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Key factors on foraging and bedding sites selection of the Asiatic ibex (*Capra sibirica*) in Central Tianshan Mountains in winter

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Abstract. Foraging and bedding sites are key ungulate demands of their habitats. Research however, on the differences between these two types of sites has been neglected. This study deals with the winter foraging and bedding site selection of the Asiatic ibex (*Capra sibirica*) in the Tianshan Mountains in the Xinjiang Uyghur Autonomous Region, China. A total of twelve line-transects were used to assist research of the Asiatic ibex within five valleys and canyons during December of 2010 and January of 2011. Ninety-five bedding and one hundred foraging sites used by the Asiatic ibex were examined and the effects of fifteen different environmental factors on habitat selection were analyzed and evaluated in this study. In comparison with its bedding sites, the Asiatic ibex in winter showed a greater preference for semi-shady slopes and higher vegetation density in its selection of foraging sites. Regarding its foraging site preferences when compared to its bedding site preferences, this species was less sensitive to deeper and greater snow cover, to a lower hiding cover level, and to greater distances from the nearest escape structures. Stepwise Discriminant Analysis showed that a group of five environmental factors played a dominant role in bedding and foraging site preferences. These factors were, in the order of their contribution value: vegetation density, hiding cover level, distance from the top of the mountain, and distance from escape structures. Using these five environmental factors alone, the ability to accurately predict bedding and foraging site preferences of the Asiatic ibex reached 93.3 %.

Key words: environmental factor, habitat selection, trade-off, Stepwise Discriminant Analysis (SDA)

Introduction

Habitat selection is the outcome of the trade-offs between the costs and benefits associated with each habitat (Sih 1980, Lima & Dill 1990). Individual animals may experience these trade-offs differently over time and space. Habitat selection will differ in accordance with short-term variations in factors such as animal activity, time of day, and weather, as well as in accordance with medium-term variations in environmental conditions and the animal's physiological state (Ratikainen et al. 2007). There are many factors which are closely related to animal's habitat selection, such as the need for forage and for protection from extreme weather and from predators (Aublet et al. 2009). For example, Asiatic ibex use rocks and cliffs for rest and protection, grassland areas for foraging, and watering sites for hydration (Fedosenko & Blank 2001).

The Asiatic ibex (*Capra sibirica*) is distributed in the mountains of Russian Siberia, Mongolia, Pakistan, India, Nepal, and Central Asia (Schaller 1977), and is a threatened species in China. It is listed as a category I protected wild animal species under the Wild Animal Protection Act of China, and is listed as "Endangered" in the China red data book of endangered animals (Wang 1998, Smith et al. 2009). The Asiatic ibex is sexually dimorphic both in size and morphology (Schaller 1977, Fedosenko & Blank 2001).

Studies of the Asiatic ibex remain relatively few in number (Shackleton 1997, Reading et al. 2007). Limited ecological studies of the Asiatic ibex outside of Russia (Fedosenko & Blank 2001) have been conducted even though its populations are distributed very widely in mountainous areas and the species typically uses common types of habitat. Grignolio et al. (2004) briefly discuss several factors that can influence the spatial behaviour as well as the size and use of the home range of the ibex and other ungulates. Some work has been done on the Asiatic ibex in its south-eastern distribution range in the north-western

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Himalayan Mountains of India (Schaller 1977, Fox et al. 1992, Johnsingh et al. 1999, Bagchi et al. 2004, Namgail et al. 2013) and in Mongolia (Dzieciolowski et al. 1980, Reading et al. 1998). Except for some field surveys regarding its distribution and population density (Xu et al. 2007), its vigilance behaviour (Xu et al. 2010), and its daytime activity allocation (Xu et al. 2006, 2012), information on the Asiatic ibex in the Tianshan Mountains of China is still quite limited. For many years, all that was well known was that the Asiatic ibex prefers rocky-cliff areas (Meklenburtsev 1948, Egorov 1955) and that altitudes (spanning from 600 up to 5000 m) and available vegetation forms (from very dry semi-desert slopes up to alpine meadows) were of slight influence (Fedosenko 2003). However, most of these works focused merely on descriptive statements of ibex habitat preferences and lacked quantitative analysis. The purpose of our study was to investigate the habitat preferences of the Asiatic ibex in the China section of the Tianshan Mountains and to substantiate previous postulations on the habitat preferences of the ibex using modern statistical techniques. Our results should prove beneficial for the development of a conservation and management strategy for the Asiatic ibex in China.

