Spatial Utilization and Microhabitat Selection of the Snow Leopard (*Panthera uncia*) under Different Livestock Grazing Intensities

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ABSTRACT: There is increasing conflict between snow leopards and humans in many protected areas, the main driver of which is the overlap in spatial utilization between snow leopards and livestock. Understanding the spatial utilization and microhabitat selection of snow leopards in areas featuring different levels of livestock grazing is important to better understand and resolve this conflict, but such studies are rare. Here, we conducted line transect and plot surveys in low- and high-grazing-disturbance areas (LGDAs and HGDAs) in Wolong National Reserve, southwestern China. We compared snow leopard spatial utilization and microhabitat characteristics between LGDAs and HGDAs. Results showed that snow leopards had aggregated distribution in both LGDAs and HGDAs, but the distribution of snow leopards in HGDAs was more centralized than in LGDAs. Herb cover and height in LGDAs were greater than in HGDAs. We fit a resource selection function (RSF) that showed that snow leopards preferentially selected higher elevation, smaller basal diameter of shrubs, and lower height of herbs in LGDAs. In contrast, there were no significant microhabitat factors in our snow leopard RSF in HGDAs. Our results indicate that high-intensity grazing tends to reduce the habitat types available to and preferential selectivity of habitat by snow leopards. We recommend that livestock grazing should be controlled to restore the diversity of the alpine ecosystems in Wolong Nature Reserve. Our findings also highlight the need for evaluating the impact of livestock grazing on rare animals in alpine environments (e.g., snow leopard) in other areas facing similar issues.

KEYWORDS: Asia; Animal studies; Ecosystem effects; Local effects

1. Introduction

With the continued development of human society, there are increasing conflicts between humans and wildlife (Rovero et al. 2020; Berger et al. 2013). Some of the most severe examples of this conflict occur between humans and large carnivores (Dickman 2009; Koziarski et al. 2016). A key driver for this conflict is domestic livestock taking up the habitat and food resources of wild ungulates, which in turn affects the survival of large carnivores (Suryawanshi et al. 2017). Research by Sharma et al. (2015) indicated that snow leopards and livestock can coexist under a certain threshold of livestock density. But, when the density is higher than this threshold, the habitat use of snow leopards will decline in the area (Sharma et al. 2015). Additionally, as wild ungulate populations decline, large carnivores begin to prey on livestock (Landa et al. 1999; Morell 2017; Suryawanshi et al. 2013). As livestock are preyed upon by large carnivores, potentially large economic losses are faced by local farmers, who may carry out retaliatory killings of large predators (Johansson et al. 2015; Bagchi and Mishra 2006). The interaction among snow leopard, pastoralists, and their livestock in Asia is a prime example of this system of human and large carnivore conflict.

Although the snow leopard was downlisted from endangered (EN) to vulnerable (VU) on the Red List of Threatened Species by the International Union for Conservation of Nature (IUCN) in 2017 (McCarthy et al. 2017), snow leopard populations have been declining and their suitable habitat has been shrinking (Liu and Han 2015). There are many factors contributing to this trend, including human disturbance and climate change (Jessica et al. 2012; Farrington and Li 2016; Alexander et al. 2016a). Livestock grazing is one of the major human disturbances throughout the snow leopard's range. Understanding the impact of livestock on snow leopard habitat is an important consideration for their conservation. There has been extensive research on the effect of livestock on many wildlife species such as the giant panda (*Ailuropoda melanoleuca*) (Wang et al. 2019; Hull et al. 2014; Zhang et al. 2017; Wei et al. 2018), the red panda (*Ailurus fulgens*) (Wang et al. 2018a), and the tiger (*Panthera tigers*) (Bargali et al. 2018; B. B. Li et al. 2020). Through the above studies, we hypothesize that the increasing livestock pressure will also negatively influence the ecology–spatial utilization and microhabitat selection of snow leopard. To verify this hypothesis, we investigated the effect of livestock grazing on two aspects of snow leopard ecology–spatial utilization and microhabitat selection in this study.

