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Altitudinal Range of Black-and-white Snub-nosed Monkeys (*Rhinopithecus bieti*) at Baima Snow Mountain, China

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Abstract: Faeces were counted along horizontal, 5.0m wide strips at altitude intervals of 100m to examine the altitudinal ranging pattern of a band of black-and-white snub-nosed monkeys (*Rhinopithecus bieti*) at Nanren (99°04’E, 28°34’N, Baima Snow Mountain Nature Reverse, Yunnan, China) at four areas in each season between 2000-2001. Faeces were also counted along vertical, 2.5m wide strips in one subvalley and on one subridge in each area. Monkeys used an altitudinal range of 3500-4300m, but preferred occupying the upper forest belt between 3900 and 4200m asl year-round, being at the highest altitude in summer, the lowest altitude in spring, and middle altitudes between autumn and winter (lower in winter than autumn). Moreover, there were secondary peaks of lower altitude use (3700m) in spring and winter. In addition, more faeces were distributed in subvalleys than on subridges in winter, this suggests that monkeys tend to spend more time in subvalleys where there is less wind and fluctuating temperatures. The significant correlation between faecal density and lichen load might indicate that altitudinal distribution of food resources may act as an important factor affecting the monkeys’ range. The monkeys might migrate to lower altitudes to eat young sprouts and leaves in spring, and to shelter from snowstorms in winter, possibly resulting in the secondary peaks at lower altitudes.

Key words: Altitudinal range; Faeces distribution; Lichen abundance; *Rhinopithecus bieti*; Temperate primates

白马雪山黑白仰鼻猴(*Rhinopithecus bieti*)垂直迁移

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摘要：2000-2001年间，在白马雪山国家级自然保护区南任村附近，通过在四个山坡每隔海拔100米的样带（宽5.0米）内搜集黑白仰鼻猴的粪便来研究猴群不同季节的垂直迁移模式。同时，通过在每个地区山脊上和山沟内搜集2.5米宽垂直样带内的粪便，来研究猴群不同季节对山脊和山沟的选择性。结果表明：猴群在海拔3500-4300米的区域活动。虽然猴群全年集中利用3900-4200米的林带；但是具有季节性差异：夏季最高（4200米），依次是秋季（4100米）和冬季（4000米），夏季最低（3900米）。另外，冬季山沟中的粪便多于山脊说明猴群在沟中停留时间长，这与沟中少风且温度高有关。不同海拔带上的粪便密度和松萝量间正相关，这意味着食物资源的垂直分布是影响猴群垂直迁移的重要因素。春季，猴群会下到低海拔采食嫩芽/叶，而冬季则下到低海拔处躲避首次大雪，这很可能导致猴群集中利用第二个海拔带。

关键词：垂直迁移；粪便分布；松萝丰富度；*Rhinopithecus bieti*；温带灵长类
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Montane, temperate primates are generally reported to commonly migrate seasonally, preferring higher altitudes in summer and lower altitudes in winter, presumably due to increased metabolic costs at higher, colder altitudes (Bishop, 1979; Hu et al, 1980). Golden snub-nosed monkeys (*Rhinopithecus roxellana*) favored conifer forests at higher altitudes in summer, in contrast with lower altitude conifer-broadleaf and broadleaf forests in other seasons (Hu et al, 1980). Some high living populations of *Presbytis entellus* are reported to move down to lower altitudes in winter (Bishop, 1977), but most do not descend (Sugiyama, 1976; Bishop, 1979). Quantitative studies of faecal distribution at different altitudes at Wuyapuya suggested that *Rhinopithecus bieti* also remained at higher altitudes (4000 m) in winter (Zhao et al, 1988). The same band of *R. bieti* was reported to stay at higher altitudes (>4000 m) where lichen density is high throughout the year (Kirkpatrick, 1996).

