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Short Note

Habitat use and separation between the Chinese serow (*Capricornis milneedwardsi*) and the Chinese goral (*Naemorhedus griseus*) in winter

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Habitat separation between closely related species is one of the most common forms of coexistence (Marsh and Harris 2000, Sébastien et al. 2003, Zhang et al. 2004, 2006). Divergent habitat use strategies may reflect evolutionary mechanisms to reduce interspecific competition (Dueser and Shugart 1978), or merely reflect different physiological or ecological requirements (Maitz and Dickman 2001). The knowledge of habitat use of sympatric species is important not only for understanding niche theory but also for planning conservation strategies.

Chinese serow and Chinese goral are listed in Appendix I of the CITES (The Convention of International Trade in Endangered Species of Wild Fauna and Flora) and classified as Category II protected species in China. These two species inhabit sympatrically the subtropical alpine forests in western Sichuan, China (Hu 1994, Wu and Hu 2001). Previous studies indicated that the ungulates exhibited partial overlap in dietary niches in winter (Wu and Hu 2001). However, it is still unclear about how the animals differ in their spatial habitat use during winter, a period critical to species survival due to food scarcity. In this study, we investigated habitat use in an attempt to identify possible mechanisms that may reduce competition between the two species.

The field work was carried out in the Tangjiahe Natural Reserve, western Sichuan, China (32°30′–32°41′ N, 104°36′–104°52′ E). The reserve covers approximately 400 km^2 of rugged ridges and narrow valleys at elevations ranging from 1100 to 4800 m a.s.l. Our study area covered a range of approximately 30 km^2 across the whole altitudinal gradient.

Vegetation types in the reserve vary along altitudinal gradients. Subtropical evergreen broadleaf forest occurs below 1600 m, where the dominant trees are *Cyclobalanopsis oxyodon*, *C. glauca*, *Cinnamomum wilsonii*, and *Phoebe neurantha*. Mixed evergreen and deciduous broadleaf forests are found between 1600 and 2100 m, with *Lithocarpus cleistocarpus*, *Taxus chinensis*, and *C. glauca* being the most common deciduous species. Mixed coniferous and deciduous broadleaf forests extend from 2100 to 2400 m where the dominant trees include *Picea brachytyla*, *Tsuga chinensis*, *Pinus armandii*, *Betulaalbo sinensis*, *Betula utilis*, *B. platyphylla*, *Acer sp*, *Tetracentron sinense*, and *Populus purdomii*. Subalpine coniferous forest consisting mainly of *Abies faxoniana* occurs between 2400 and 3600 m, with alpine shrubs and grassland present above 3600 m.

It is difficult to observe forest-dwelling ungulates. Therefore, following an earlier study on these species (Wu et al. 2000, 2002), we used feces deposits together with tracks in the snow as indicators of habitat selection. We walked randomly through different habitat types to search for feces and footmarks in the snow left by the two species. Around each plot, we established four independent sampling units; five 1 m×1 m plot, two 2 m×20 m rectangular transects (each 2 m×10 m), one 10 m×10 m square and one 20 m×20 m plot (Figure 1). We measured 14 variables potentially associated with habitats of the two ungulates (Table 1), according to the methods modified by Wei et al. (2000), based on Dueser and Shugart (1978) who investigated the giant panda (*Ailuropoda melanoleuca*) and the red panda (*Ailurus fulgens*) in forest habitats in western Sichuan. In total, 80 plots (40 for each species) were sampled between December 2005 and March 2006.

The Mann-Whitney U-test was used to compare differences in use of habitat variables by ungulate species. We also performed a stepwise discriminant function analysis to identify variables that differed significantly between species. All values are given as the mean± standard deviation (SD), and statistical tests were two-tailed.

The Mann-Whitney U-test revealed that out of the 14 habitat variables, 10 were significantly different between species (Table 2). However, only 7 of the 10 habitat variables (altitude, slope position, slope degree, distance to road, distance to shrub, tree canopy, and shrub density) were included in the discriminant function analysis as significant predictors of the habitats used by the two species (Table 3). This analysis correctly classified 97.5% (78 of 80 samples) of the habitat samples according to species, 97.5% for the serows and 97.5% for the gorals.