Spatial utilization of wildlife is a function of the distribution of their population, their range of activity within that distribution, response to habitat changes, and other factors

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(Zhang et al. 2019; Bai 2017; Lukarevskiy et al. 2019). Previous research has found that the spatial ranges of livestock and snow leopards often overlap significantly, leading to high risks of snow leopard–livestock conflicts (Shi et al. 2019). Unfortunately, most current studies on the spatial distribution of snow leopards are only predictions of their distribution in a certain region based on data from another (Ghoshal et al. 2019; Thinley et al. 2014; Jackson 2002). Few studies have considered the effects of livestock grazing on distributions of snow leopards in China. Research on the habitat selection of snow leopards has mainly focused on the comparison of single habitat features between the regions where snow leopards appear and do not appear, and multiple habitat variables have not been comprehensively considered (Xu et al. 2006; Qiao et al. 2017; Sandeep et al. 2006). Additionally, previous studies on habitat selection of snow leopards have mainly focused on topographic variables (elevation, slope, etc.), ignoring detailed vegetation variables (shrub height, number of shrubs, herb coverage, etc.) that can be very important in determining wildlife habitat selection (Tang et al. 2017; Bai et al. 2020). Investigating a wider range of habitat factors will result in a better understanding of the impact of livestock on the space use and microhabitat selection of snow leopards, which will inform appropriate adjustments to the management of livestock and alleviate the conflict between human and leopards. To achieve this, we conducted surveys to record snow leopard sign in low-grazing-disturbance areas (LGDAs) and high-grazing-disturbance areas (HGDAs). We also surveyed sample plots to measure diverse habitat information (including topographic and detailed vegetation variables) to understand the difference in snow leopard microhabitat use under different grazing conditions.

2. Study area

We conducted our study in Wolong Nature Reserve (102°52′–103°24′E, 30°45′–31°25′N), which is located in Sichuan Province in southwestern China (Fig. 1). The reserve covers an area of approximately 2000 km^2, with diverse habitat types including forests, meadows, and alpine screes, occurring across elevations ranging from 1190 to 6250 m. The forest types include evergreen broadleaf forest, deciduous and evergreen broadleaved forest, deciduous broadleaved forest, mixed coniferous broadleaved forest, coniferous forest, and alpine shrubland. Common plan species in the reserve include *Abies fabri (Mast.) Craib.*, *Betula albosinensis Burk.*, *Rhododendron L.*, *Fargesia robusta Yi*, *Bashania fangiana (A. Camus) Keng f.*, and others. The annual average temperature is 8.7°C, and the annual average precipitation is 890 mm. The reserve is rich in animal and plant resources, with about 450 vertebrate species and 1898 higher plant species (Cheng et al. 2015). Rare and threatened species that occur in the park include the snow leopard, giant panda, sambar deer (*Rusa Unicolor*), golden snub-nosed monkey (*Rhinopithecus Roxellana*) (Hou et al. 2018; Shi et al. 2017), gong tong (*Davidia involucrata Baillon*), and shui shan (*Metasequoia glyptostroboides* Hu and W. C. Cheng) (Zhang et al. 2005). The reserve is part of the Qionglai Mountain range, which is the southeastern edge of the global distribution of snow leopards (Lu et al. 2019). The snow leopard was first detected in Wolong by infrared camera traps in 2009 (Qiao et al. 2017), and thus research into snow leopards there has only begun relatively recently. Currently there is no accurate estimate of the snow leopard population in Wolong Nature Reserve. Many reserves have only one flagship species, which provides protection to other species through its umbrella function, but studies have shown that the umbrella function of flagship species may not provide sufficient protection for other species (S. Li et al. 2020; Wang et al. 2021). Wolong Nature Reserve mainly focuses on the protection of giant pandas with little focus on the protection of snow leopards, leading to a relative lack of research on snow leopards and their alpine ecosystem. For example, research on livestock grazing effects has been concentrated in low-elevation areas within giant panda habitat (Wang et al. 2019), while there has been no research on the effects of livestock grazing on the ecology and conservation of snow leopards in Wolong Nature Reserve.