Material and Methods

Study area

Our study area was located in the Khabir Ga Mountains (a section of the central Tianshan mountain range), northwest Hejing County, Bayingolin Mongolian Autonomous Prefecture, the Xinjiang Uyghur Autonomous Region, China (43°07′-43°27′ N, 86°01′-86°29′ E) (Fig. 1). The typical landscape there consists of rugged ridges and narrow canyons, with an elevation between 2801 and 4537 m. Its climate is cold and arid. The annual average temperature is –4.7 °C and the mean annual precipitation is between 280-350 mm. The summer is short and cool, with an average July temperature of approximately 20 °C. The winter season is long and cold with an average temperature of −15 °C in January. The primary vegetation is needle grass (*Stipa* spp.), edelweiss (*Leontopodium leontopodioides*), Chinese cinquefoil herb (*Potentilla* spp.), and alliums (*Allium* spp.). Residing there are also many protected animals such as the argali sheep (*Ovis ammon*), the snow leopard (*Panthera uncia*), the wolf (*Canis lupus*), the stoat (*Mustela erminea*), the lynx (*Lynx lynx*), the cinereous vulture (*Aegypius monachus*), and the golden eagle (*Aquila chrysaetos*).

Searching and positioning

Twelve line-transects were established as we searched for ibex in five valleys and canyons from December of 2010 to January of 2011 (Fig. 1). Transects were selected randomly. Line-transects were laid from the canyon floor to the ridge and covered all habitat types in the region. Due to the huge mountains and the wide basin in the study area, direct observation was used to study the ibex habitat. Using a telescope we observed foraging and bedding sites from great distances until the ibex departed and were out of our view. At that point, one team member, using the telescope, guided another to the targeted site. Bedding sites were confirmed on the basis of the detection of certain physical traces which surrounded fresh bedding sites, including fecal pellets, footprints, urine, and hair. We way-pointed all foraging and bedding sites using a Garmin-72 GPS unit.

Observation parameters

We created 10 × 10 m square quadrants with the either ibex's foraging or bedding traces at the centre. In this quadrant, we created five 1 × 1 m small square quadrants, with one in the centre and one in each of

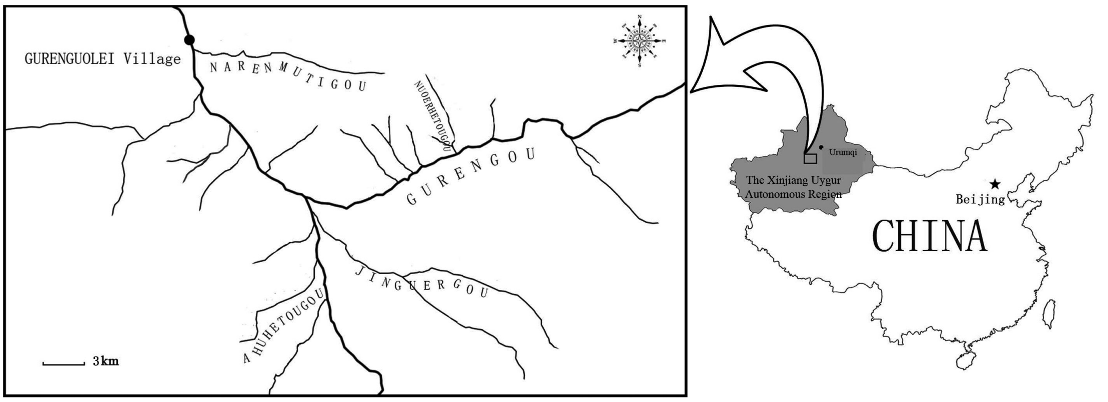

Fig. 1. Study area in the Tianshan Mountains, Northwest China.

the four corners, to use to measure and record fifteen environmental factors. In this winter survey, 95 foraging site quadrants and 100 bedding site quadrants were established and analyzed. Environmental factor classification and measuring methods were based on Oil (1996), Zhang & Ma (2000), Liu et al. (2005), and Li et al. (2013) and are as follows:

Slope Position (SP) – habitats were divided into three sections: the upper 1/3 of the slope, the middle 1/3 of the slope, and the lower 1/3 of the slope on which they lay. Slope (S) – slopes were measured in five non-adjacent 1 × 1 m quadrants using a declinator and the average value was determined. Slope Direction (SD) – with an increase in latitude, the solar height angle and the ecliptic plane angle also change. The latitude of Xinjiang's Tianshan area forced several alterations to the standard definition of the sunny slope in relation to a compass. Here, the sunny slope does not face due south, but is oriented somewhat to the southeast. Accordingly, others slopes must also be reoriented. So our slope directions were divided into three types: the sunny slope (S 67.5° E ~ S 22.5° W), the semi-shaded slope (N 22.5° E ~ S 67.5° E, S 22.5° W ~ N 67.5° W), and the north slope (N 67.5° W ~ N 22.5° E). Altitude (A) – we recorded the altitude of the quadrants using the Garmin-72 GPS unit. Landscape Type (LT) – the landscape within the study area was divided into four types: gentle slopes with alpine meadows, gentle slopes with alpine grasslands, steep gravel, and bare rock cliffs. The alpine meadows consist of perennial grass under moderate moisture conditions and the alpine grasslands are dominated with dry herbs and other vegetation. Distance to Human Settlements (DHS) – settlements included locations of herdsmen's shelters and mining sites. We measured the distance of the settlements from our quadrants using the Garmin-72. Distance to Roads (DR) – we measured the geodesic distance from the quadrants to the nearest road using either a meter stick or the Garmin-72. Vegetation Height (VH) – we measured the vegetation height in the five 1 × 1 m quadrants. This then was used to calculate an average vegetation height for the large quadrants. Vegetation Density (VD) – we counted the number of individual plant specimens in each of the five 1 × 1 m quadrants and labelled this as vegetation density. These numbers were then used to calculate an average vegetation density for the large quadrants. Snow Depth (SD) – we measured the snow depth in the five 1 × 1 m quadrants. These values were then used to calculate an average snow depth for the large quadrants. Snow Cover (SC) – we measured the percentage of the ground surface in each of the five 1 × 1 m quadrants which was covered by snow. These values were then used to calculate an average snow cover percentage for the large quadrants. Hiding Cover Level (HCL) – we erected a one meter-high wooden measuring stick in the centre of each of the five small quadrants. The portion (as a percentage) of the meter stick that was visible from a distance of 20 meters to the north, to the south, to the east, and to the west was observed and recorded. These figures were then used to calculate an average hiding cover level for the large quadrants (Liu et al. 2005). Number of Plant Species (NPS) – we counted the number of plant species within the five 1 × 1 m quadrants. These were then used to calculate an average number of species for the large quadrants. Distance to the Top of the Mountain (DTM) – we measured the geodesic distance from bedding or foraging sites to the top of the nearest mountain. Distance to Escape Structures (DES) – we measured the geodesic distance from bedding or foraging sites to the nearest bare rock cliff.

Statistical analyses

We entered all the field data into Microsoft Excel 2003 and used SPSS 19 for Windows to perform the statistical analysis. All twelve categories of numeric environmental data were tested for normality (Kolmogorov-Smirnov test). We used the Mann-Whitey U test ($P < 0.05$) and T test ($P > 0.05$) to identify the differences in the nine numerical environmental factors on foraging and bedding site preferences. Throughout this paper, values are presented as mean ± standard error, and the significance level was set at $\alpha = 0.05$. The chi-square test was used to identify the differences in the data pertaining to the three non-numeric environmental factors. We also performed Stepwise Discriminant Analysis (SDA) to determine the dominant factors in habitat selection. The Wilk's K value was selected as a discriminant index of foraging and bedding sites of the ibex – the smaller the value, the stronger its ability to make discriminations.

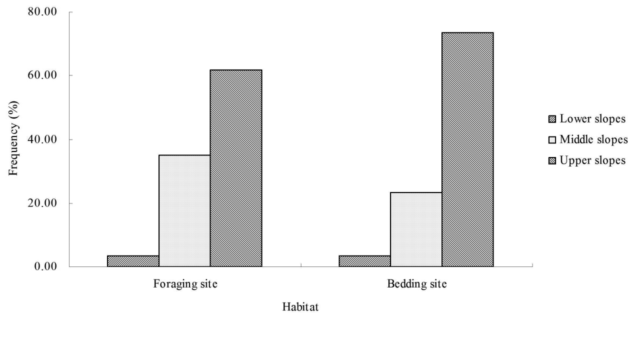

Fig. 2. Slope location preference of Asiatic ibex for winter foraging and bedding sites.

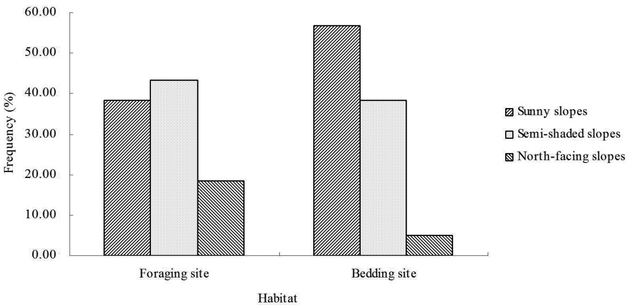

Fig. 3. Slope direction preference of Asiatic ibex for winter foraging and bedding sites.