Across temperate-living primates, factors such as seasonal availability of food resources, temperature and human activities are all thought to influence their choice of altitudes (Kirkpatrick & Long, 1994). The irregular pattern of altitudinal range in *R. roxellana*, for example, was influenced by the phenology of broadleaf trees (Hu et al, 1980; Shi et al, 1982; Li et al, 2000). Food availability was probably the crucial factor affecting migration in winter (*Macaca fuscata*: Suzuki, 1965; *P. entullus*: Bishop, 1979). Similarly, some groups of *P. entellus* are reported to use northern and colder slopes at higher altitudes with available foods during winter (Sugiyama, 1976). Although the use of higher altitudes by this study band of *R. bieti* year-round has been suggested to relate to the density of lichens present (Kirkpatrick et al, 1998), the evidence was circumstantial. Moreover, there was no significant correlation between the altitudinal range of the monkeys and temperature, and human activities also did not seem to influence the choice of altitude for the band (Kirkpatrick, 1996).

R. bieti at Wuyapuya was reported to use a wide range of elevations (3500-4600 m), and to feed mainly on the lichen (*Bryoria*) growing on conifer trees (Kirkpatrick, 1996). This study is designed to clarify whether they used differential altitudes or stayed at the same altitude throughout the year and to examine the influence of lichen distribution on the choice of altitudes.

1 Materials and Methods

1.1 Study site and langur group

The study site was at Nanren (99°04'E, 28°34'N, Baima Snow Mountain Nature Reserve, Yunnan, China) in the northern range of the band of *R. bieti*, which is the same band studied by Kirkpatrick (1996). Vegetation has striking altitudinal zonation. In general, alpine meadows give way to fir forests at lower than 4300m, and fir forests give way to oak forests, pine forests, and low oak shrub at 3800-3600 m. Chaparral and barren rock were lower than 3400 m (Wu, 1993; Li & Walker, 1986). The high altitudes favored by the monkeys are covered mainly with fir forests, although they also have some evergreen oak forest and broadleaf, deciduous trees (Kirkpatrick, 1996). For sampling areas, they were primarily covered with coniferous forests, besides broadleaf trees between 3750-3700m and below 3500m in area I, and oak trees below 3700 m in areas III and IV (Fig. 1). In addition, there are no trees below approximately 3600 m around Naren village.

Local people log conifers mainly at lower altitudes in area III and IV in May, and send timbers in November every year. In general, livestock graze through the alpine meadows above the monkeys' range during the period from the middle of May to the end of October. Moreover, the majority of local people begin to collect Chinese Caterpillar Fungus (*Cordyceps sinensis* (*Berk.*) *Sacc.*) in the alpine meadow (> 4200 m), and women and children look for Yellow Morel (*Morchelella esculenta*) in low altitude fir forests (<3800 m).

The study group contained more than 175 individuals and was typically composed of one male and multiple female units (OMUs) that travel together as a cohesive band, with a sex ratio of about three females to one male. Home range size is 25.25 km^2 over the 2-year study period. The mean daily travel distance is 1310±425 m, with individual days spanning 300-2400 m. The monkeys occurred at altitudes between 3500 and 4600 m, with a mean of 4080 m. They mainly fed on the lichen (*Bryoria spp*) at this study site (Kirkpatrick et al, 1998).

Temperature was recorded in Naren village (3400 m) via a mechanical recorder (Changchun Weather equipment Factory). Daily temperature was calculated as the mean of 12 temperature records taken per day, taken at 2hr intervals. From the period 11 April to 21 June 2001, mean daily temperature was 6.1 °C. It was 13.2 °C from 5 August to 21 September 2001, 4.8 °C from 1 October to 30 November 2001, and -1.3°C in December 2001.