Snow leopards are mainly distributed in the Yinchanggou, Weijiagou, and Tizigou regions in the southwest of Wolong Nature Reserve (Tang et al. 2017), where livestock are widely distributed as well. We focused on Yinchanggou and Weijiagou as our research areas, where the density of livestock signs is 0.17 and 5.84 km^2, respectively. Wolong Nature Reserve had 5000 permanent residents in 2009 (Liu et al. 2009), and their main source of income has traditionally been livestock grazing and farming (Hull et al. 2014; Zhang et al. 2017). Although tourism has become a bigger part of the local population's income, the number of livestock in the reserve has been increasing in recent years (Wang et al. 2018b; Zhang et al. 2018). Many livestock are grazed in the alpine meadow ecosystem in Wolong Nature Reserve, where they compete with blue sheep (*Pseudois nayaur*), goral (*Naemorhedus*), marmot (*Marmota*), and other herbivores (Lu et al. 2019).

3. Methods

a. Data collection

We used results from a questionnaire survey administered to 202 local farmers on the distribution of livestock in Wolong Nature Reserve (Wang et al. 2018b) to define HGDAs versus LGDAs. Specifically, we defined Weijiagou as an HGDA because of a relatively high livestock sign density of 5.84 animals km^{-2} and defined Yinchangou as an LGDA because of its relatively low livestock sign density of 0.17 animals km^{-2} (Fig. 1). The elevation span and vegetation communities of two mesoscale study areas (Yinchanggou and Weijiagou) are similar. Additionally, the two areas are not far apart and have no significant barriers in between, so the wildlife in the two areas are not isolated from each other. Therefore, the comparison of livestock effects between the two areas is robust. To sample for snow leopard presence and habitat characteristics, we used line transect and sample plot methods. We set up line transects in a systematically random manner, with each line transect at least 3 km in length and separated by at least 500 m. The research team walked the line transects to find signs of snow leopard (e.g., feces and footprint) with the help of experienced guides.