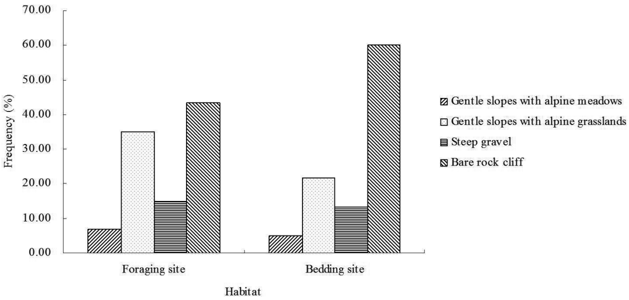

Fig. 4. Landscape type preference of Asiatic ibex for winter foraging and bedding sites.

preferences when foraging and bedding sites were compared (Table 1).

Two independent samples of the Mann-Whitey U test indicated that the Asiatic ibex showed higher preference for shorter distances to the top of the mountain (P < 0.01) and thinner snow depths (P < 0.05) for bedding. No significant differences were found in ibex preferences of slope angle, distance from the nearest human settlement, vegetation height, distance from the nearest road, or the number of plant species (P > 0.05) when comparing their foraging and bedding site selections (Table 1).

There were no significant differences in slope position (χ^2 = 2.01, df = 2, P = 0.367 > 0.05) (Fig. 2) or choice of landscape types (χ^2 = 3.70, df = 3, P = 0.296 > 0.05) (Fig. 3) between foraging and bedding sites of ibex in winter. There was however a significant difference in slope direction (χ^2 = 6.88, df = 2, P = 0.032 < 0.05) (Fig. 4).

Ibex preferred to bed on sunny slopes more often than on semi-shaded slopes (χ^2 = 4.04, df = 1, P = 0.044 < 0.05), and on bare rock cliffs more often than on gentle slopes with alpine grasslands (χ^2 = 18.25, df = 1, P = 0.000 < 0.01). On the other hand, ibex preferred to forage in alpine meadows on gentle slopes more often than on bare rock cliffs (χ^2 = 6.40, df = 1, P = 0.011 < 0.05).

Table 1. Comparison of the influence of isolated environmental factors on winter foraging and bedding site preferences of the Asiatic ibex (Mean ± SE).

Environmental factors	Foraging sites	Bedding sites	Mann-Whitey U test Z	T test	P
Altitude (m)	3318.00 ± 156.38	3373.82 ± 197.80	-	–1.241	0.219
Slope angle (º)	32.30 ± 5.75	34.62 ± 6.69	–1.744	-	0.081
DR (m)	1666.67 ± 472.22	1541.18 ± 480.60	-	1.051	0.297
DHS (m)	1541.18 ± 480.60	1700.00 ± 387.30	–0.228	-	0.819
VH (cm)	45.53 ± 4.68	32.53 ± 21.59	–1.767	-	0.077
VD (%)	54.83 ± 15.89	25.44 ± 16.21	-	7.306	0.000**
NPS	5.33 ± 1.65	4.97 ± 1.88	–0.774	-	0.439
SD (cm)	9.62 ± 3.60	6.67 ± 2.41	–2.539	-	0.011**
SC (%)	32.38 ± 17.51	15.33 ± 8.55	-	3.863	0.001**
HCL	8.48 ± 2.59	12.63 ± 2.94	-	–5.248	0.000**
DTM (m)	149.33 ± 100.34	55.29 ± 32.87	–4.764	-	0.000**
DES (m)	46.80 ± 29.78	16.38 ± 11.76	-	7.359	0.000**

** Significant difference (P < 0.01), (NS) No significant difference (P > 0.05).

Results

The role of environmental factors in foraging and bedding site selection

In bedding selection, the Asiatic ibex showed higher preferences for locations which were characterized by lower vegetation density, shorter distances from the nearest escape structures, higher hidden cover levels, and less snow cover (P < 0.01). There were no significant differences in altitude and distance to road

Compared with bedding sites, the Asiatic ibex showed greater preference in winter for foraging sites offering higher vegetation density, deeper snow, greater snow cover, a lower hiding cover level, further distances away from the top of the hill, further distances away

Table 2. Regression discriminant analysis of winter foraging and bedding site preferences of the Asiatic ibex.

