

Summer habitat use and coexistence of Chinese goral (*Naemorhedus griseus*) and Siberian roe deer (*Capreolus pygargus*) in Taihang mountain, China

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Abstract. Wild animals can adapt to their environments under natural selection pressure. Sympatric species with similar niches compete and achieve coexistence through habitat separation. Using the line transect method from July to September 2019, we examined summer habitat use and niche overlap between Chinese goral (*Naemorhedus griseus*) and Siberian roe deer (*Capreolus pygargus*) in the Taihang mountains surrounding Beijing, China. We found that Chinese goral preferred habitats with higher elevation, tree density, vegetation, cover, and a number of stumps. In contrast, tree diameter at breast height, number of fallen wood, and dry grass cover in habitats of Chinese goral were significantly lower than those of Siberian roe deer. It used shrub habitats with moderate to poor shelter from the winds, while Siberian roe deer used both tree and shrub habitats with good hiding cover and good shelter from the winds. Siberian roe deer were more likely to occur in habitats far from human communities. The two species showed marked niche overlap (Pianka's index = 0.869). To reduce competition and coexist in the same region, both species were separated mainly in spatial and trophic niches. Therefore, maintaining valuable shrub habitats in higher elevations and tree and shrub habitats far from human settlements will facilitate the coexistence of the two ungulates.

Keywords: Chinese goral (*Naemorhedus griseus*), Siberian roe deer (*Capreolus pygargus*), habitat use, niche overlap, coexistence.

Introduction

Habitat is the essential condition for wildlife existence and directly affects their distribution, populations, and reproduction success (Lin & Batzli 2001, Bailly et al. 2016). Many factors may influence habitat use patterns, and previous descriptive works have focused on mechanisms of habitat use under the interaction of sympatric species (Benítez-López et al. 2014, Sushma & Singh 2004, Estevo et al. 2017). Sympatric species cannot coexist in identical niches due to interspecific competition limiting their habitat resources (Hardin 1960). Hence, diverse habitat selection strategies are developed among sympatric species to form niche separation in spatial, trophic, temporal, or other dimensions that favor their coexistence (Lisicic et al. 2012, Henley et al. 2007, Biedma et al. 2020): food, activity range and activity time are the main expressions of variant ecological factors in those different dimensions (Granrothwilding & Phillips 2019, Greve et al. 2019, Charter et al. 2018).

Chinese goral (*Naemorhedus griseus*), listed as a Vulnerable (VU) species in the IUCN Red List, Red List of China's Vertebrates, and class II Chinese protected animal, is distributed in China, India, Thailand, and Vietnam (Khonmee et al. 2014). This small ungulate is a diurnal animal, active in the early morning and late evening (Liu & Zhang 2018). They adapt to different habitat types and change habitat preference by season; for example, they prefer higher elevations in subtropics in summer but move to lower elevations during winter (Chen et al. 2009, 2012). Siberian roe deer (*Capreolus pygargus*) is a common Asian herbivore (Lovari et al. 2016) with a similar size to *N. griseus*, listed as Least Concern (LC) species in the IUCN Red List and Red List of China's Vertebrates. They are mostly active during sunrise and sunset (Cederlund 1989). Broad-leaved forests and farmlands are important habitat types for *C.*

pygargus (Wu et al. 2016). They are also described as using sparse forest cover and denser shrub cover, living at lower altitudes, and avoiding high tree stem density and thick snow (Jiang et al. 2008, 2009). According to the seasons or local climate conditions, roe deer demonstrated opposite response to the human activities, for instance, in cold areas like Norway, European roe deer (*Capreolus capreolus*) could be more tolerant to human-dominated landscapes due to available food in forest-field edges (Torres et al. 2011a). In contrast, European roe deer living in warmer Portugal could forage adequately in areas far from human settlements (Jiang et al. 2008, Torres et al. 2011b; Bonnot et al. 2013).

Many works focus on the mechanisms of coexistence among sympatric ungulates. Chen et al. (2009) identified half of their research habitat variables, including elevation, slope position, slope gradient, etc., as being significantly different between habitats used by Chinese serow (*Capricornis milneedwardsi*) and *N. griseus* that formed niche separation and coexistence. Wild herbivores may change their diet composition in pastoral areas by choosing less preferred plants by free-ranging livestock to reduce food competition (La Morgia & Bassano 2009, Wam & Herfindal 2018). Namgail et al. (2004) found that Tibetan argali (*Ovis ammon hodgsoni*) and blue sheep (*Pseudois nayaur*) living in the same region differed in plant use and the distance of their habitats from cliffs. Different diet composition and distribution patterns of sympatric four-horned antelope (*Tetracerus quadricornis*) and barking deer (*Muntiacus vaginalis*) in Nepal and India were also found (Pokharel et al. 2015). Some views believed that resource partitioning was sometimes not primarily caused by competition but due to physiological conditions like body size, energy expenditures, or nutritional requirements that shaped resource partition (Jenkins & Wright 1988). However, when resources become limiting, coexisting species would be more likely to confront high overlap generally, increasing competition (Forsyth, 2000,

Gordon & Illius 1989).