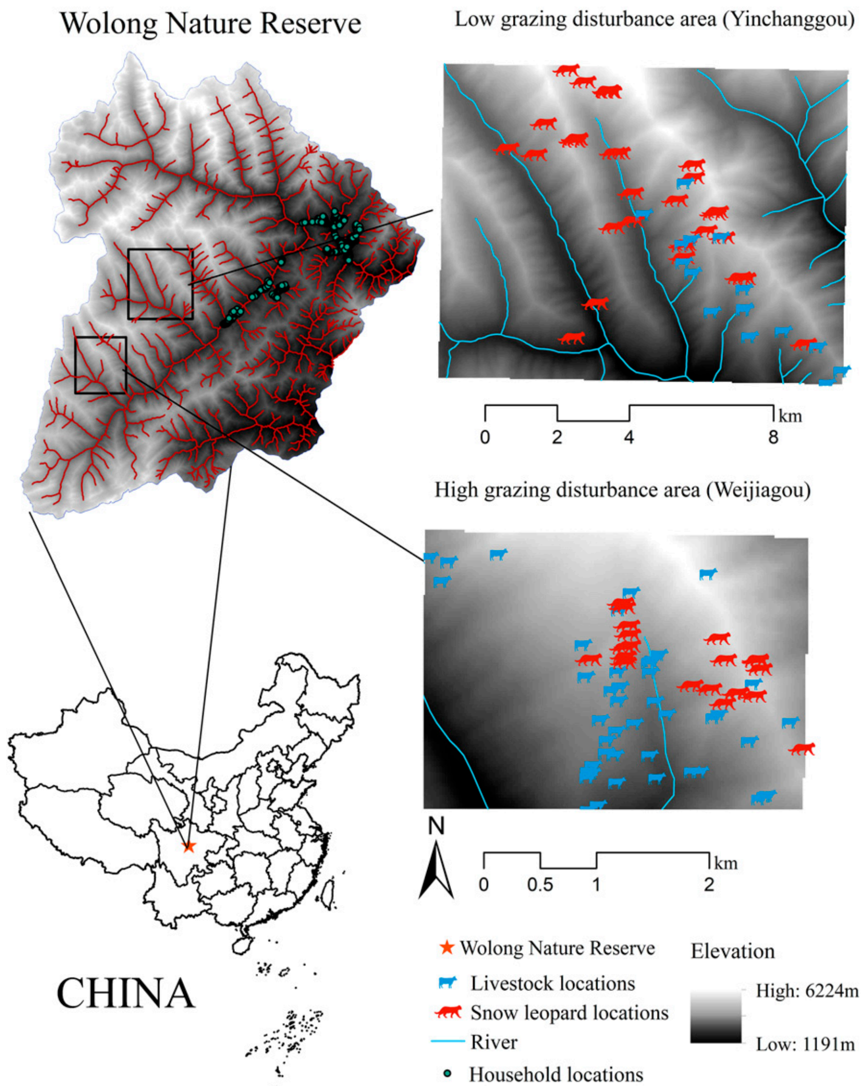

FIG. 1. Map and location of Wolong Nature Reserve in Sichuan. Livestock and snow leopard locations in LGDAs and HGDAs are also depicted.

In the process of walking line transects, we slightly adjusted their direction to avoid dangerous conditions. All members of the investigation team were trained to identify the signs of snow leopards before the survey began. If snow leopard sign was found along the line transect, we then set up a sample plot (20 m × 20 m) around it. Each potential sign was photographed and associated samples (e.g., feces and hair) were brought back to China West Normal University. The "Snow Leopard Survey Technology Manual" jointly formulated by Peking University and Shanshui Nature Conservation Center and "A Guide to the Mammals of China" and the corresponding references (Anwar et al. 2011; Ma et al. 2005; Xu et al. 2005; Liu et al. 2003) were then used to confirm the collected signs as those of snow leopards. Invited mammalogy experts from China West Normal University and the Key Laboratory of Southwest China Wildlife Resources Conservation (China West Normal University) confirmed whether the photographs and samples were signs of snow leopards. In addition to the snow leopard plots, we set up control plots in areas where there were no signs of snow leopards. We established these plots in a random manner so that the minimum distance between two plots was 500 m, and the maximum distance was not more than 600 m. We employed this spacing interval to reduce the influence of excessive changes in environmental conditions between two plots on the analysis.

We established a total of 142 sample plots in the summer 2019 and 2020, with 92 plots (44 observation plots and 48 control sample plots) in LGDAs and 50 plots (18 observation plots and 32 control sample plots) in HGDAs. Each 20 m × 20 m plot contained 4 shrub subplots (10 m × 10 m) and 3 herb subplots (1 m × 1 m) (Fig. 2). We measured several microhabitat factors in each main plot, including the elevation, slope (0°–5°, 6°–15°, 16°–30°, 31°–45°, 46°–60°, and ≥61°), slope aspect (north, northeast, east, southeast, south, southwest, west, and northwest), slope location (ridge, the bottom of the slope, the