Variable No.	Variables	Discriminant coefficient	Wilks' λ	F	P
1	DSM (m)	0.379	0.590	82.165	0.000**
2	VD (%)	0.672	0.408	84.937	0.000**
3	SC (%)	0.551	0.302	89.478	0.000**
4	HCL	–0.471	0.263	80.702	0.000**
5	DES (m)	–0.283	0.248	69.300	0.000**

** Significant difference ($P < 0.01$).

from the nearest escape structures, and semi-shady slopes.

Stepwise discriminant analysis

Results of SDA on foraging and bedding site selection showed an Eigen value of 3.722 and a canonical correlation coefficient of 0.888, which together account for all of the variance (100 %). There was a higher degree of separation between foraging and bedding sites in the canonical coefficient histogram.

The Wilks' K value also revealed a very significant difference between foraging and bedding site selection (Wilks' K = 0.212, $\chi^2 = 171.532$, df = 15, P = 0.000 < 0.001). Fisher's linear discriminant function when applied to the bedding and foraging habitat of ibex in winter was as follows: F = –0.242 × A + 0.081 × S – 0.172 × SP – 0.057 × SD – 0.071 × DR + 0.202 × DHR + 0.294 × DSM + 0.059 × LT + 0.165 × VH – 0.467 × HCL + 0.701 × VD + 0. 241 × NPS + 0.235 × SD + 0.502 × SC + 0.167 × DES (cut point is 0). SDA showed a group of five environmental factors which played a dominant role in preferences for foraging and bedding habitat. They are listed here in the order of their contribution value from the highest to the lowest; vegetation density, snow cover level, hiding cover level, distance from the top of the mountain, and distance from escape structures (Table 2). Using the above five environmental factor variables alone, the rate of accuracy in predictions regarding foraging and bedding site preferences reaches 93.3 %. Here the 93.3 % refers to the making of categorical predictions regarding the two sites. That is to say, 93.3 % of the groupings made using these factors will be correct.

Discussion

Habitat selection

Animal choice of habitat and food resources is typically based on biomass, the space utilization of predators, vegetation cover, and snow conditions (Schaefer & Messier 1995, Marell & Edenius 2006). The descriptive statistics and test results regarding these habitat factors show that there are very significant differences between the selection of foraging and of bedding sites of ibex in winter. These differences lie mainly in vegetation destiny, distance from the nearest escape structure, distance to the top of the mountain, hiding cover level, and the snow cover. Compared with bedding sites, the foraging sites of the Asiatic ibex in winter showed a greater preference for higher vegetation density, deeper snow, greater snow cover, a lower hiding cover level, a distance further from the top of the mountain, a distance further from the nearest escape structures, and semi-shady slopes.

The SDA results also showed that the degree of influence of environmental factors on foraging choices was different from that on bedding site choices. Variations in the ibex's choice of foraging and bedding sites can be explained by weather, predators, and food resources. Optimal foraging theory indicates that an animal should forage in areas where its intake rate is highest and predation risk lowest (Houtman & Dill 1998). Although the ibex may be safer on the cliffs (hence bedding site preference), there is less forage available for them there. Therefore, they move away from such bedding sites to forage and have to strike a balance between food acquisition and predator avoidance when foraging away from the bedding area. Key factors influencing habitat use of the Himalayan ibex in comparison, included predation, winter snow cover, forage availability, and human activity (Fox et al. 1992).

The vertical migration of the Asiatic ibex is dependent on season, snow cover depth, abundance of biting insects, and disturbance from human activity (Fedosenko & Savinov 1983, Fedosenko & Blank 2001, Fedosenko 2003). Gender is another factor in habitat selection, with female ibex having more of a preference for rugged rocky areas than do males, especially during the birthing period (Fedosenko 2003).

