WINTER HABITAT PARTITIONING BETWEEN ASIATIC IBEX AND BLUE SHEEP IN LADAKH, NORTHERN INDIA

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Abstract - Asiatic ibex *Capra ibex sibrica* and blue sheep *Pseudois nayaur* are the most abundant wild ungulates in the Ladakh Region of the Indian Trans-Himalaya. Both species use rugged terrain to escape predation, and the competitive exclusion principle suggests that the distribution of one species may be affected by the presence of the other. I evaluated habitat use by these mountain ungulates in the Shun Gorge, at the eastern boundary of ibex distribution in the Zangskar Mountains, Ladakh, India. I hypothesised that due to their high affinity toward cliffs as a predator escape strategy, ibex and blue sheep overlap in their habitat use, especially in winter when they are likely to be confined by snow cover. Resource selection indices and chi-square statistics revealed that both ibex and blue sheep prefer habitat close (1-50 m) to cliffs. The two species were also similar in their use of habitat in terms of slope angle, except that ibex avoided gentle slopes (<15°) and blue sheep avoided very steep slopes (>45°). Both used habitats in terms of elevation and snow cover non-selectively except that blue sheep avoided very low areas (<4000 m), and ibex avoided snow-free areas. I suggest that there is high potential for competition between the two species, and the presence of one species may negatively influence the distributional pattern of the other.

Keywords - Asiatic ibex, *Capra ibex,* blue sheep, *Pseudois nayaur,* resource selection, habitat partitioning, Zangskar, Ladakh, Trans-Himalaya

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1. Introduction

Large herbivores with similar ecological requirements are expected to partition resources to coexist, especially in areas where the resources are in short supply (Wiens, 1977; De Boer & Prins, 1990). Understanding the mechanism of such resource partitioning is a central issue in community ecology (Ricklefs, 1990). Resource partitioning is accomplished through evolutionary divergence of resource use by co-occurring species (Walter, 1991), apparently in response to competition. Nevertheless, some ecologists argue against the importance of competition in the differential use of resources by sympatric species, and contend that predation may also lead to niche differentiation (Hairston *et al*., 1960; Holt, 1977; Repasky, 1996), as predatory risk provides an axis along which habitat partitioning can occur (Holt, 1989). In areas where competition does structure communities, species should segregate along at least one resource dimension in the Hutchinsonian niche hypervolume (Schoener, 1974).

As per the competitive exclusion principle, when two species co-occur in an area and depend on the same limited resources, the dominant species competitively exclude the subordinate one, as exemplified by Gause's experimental work (Gause, 1934). Therefore, the range of a species can be reduced by the presence of other species with similar ecological requirements (Connell, 1961). Studies on resource partitioning by ecologically similar wild ungulates were carried out extensively in North America and Africa (Lamprey, 1963; Jarman & Sinclair, 1979; Hanley & Hanley, 1982; Jenkins & Wright, 1988; Voeten & Prins, 1999), but there is little information on the niche separation amongst wild ungulates of the Trans-Himalayan ecosystem of south Asia. Wildlife managers in this mountainous region, therefore, rely on information generated from studies in the tropical and sub-tropical regions, which may not necessarily be applicable to this dry alpine ecosystem with a unique assemblage of large herbivores.

In this study, I looked at the differential habitat use by two mountain ungulates: Asiatic ibex *Capra ibex sibrica* (hereafter ibex) and blue sheep *Pseudois nayaur* in the Zangskar

Mountains of Ladakh, India. These are the most abundant wild ungulates in the region with blue sheep's population (c. 11,000 individuals) reaching almost double the number of ibex (Fox *et al.*, 1991). Blue sheep also has a wider distribution in the region, mostly in the eastern part and ibex has a relatively narrower distribution in the western part (Fox *et al.*, 1991). Fox *et al.* (1992), however, reported a relatively higher abundance of ibex in central Ladakh (despite its dryness and low vegetation), which they attributed to the lack of snowpack that might had encouraged ibex populations to overwinter in the region. The two species constitute the most important prey species of the highly endangered snow leopard *Uncia uncia* (Mallon, 1991; Oli *et al.*, 1993).

Ibex and blue sheep have similar anti-predator habitat requirements, as both use rugged terrain to escape predation (Bhatnagar, 1997; Namgail *et al.*, 2004). Preliminary observations on the habitat use by these species also revealed that they are similar in the use of habitat variables such as altitude, slope angle, rock type etc. (Mallon, 1991). Therefore, it is possible that they compete for some resources, and the presence of one species could negatively affect the other species. There is anecdotal information on their distributions that support such contentions, e.g., across large mountainous tracts of northwestern Tibetan Plateau, the distributions of these species demarcate often abruptly, thereby suggesting competitive exclusion of one species by the other (Schaller, 1998).

