Front. Biol. China 2008, 3(2): 232–235
DOI 10.1007/s11515-008-0035-9

RESEARCH ARTICLE

Habitat selection of the Tibetan Snow Cock *Tetraogallus tibetanus* in the spring in Lhasa

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Abstract The habitat selection of Tibetan Snow Cocks in shrub vegetation was investigated in Lhasa, Tibet, China, between March and April, 2005. Fourteen parameters were measured. These include altitude, slope, slope aspect, slope position, vegetation cover, plant type and other environmental parameters. Results show that Snow Cocks favor foraging in areas where vegetation cover was small and close to the residents' houses. Supplementary food supplied by humans has caused Snow Cocks to decrease their foraging range. Snow Cocks also favor roosting in areas with low vegetation, sparse grass, short grass, large rocks and close to houses. The Snow Cocks' activity in the study areas show a close relationship with human activities.

Keywords Tibetan Snow Cock (*Tetraogallus tibetanus*), habitat selection, forging habitat, day roosting

1 Introduction

The Tibetan Snow Cock *Tetraogallus tibetanus* is a protected species in China and is mainly distributed across the Qinghai-Tibet Plateau and around high mountainous areas such as Tibet, southern Xinjiang, Qinghai, south and southeast Gansu, northwest Sichuan and northwest Yunnan, China. Its distribution ranges northward along the Kunlun Mountains, the Pamirs and the Altyn Tagh, eastward to the Qilian Mountains, while Kashmir, the entire Himalayas and the Hengduan Mountains make up its western and southern boundaries, respectively (Zheng, 1978; Zheng, 2005).

The habitat, as the sum of diverse environmental resources, makes possible the existence of animal life and activities. For birds, habitat refers to the particular environment and location where specific individuals and biological communities in a particular life-history stage live. Habitat plays an important role in the avoidance of predators, protection from adverse weather conditions, providing for sufficient food resources and for suitable places for breeding. In essence, it provides the basic conditions for their survival and reproduction (Zhang and Zheng, 1999).

Habitat quality directly affects the birds' geographic distribution, population density, breeding success rate, survival rate of adult birds, etc (Cody, 1985). Therefore, habitat research has become an important aspect of the ecology in birds (Zhang and Zheng, 1999) and it may provide the most effective protective measures to save rare and endangered species and for biodiversity.

Birds can select the most suitable habitat for themselves from a variety of available habitat types in a phenomenon known as habitat selection (Partridge, 1978). Habitat selection by birds at different spatial scales is a very complex process resulting from the combined effects of multi-level ecological environmental factors (Yang et al., 2000). Thus, it is necessary to study the relationship between birds and their habitats to understand how species adapt to their environment (Cody, 1985).

Few research studies exist on Snow Cocks worldwide. Most studies mainly focus on *Tecraogallus himalayensis* (Liu and Wang, 1990; Bland, 1990; Huang et al., 1994; Chang et al., 1994; Wei and Cheng, 2004), but very few on *Tetraogallus tibetanus* (Zheng and Pi, 1979). Thus, we studied the habitat selection of *Tetraogallus tibetanus* to provide basic information that may help to protect this species.

2 Study area and methods

2.1 Study area

Fieldwork was carried out during March and April of 2005 in the Lhasa Mountains (29°27′N, 91°01′E), Tibet,

Translated from *Zoological Research*, 2006, 27(5): 513–517 [译自: 动物学研究]

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China. Vegetation in the study area is mainly scrub and meadow. On south-facing slopes, the plant community consists mainly of *Rosa sericea* and *Berberis hemleyana* at 4000–4500 m, and *Potentilla fruticosa* at 4500–4900 m. On north-facing slopes, *Spirace alpira* appears at 4000–4200 m, and *Rhododendron* spp. and *Salix sclerophylla* at 4200–4900 m. Alpine meadows occur between 4900 and 5200 m. Streams can be found on both slopes and they share some dominant plants with surrounding communities. However, *Caragana microphylla*, *C. jubata*, *Kobresia bellardii*, *Leontopodium* sp., *Carex* sp., *Poa annua* L., *Polygonum* spp. are unique to them.

Our study areas were located around religious places where wildlife was better protected by nuns and monks who also helped facilitate our study.

2.2 Data collection

Snow Cocks habitats were divided into two categories, foraging habitat and day roosting habitat. A 10 m × 10 m area where Snow Cocks foraged or roosted for more than 5 minutes was used as the basic sampling unit to measure the following 14 parameters: altitude, slope degree, slope aspect, slope position, vegetation cover, shrub cover, shrub height, shrub species, grass cover, grass height, grass species, rock cover, sample plot distance from the nearest human structure or dwelling (including monasteries, caves used by lamas, and ranch residential areas) and sample plot distance from water sources (including springs, gullies and place where residents fetched water). There were 28 foraging habitat samples and 19 day roosting samples. Slope position, that is, the location of a sample plot on the slope, included upslope, middle slope and down slope which were coded as 1, 2, or 3. For the slope aspect, the one facing south was regarded as zero, westward along the clockwise rotation degree was positive, and the opposite was negative. Shrub cover was calculated with the ellipse formula $S = 1/(4n \cdot a \cdot b)$ (long axis and short axis of the ellipse denoted with a and b, respectively). The cover of rock was calculated with the formula $S = a \cdot b$ (a and b were length and width, respectively). Shrub height was measured using a tape measure. Grass cover and height were measured using 1 m × 1 m sub-sample plots. A total of 5 sub-sample plots (4 in each 1/4 diagonal from the corners, 1 in the center) were analyzed within each of the 10 m × 10 m sample plots.