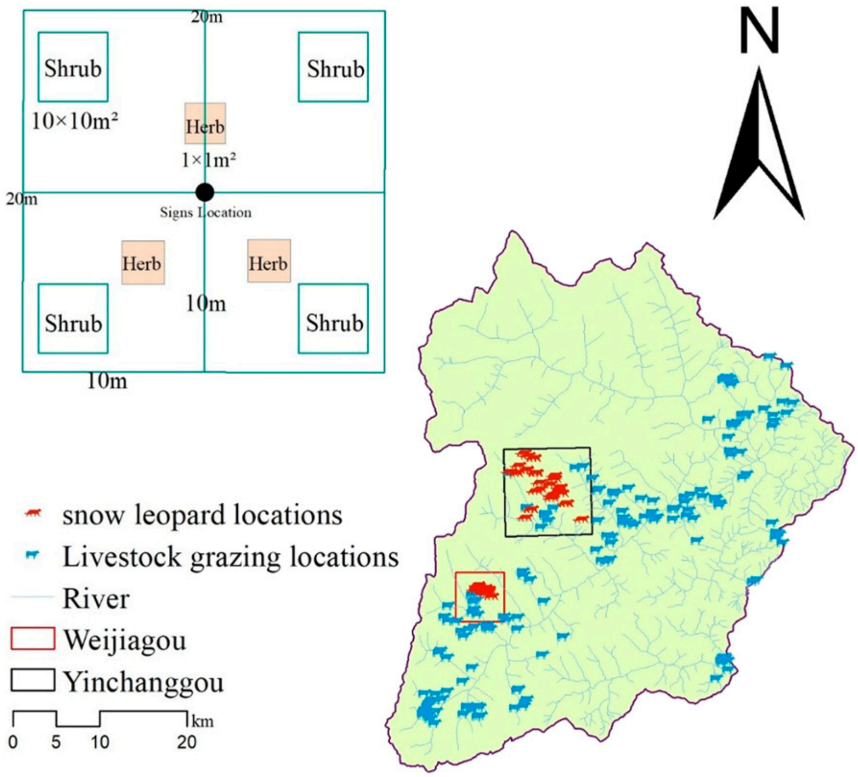

FIG. 2. Livestock grazing and snow leopard locations in Wolong Nature Reserve. The inset is the study design that we used for individual plots.

middle of the slope, and the top of the slope), terrain ruggedness (flat, rugged, lightly steep, middling steep, and highly steep), and vegetation type (mixed broadleaf, shrub forest, meadow, and alpine screes). We counted the number of shrub species and the basal diameter, height, number, and coverage of shrubs in the shrub subplots and the number of herb species and the height and coverage of herbs in the herb subplots.

b. Data analysis

We used the nearest point index R and geographical concentration index G (Yang et al. 2019) to understand the distribution and degree of concentration of snow leopards in LGDAs and HGDAs. The nearest point index formula is as follows:

$$R = \frac{\overline{d}_{\min}}{E(d_{\min})},$$

where $\overline{d}_{\min}$ is the average of the observed nearest point distance among snow leopard sites and $E(d_{\min})$ is the average of the theoretical nearest point distance between a random distribution of sites. An R value equal to 0 indicates a uniform distribution of points, $0 < R < 1$ indicates an aggregated distribution, and an R value equal to 1 indicates a random distribution.

To calculate $E(d_{\min})$, we used the following formula:

$$E(d_{\min}) = \frac{1}{2\sqrt{n/A}},$$

where n is the number of subjects in the corresponding plot and A is the acreage of the plot. We used ArcGIS10.2 software to get the nearest point distances and calculated the averages in Microsoft Excel 2010. We also used the geographical concentration index:

$$G = 100 \times \sqrt{\sum_{i=1}^{n} (X_i/T)^2},$$

where X_i is the number of subjects in plot i, T is the total number of subjects, and n is the number of plots. The possible range of G values is 0–100, with larger values indicating greater degrees of concentration.

Kolmogorov–Smirnov (K-S) tests showed that our continuous variables were normally distributed, and we thus conducted independent-samples t tests to test for significant differences in elevation and vegetation factors between LGDAs and HGDAs. Vegetation factors included the number of shrub species, basal diameter, height, number, and coverage of shrubs and the number of herb species, height, and coverage of herbs. We conducted nonparametric (Mann–Whitney) tests to examine the differences in slope, slope aspect, slope location, terrain ruggedness, and vegetation type between LGDAs and HGDAs. We conducted a chi-square test to examine whether snow leopards were selective for certain values of five categorical variables (slope, slope aspect, slope location, terrain ruggedness, and vegetation type) in LGDAs and HGDAs, respectively.

Resource selection functions (RSF) are commonly used to study the relationship between wildlife and their habitat (Gillies et al. 2010). We built RSFs using generalized linear models in LGDAs and HGDAs separately according to the following formula:

$$g(\mu_i) = \beta_0 + \beta_1 x_1 + \beta_1 x_2 + \cdots + \beta_i x_i + \cdots + \beta_n x_n,$$

where $g(\mu_i)$ is the relative probability of selection and β_n is the coefficient for the nth predictive environmental variable x_n (Bai et al. 2020). Before building the model, all continuous variables were standardized according to zero-mean normalization. We also excluded variables so that no pair of variables had a Pearson correlation coefficient greater than 0.6. The variables shrub height and number of shrub species were omitted in the RSF of LGDAs, and the shrub height, shrub cover, and number of shrub species were deleted in the RSF of HGDAs. We modeled the relative probability of selection as a binomial distribution with a logistic link function. The response variable in our RSF was coded as snow leopard detection locations (1) and snow leopard nondetection locations (0). We present results from the most-supported model. The t tests and Mann–Whitney tests were conducted with SPSS 16.0 software, and building the resource selection models was conducted with R 4.0.2 software. For all statistical analyses, we set the significance level to 0.05.