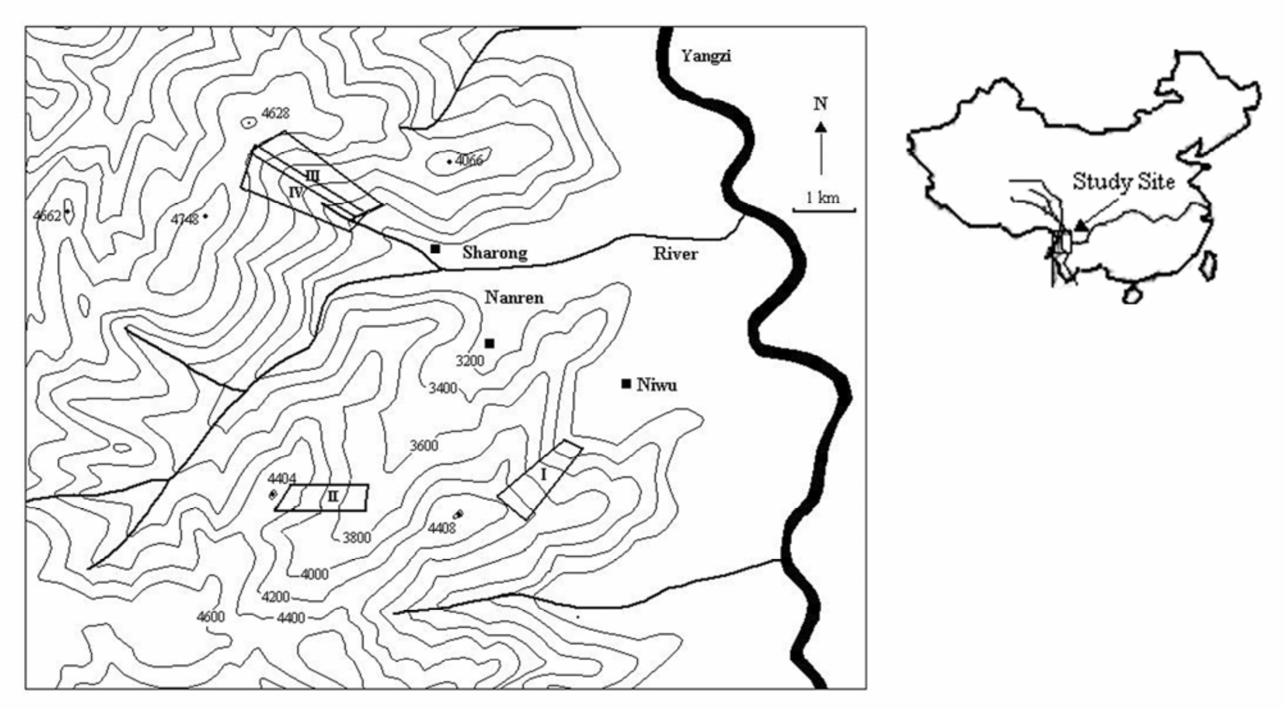

Fig. 1 The location and shape of sampling areas at Baima Snow Mountain, Yuanan, China
■ represented villages surrounding the range of monkeys.

1.2 Data collection

We used two methods to determine sampling areas. When monkeys were followed in summer and autumn, sampling areas could be decided directly. In spring and winter, the areas were indirectly determined by surveying the distribution of faeces across the home range, which seemed to be the same as faecal distribution observed by direct observations. Locations and shapes of four sampling areas, which are located by lateral subridges, are shown in Fig. 1. Sampling periods were from 7 to 15 June (labeled as spring) in 2001, 10 to 20 September (summer) in 2001, and 6 to 18 November (autumn) in 2001, and 10 to 25 April (winter) in 2001.

Two people counted similar appearances of faeces along horizontal, 5.0m wide strips at altitude intervals of 100m fixed by a barometer from one lateral boundary to another in each area. Moreover, a single observer counted faeces along vertical, 2.5m wide strips in one subvalley and on one subridge in each area (Zhao et al, 1988). These strips spanned from the bottom of valleys or the lowest limits of forests to the upper limits of conifer forests. Sampling period (days) spent in each survey area in each season is shown in Tab. 1.

Faeces of *R. bieti* look like beads, so it is easy to distinguish from the faeces of other animals. Moreover, there is only one band of *R. bieti* in this area (Kirkpatrick, 1996). Our observation of a captive group of *R. bieti*, maintained in the Kunming Institute of Zoology, the Chinese Academy of Science, showed that the monkeys tended to randomly defecate at any time of the day and in any place within an enclosure. Pellet sizes of captive *R. bieti* positively correlate with animal size (Zhao et al, 1988). Furthermore, the amount of faeces pellets is assumed to correlate positively with the number of anim-

Tab. 1 Sampling days spent in each survey area in each season at Baima Snow Mountain, China

	Area I	Area II	Area III	Area IV	Total
Spring	2	2	2	3	9
Summer	2	3	3	3	11
Autumn	3	3	3	4	13
Winter	3	4	4	5	16
Total	10	12	12	15	49

als present and the amount of time animals stayed in a region, so faeces can be indirectly used to specify the range of the monkeys (Zhao et al, 1988).