This paper describes the habitat use and coexistence of *N. griseus* and *C. pygargus* in northeast Taihang mountain, China. We compared the summer habitat use of both species and analyzed their niche differentiation and overlap. Based on niche theory, we hypothesize that the two sympatric species formed partition on habitat use, and hence we tested it based on the diet, landform, and spatial distribution. We believe that our research contribution is not limited to the population protection and habitat management of these two species but also improves understanding of urbanization's effect on wild ungulates and maintains biological diversity in areas close to megacities.

Material and Methods

Study area

Northeastern Taihang Mountain (N 34°34'–42°10', E 110°14' – 119°50'), located in north China, surrounding Beijing (Figure 1), is characterized by a typical continental monsoon climate with an average annual temperature of 6–10 °C and average annual precipitation of 700 mm. The region covers a wide range of topography and landform, with the highest peak at 2116 m a.s.l. and hills, middle and lower mountains existing below 1000 m.

The study area is dominated by broadleaved deciduous forests, mostly *Quercus* spp., mixed with warm coniferous forest. Deciduous broad-leaved forests, including *Q. dentata*, *Q. wutaishansea*, *Q. mongolica*, *Q. variabilis*, and *Q. dentata* are distributed below 700 m, mixed coniferous broad-leaved forests, including *Betula platyphylla*, *Abies nephrolepis*, are distributed between 700 m and 1500 m, and coniferous forests, including *Pinus armandii* Franch., *Larix gmelinii* var.

principis-rupprechtii are distributed between 1500 m and 2000 m a.s.l. Other ungulates, such as wild boar (*Sus scrofa*), and large predators, including leopard (*Panthera pardus*) and wolf (*Canis lupus*) also inhabit this area (Ning 2012, Li et al. 2013, Wu, 2010). Unfortunately, their population densities and trends are unknown, except for a few studies that reported *N. griseus* and other larger mammals in one district of Beijing were almost scarce (Ji et al. 2020).

Investigation methods

We conducted a transect line survey between 10th July and 15th September 2019. The transect lines were planned to cover nature reserves and forest parks with different land use, vegetation types, and human disturbances proportionally to the habitat area. Fifty-eight percent of these transects were placed in forests, 30% in meadows, 12% in human-dominated landscapes like farmlands, as representative of the entire field area, in which forests covered 50%, meadows covered 40%, and human-dominated landscapes covered 10% (Lou et al., 2019). Totally, 153 transect lines were set, each 3 km long and 10 m wide. Three to five investigators walked in parallel along the transect lines at a speed of 0.5–1 km/h from early morning to afternoon.

The utilized habitat was determined only when the pellets were observed. Except for direct observation, it is difficult to distinguish presence signs such as footprint, feeding sites, resting sites, or hairs between two ungulates; however, there is a significant difference in pellets of *N. griseus* and *C. pygargus*. Pellets of *N. griseus* are significantly smaller and thinner, while pellets of *C. pygargus* are bigger and round. In addition, there are no other ungulates with similar pellet shape and size in the area, so we can confirm that the spotted pellets belong to *N. griseus* or *C. pygargus*. We set 20 × 20 m plots and recorded habitat variables (Table 1) wherever we directly observed *N. griseus* or *C. pygargus* or observed their pellets. Habitat variables of other ungulates were defined based on the reports (Wang et al. 2018) in Table 1.