4. Results

a. Spatial utilization in LGDAs and HGDAs

The sign density of snow leopards and blue sheep in HGDAs was larger than that in LGDAs. Specifically, these species had sign densities of 0.45 and 1.39 km^2 in LGDAs and sign densities of 2.50 and 7.75 km^2 in HGDAs, respectively. Higher sign densities do not necessarily indicate a larger number of individuals—it may just be a reflection of the activity of the populations being more concentrated. Snow leopards, livestock, and blue sheep all featured aggregated distributions in both LGDAs and HGDAs (Table 1), but the distribution of snow leopards in HGDAs ($G = 61.68$) was more concentrated than that in LGDAs ($G = 80.13$).

b. Microhabitat-use differences between LGDAs and HGDAs

We analyzed a total of 14 habitat characteristics, and 6 were significantly different between LGDAs and HGDAs ($p < 0.05$). We found greater height and coverage of herbs but lower herb species diversity in LGDAs. The slope, slope aspect and vegetation type were also significantly different between LGDAs and HGDAs (Table 2). Relative to the LGDAs, there was an additional slope category with snow leopard sign in HGDAs: greater than or equal to 61° (≥61°). Relative to the HGDAs, there were additional slope aspects containing snow leopard sign (east and northwest) and additional vegetation types (mixed broadleaf–conifer forest and shrub forest) in LGDAs.

According to the chi-square test, we also found that the selection of snow leopard in response to five categorical variables was significant in LGDAs but not in HGDAs (Table 3). In other words, there was more selectivity in the slope, slope aspect, slope location, terrain ruggedness, and vegetation type variables by snow leopards in LGDAs.

TABLE 1. The nearest point index R result and distribution type of species in LGDAs and HGDAs.

Species	$\bar{d}_{\min}$	$E(d_{\min})$	R	Distribution type
LGDAs				
Snow leopard	0.0019	0.5959	0.0032	Aggregated
Livestock	0.0055	0.6472	0.0081	Aggregated
Blue sheep	0.0012	0.3223	0.0037	Aggregated
HGDAs				
Snow leopard	0.0012	0.1704	0.007	Aggregated
Livestock	0.0013	0.1913	0.0067	Aggregated
Blue sheep	0.0012	0.1788	0.0067	Aggregated

c. Microhabitat selection in LGDAs and HGDAs

In LGDAs, the final model predicting microhabitat selection of snow leopards was significantly affected by elevation, shrub basal diameter, and shrub height ($p < 0.05$). Snow leopards preferentially selected higher elevations, areas with shrubs that had smaller basal diameter, and areas where herb height was lower (Table 4; Fig. 3). In HGDAs, the final model included no significant variables predicted to affect the microhabitat selection of snow leopards (Table 4).

5. Discussion

The rapid development of livestock rearing is profoundly affecting natural ecosystems (e.g., freshwater systems, forests, grasslands) around the world (Liu et al. 2015). With increases in the population and activity range of livestock, there has been corresponding loss and fragmentation of many rare wildlife's habitat. This is the case even for species that live at high elevation areas, such as snow leopard and blue sheep (Shi et al. 2019; Khan et al. 2016). Some studies have found that the distribution of snow leopards is dependent on that of blue sheep, their main prey species (J. Li et al. 2020; Alexander et al. 2016b). With livestock occupying the space and food resources of blue sheep, their viability in the ecosystem decreases (Karimov et al. 2018). Although some studies in recent years have shown that livestock make up an increasing proportion of the snow leopard's diet, the snow leopard's main food source is still blue sheep (Oli et al. 1993; Bagchi and Mishra 2006; Lu et al. 2019; Shehzad et al. 2012). The availability of this prey is an important factor affecting the habitat selection of snow leopard (J. Li et al. 2020; Alexander et al. 2016b; Mosheh and Som 2009). As space utilization of blue sheep is reduced under the impact of livestock, the space available for snow leopards is in turn smaller. Because there are more human activities in HGDAs such as feeding livestock with salt, medicine, and shearing, snow leopards may also avoid specific areas with increased human activity there (Wolf and Ale 2009). We posit that snow leopard sign was more concentrated in HGDAs for this reason.