Twenty-seven 10 m × 10 m sample plots with little or no Snow Cocks were chosen as controls in the study area.

2.3 Data processing

The Mann-Whitney, nonparametric U-test was used to analyze the differences in each of the 14 parameters between the foraging habitats and the control sample, and between roosting habitat and the control sample. Also calculated were the partial correlation coefficient among variables in the foraging habitat and the Spearman correlation coefficient among variables in the day roosting habitat. When the absolute value of the partial correlation coefficient or Spearman's correlation coefficient "r" between two variables was greater than or equal to 0.60, the one with important biological significance was used for the next step analysis (Lahaye and Gutierrez, 1999). The remaining habitat variables were analyzed using stepwise discriminant analysis to determine the key factor that impacted the habitat selection of Snow Cocks.

All calculations were carried out via computer using SPSS13.0 software.

3 Results and analysis

3.1 The terrain and distance factor

Results from the analysis of terrain and distance factors are presented in Table 1. In the foraging habitat and the day roosting habitat, slope position, slope degree and slope aspect, show no significant difference with control areas, respectively (Table 1). Furthermore, the altitude of the foraging habitat (4483.36 $\pm$ 101.57 m) and of the day roosting habitat (4539.47 $\pm$ 105.03 m) show no significant difference with the control areas (4499.07 $\pm$ 78.10 m), respectively (Table 1). These indicated that the activity of Snow Cocks had no special requirements for the above factors.

As shown in Table 1, Snow Cocks favor foraging and roosting in areas closer to the residents' homes than in the control areas. Rock cover had no significant difference between the foraging habitat and the control area, but had a very significant difference between the day roosting and the control area (Table 1). This indicated that Snow Cocks favor roosting in areas with large rocks.

3.2 Vegetation factors

Vegetation cover and shrub cover did show very significant differences and there was a significant difference in the shrub species between the foraging habitat and the control areas (Table 1) which suggested that the foraging habitat had lower vegetation and shrub cover and fewer shrub species than the control areas.

Additionally, vegetation cover, grass cover and grass types had very significant differences, and shrub cover shows a significant difference between the day roosting and the control areas (Table 1). These show that the day roosting areas had lower vegetation and shrub cover, fewer grass types and lower grass cover than the control areas.

Table 1 Comparison of variables between foraging habitats, day roosting habitats and control areas of Snow Cocks during Spring of 2005

variable	foraging habitat	day roosting	control area	foraging vs control	roosting vs control
	$n = 28$	$n = 19$	$n = 27$	Z	Z
AL/m	4493.46 ± 101.57	4539.26 ± 105.03	4499.07 ± 78.10	−0.210	−1.216
SLP	2.14 ± 0.89	2.74 ± 0.73	2.18 ± 0.92	−0.617	1.799
SLA	31.25 ± 43.52	36.05 ± 29.89	27.69 ± 40.94	−0.026	−1.419
SLD	25 ± 9.88	28.55 ± 11.10	27.98 ± 12.12	−1.024	−0.236
VC	16.89 ± 14.67	15.37 ± 11.77	28.69 ± 16.17	−3.072**	−3.057**
SC	7.30 ± 7.50	8.60 ± 8.70	15.94 ± 11.67	−2.934**	−2.566*
SH/cm	76.54 ± 66.74	83.29 ± 44.15	73.65 ± 36.10	−0.582	−0.614
ST	1.79 ± 1.26	2.21 ± 1.08	2.63 ± 1.24	−2.449*	−1.436
GC	7.83 ± 6.84	3.66 ± 1.96	8.64 ± 8.53	−0.539	−3.270**
GH/cm	1.60 ± 1.73	1.53 ± 1.07	1.89 ± 1.18	−1.804	−1.150
GT	2.50 ± 0.74	2.21 ± 1.08	2.81 ± 1.02	−1.128	−3.681**
RC	6.71 ± 11.67	25.17 ± 27.49	4.30 ± 9.09	−1.584	−3.275**
DH/m	38.46 ± 53.78	36.44 ± 29.22	99.44 ± 91.18	−3.156**	−2.601**
DW/m	92.93 ± 66.60	98.68 ± 48.01	134.07 ± 87.02	−1.725	−1.208

Note: *$P < 0.05$ (Mann-Whitney U-test); **$P < 0.01$ (Mann-Whitney U-test). AL: altitude; SLP: position on slope; SLA: slope aspect; SLD: Slope degree; VC: vegetation cover; SC: shrub cover; SH: Average height of shrub; ST: shrub type; GC: grass cover; GH: average height of grass; GT: grass type; RC: rock cover; DH: distance to houses; DW: distance to water.