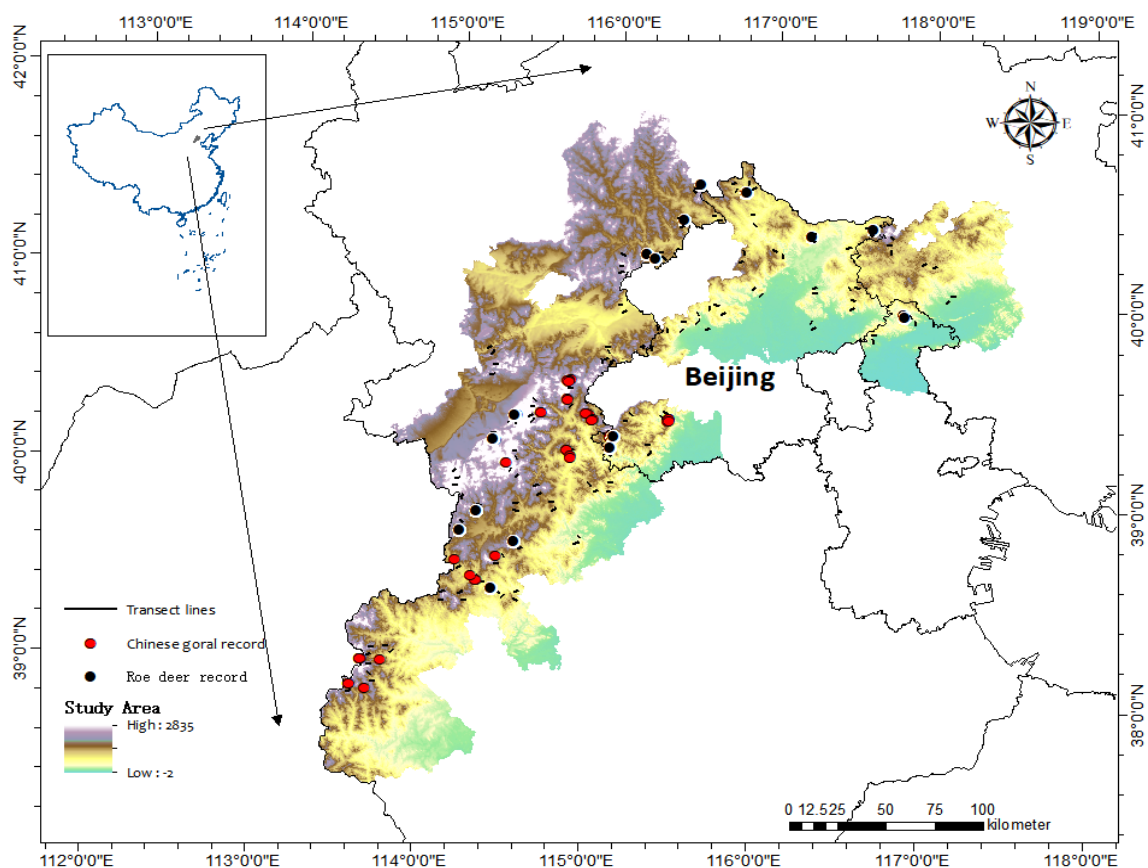


Figure 1. Study area and location of sampling sites in northeastern Taihang Mountain.

Table 1. Variables used to characterize the habitat of Chinese goral (*Naemorhedus griseus*) and Siberian roe deer (*Capreolus pygargus*).

Ecological variables	Variable definition and description
Elevation (m)	Elevation at the center point of the plot. Four groups: < 400 m, 400–799 m, 800–1199m, ≥ 1200 m.
Tree canopy (%)	Average canopy cover of trees in the sample plot. Four groups: 0–24.9%, 25–49.9%, 50–74.9%, 75–100%.
Tree diameter at breast height (DBH, cm)	Average DBH of trees closest to the center point (DBH > 10 cm, up to 1.3 m high) in 20 m × 20 m plots. Four groups: 0–9cm, 10–19 cm, 20–29 cm, ≥ 30 cm.
Tree height(m)	Average height of trees closest to the center point (DBH > 10 cm) in 20 m × 20 m plots. Four groups: 0–9 m, 10–14 m, 15–19 m, ≥ 20 m.
Tree density(/plot)	Number of trees (DBH > 10 cm, tree height > 2 m) in 20 m × 20 m plots. Four groups: 0–19, 20–39, 40–59, ≥ 60.
Shrub height (m)	Average shrub height in 20 m × 20 m plots. Four groups: 0–0.9 m, 1–1.9 m, 2–2.9 m, ≥ 3 m.
Shrub canopy (%)	Average canopy cover of shrub in the sample plot. Four groups: 0–24.9%, 25–49.9%, 50–74.9%, 75–100%.
Vegetation cover (%)	Average ground-plant coverage in 20 m × 20 m plots. Four groups: 0–24.9%, 25–49.9%, 50–74.9%, 75–100%.
Number of stumps	Number of stumps in 20 m × 20 m plots. Four groups: 0–2, 3–5, 6–8, ≥ 9.
Number of fallen wood	Number of fallen wood in 20 m × 20 m plots. Four groups: 0–4, 5–9, 10–19, ≥ 20.
Dry grass cover (%)	Average dry grass coverage in 20 m × 20 m plots. Four groups: 0–24.9%, 25–49.9%, 50–74.9%, 75–100%.
Slope aspect	Four categories: east slope (45–135°), south slope (136–225°), west slope (226–315°), and north slope (316–45°).
Slope gradient (°)	Three categories: gentle slope (≤ 30°), moderate slope (30–60°), and steep slope (≥ 60°).
Slope position	Three categories: lower slope (including valley), middle slope (including mountainside), and upper slope (including ridge).
Vegetation type	Main vegetation types: forest (including coniferous and broadleaf mixed forests, coniferous, deciduous broad-leaved forests), shrub, meadow, and farmland.
Hiding cover	At the height of 1m, the visual distance of the sample ground in four directions is classified into three categories: good (≤ 10 m), moderate (10–20 m), and poor (≥ 20 m).
Shelter from the winds	Wind prevention in the plots classified into three categories: good (calm), moderate (breeze), and poor (strong breeze).
Soil moisture degree	Soil moisture degree is classified into four categories: wet (possible to squeeze water out), relatively wet (can form a lump), relatively dry (can form a lump but will lose after losing grip), and dry (cannot form a lump)
Distance to water resources	The distance from the plot to the water source (spring, river, and other water bodies without snow) with three categories: close (≤ 500 m), moderate (501–1000 m), and far (≥ 1000 m)
Disturbance intensity	Disturbance intensity of human impact three categories: strong (vegetation destroyed, or frequent human activities), moderate (vegetation disturbed, or occasional human activities), and weak (almost no disturbance).
Distance to anthropogenic disturbance	The distance from the sample site to the nearest anthropogenic disturbance (like traveling, transporting, farming, or grazing), three categories: close (≤ 500 m), moderate (501–1000 m), and far (≥ 1000 m).
Distance to communities	The distance from the sample site to the nearest community, three categories: close (≤ 500 m), moderate (501–1000 m), and far (≥ 1000 m).