Use of faecal density as an index of habitat use for comparisons between seasons and habitats relies on two assumptions. One is that faeces can be detected at the same rate in all habitats and seasons. This assumption may be violated by the presence of such factors as growing shrubs and weeds in spring and summer, and fallen leaves and snow in autumn and winter, which may have a somewhat negative effect on detecting or counting faeces. A second assumption is that the decay rates of faeces are consistent in all seasons and habitats. Fresh faeces can persist if they are not infected by beetles/worms for at least 1.5 months in spring and summer, which was determined by the interval between the first observation of monkeys and the day when faeces were sampled. They can exit for much longer than 1.5 months due to lower temperatures in autumn and winter. Moreover, a kind of chafer (in the family *Aphodiidae*, Xiao NN, pers. comm., and its body length is as small as 3mm) does not dispose of all faeces but only digs small holes in faeces in this study area. This means that decay rate of faeces at the study site is much lower than that caused by other kinds of scavengers at other southern sites. Although decay rate is more rapid at lower altitudes than higher altitudes in warmer months, "decayed" faeces can have the same value as the whole ones in indicating habitat use. In general, it is impossible for all faeces deposited in spring/summer to keep to the next season, they can however be easily distinguished on the basis of their appearance and luster differences. Furthermore, faeces can also be discriminated between autumn and winter and between spring and the last winter based on differences in luster, appearance and the decomposed extent of faeces. Thus, faeces defecated by the monkeys in one season cannot be mistaken to be left over from the last/next season. This method can thus provide a relatively accurate measure of the use of a particular altitude for at least two months in spring and summer, and for more long periods in autumn and winter.

During sampling, two points at both ends of each strip and some inflexions at vertical strips were localized with the aid of GPS. The length of horizontal strips was calculated on the basis of GPS points and contours in a 1: 25,000 topographical map. Lengths of vertical strips were also computed in terms of GPS points and inflexions at strips in the map. Due to the effects of rugged terrain, there might be differences and some deviations in strip lengths. So the difference in transect length was accounted for by standardizing a "faeces/ 10 m length" number for each elevation gradient of interest. Horizontal strip length, faeces number and density in different seasons are presented in Tab. 2 (see Results).

To specify the relation between abundance of the lichen (*Bryoria spp*) and range pattern, the mean lichen coverage of all trees in three 10 x 20 m^2 quadrats at each altitude was assigned to one of five categories after an inspection of their crowns. "1" means 0-5%; "2" means 5-25%; "3" means 25-50%; "4" means 50-75%; and "5" means > 75%. Three spots at the same altitude were surveyed, one distributed on a subridge, one in a subvalley, and one on a place 50m away from the right borderline of each area. Furthermore, the lichen abundance at different elevation gradients was estimated at every 100-m in each of the four areas.

1.3 Data analysis

Faecal pellets indicate one or two instances where the monkeys use this elevation as a sleeping site, or it could indicate a frequent and even use of this elevation over a long period; therefore, pellet counts under sleeping trees were omitted when faecal density was calculated. We used Spearman rank correlations (1-tailed) to correlate faecal density with lichen load in four seasons, and to correlate frequently used forest belts with seasonal mean temperatures, assuming that monkeys might descend when the temperature was lower. Kolmogorov-Smirnov tests (2-tailed) were used to compare the differences in faecal density between subridges and subvalleys in four areas.