Blue sheep may use large boulders and scree of slate talus as escape terrain in parts of the Tibetan Plateau with low availability of cliffs (Harris & Miller, 1995). Furthermore, in other areas where the two species co-occur, blue sheep are reported to explore the open slopes near cliffs more often than ibex (Wegge, 1989; pers. obs.). The former is therefore more flexible in its habitat use, and may have a competitive advantage over ibex. The Shun Gorge marks the eastern boundary of ibex distribution in the Zangskar Mountains of the Indian Trans-Himalaya (Namgail, 2004), while along the Himalayan Range to the south its eastern limit terminates abruptly at the Sutlej Defile (Fox *et al.*, 1992). Based on the competitive exclusion principle, one can therefore speculate that competition with blue sheep may limit its eastward distribution. A study was thus carried out in the Shun Gorge to assess the degree of overlap and possible competition between these ecologically similar species. Based on their similar anti-predator habitat requirements, I predicted a high overlap between the two species in the use of habitat, especially in winter when snow cover is likely to restrict them to limited grazing grounds.

2. Methods

2.1. Study area

The Shun Gorge (33°N, 77°E) is located in the Zangskar Range, Ladakh, India, and encompasses c. 70 sq. km. As other parts of Zangskar, it remains cut off from the rest of Ladakh in winter (Nov.-Apr.), when the only motorable road from Kargil is blocked by heavy snow. Thus during winter, it can only be accessed through a trek of c. 15 days over the frozen Zangskar, Lungnak and Tsarab rivers. Topographically, the area is characterised by rugged terrain, with low river bluffs along the Tsarab River. Elevation ranges from 3500-5000 m. Precipitation is mostly in the form of snow during winter (Nov.-Feb.), and during the study period, I recorded about a meter of snow on the upper slopes.

No ungulates are found in the area except the study species and domestic yak, horse, sheep and goats. The sheep and goats were herded on the river bluffs near the villages, and were sometimes taken to the side-valleys, depending on the depth of snow. The yaks and horses ventured out far away from the villages but not far enough to disturb the ibex and blue sheep, which generally occurred on higher reaches. There are two villages *viz.*, Yarshun (7 households) and Marshun (3 households) in the study area, with a total human population of *c.* 50 people.

Both wild and domestic ungulates are preyed on by the snow leopard, wolf *Canis lupus chanku*, and to a less extent by lynx *Lynx l. isabellina*. Avian predators like the golden eagle *Aquila chrysaetos* sometimes prey on the lambs of both domestic and wild ungulates. See Namgail (2004) for more information on wildlife and natural history of Zangskar.

3. Field methods

The study was conducted between 12 Jan. –20 Feb. 2002. The length of the study period was constrained by the remoteness and inaccessibility of the study area. During the study, I walked on the frozen Tsarab River, looking for ibex and blue sheep. Two permanent trails: one upstream (*c.* 5 km) and one downstream (*c.* 3 km) from Marshun Village were established on and along the river. Each trail was walked at least 15 times during the study period. The observations were aided by 8x40 binoculars and a 15-45X spotting scope.

Whenever a group of animals was encountered, I recorded the time, date, species and habitat characteristics such as distance to cliff, slope angle, elevation and snow cover. All these habitat variables were visually estimated except elevation, which was determined from a 1: 250, 000 topographic map, and the accuracy was often checked by using a Global Positioning System (GPS). For estimating the proportions of available habitat, 149 random points were plotted on a 1: 250,000 topographic map of the area (Marcum & Loftsgaarden, 1980), which were then located on the ground and the habitat characteristics at these sites were sampled in the same way as described for habitat use.

4. Analytical methods

The selection of habitat by ibex and blue sheep were determined by estimating selection ratios (ratio of the proportion of habitat use and available) for different habitat units. The value of the selection ratio of a habitat unit is proportional to the probability of that unit being utilized by the study animals (Manly *et al.*, 1993). Due to the small size of the study populations, I needed to include re-sighted groups in the analysis, but the long observation interval (one observation on a group/day) should minimise the autocorrelation. Since the available habitat was estimated, and individual animals were not identified, the data conformed to the design I format (Thomas & Taylor, 1990) with sampling protocol A (Manly *et al.*, 1993). For statistical analyses, the habitat variables were classified into distinct categories, and the selection ratio ($\hat{w}_i$) for each category was calculated as

$$\hat{w}_i = o_i / \pi_i \qquad \text{Eqn. 1}$$

where o_i is the proportion of used units in category i, and π_i is the proportion of available resource units in category i. Subsequently, the standard error of a selection ratio was calculated as

$$se(\hat{w}_i) = \hat{w}_i \sqrt{\{1/u_i - 1/u_+ + 1/m_i - m_+\}} \qquad \text{Eqn. 2}$$

where u_i is the used resource units in category i, u_+ is the total number of used units sampled, m_i is available resource units in category i and m_+ is the total available units in category i.