Data Analysis

Mann-Whitney U test was used to compare differences in 11 continuous variables between used plots of *N. griseus* and *C. pygargus*, including elevation, tree canopy, tree DBH, tree height, tree density, shrub height, shrub canopy, vegetation coverage, number of stumps, number of fallen wood and dry grass cover. To present the differences of each continuous variable visually in the figure, deviation standardization was used to eliminate the dimensional influence and allow the comparison of all variables simultaneously. The standardization formula is:

$$x = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}$$

where x_i : the value of variable i , x_{\max} : the maximum value in x_i ; x_{\min} : minimum value in x_i .

Chi-square test was used to compare the differences in 11 discrete variables between used plots of *N. griseus* and *C. pygargus*,

including slope aspect, slope gradient, slope position, vegetation type, hiding cover, shelter from the winds, soil moisture degree, distance to water resources, distance to communities, distance to anthropogenic disturbance and disturbance intensity.

Niche overlap was calculated using Pianka's index (Pianka 1974, La Morgia & Bassano 2009):

$$C = \frac{\sum P_{1i} P_{2i}}{\sqrt{\sum P_{1i}^2 \sum P_{2i}^2}}$$

where P_{1i} and P_{2i} are proportions of the variable i of two species, respectively. It quantifies niche overlap ranging from 0 (indicating no overlap) to 1 (complete overlap) for each species. $C > 0.6$ was considered a significant niche overlap for the resource(s) examined (Mathur 1977, Wathne et al. 2000). Pearson's correlation matrix was used to identify collinearities between variables ($r_s < 0.7$ will be acceptable) that avoids the variables being collinear with each other (Pokharel et al. 2015).

Results

Continuous variables of *N. griseus* (n = 56) and *C. pygargus* (n = 41) resulted, as shown in Table 2. The elevation (863.28 ± 61.55 m), tree density (16.38 ± 2.21 /plot), vegetation cover ($59.91\% \pm 3.77\%$) and number of stumps (0.54 ± 0.3 /plot) in habitats of *N. griseus* were significantly higher than those of *C. pygargus* ($P < 0.05$), which as elevation (663.02 ± 46.39 m), tree density (15.15 ± 3.71 /plot), vegetation cover ($45.24\% \pm$

4.83%) and number of stumps (0.5 ± 0.14 /plot). The tree DBH (16.87 ± 1.91 cm), number of fallen wood (0.39 ± 0.19), and dry grass cover ($3.57\% \pm 1.49\%$) in the habitats used by *N. griseus* were highly significantly lower than the tree DBH (29.24 ± 3.27 cm), number of fallen woods (3.73 ± 0.89) and dry grass cover ($36.75\% \pm 5.74\%$) in the habitats used by *C. pygargus* ($P < 0.01$). The two species had different choice patterns for other continuous variables, which were not significant ($P > 0.05$).

Table 2. Statistics of continuous variables in habitats of Chinese goral (*Naemorhedus griseus*) (n = 56) and Siberian roe deer (*Capreolus pygargus*) (n = 41) (* difference significant at $P < 0.05$); ** - $P < 0.01$)