TABLE 2. Difference tests (t test and Mann–Whitney test) comparing habitat characteristics between LGDAs and HGDAs; SD is standard deviation. An asterisk indicates significant differences ($p < 0.05$).

Habitat characteristics	Mean ± SD LGDAs	Mean ± SD HGDAs	t	p
		t test		
Elev (m)	4131.98 ± 43.59	4058.61 ± 26.83	1.433	0.157
No. of shrub species	2.00 ± 0.37	1.36 ± 0.15	1.568	0.133
Basal diam of shrubs (cm)	2.85 ± 0.77	1.95 ± 0.71	0.790	0.437
Height of shrubs (cm)	33.64 ± 9.07	20.14 ± 2.09	1.450	0.165
No. of shrubs	8.80 ± 3.47	9.68 ± 2.25	−0.085	0.933
Coverage of shrubs (%)	31.35 ± 6.89	21.00 ± 3.82	1.315	0.201
No. of herb species	5.13 ± 0.40	6.22 ± 0.34	−2.074	0.043*
Coverage of herbs (%)	55.74 ± 4.89	42.28 ± 4.50	2.027	0.048*
Height of herbs	12.55 ± 1.12	4.13 ± 0.48	6.870	0.000*
		Mann–Whitney test		
Slope	—	—	—	0.024*
Slope aspect	—	—	—	0.027*
Slope location	—	—	—	0.322
Terrain ruggedness	—	—	—	0.150
Vegetation type	—	—	—	0.013*

In addition to the availability of prey and human disturbance (Sharma et al. 2015), there are many factors affecting the habitat selection of snow leopards (J. Li et al. 2020), including elevation (Alexander et al. 2016b), terrain (Sharma et al. 2015), and vegetation type (Tang et al. 2017). We used RSFs to investigate the effects of multiple variables on the habitat selection of snow leopards. Elevation has always been an important environmental variable in the study of snow leopard habitat selection. Numerous studies have shown that snow leopards tend to choose higher elevations (Tang et al. 2017; Qiao et al. 2017; Xu et al. 2006), and we also obtained this result in our RSF. As elevation increases, vegetation cover gradually decreases and is replaced by alpine screes. Snow leopards are opportunistic predators (Maheshwari and Sathyakumar 2020; J. Li et al. 2020) that camouflage themselves by using environmental factors to improve the success rate of predation. The unique body color and pattern of snow leopards allow snow leopards to better hide in the alpine scree environment of high elevations. In addition to this, high elevations are often accompanied by steep and rugged terrain that the unique body structure of snow leopards is well suited for in hunting prey species. More important, there are relatively few large carnivore species distributed in high elevation areas, which reduces competition for resources (Hong et al. 2020).

At present, there are few studies on the selection of vegetation type and structure by snow leopards. Potential reasons for this include the following: 1) Snow leopards are carnivores and do not directly consume plant material—therefore, the influence of vegetation on snow leopards has been ignored. 2) Plant communities and vegetation structure in the high elevation ecosystem are relatively simple. There is little change in vegetation between different areas, likely resulting in a lack of interest in vegetation research by snow leopard researchers. However, with the continuous expansion of livestock grazing in recent years (Wang et al. 2019), its impact on the vegetation of high-elevation ecosystems has become increasingly significant. Different grazing intensities have different effects on vegetation in different regions. Therefore, our study fills an important knowledge gap concerning the vegetation selection of snow leopards in areas of different grazing intensities.

According to our RSF, we found that snow leopards tended to choose areas in which shrubs had smaller basal diameters and herbs had lower heights. Snow leopards not only use alpine screes habitats, but they also use alpine meadow habitats (Hong et al. 2020; J. Li et al. 2020). Snow leopards living in alpine meadows still need to hide when hunting prey, and shrubs with smaller basal diameter can provide good hiding

TABLE 3. The chi-square test of five categorical variables in LGDAs and HGDAs, separately; df indicates degrees of freedom. An asterisk denotes significant differences ($p < 0.05$).