2 Results

Although the band of *R. bieti* used an altitudinal range of 3500-4300m, they most commonly occupied the upper forest belt from 4200 to 3900m in all four seasons. Within this range, the monkeys favored the highest altitudes in summer and the lowest in the spring. In the winter, they utilized somewhat higher altitudes than in spring, and somewhat lower still than in autumn. Moreover, there were the secondary peaks of lower altitude use (3700 m) in spring and winter (Tab. 2). Faeces were distributed across a wider range of altitudes in winter than in autumn (Mann-Whitney U test: $U = 27$, $n_1 = 11$, $n_2 = 10$, $P = 0.037$). There are significant correlations between faecal density and lichen load in all

Tab. 2 Length of horizontal, 5 m wide strip, number of faeces (pellets), lichen load and faecal density (pellets/10 m) at different altitudes in four areas at Baima Snow Mountain

Altitude (m)	Area I							Area II						
	LS[1]	ML[2]	Spring		Su	Au	Wi	LS	MLA	Sp	Summer		Au	Wi
			NF[3]	FD[4]	NF	NF	NF			NF	NF	FD	NF	NF
4400														
4300								300	2	0	0	0	0	0
4200								325	5	0	321	9.9	0	0
4100	300	2	0	0	0	0	0	300	4	0	9	0.3	0	0
4000	200	4	28	1.4	0	0	0	310	3	0	6	0.2	0	0
3900	230	4	354	15.4	0	0	0	280	3	0	0	0	0	0
3800	320	3	70	2.2	0	0	0	300	2	0	0	0	0	0
3700	280	2	218	7.8	0	0	0	270	2	0	0	0	0	0
3600	220	2	26	1.2	0	0	0							
3500	310	1	16	0.5	0	0	0							
3400	100	1	0	0	0	0	0							
Total	1960		712					2085			336			

Altitude (m)	Area III							Area IV						
	LS	MLA	Sp	Su	Autumn		Wi	LS	MLA	Sp	Su	Au	Winter	
			NF	NF	NF	FD	NF			NF	NF	NF	NF	FD
4400	830	1	0	0	0	0	0							
4300	820	2	0	0	43	0.5	0	200	1	0	0	0	0	0
4200	800	5	0	0	354	4.4	0	280	2	0	0	0	73	2.6
4100	500	4	0	0	527	10.5	0	240	5	0	0	0	46	1.9
4000	550	4	0	0	0	0	0	270	4	0	0	0	413	15.3
3900	560	3	0	0	0	0	0	220	3	0	0	0	81	3.7
3800	300	3	0	0	0	0	0	180	3	0	0	0	54	3
3700	280	2	0	0	0	0	0	260	3	0	0	0	146	5.6
3600	200	2	0	0	0	0	0	160	2	0	0	0	73	4.6
3500	150	1	0	0	0	0	0	120	2	0	0	0	2	0.2
3400	100	1	0	0	0	0	0	100	1	0	0	0	0	0
Total	5090				924			2030					888	

[1] LS, length of the horizontal, 5 m wide strip (m).

[2] ML, mean rank of lichen load in three 10×20 m^2 quadrats at intervals of 100 m altitudes.

[3] NF, number of faeces (pellets) in the strips.

[4] FD, faecal density (pellets /10 m); Sp, spring; Su, summer; Au, autumn; Wi, winter.

four seasons (Spearman Rank Correlations: $r_s = 0.70$, $n = 8$ altitudes, $P = 0.026$ in spring; $r_s = 0.90$, $n = 7$ altitudes, $P = 0.003$ in summer; $r_s = 0.54$, $n = 11$ altitudes, $P = 0.043$ in autumn, $r_s = 0.63$, $n = 10$ altitudes, $P = 0.03$ in winter). There is no significant correlation between densely used altitudes and mean seasonal temperatures in all four seasons ($r_s = -0.4$, $n = 4$, $P = 0.6$).

Faeces were distributed across a wider range of altitudes in subvalleys than on subridges in winter (Kolmogorov-Smirnov test: $Z = 1.49$, $df = 2$, $P = 0.02$), but faecal distribution was not significantly different between subvalleys and subridges in the other three seasons (K-S test: $Z < 0.71$, df = 2, $P > 0.05$) (Tab. 3). More faeces of the monkeys were found in broadleaf forests at lower altitudes in area I in spring. However, we did not find more faeces within broadleaf forests in the other three seasons during our observation periods. On the other hand, after a snow on 21st November, the monkeys descended as low as 3540 m confirmed by faeces, and stayed for a short period, then returned to higher altitudes.