Ecological variables	Item	Frequency		Mean \pm SE		Z
		<i>N. griseus</i>	<i>C. pygargus</i>	<i>N. griseus</i>	<i>C. pygargus</i>	
Elevation (m)	< 400	11	4			
	400-799	14	24			
	80-1199	18	9	863.28 ± 61.55	663.02 ± 46.39	-2.40*
	> 1200	13	3			
Tree canopy (%)	0-24.9%	20	18			
	25-49.9%	16	4	43.30 ± 4.01	40.73 ± 5.34	-0.41
	50-74.9%	8	10			
	75-100%	12	9			
Tree DBH (cm)	0-9	21	4			
	10-19	17	6	16.87 ± 1.91	29.24 ± 3.27	-2.75**
	20-29	4	3			
	≥ 30	6	17			
Tree height (m)	0-9	35	19			
	10-14	9	9	8.85 ± 0.91	8.27 ± 0.85	-0.22
	15-19	1	2			
	≥ 20	3	0			
Tree density (/plot)	0-19	35	32			
	20-39	10	3	16.38 ± 2.21	15.15 ± 3.71	-1.37
	40-59	5	3			
	≥ 60	0	2			
Shrub height (m)	0-0.9	15	8			
	1-1.9	36	31	1.38 ± 0.07	1.49 ± 0.07	-1.00
	2-2.9	2	2			
	≥ 3	0	0			
Shrub canopy (%)	0-24.9%	10	8			
	25-49.9%	22	16	52.05 ± 3.46	49.51 ± 3.62	-0.64
	50-74.9%	12	8			
	75-100%	12	9			
Vegetation cover (%)	0-24.9%	13	16			
	25-49.9%	11	8	59.91 ± 3.77	45.24 ± 4.83	-2.48*
	50-74.9%	10	8			
	75-100%	22	9			
Number of stumps	0-2	53	40			
	3-5	2	0	0.54 ± 0.3	0.5 ± 0.14	-2.56*
	6-8	0	0			
	≥ 9	1	0			
No of fallen wood	0-4	54	27			
	5-9	2	10	0.39 ± 0.19	3.73 ± 0.89	-4.00**
	10-19	0	3			
	≥ 20	0	0			
Dry grass cover (%)	0-24.9%	54	18			
	25-49.9%	1	9	3.57 ± 1.49	36.75 ± 5.74	-5.56**
	50-74.9%	1	2			
	75-100%	0	11			

Habitat differences between *C. pygargus* and *N. griseus* are shown in Figure 2. The elevation, tree density, and vegetation cover of the habitats of *N. griseus* were higher than those of *C. pygargus* without overlap between the two species.

The tree DBH, tree height, number of stumps, number of fallen wood, and dry grass coverage of *C. pygargus* were higher than those of *N. griseus*. The overlap of the tree canopy, shrub coverage, and shrub height between the two species was higher.

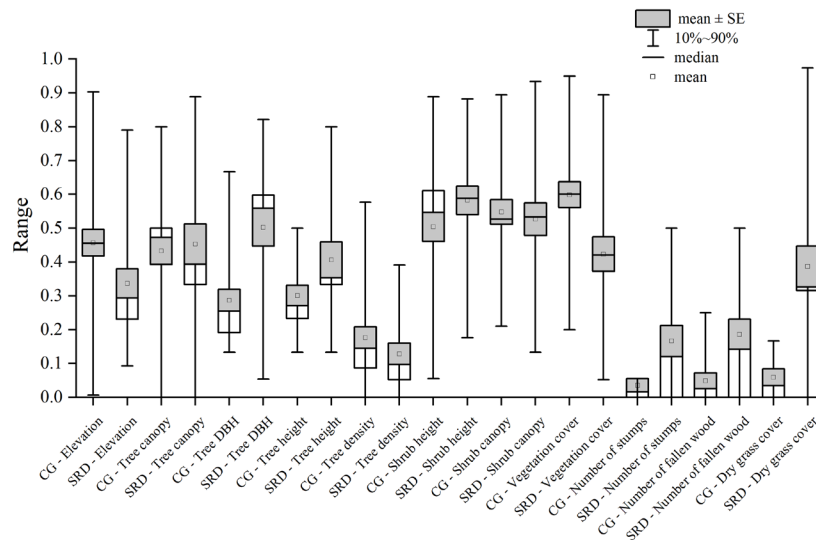


Figure 2. Habitat overlap of sympatric Chinese goral (*Naemorhedus griseus*) and Siberian roe deer (*Capreolus pygargus*) in Taihang Mountain.

There were significant differences in vegetation type, hiding cover, shelter from the winds, and distance to communities between the two species ($P < 0.05$; Table 3). *N. griseus* often occurred in shrubs (62.5%) and occasionally in used farmland (8.9%), while *C. pygargus* occurred in both tree (51.2%) and shrub (48.8%) habitats and didn't occur in farmland (0%). Moreover, *N. griseus* used habitats with poor hiding cover (41.8%) and poor shelter from the winds (39.3%), while *C. pygargus* used habitats with good hiding cover (61.0%) and good shelter from the wind (41.5%). Both species used habitats close to water resources with weak disturbance intensity, and *C. pygargus* used the area far from the community (> 500 m, 87.5%) than *N. griseus*.

All the variables were analyzed for niche overlap (results of correlation analysis shown in Table A1 of Appendix). Pianka's index of niche overlap among *C. pygargus* and *N. griseus* was 0.869, which was far higher than the threshold value of 0.6, indicating significant overlap. Except for tree DBH, which was 0.573, the Pianka's indexes of all variables were over 0.6 (Figure 3), indicating significant overlap. The species had the highest overlap in shrub coverage and number of stumps (0.999), followed by shrub height (0.990) and distance to anthropogenic disturbance (0.984). The degree of overlap on tree DBH was the lowest (0.573). *N. griseus* used tree DBH below 20 cm, while *C. pygargus* used tree DBH above 40 cm. Lower overlap values of hiding cover and elevation, 0.781 and 0.782 respectively, were greater than 0.6, indicating significant overlap. *N. griseus* was found in habitats with elevations higher than 800 m and with poorer hiding cover. In comparison, roe deer mainly occurred in habitats with elevations of 400–800 m and with better hiding cover.