3.3 Main habitat selection factor

3.3.1 Foraging habitat selection factor

In order to test independence among habitat parameters, four parameters (VC, SC, ST, DH) that had shown significant differences between the foraging habitat and the control area (see Table 1) were analyzed using partial correlation methods. It was found that partial correlation coefficients between vegetation cover and shrub cover and between shrub cover and shrub types in the foraging habitat were greater than 0.6 ($r = 0.882$, $df = 24$, $P = 0$). Therefore, we did a stepwise discriminant analysis for the remaining three variables (excluding VC). Finally, we determined the key factor impacting the foraging habitat selection (Table 2). As shown in Table 2, shrub cover and distance to houses played a major role in accordance with the size of contribution. The standardized canonical discriminant function is $y = 0.674 \times$ shrub cover $+ 0.592 \times$ distance to houses (the correct rate of discrimination was 72.7%).

Table 2 Outcomes of the stepwise discriminant analysis of habitat variables between foraging habitat and control area of Tibetan Snow Cocks during the spring 2005

variable	coefficients	Wilks'λ	F	df_1	df_2	P
shrub cover	**0.674**	0.831	10.767	1	53	0.002
distance to houses	**0.592**	0.767	7.882	2	53	0.001

3.3.2 Day roosting selection factor

Six parameters that had a significant difference between day roosting and control areas were analyzed using partial correlation analysis (Table 1). The partial correlation coefficient between vegetation coverage and shrub cover in day roosting was greater than 0.6 ($r = 0.882$, $df = 24$, $P > 0.0001$). Therefore, we removed the vegetation coverage characteristics and then performed a stepwise discriminant analysis using the remaining five variables to determine the key factor that impacted the day roosting selection (Table 3). Table 3 indicates that grass cover and rock cover played a major role in accordance with the size of its contribution. Its standardized canonical discriminant function is $y = 0.691 \times$ grass cover $-0.600 \times$ rock cover (the correct rate of discrimination was 80.4%).

Table 3 Outcomes of the stepwise discriminant analysis of habitat variables between the day roosting and the control areas of Tibetan Snow Cocks during the spring 2005

variable	coefficients	Wilks'λ	F	df_1	df_2	P
type of grass	**0.691**	0.753	14.129	1	43	0.001
cover of rock	**−0.600**	0.666	10.543	2	42	0.0001

4 Discussion

From the above analyses, we conclude that in our study areas, Snow Cock foraging was mainly concentrated in low shrub cover, near residential areas, where animals had been well protected for centuries because hunters were not allowed around the monastery. Human activities not only hurt the survival of Snow Cocks, but also enhanced the relationship between humans and Snow Cocks. Snow Cock night roosting is at the west peak from the monastery, about 3000 m in a straight-line distance. From morning until night, Snow Cocks flew around the monastery to forage. Boutin (1990) discovered some birds with additional food had relatively smaller home ranges.

Our results support this in that Snow Cocks around the monastery with supplementary food have smaller foraging ranges. Also, Lu and Zheng (2002) found similar results in the Tibetan Eared Pheasant *Crossoptlion harmani* right in our study areas.

Some studies show that predation pressure significantly affected the habitat selection of animals. Animals can select habitats where they could effectively escape from predators to reduce the risk of prey (Houtman and Dill, 1998). Study areas, such as the Buddhist monastery, houses of monks and nuns, caves with lamas, and houses of ranchers could provide shelter for Snow Cocks. Therefore, residential areas became good shelters for Snow Cocks. This is another reason why Snow Cocks favor foraging and roosting near residential areas.

Because of the supplementary food and the protection of humans, Snow Cock foraging activities were more dependent on humans. Thus, the foraging habitat they selected had lower shrub coverage. In addition, while foraging, lower shrub ground cover can help Snow Cocks see farther and thus could detect predators effectively and find shelter quickly.

Snow Cocks roost in areas with large rocks for several reasons: ① Rocks provide concealing shelter for Snow Cocks because their body color is white and gray which is similar to the color of the granite. They could more easily remain undetected by predators (only Golden eagle was observed as a potential predator). ② Rocks provide good shade from sunlight. ③ Rocks could be used as a platform to quickly climb and glide away when predators began their attack. Snow Cocks are not good at flying compared with some other birds, partly because their body is huge and unsuitable for long flights. Thus, they can only climb to a certain point and subsequently carry out a downward glide. Large rocks just play the role of a platform.

In short, human activities were the main influencing factors on habitat selection of Snow Cocks. To obtain additional food and protection, they forage and roost near the residents' houses. The monastery, thus, played a key role for the survival and reproduction of Snow Cocks. This suggests that only when humans recognize the importance of wildlife can wild animals be perfectly protected. The extinction of some species can be prevented if we actually do more active protection.

Acknowledgments We thank the monks and nuns of Xiong-se monastery. They gave us both a lot of understanding and support on this study.

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