Our results suggested that the two species exhibited different selection for habitat variables. Serow preferred higher altitudes, steeper slopes, areas with lower canopy, and higher shrub density, and did not move as far from shrubs as goral.

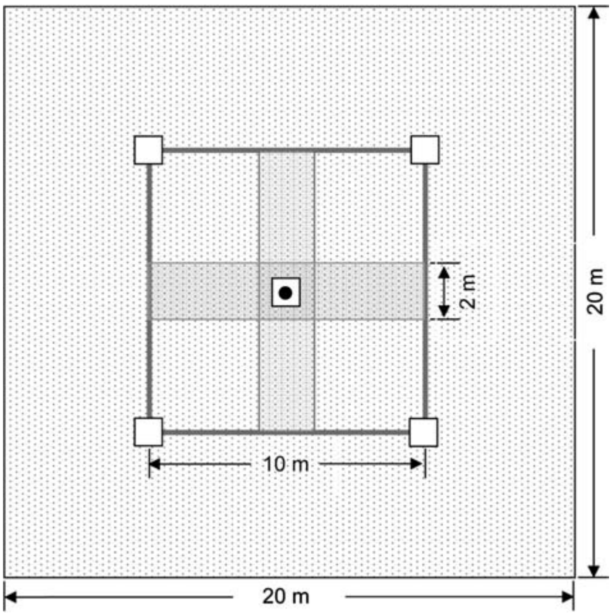

Figure 1 Plot arrangement for habitat sampling at sites used by Chinese serow and Chinese goral in winter, in western Sichuan, China. Black point in the center is the location of the feces and/or tracks.

Previous studies have indicated that habitat separation is the most common form of niche partitioning in sympatric species of mammals (Brown and Lieberman 1973, Dueser and Shugart 1978, Van Horne 1982, Wang 1995, Wei et al. 2000, Zhang et al. 2004). Schoener (1974) considered habitat separation to be responsible for multiple species coexistence. Seven of the 14 variables evaluated in this study differed significantly between the two plots of the ungulates, indicating clear habitat separation between species. In addition, our data also indicated that a significant difference in habitat variables between the two species may allow their coexistence, similar to the pattern previously studied between the giant and red panda (Wei et al. 2000, Zhang et al. 2006).

Our results suggest that Chinese serow preferred stands with steep slopes, high slope position, adjacent to shrubs, and with high shrub density; whereas Chinese goral selected stands with gentle slopes, low slope position, and lower shrub density. This pattern is similar to previously reported habitat use patterns of Chinese serow and Chinese goral (Wu and Hu 2001, Wu et al. 2002). The observed habitat use differences between the two species may be due to their foraging habits. Some researchers have reported that in winter Chinese serow fed mainly on leaves and twigs of deciduous broadleaved trees and shrubs (Song et al. 2005), whereas Chinese goral fed mainly on grasses (Wu et al. 2005). Recent studies of gray goral (*Naemorhedus goral*) showed that this species fed almost entirely on grasses (Mishra and Johnsingh 1996, Fakhar-i-Abbas et al. 2008).

In our study, we found that habitats used by Chinese serow were at higher elevations with lower canopy cover than that of the gorals, this is consistent with previous results (Wu and Hu 2001, Wu et al. 2002). Possibly, Chinese goral, through food-based and less heat-loss migration to low altitude areas, might survive in deprived and cold winters (Wu and Hu 2001, Wu et al. 2002). Simultaneously, the different distributions of higher elevation deciduous broadleaf trees and lower elevation subtropical evergreen broadleaf forest affect canopy cover which influences low canopy cover preferred by the serow.

Chinese serow also used sites closer to roads than Chinese goral. Perhaps this difference is because there were less human activities at high elevations and thus the serow could use areas near roads. Yet, the gorals

Table 1 Description of 14 habitat variables measured at locations used by Chinese serow and the Chinese goral in winter, in western Sichuan, China.