Discussion

Food primarily affects habitat selection (Beest et al. 2010). Tang et al. (2018) reported that *N. griseus* mostly foraged the tender leaves of shrubs and occasionally foraged on Gramineae grasses. In summer, the dietary preference of *C. pygargus* was mostly herbaceous plants like forbs-climbers and graminoids, with a smaller portion of woody forage (Adhikari et al. 2016, Argunov & Stepanova 2011). It was reported that the deciduous and evergreen woody plants, including variant arbors and shrubs, were the main food of European roe deer in many seasons (Degmecic et al. 2011, Torres et al. 2011a, Sanguiliano et al. 2016). In this study, shrubs were the dominant food in *N. griseus*'s diet in summer. They often used cliffside shrubs for foraging and avoiding danger from their predator. Our study found that both shrubs and trees contributed as the primary food demand source for *C. pygargus*. They mostly foraged fresh green parts of herbaceous plants, trees, shrubs, and fruit occasionally. Oak acorns or other fruit dropping from mature trees were also nutritious food sources for roe deer species (Degmecic et al. 2011). During summer, feeding high nutritious food helps young ungulates gain muscle bulk quickly and promote body development (Argunov & Stepanova 2011). Furthermore, *N. griseus* occurred mainly in shrub habitats, while *C. pygargus* occurred more in tree habitats, through which the separation of the spatial and trophic niches was achieved. However, the limited information on population density and trends of the two species hindered us from further evaluating the intensity of competition between *C. pygargus* and *N. griseus*, which could help us judge whether the niche separation resulted

Table 3. Differences of discrete variables in microhabitats selected by Chinese goral (*Naemorhedus griseus*) (n = 56) and Siberian roe deer (*Capreolus pygargus*) (n = 41) (* difference significant at $P < 0.1$, * – at $P < 0.05$; ** – $P < 0.01$)

Ecological variables	Item	Frequency		Percentage		Chi-square test
		<i>N. griseus</i>	<i>C. pygargus</i>	<i>N. griseus</i>	<i>C. pygargus</i>	
Slope aspect	East	12	6	21.4%	15.0%	$\chi^2 = 7.074^+$
	South	14	7	25.0%	17.5%	
	West	6	13	10.7%	32.5%	
	North	24	14	42.9%	35.0%	
Slope gradient	Gentle	39	34	69.6%	82.9%	$\chi^2 = 2.585$
	Moderate	12	4	21.4%	9.8%	
	Steep	5	3	8.9%	7.3%	
Slope position	Upper	18	18	32.7%	46.2%	$\chi^2 = 5.434^+$
	Middle	13	13	23.6%	33.3%	
	Lower	24	8	43.6%	20.5%	
Vegetation type	Meadow	0	0	0	0	$\chi^2 = 7.629^*$
	Farmland	5	0	8.9%	0.0%	
	Shrub	35	20	62.5%	48.8%	
	Tree	16	21	28.6%	51.2%	
Hiding cover	Good	20	25	36.4%	61.0%	$\chi^2 = 14.241^{**}$
	Moderate	12	13	21.8%	31.7%	
	Poor	23	3	41.8%	7.3%	
Shelter from the winds	Very good	10	2	17.9%	4.9%	$\chi^2 = 12.850^{**}$
	Good	7	17	12.5%	41.5%	
	Moderate	17	12	30.4%	29.3%	
	Bad	22	10	39.3%	24.4%	
Soil moisture degree	Wet	17	7	30.4%	17.5%	$\chi^2 = 3.775$
	Relatively wet	20	21	35.7%	52.5%	
	Relatively dry	10	8	17.9%	20.0%	
	dry	9	4	16.1%	10.0%	
Distance to water resources	Near	29	29	51.8%	72.5%	$\chi^2 = 4.696^+$
	Moderate	16	5	28.6%	12.5%	
	Far	11	6	19.6%	15.0%	
Disturbance intensity	Weak	25	22	48.1%	71.0%	$\chi^2 = 5.857^+$
	Moderate	17	8	32.7%	25.8%	
	Strong	10	1	19.2%	3.2%	
Distance to anthropogenic disturbance	Near	30	20	57.7%	64.5%	$\chi^2 = 1.299$
	Moderate	10	7	19.2%	22.6%	
	Far	12	4	23.1%	12.9%	
Distance to communities	Near	21	5	37.5%	12.5%	$\chi^2 = 7.915^*$
	Moderate	17	20	30.4%	50.0%	
	Far	18	15	32.1%	37.5%	

from limited temporal resources (Putman 1996).