Snow

Snow is considered a limiting factor in ungulate habitat selection in winter. When snow completely covers the ground, the animals' movements are inhibited, and the search for bedding sites, the search for replacement foraging sites, and the flight from predators all consume more time and energy (Mysterud & Østbye 1999). The white-tailed deer (*Odocoileus virginianus*) of North America can always be found bedding in the vicinity of their regular foraging paths, which reduces energy consumption during foraging in winter (Armstrong et al. 1983). The winter foraging and bedding sites of the ibex show no significant difference in altitude, suggesting that daytime vertical migration is not frequent, probably due to the limitations that snow places on their activity. Snow is indeed a limiting factor on the bedding habitat selection of herbivorous ungulates (Mysterud & Østbye 1995). Obviously, in comparison to areas with deeper snow cover, cratering (pawing down through the snow to reach vegetation) in places with less deep snow cover consumes less energy, which can be critical for the ibex in maintaining a balance between energy intake and output during the cold winter. Snow depth is the most powerful limiting factor and the Asiatic ibex avoids areas and slopes with deep snow cover, migrating to lower elevations or even other mountain ridges (Fedosenko & Blank 2001, Fedosenko 2003). Winter snow forced the Alpine ibex (*Capra ibex*) to stay on rock surfaces for a longer time (Grignolio et al. 2003) and was one of the chief factors limiting population growth (Jacobson et al. 2004). In our study area, due to the influence of topography and wind, snow cover is usually shallower in the areas near bare rock cliffs. Here it is possible that actually less snow was just an incidental feature of rocky structures being typical bedding sites and of comparatively more snow being typical of vegetated slopes. Rock is heated quickly and snow does not accumulate as easily on rock. The Asiatic ibex selection of bedding sites with less snow cover and snow depth in the vicinity of bare rock cliffs also helps to reduce heat loss.

Anti-predation

Ungulates must choose suitable habitat which serves to decrease the risk of predation (Houtman & Dill 1998). The high preference for bedding sites close to cliffs is consistent with the results obtained in other studies on ibex in India and in the Tomur Mountains (Fox et al. 1992, Xu et al. 2007) and with studies on the Himalayan blue sheep (*Pseudois nayaur*) (Namgail et al. 2004) which share a similar ecological niche with the ibex. Such preferences reflect the importance of cliffs as escape terrain, and perhaps high predation pressure in the particular area as well. Several times during our field investigation we observed the presence of wolves. This suggests there is a high density of large carnivores in the Tianshan Mountains. Bare rock cliffs turn into important escape terrain in an area with high predation risk (Namgail 2006). In addition, the cliffs and other escape structures can block wind and favour heat-retension during the night (Liu et al. 2005). The body structure of ibex is highly suited for bare rock cliff habitat, especially in that their relatively short and stout limbs enable flexibility of movement and evasion from predators in steep and rugged terrain (Bleich 1999). Steep terrain is an ideal environment for mountainous ungulates to escape predators (Oil 1994). Ibex often select bedding sites high up on the mountain which can afford them ample time to detect and avoid predators. In some habitats, the Siberian ibex will run from the upper plateaus down to the rugged slopes which are situated lower than their foraging sites in order to escape from carnivores (Fedosenko 2003).

Food

In our study area, December and January are difficult times for the ibex. The greatest snowfall and the deepest snow cover make this a harsh period, one in which animal mortality is at its highest. The key in herbivores surviving the winter is obtaining the energy they need while minimizing energy loss (McCorquodale 2003). Food availability is the most important factor in habitat selection (Frankin et al. 1975). High plant density means, to a certain extent, a greater availability of food and therefore, ibex prefer to forage in those areas with higher plant density in contrast with bedding sites, where plant density is less important to them. The ibex selection of bare rock cliffs as bedding sites can minimize the risk of predation. However, bare rock cliffs are not suitable for plant growth, and therefore, the ibex have to leave the cliffs to forage. The Alpine ibex (*C. ibex*) stay in high altitude areas above the tree line and prefer alpine pastures and stony ravines in summer (Grignolio et al. 2003). During the heat of the day, the ibex alternately rest in stony ravines for shade and forage out on the grasslands, which can provide high-quality nutrition (Grignolio et al. 2003).

A semi-shady slope with abundant plant species and partial snow cover is favored by ibex for foraging and watering. Sunny slopes with adequate lighting, which heat up quickly, and which have lower degrees of snow cover are favoured by ibex as they help to reduce energy loss and conserve heat. In our study area, snow mainly accumulated on shady slopes and at the bottom of ravines and canyons. Our finding that the Asiatic ibex prefer to bed on sunny slopes in winter corresponds to the behaviour of the Himalayan blue sheep (*Pseudois nayaur*) in the Helan Mountains (Liu et al. 2005) and the argali sheep (*Ovis ammon*) in the Altai (Chu et al. 2009) and Tianshan Mountains (Li et al. 2014). Our findings show that there is no significant difference in altitude preference regarding foraging and bedding site selection, and suggest a limited vertical migration during daytime activity. The ibex move regularly between foraging and bedding sites with differing slope direction to meet their demand for food and refuge in winter. Our research indicated that there was obvious habitat segregation between foraging and bedding sites for the Asiatic ibex in winter.