Variables	Description
Altitude	Altitude on each 20 m×20 m plot (with a GPS)
Slope aspect	Aspect of a 20 m×20 m plot (with a compass), defined into four categories: east (45–135°), south (135–225°), west (225–315°), and north (315–45°)
Slope position	Three categories: upper middle and lower slopes, divided the mountain by 1/3
Slope degree	From 0° to 90°, using every 10° interval as a category (with a compass)
Distance to road	Average distance to the nearest road from the center in each 20 m×20 m plot (from eyeballing), three categories: <500 m, 500–1000 m, >1000 m
Distance to rock	Average distance to the nearest rock from the center in each 10 m×10 m plot (with a measuring reel)
Distance to water	Average distance of a 20 m×20 m plot to the nearest stream (by eyes). Three categories: <500 m, 500–1000 m, >1000 m
Distance to tree	Average distance to the nearest tree from the center in each 10 m×10 m plot (with a measuring reel)
Distance to shrub	Average distance to the nearest shrub from the center in each 10 m×10 m plot (with a measuring reel)
Vegetation type	Six categories: evergreen broadleaf forest, mixed evergreen and deciduous broadleaf forest, mixed coniferous and deciduous broadleaf forest, coniferous forest, shrub, naked land
Tree size	Average diameter at breast height of the nearest trees from the center in each 10 m×10 m plot (with a measuring reel)
Tree cover	Canopy of overstory in each 20×20 m plot (by estimation), divided into five categories: <20%, 20–40%, 40–60%, 60–80%, >80%
Shrub density	Average number of shrubs in two 2 m×10 m rectangular transects
Herb cover	Average overcast of herbage in five 1 m×1 m plots of each 20 m×20 m plot (from eyeballing), divided into five categories: <20%, 20–40%, 40–60%, 60–80%, >80%

Table 2 A comparison of habitat variables (mean±SD) between the Chinese serow and the Chinese goral, in winter, in western Sichuan, China.

Habitat variable	Serow (n=40)	Goral (n=40)	Mann-Whitney U-test	
			Z	p
Altitude	1756±410	1337±180	4.65	0.001
Slope aspect	1.58±0.81	1.88±0.85	1.69	0.091
Slope position	1.28±0.45	1.00±0.00	3.55	0.001
Slope degree	3.85±1.61	2.08±0.80	5.19	0.001
Distance to road	1.05±0.22	1.33±0.47	3.13	0.002
Distance to rock	1.03±1.58	1.52±0.78	3.73	0.001
Distance to water	1.00±0.00	1.18±0.38	2.75	0.006
Distance to tree	1.20±0.46	1.38±0.59	1.54	0.124
Distance to shrub	1.08±0.27	1.65±0.89	3.69	0.001
Vegetation type	2.30±0.65	1.75±0.44	4.02	0.001
Tree size	23.45±15.88	16.43±4.97	0.52	0.605
Tree cover	1.18±0.38	1.65±0.74	3.25	0.001
Shrub density	35.20±11.59	20.15±6.20	5.67	0.001
Herb cover	1.15±0.36	1.10±0.30	0.67	0.502

Table 3 Summary of stepwise discriminant function analysis entered in the canonical discriminant functions.

	Discriminant function 1
Eigenvalue	3.383
% Eigenvalue associated with the function	100.0
χ^2-statistic	110.089
Significance (degrees of freedom)	p<0.001
Standardized discriminant function coefficients	
Altitude*	0.674
Slope position*	0.405
Slope degree*	0.387
Distance to road*	-0.357
Distance to shrub*	-0.340
Tree cover*	-0.580
Shrub density*	0.507

*Variable significantly contributing to discriminating power.

distributed in low elevations might stand on sites far from roads to avoid heavy disturbance from humans.

Habitat destruction due to clearing of primary broadleaf forest was the primary threat to the two species until Tangjiahe was designated as a Local Nature Reserve in 1978. Currently, disturbance from greater human activities is the main threat, which results from tourism development of Tangjiahe. Based on our findings, mapping and assessing the habitat suitability, together with a long-term ecological investigation on Chinese serow and Chinese goral is important for the conservation and management of these two species.

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