Wild animals have a preference for temperature, and the influence of environmental temperature on habitat use is reflected in the choice of elevation and slope direction (Zhang et al. 2013, Lu et al. 2016). The study area is located in the north of China and has a typical continental climate, causing higher temperatures on the south slope due to direct sunlight in summer. Hence, both *N. griseus* and *C. pygargus* used less south slope habitat, occurred at the shade slope habitat on the north slope, which showed an adaptive strategy to avoid daytime high temperatures in summer. Besides, the higher-altitude utilization of *N. griseus* represented in our study may also be one of the strategies to avoid high temperatures. In this case, lower altitude habitat could help *C. pygargus* by reducing competition and

achieving spatial niche separation. Similar results have been reported in other studies. For example, Ferretti et al. (2011) reported that in the Mediterranean region, *C. capreolus* was more negatively influenced by sympatric fallow deer (*Dama dama*), and they preferred to use habitats where fallow deer were rare.

Human disturbance can greatly influence habitat selection and utilization of naturally alert wild ungulates (Gaynor et al. 2018). As prey species, ungulates would modify their use of space according to the extent of predation risk and avoid the habitats close to human disturbance (Jiang et al. 2008). However, our results rejected this expectation as both *N. griseus* and *C. pygargus* occurred more at places close to the habitat with human disturbance (< 500 m), mainly including roads, traffic, grazing, and

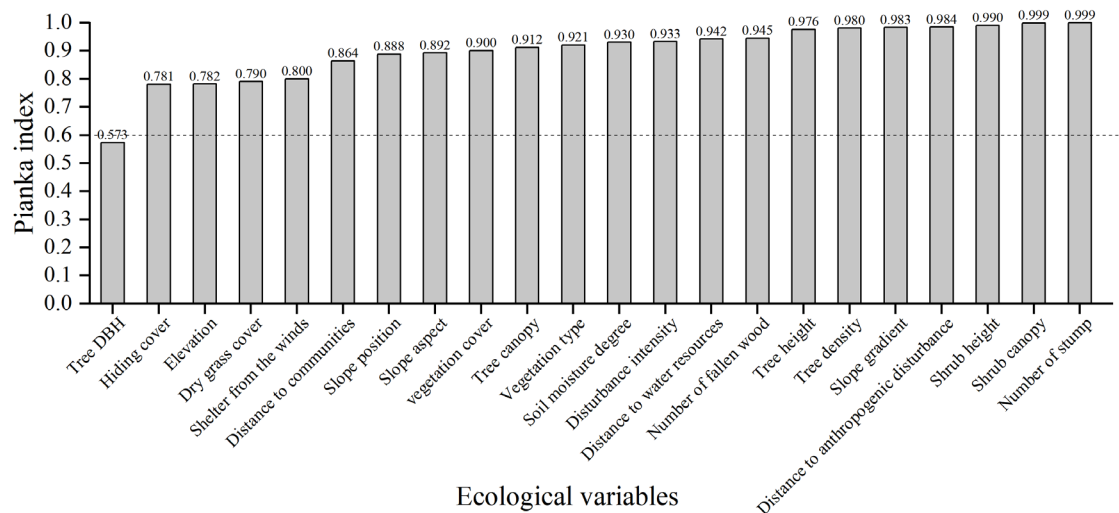


Figure 3. Niche overlap of sympatric Chinese goral (*Naemorhedus griseus*) and Siberian roe deer (*Capreolus pygargus*), calculated as Pianka's index for environmental variables.

agricultural activities.

The most likely explanation was related to local water sources distribution and food requirements. Due to the arid climate, human villages and farming activities in our study area were mainly distributed near the water source, and for wild ungulates, water supply was rigid demand (Wang et al. 2018). Water resource availability is the key factor in restricting wildlife habitat use, determined by water distribution and the distance to them. The rigid demand for water drives *N. griseus* and *C. pygargus* to use such areas with high human disturbance intensity. In addition, the level of plant diversity is relatively high, and food resources tend to be better at the junction of agricultural areas with more human activity and natural ecosystems such as forests (Caruso et al. 2011). The vegetation in the study area is mostly natural or secondary artificial with shrubs and trees, and the forest-farmland ecotone has more marginal habitats that provide rich food and shelter (Torres et al. 2011a, Zhang, 2015) leading to similar selection and utilization of both *N. griseus* and *C. pygargus*. The proximity to human-disturbed habitats is also related to the socio-economic development of the study area. Since 2000, the scale of infrastructure and road construction in the study area has significantly expanded, while the size of cultivated land, grassland, and woodland has shrunk, resulting in habitat fragmentation (Zhu et al. 2003, Wu et al. 2015). It is difficult to find an extensive and intact habitat undisturbed by humans, leaving no choice for wildlife to reside close to the human interference. Recent laws and regulations are encouraging because they ban illegal hunting and wild animal consumption, and raise awareness among local people to protect and develop a positive attitude towards wild animals.