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Literature

Armstrong E., Euler D. & Racey G. 1983: Winter bed-site selection by white-tailed deer in central Ontario. *J. Wildlife Manage. 47: 880−884.*

Aublet J.-F., Festa-Bianchet M., Bergero D. & Bassano B. 2009: Temperature constraints on foraging behavior of male Alpine ibex (*Capra ibex*) in summer. *Oecologia 159: 237–247.*

Bagchi S., Mishra C. & Bhatnagar Y.-V. 2004: Conflicts between traditional pastoralism and conservation of Himalayan ibex (*Capra sibirica*) in the Trans-Himalayan Mountains. *Anim. Conserv. 7: 121−128.*

Bleich V.-C. 1999: Mountain sheep and coyotes: patterns of predator evasion in a mountain ungulate. *J. Mammal. 80: 283−289.*

Chu H.-J., Jiang Z.-G., Qi Y.-J., Tao Y.-S. & Li B. 2009: Winter bed-site selection by argali *Ovis ammon sairensis*, *O. a. darwini* in Mt. Kekesen and Mt. Kalamaili in southern Altai Mountains. *Acta Theriol. Sin. 29: 125−132.*

Dzieciolowski R., Krupka J., Bajandelger X. & Dziedzic R. 1980: Argali and Siberian ibex populations in the Khuhsyrh reserve in Mongolian Altai. *Acta Theriol. 25: 213–219.*

Egorov O.-V. 1955: Ecology of Siberian capricorn (*Capra sibirica* Meyer). *Trans. Zool. Inst. 17: 7–134. (in Russian)*

Fedosenko A.-K. 2003: Siberian ibex in Russia and adjacent countries (state of populations, ecology, behavior, safety and economic use). *Centrokhotcontrol Press, Moscow. (in Russian)*

Fedosenko A.-K. & Blank D.-A. 2001: *Capra sibirica*. *Mamm. Species 675: 1–13.*

Fedosenko A.-K. & Savinov E.-F. 1983: The Siberian ibex. In: Gvozdev E.-V. & Kapitonov V.-I. (eds.), Mammals of Kazakhstan. *Nauka of Kazakh SSR, Alma-Ata 3 (3): 92–113. (in Russian)*

Fox J.-L., Sinha S.-P. & Chundawat R.-S. 1992: Activity patterns and habitat use of ibex in the Himalaya mountains of India. *J. Mammal. 73: 527−534.*

Franklin W., Mossman A. & Dole M. 1975: Social organization and home range in Roosevelt elk. *J. Mammal. 56: 102–118.*

Grignolio S., Parrini F., Bassano B., Luccarini S. & Apollonio M. 2003: Habitat selection in adult males of Alpine ibex, *Capra ibex ibex*. *Folia Zool. 52: 113−120.*

Grignolio S., Rossi I., Bassano B., Parrini F. & Apollonio M. 2004: Seasonal variations of spatial behaviour in female Alpine ibex (*Capra ibex ibex*) in relation to climatic conditions and age. *Ethol. Ecol. Evol. 16: 255−264.*

Houtman R. & Dill L.-M. 1998: The influence of predation risk on diet selectivity: a theoretical analysis. *Ecol. Evol. 12: 251−262.*

Jacobson A.-R., Porovenzale A., von Hardenberg A., Bassano B. & Festa-Bianchet M. 2004: Climate forcing and density dependence in a mountain ungulate population. *Ecology 85: 1598–1610.*

Johnsingh A.J.T., Stuwe M., Rawat G.-S., Manjrekar N. & Bhatnagar Y.-V. 1999: Ecology and conservation of Asiatic ibex (*Capra ibex sibirica*) in Pin Valley National Park, Himachal Pradesh, India. *Wildlife Institute of India, Dehra Dun, India.*

Li Y., Yu Y.-Q., Shi J. & Shi L. 2013: Foraging and bed site selection of Tianshan argali (*Ovis ammon karelini*) in Central Tianshan Mountains in summer. *Acta Ecol. Sin. 33: 7644−7650*.

Li Y., Yu Y.-Q. & Shi L. 2014: Habitat segregation between foraging and bed site of Tianshan argali (*Ovis ammon karelini*) in Central Tianshan Mountains in winter. *Chin. J. Ecol. 33: 358−364.*

Lima S.-L. & Dill L.-M. 1990: Behavioral decisions made under the risk of predation: a review and prospectus. *Can. J. Zool. 68: 619−640.*

Liu Z.-S., Cao L.-R., Wang X.-M., Li T. & Li Z.-G. 2005: Winter bed-site selection by blue sheep (*Pseudois nayaur*) in Helan mountains, Ningxia, China. *Acta Theriol. Sin. 25: 1−8.*