	LGDAs			HGDAs		
Categorical variables	Chi-square	df	p	Chi-square	df	p
Slope	13.273	3	0.004*	3.667	4	0.453
Slope aspect	12.182	5	0.032*	6.444	3	0.092
Slope location	45.773	4	0.000*	2.333	2	0.311
Terrain ruggedness	28.909	3	0.000*	1.000	2	0.607
Vegetation type	22.591	4	0.000*	2.130	1	0.144

TABLE 4. The factors influencing the microhabitat selection of snow leopard through binary logistic regression (variables in the equation) in LGDAs and HGDAs. One and two asterisks denote contributions to the model that are significant at $p < 0.05$ and $p < 0.01$, respectively.

Factors	Estimate	Std error	Z value	Pr(>|z|)
LGDAs				
Intercept	−12.5294	5.3363	−2.348	0.0189*
Elev	0.0038	0.0013	2.921	0.0035**
Basal diam of shrubs	−0.3979	0.1211	−3.286	0.0010**
Height of herbs	−0.0856	0.0397	−2.155	0.0312*
HGDAs				
Intercept	−1.4386	561.7403	−0.003	0.9979
Height of herbs	−0.3253	0.1911	−1.702	0.0887
No. of shrubs	−1.978	0.1109	−1.783	0.0746
Slope location (the bottom of slope)	−16.5158	1507.3048	−0.011	0.9913
Slope location (the middle of slope)	−6.0120	1123.4784	−0.005	0.9957
Slope location (the top of slope)	−3.5750	502.4352	−0.007	0.9943

conditions and will not overly hinder snow leopard movement when chasing prey (Hong and Zhang 2021). The selection of areas with lower herbs may be related to the fact that snow leopards are top predators in the high elevation ecosystem and thus do not need to avoid predators themselves. When snow leopards are not hunting, they might then choose areas with lower herb heights as it costs less energy to move around as compared with areas with higher herb heights. Lower herbs might also enhance the field of vision for snow leopards surveying for prey.

Our results showed that elevation, basal diameter of shrubs and herb height influenced the microhabitat selection of snow leopard in LGDAs and that no factors significantly affected the microhabitat selection of snow leopard in HGDAs. Together with the results of our chi-square tests of categorical habitat factors and snow leopard presence, this indicates that snow leopards may be more selective of environmental factors under low disturbance conditions, while high human disturbance might limit their potential to select for preferred habitat. We also found that the height and coverage of herbs, and thus overall herb biomass, decreased with high livestock sign density (5.84 km^2) (Table 2). This reduces the forage available to wild ungulates like blue sheep, likely leading to smaller populations there and in turn less prey availability for snow leopards.

6. Conclusions

Our study confirmed that livestock grazing has significant impacts on the distribution and microhabitat selection of snow leopards and explained the possible reasons for these effects. We recommend that grazing intensity be controlled with the aim of restoring the habitat complexity and diversity of the alpine environments frequented by snow leopards. This will allow the distribution of the snow leopards to remain more dispersed and allow for more selectivity of habitat factors. By controlling the area and intensity of livestock grazing, direct human–snow leopard conflict can also be minimized. We believe this study is valuable for improving the management of livestock and wildlife and that similar research should be considered in other reserves.

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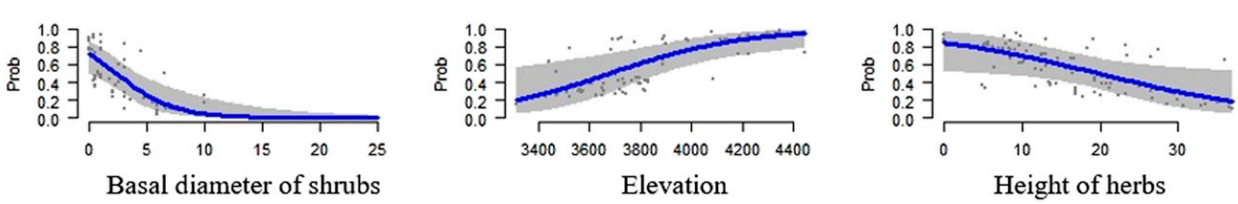

FIG. 3. Relative probability of selection for the factors in the optimal resource selection function in LGDAs.

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