To statistically test for habitat selection, i.e., whether sample proportion of used resource units were significantly different from the sample proportion of available units, the modified χ^2: log-likelihood Chi-square statistic (χ_L^2) for each habitat variable was calculated as

$$\chi_L^2 = 2 \sum \{u_i \log_e \{u_i/E(u_i)\} + m_i \log_e \{m_i/E(m_i)\}\} \qquad \text{Eqn. 3}$$

where $E(u_i)$ is the expected value of u_i, and $E(m_i)$ is the expected value of m_i. If the χ_L^2 was significant for a habitat variable (i.e., habitat selection), simultaneous Bonferroni-adjusted 95% confidence intervals were calculated for each category of that variable (to check which categories are creating the significance) as

$$\hat{w}i \pm Z_{\alpha/(2I)}\, se(\hat{w}i) \qquad \text{Eqn. 4}$$

where I is the number of habitat categories and se ($\hat{w}_i$) is the standard error of selection ratio. A habitat was used selectively, if the confidence limit for that habitat excluded 1. If selected, a habitat was preferred if the interval was > 1, and avoided if < 1 (Manly *et al.*, 1993).

Univariate t-tests were used to statistically test for significant differences in the use of habitat in terms of distance to cliff, slope angle, elevation and snow cover by ibex and blue sheep. The slope angle and elevation were normally distributed, and the distance to cliff and snow cover were log and arcsine transformed, respectively. Overlap in habitat use by ibex and blue sheep was calculated using Pianka's index (Pianka, 1973).

$$Ojk = \frac{\sum P_{ij} \cdot P_{ik}}{\sqrt{\sum P_{ij}^2 \cdot \sum P_{ik}^2}} \qquad \text{Eqn. 5}$$

Tab. 1 - Estimated habitat selection indices for Asiatic ibex and blue sheep in Zangskar, Ladakh, India. $\hat{w}_i$ estimated habitat selection ratio; se($\hat{w}_i$) standard error of selection ratio; $\hat{w}_i$ (l) and $\hat{w}_i$ (u) 95% lower and upper confidence limits, respectively.

	Asiatic ibex				Blue sheep			
Variable	$\hat{w}_i$	se ($\hat{w}_i$)	$\hat{w}_i$ (l)	$\hat{w}_i$ (u)	$\hat{w}_i$	se($\hat{w}_i$)	$\hat{w}_i$ (l)	$\hat{w}_i$ (u)
Distance to cliff (m)								
0	0.560 ^{0}	0.198	0.116	1.004	0.322 $^-$	0.125	0.042	0.602
1-50	1.709 $^+$	0.293	1.053	2.365	1.626 $^+$	0.263	1.037	2.215
51-100	0.560 ^{0}	0.262	0.000 †	1.147	1.030 ^{0}	0.322	0.309	1.751
>100	0.689 ^{0}	0.375	0.000 †	1.529	0.792 ^{0}	0.351	0.006	1.578
Slope angle (deg.)								
<15	0.395 $^-$	0.237	0.000 †	0.926	0.952 ^{0}	0.338	0.195	1.709
16-30	0.945 ^{0}	0.197	0.504	1.386	1.341 ^{0}	0.202	0.889	1.793
31-45	1.809 ^{0}	0.423	0.861	2.757	0.905 ^{0}	0.251	0.343	1.467
>45	0.448 ^{0}	0.272	0.000 †	1.057	0.196 $^-$	0.145	0.000 †	0.521
Elevation (m)								
<4000	0.704 ^{0}	0.209	0.236	1.172	0.294 $^-$	0.113	0.041	0.547
4001-4150	1.313 ^{0}	0.326	0.583	2.043	1.776 ^{0}	0.351	0.990	2.562
4151-4300	1.976 ^{0}	0.606	0.619	3.333	2.077 ^{0}	0.575	0.789	3.365
>4300	0.560 ^{0}	0.347	0.000 †	1.337	0.490 ^{0}	0.273	0.000 †	1.102
Snow cover (%)								
0	0.395 $^-$	0.160	0.037	0.753	0.909 ^{0}	0.209	0.441	1.377
1-25	2.239 ^{0}	1.047	0.000 †	4.584	0.736 ^{0}	0.436	0.000 †	1.713
26-75	1.990 ^{0}	0.586	0.677	3.303	1.553 ^{0}	0.451	0.543	2.563
>75	0.833 ^{0}	0.194	0.398	1.268	0.890 ^{0}	0.173	0.502	1.278