Marell A. & Edenius L. 2006: Spatial heterogeneity and hierarchical feeding habitat selection by reindeer. *Arct. Antarct. Alp. Res. 38: 413−420.*

McCorquodale S.-M. 2003: Sex-specific movements and habitat use by elk in the Cascade Range of Washington. *J. Wildlife Manage. 60: 729−741.*

Meklenburtsev R.-N. 1948: Pamir argali *Ovis polii polii* Blyth. *Bull. Mosc. Soc. Natur. Biol. Ser. 53 (5): 65–84. (in Russian)*

Mysterud A. & Østbye E. 1995: Bed-site selection by European roe deer (*Capreolus capreolus*) in southern Norway during winter. *Can. J. Zool. 73: 924−932.*

Mysterud A. & Østbye E. 1999: Cover as a habitat element for temperate ungulates: effects on habitat selection and demography. *Wildlife Soc. Bull. 27: 385−394.*

Namgail T. 2006: Winter habitat partitioning between Asiatic ibex and blue sheep in Ladakh, northern India. *J. Mt. Ecol. 8: 7−13.*
Namgail T., Fox J.-L. & Bhatnagar Y.-V. 2004: Habitat segregation between sympatric Tibetan argali *Ovis ammon hodgsoni* and blue sheep *Pseudois nayaur* in the Indian Trans-Himalaya. *J. Zool. Lond. 262: 57−63.*
Namgail T., van Wieren S.E. & Prins H.H.T. 2013: Distributional congruence of mammalian herbivores in the Trans-Himalayan Mountains. *Curr. Zool. 59: 116–124.*
Oil M.-K. 1994: Snow leopards and blue sheep in Nepal, densities and predator: prey ratio. *J. Mammal. 75: 998−1004.*
Oil M.-K. 1996: Seasonal patterns in habitat use of blue sheep *Pseudois nayaur* (Artiodactyla, Bovidae) in Nepal. *Mammalia 60: 187−193.*
Ratikainen I.-I., Panzacchi M., Mysterud A., Odden J., Linnell J. & Andersen R. 2007: Use of winter habitat by roe deer at a northern latitude where Eurasian lynx are present. *J. Zool. Lond. 273: 192−199.*
Reading R.-P., Amgalanbaatar S., Kenny D., Denicols A. & Tuguldur E. 2007: Siberian ibex (*Capra sibirica*) home ranges in Ikh Nart Nature Reserve, Mongolia: preliminary findings. *Mong. J. Biol. Sci. 5 (1−2): 29−36.*
Reading R.-P., Amgalanbaatar S. & Lhagvasuren L. 1998: Biological assessment of three beauties of the Gobi National Conservation Park, Mongolia. *Biodivers. Conserv. 8: 1115−1137.*
Schaefer J.-A. & Messier F. 1995: Habitat selection as a hierarchy: the spatial scales of winter foraging by muskoxen. *Ecography 18: 333−344.*
Schaller G.-B. 1977: Mountain monarchs: wild sheep and goats of the Himalaya. *University of Chicago Press, Chicago.*
Shackleton D.-M. 1997: Wild sheep and goats and their relatives. *Information press, Oxford: 163−164.*
Sih A. 1980: Optimal behavior: can foragers balance two conflicting demands? *Science 210: 1041−1043.*
Smith A.-T., Xie Y. & Chen Y.-X. 2009: A guide to the mammals of China. *Hunan Education Press, Changsha.*
Wang S. 1998: China red data book of endangered animals (mammal). *Science Press, Beijing, China.*
Xu F., Ma M. & Wu Y.-Q. 2006: Winter daily activity rhythm and time budget of ibex (*Capra ibex*) in Tomur Protected Area, Xinjiang. *Chin. J. Zool. 41: 139−141.*
Xu F., Ma M. & Wu Y.-Q. 2007: Population density and habitat utilization of ibex (*Capra ibex*) in Tomur National Nature Reserve, Xinjiang, China. *Zool. Res. 28: 53−55.*
Xu F., Ma M. & Wu Y.-Q. 2010: Group size and sex effects on vigilance: evidence from Asiatic ibex, *Capra sibirica* in Tianshan Mountains, China. *Folia Zool. 59: 308−312.*
Xu F., Ma M., Wu Y.-Q. & Yang W.-K. 2012: Winter daytime activity budgets of Asiatic ibex *Capra sibirica* in Tomur National Nature Reserve of Xinjiang, China. *Pakistan J. Zool. 44: 389−392.*
Zhang H.-H. & Ma J.-Z. 2000: Preliminary research on the habitat selection of sable in spring and summer. *Acta Zool. Sin. 46: 399−406.*