3 Discussion

The study band of *R. bieti* utilized an altitudinal range of 3500-4300m, but they tended to occupy the upper forest belt between 4200 and 3900 m during all

Tab. 3 Length of vertical, 2.5 m wide strip, numbers of faeces (pellets) and faecal density (pellets /10 m) between sub-valley and su-bridge at different altitudes in four areas at Baima Snow Mountain

Altitude	Area I								Area II							
	Sub-valley				Sub-ridge				Sub-valley				Sub-ridge			
	Spring			Os[1]	Spring			Os	Summer			Os	Summer			Os
	LS[2]	NF[3]	FD[4]	FD	LS	NF	FD	FD	LS	NF	FD	FD	LS	NF	FD	FD
4500																
4400									100	0	0.0	0	200	0	0.0	0
4300									250	76	3.0	0	260	1	0.1	0
4200									170	100	5.9	0	180	12	0.7	0
4100	100	0	0.0	0	125	0	0.0	0	160	0	0.0	0	180	8	0.0	0
4000	150	50	3.3	0	300	47	1.6	0	200	0	0.0	0	200	0	0.0	0
3900	225	210	9.3	0	150	768	51.2	0	180	0	0.0	0	200	0	0.0	0
3800	250	72	2.8	0	275	95	3.5	0	190	0	0.0	0	220	0	0.0	0
3700	225	3	0.1	0	275	34	1.2	0	210	0	0.0	0	200	0	0.0	0
3600	225	50	2.2	0	275	30	1.1	0								
3500	225	23	1.0	0	200	0	0.0	0								
3400	200	6	0.3	0	200	0	0.0	0								
3300	80	0	0.0	0	150	0	0.0	0								
Tatal	1680	414			1950	974			1460	176			1640	21		

Altitude	Area III								Area IV							
	Sub-valley				Sub-ridge				Sub-valley				Sub-ridge			
	Autumn			Os	Autumn			Os	Winter			Os	Winter			Os
	LS	NF	FD	FD	LS	NF	FD	FD	LS	NF	FD	FD	LS	NF	FD	FD
4500					75											
4400	120	0	0.0	0	180	1	0.1	0	60	0	0.0	0	100	0	0.0	0
4300	180	0	0.0	0	200	50	2.5	0	160	10	0.6	0	200	0	0.0	0
4200	170	12	0.7	0	180	82	4.6	0	180	13	0.7	0	300	0	0.0	0
4100	190	8	0.4	0	150	4	0.3	0	150	161	10.7	0	280	14	0.5	0
4000	250	0	0.0	0	220	0	0.0	0	200	308	15.4	0	250	105	4.2	0
3900	240	0	0.0	0	240	0	0.0	0	200	156	7.8	0	300	18	0.6	0
3800	200	0	0.0	0	180	0	0.0	0	210	50	2.4	0	250	10	0.4	0
3700	160	0	0.0	0	160	0	0.0	0	150	15	1.0	0	230	5	0.2	0
3600	250	0	0.0	0	250	0	0.0	0	150	11	0.7		300	0	0.0	0
3500	250	0	0.0	0	250	0	0.0	0	120	11	9.0		200	0	0.0	0
3400	110	0	0.0	0	110	0	0.0	0	100	0	0.0		80	0	0.0	0
3300																
Tatal	2120	20			2195	137			1680	735			2490	152		

[1] Os, other three seasons except the season that is not abbreviated in each area.

[2] LS, length of the vertical, 2.5 m wide strip (m).

[3] NF, number of faeces (pellets) in the strips.

