered sleeping sites close to the boundary.

In this study, however, sleeping sites were established in nearly all parts of the home range, including core zones and boundary areas. These findings correspond with observations of site selection in gibbons and Francois’ langurs (Reichard 1998; Zhou *et al.* 2009). Reichard (1998) reports that the sleeping sites of wild white-handed gibbons were distributed throughout their home ranges, including areas overlapping with neighbors’ ranges. According to Norconk (1986) a few

Table 1 Frequency of the different types of sleeping sites and their intensity of use by *Rhinopithecus bieti* in the Samage Forest

Code	Vegetation type	Spring	Summer	Autumn	Winter	Total frequency	% (F)
1	M			1		1	0.7
2	M			2		2	1.5
3	M			3		3	2.2
4	M	1		2		3	2.2
5	E			2		2	1.5
6	M	1		5		6	4.4
7	M		1	4		5	3.6
8	M		3	1		4	2.9
9	M			2		2	1.5
10	M			2		2	1.5
11	M	1		1		2	1.5
12	E				1	1	0.7
13	M			2	2	4	2.9
14	M	1				1	0.7
15	M	1				1	0.7
16	P	1				1	0.7
17	M	2			1	3	2.2
18	M	1				1	0.7
19	M	1				1	0.7
20	M	1		1		2	1.5
21	D	1	2	1	1	5	3.6
22	M	2	1	2		5	3.6
23	M	1				1	0.7
24	M	1	2	3	1	7	5.1
25	D			1		1	0.7
26	D			1		1	0.7
27	M				1	1	0.7
28	P	1				1	0.7
29	M	1				1	0.7
30	M	1				1	0.7
31	M	1			2	3	2.2
32	M	2		2		4	2.9
33	M	2			2	4	2.9
34	M	2	2		1	5	3.6
35	M	1	1		1	3	2.2
36	M	1	2		1	4	2.9
37	M		1			1	0.7
38	M	1			1	2	1.5
39	M			2		2	1.5
40	M	1	2	5		8	5.8
41	M		1	2		3	2.2
42	M	1		2		3	2.2
43	D		1			1	0.7
44	M		1	2		3	2.2

Table 1 Continued

Code	Vegetation type	Spring	Summer	Autumn	Winter	Total frequency	% (<i>F</i>)
45	M		1	2		3	2.2
46	D		1			1	0.7
47	M				1	1	0.7
48	M				1	1	0.7
49	M	2			1	3	2.2
50	M		2	1		3	2.2
51	P				1	1	0.7
52	M		1	2		3	2.2
53	P			2		2	1.5
54	P			2		2	1.5

M, mixed forest; E, evergreen broadleaf forest; D, dark conifer forest; P, Yunnan pine forest; % (*F*), percentage of total frequency.

sleeping sites of a group of moustached tamarins [*Saguinus mystax* (Spix, 1823)] were situated within 100 m of their range boundary, and half of their sleeping sites were located within zones of overlap with neighboring groups. In terms of the number and distribution of sleeping sites, *R. bieti* revealed no preference for either. Grueter (2009) suggests that this monkey group has a comparatively low index of defendability. They did not effectively maintain an exclusive territory (Mitani & Rodman 1979). Although some indirect evidence implied that another small group partially shared the same space, we recorded no intergroup aggression in the course of study. Thus, range or resource defense does not influence the distribution of sleeping sites of *R. bieti*.

Food access hypothesis

Access to food resources might be a key factor influencing the distribution and use of sleeping sites in *R. bieti* in the Samage Forest. Our results indicate that the group often slept in trees near commonly used food sources. In this study, almost half of the sleeping sites (24) overlapped spatially with feeding sites, and the other sleeping sites were close to feeding sites. We also found that sleeping sites were almost exclusively associated with mixed deciduous broadleaf/conifer forest. The Samage Forest contains floristic elements of both subtropical and temperate biomes, and previous research has revealed that mixed deciduous broadleaf/conifer forest constitutes by far the most frequently visited vegetation type, after controlling for habitat availability (Li *et al.* 2008). The reason for its superiority lies in the seasonal abundance of heavily exploited and preferred food

items, namely flush leaves in spring, bamboo shoots in summer, and fruits in fall (Li *et al.* 2008; Grueter 2009).

Some primates tend to choose sleeping sites near their most commonly used food resources (Raemaekers 1977; von Hippel 1998; Day & Elwood 1999; Xiang *et al.* 2010). For siamangs [*Hylobates syndactylus* (Raffles, 1821)], sleeping trees were usually near 1 or more of 7 or 8 groups of feeding trees frequently used in the late afternoon (Chivers 1974). Spider monkeys (*Ateles geoffroyi* Kuhl, 1820) choose the sleeping place closest to their feeding area (Chapman *et al.* 1989). François' langurs [*Trachypitecus francoisi* (Pousargues, 1898)] show a similar tendency (Zhou *et al.* 2009). The langurs' feeding activities were concentrated in several small areas, even though their feeding activities were distributed over most of the quadrats in the home range (Hu 2007). The sleeping sites used often by langurs were situated near the most-frequented feeding sites, and were also used repeatedly over the long term (Wang *et al.* 2011). An analysis of distance between sleeping sites and the last group feeding site, as well as the morning group feeding site the next day revealed similar patterns. A similar result was found in spider monkeys in Santa Rosa National Park, who selected sleeping sites closest to their current feeding area. These sleeping sites were used repeatedly (Chapman *et al.* 1989). In this study, we also found that sleeping sites were reused by *R. bieti* in different degrees. Reuse of sleeping sites might be a trade-off between using optimal sites owing to high quality foods (Sigg & Stolba 1981).

The strategy of establishing sleeping sites within foraging cells might reduce the time and energetic cost of

travel. Smith *et al.* (2007) suggest that animals might choose where to sleep based on where they plan to feed the subsequent day. In this study, the distance between sleeping sites and feeding sites was small, from 0 to 250 m away. This finding reflects the potential need of the group to minimize travel costs. Similarly, *R. bieti* was found to spend the night only in mixed deciduous broadleaf/conifer forest where the availability of fruits was high in autumn; we observed this at Xiangguqing, another site within the Samage Forest (D. Li, unpubl. data).

In summary, Yunnan snub-nosed monkeys continually change their behavior and ecology with the environment. Previously, predation avoidance was the main factor in the choice of sleeping site in the Samage Forest, where the risks of predation were high (S. Feng, pers. comm.). However, a strategy to maximize foraging has become the most important factor in the choice of sleeping site because the risks of predation are now low. The change reflects the ecological flexibility of this species.

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