There was a significant variance in the distance between the communities between the two species. *C. pygargus* had less usage of the habitat closer to the community than *N. griseus*, thus exhibiting some spatial separation. The higher space use of areas close to human communities by *N. griseus* might be the need for high-quality food. The regions surrounding communities provide sufficient food resources

for wildlife (Pautasso 2007), and in our study area, with natural secondary shrub and economic forests such as apricot, wild peach, and walnut distributed, as well as abundant water sources, the human residential area became an attractive food source for *N. griseus*. Stumps in habitats of *C. pygargus* were less represented than in habitats of *N. griseus*, which demonstrated that they stayed far away from human communities because the number of stumps could represent a regional logging and economic forest planting intensity. Indices of overlap suggested the potential for interspecific competition occurred between *N. griseus* and *C. pygargus*. It will develop into real competition if shared resources are in short supply. Hence, to reduce potential resource competition, the choice of distance to communities between the two species and the community resulted in the separation of their spatial niche and reduced spatial competition.

In conclusion, in summer, *N. griseus* and *C. pygargus* had different habitat use strategies when facing high niche overlap. *N. griseus* used the shrub habitat in higher elevations and tended to forage around the human activity area, while *C. pygargus* live in lower elevations and far away from human communities in summer. Furthermore, we recommend the need for further habitat surveys in other seasons. Future studies should evaluate the population densities and trends of local species that enable us to investigate the state of species more deeply and give more effective suggestions on wildlife conservation.

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+ Appendix - Table A1.

Appendix

Table A1. Correlations between ecological variables in the range of sympatric Chinese goral (*Naemorhedus griseus*) and Siberian roe deer (*Capreolus pygargus*). Pearson correlation coefficients presented: Correlations, significant at $P < 0.05$, shown in *italics*, those significant at $P < 0.01$ – in **bold**.

Factor	No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Elevation	1	1.00	-0.16	-0.04	0.13	-0.10	-0.14	-0.17	0.33	-0.07	-0.16	-0.06	0.04	0.25	-0.04	-0.12	0.09	0.13	0.19	-0.23	0.36	-0.03	0.29
Tree canopy	2	1.00	0.36	0.50	0.37	0.15	-0.16	-0.32	0.02	0.36	0.12	-0.04	0.07	-0.15	0.50	0.23	0.37	0.37	-0.45	-0.09	0.03	-0.31	-0.06
DBH	3	1.00	0.56	-0.29	0.37	-0.04	-0.20	0.02	0.57	0.65	-0.21	0.06	-0.15	0.42	0.37	0.11	-0.12	-0.46	0.08	-0.18	-0.33		
Tree height	4	1.00	1.00	-0.08	0.32	-0.29	0.01	0.02	0.26	0.23	-0.20	0.22	-0.11	0.45	0.17	0.10	-0.24	-0.29	0.07	-0.17	-0.10		
Tree density	5	1.00	1.00	-0.31	-0.17	-0.08	0.35	-0.14	-0.26	-0.08	-0.03	-0.02	0.28	-0.10	0.08	-0.36	0.24	-0.17	-0.20	0.09			
Shrub height	6	1.00	0.33	-0.03	-0.05	0.30	0.22	0.01	-0.02	0.11	0.15	0.37	0.15	-0.02	-0.33	0.05	-0.06	-0.30					
Shrub canopy	7	1.00	1.00	-0.04	-0.01	-0.06	0.04	0.16	0.03	0.12	-0.12	0.14	-0.09	-0.01	0.08	-0.04	0.13	-0.12					
Vegetation cover	8	1.00	-0.02	-0.47	-0.17	0.12	-0.04	0.20	-0.24	-0.07	-0.15	0.10	-0.06	-0.07	0.05	0.14							
Number of stumps	9	1.00	0.21	0.03	-0.01	0.04	-0.18	0.25	0.03	0.06	0.00	0.10	-0.07	-0.17	-0.09								
Number of fallen wood	10	1.00	0.56	-0.09	-0.08	-0.23	0.45	0.32	0.18	-0.11	-0.26	0.20	-0.29	-0.22									
Dry grass cover	11	1.00	1.00	0.00	-0.08	-0.10	0.29	0.30	-0.02	-0.03	-0.35	0.20	-0.20	-0.32									
Slope aspect	12	1.00	1.00	-0.17	0.18	-0.14	0.03	0.17	-0.11	0.07	0.11	0.10	0.27										
Slope gradient	13	1.00	-0.39	0.19	0.03	0.04	0.13	0.01	0.27	-0.06	0.18												
Slope position	14	1.00	1.00	-0.32	-0.21	-0.13	-0.02	-0.12	-0.44	0.42	-0.33												
Vegetation type	15	1.00	1.00	0.28	0.23	-0.05	0.09	-0.31	-0.07														
Hiding cover	16	1.00	1.00	0.57	-0.18	-0.27	0.33	-0.33	0.04														
Shelter from the winds	17	1.00	-0.34	-0.13	0.30	-0.19	0.24																
Soil moisture degree	18	1.00	0.06	0.04	0.16	-0.03																	
Distance to water	19	1.00	-0.02	-0.08	0.30																		
Distance to communities	20	1.00	-0.30	0.43																			
Disturbance intensity	21	1.00	-0.29																				
Distance to disturbance	22	1.00																					