[4] FD, faecal density (pellets/10 m).

four seasons. Kirkpatrick et al (1998) reported that the monkeys also showed almost the same altitudinal range of habitat use and were often found at higher altitudes with denser lichens, across the year. The range of altitudes used and forest belt used most heavily in winter were the same as reported by Zhao et al (1988), which only presented faecal density data at different altitudes in winter. *Rhinopithecus roxellana* favored conifer forests at higher altitudes for the majority of the winter period (Shi et al, 1982; Hu et al, 1980). The pattern seen for *R.*

bieti is similar to that of most high living troops of *P. entellus*, in that neither species migrated down to lower altitudes in winter (Sugiyama, 1976; Bishop, 1979).

The band of *R. bieti* was at the highest elevation in summer, the lowest altitude in spring, and middle altitudes in winter and autumn during this study period. The west ridge troop of *R. roxellana* at Yuhuangmiao in Mt. Qiling also showed a similar pattern of altitudinal range: summer > autumn > winter/spring (Li et al, 2000).

Since it is difficult to follow monkeys in all four seasons due to steep slopes, deep gorges and their wariness of humans, we found faeces of the monkeys only in one survey area per season. Implying that, the monkeys used different portions of their home range seasonally. Moreover, the use of different areas in different seasons by this study band of *R. bieti* suggests that they abandon some sections of their home range for long periods. Kirkpatrick et al (1998) also reported the same pattern for this band of *R. bieti* by direct observation.

Across temperate-living primates, factors such as food resources and human activities interact with temperature to determine the use of altitudes (Kirkpatrick & Long, 1994). Some primates appear to use altitudes in their home range differently in relation to the density of available foods (*Macaca fuscata*: Wada & Tokida, 1981; *Gorilla beringei*: Fossey, 1974; *Colobus badius tephrosceles*: Clutton-Brock, 1975). For two other species of high altitude primates, seasonal changes in the range were associated with shifts in feeding patterns in different forests during different seasons (*P. entellus*: Curtin, 1975; *R. roxellana*: Li et al, 2000). The band of *R. bieti* at Jinsichang preferred lower altitudes with abundant bamboo leaves (Yang, 2003). However, given that lichen is the main food for the monkeys in this study (Kirkpatrick et al, 1998), and the correlation between faecal density and lichen load observed, we would expect that the monkeys' range is determined by differences in lichen density in different habitats. Additionally, *R. bieti* might migrate to eat young sprouts and leaves of broadleaf trees at lower altitudes, possibly relating to the secondary peaks of lower altitude use (3700 m) in spring; which has also been reported before (*R. roxellana*: Shi et al, 1982; *R. brelichi*: Tan, 1985). Thus, we suggest that the altitudinal distribution of food resources may play an important role in regulating the altitudinal pattern range. In winter, the inconsistency between densely used altitudes and abundant lichen belts might indicate willingness to trade-off foraging in more resource rich habitats for the chance to reduce heat loss by utilizing lower altitudes.

In our study, there was no significant correlation between densely used altitudes and seasonal mean temperatures; which is similar to a previous report (Kirkpatrick et al, 1998). This may be due to the small sample size of seasonal temperature records. However, the band of *R. bieti* might descend to lower altitudes for shelter from sudden snowstorms, which might result in the second peak of habitat use, then return to higher altitudes in winter; similar findings to previous reports (*R. bieti*: Kirkpatrick et al, 1994; *R. roxellana*: Shi et al, 1982; *R. brelichi*: Tan, 1985).

As a juvenile *R. bieti* male from this population was killed during the study, the monkeys were wary of humans; there were not any human activities in the monkey's range in winter. Thus, the difference in faecal distribution between winter and autumn suggests that the avoidance of lower altitudes in area III might be due to villagers dragging lumber through the area. Human activities such as cattle farming and logging have also been suggested to influence the habitat use of *R. roxellana* (Li et al, 2000).

Monkeys such as *P. entellus*, which is used to colder climates, seek sunlight at higher places in winter, presumably being greater on ridges than in valleys (Bishop, 1979). A group of Japanese monkeys selected roosting sites in valleys with less strong winds, than ridges in winter (Wada & Tokida, 1981). The fact that we recorded more faeces in subvalleys than on subridges in winter suggests this band of *R. bieti* spent more time in subvalleys where there was less wind and milder temperatures, possibly using it as a sleeping site.

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