$^+$ (preference); $^-$ (avoidance); ^{0} use in proportion to availability; † inferences are less reliable due to very few observations (ui < 5).

where O_{jk} is the measure of overlap between species j and k, and P_{ij} and P_{ik} are the proportions of time spent by species j and k respectively on resources i-n. Overlap is complete when $O_{jk} = 1$ and absent when $O_{jk} = 0$.

5. Results

Forty-six observations on ibex and 70 on blue sheep were made during the study period. During surveys in the study area, I counted a maximum of 35 ibex and 67 blue sheep. Assuming that I counted all the animals in the *c.* 70-km^2-gorge, the above figures translate to an ibex density of 0.5/km^2 and a blue sheep density of 0.96/km^2. Habitat selection pattern by the two species is given in Table 1, while Table 2 presents the means (± SE) of the habitat variables used by the two species and their overlap.

Habitat use and overlap

Ibex preferred habitats close to cliffs (1-50 m; $\chi_L{}^2$= 8.92, $p < 0.05$), and their use of other distance categories were in proportion to their respective availabilities (Table 1). Blue sheep showed a similar pattern of habitat use, but used cliffs (0 m) significantly less than in proportion to their availability ($\chi_L{}^2$= 14.2, $p < 0.05$). Ibex also avoided gentle slopes (<15°; $\chi_L{}^2$= 8.59, $p < 0.05$), while blue sheep avoided very steep slopes (>45°; $\chi_L{}^2$= 8.80, $p < 0.05$), but both species used other slope categories similarly and non-selectively (Table 1).

Both species used elevation non-selectively, except that blue sheep avoided habitats at very low elevation (<4000 m; $\chi_L{}^2$= 23.49, $p < 0.05$; Table 1). They also used areas with varying snow cover non-selectively except that ibex avoided snow-free areas ($\chi_L{}^2$= 12.21, $p < 0.05$). The t-test statistics also revealed a high similarity in habitat use, differing significantly only in the use of slope angle (t = 2.589, $p <0.01$; Table 2), which was further confirmed by the relatively less overlap (O_{jk} = 0.88) between the two species in the use of this variable (Table 2).

6. Discussion

Results showed that ibex and blue sheep overlap in their habitat use. But mechanisms other

Tab. 2 - Mean (+ SE) of habitat use and overlap (O_{jk}) between ibex and blue sheep in Zangskar, Ladakh, India.

Habitat variable	Blue sheep	Asiatic ibex	*t*-value	*p*	O_{jk}
Distance to cliff (m)	42 ± 4.905	36 ± 5.871	0.247	0.810	0.92
Slope angle (degrees)	27 ± 1.122	32 ± 1.634	2.589	0.010*	0.88
Elevation (m)	4143 ± 13.211	4092 ± 32.576	1.751	0.082	0.95
Snow cover (%)	52 ± 4.873	53 ± 5.496	1.902	0.060	0.98

* Statistically significant

than snow cover restricting the two species to limited grazing grounds are responsible for such high overlap, because the two species did not prefer the snow-free areas as expected under this assumption. During the study period, the two species were seen feeding in close proximity (<20 m) on three occasions. Such sociality is a common feature of the ungulate communities of eastern Africa, and has been viewed as a response to high predation pressure (Sinclair, 1985). The high overlap between ibex and blue sheep in their habitat use could be related to their occurrence in close proximity for mutual protection against predator.

The high overlap in habitat use by these species in the Zangskar Mountains may also imply: (a) that resources are abundant and they can coexist without strong competition (b) that they differ in the use of their diet (c) that not enough time has elapsed for evolutionary divergence of resource use. The first explanation is untenable, since the Trans-Himalayan Mountains support very low plant biomass (Chundawat & Rawat, 1994; Mishra, 2001). The second explanation is likely to account for the high overlap in habitat use, as diet separation allows the co-occurrence of species in the same habitat (Schoener, 1974; Pianka, 1994). The dietary use and overlap between them need to be investigated to shed light on this aspect. The third explanation is also defensible, as the resource partitioning between co-occurring species is an evolutionary process (Walter, 1991).

The high preference for habitat close to cliff (1-50 m) by both species is consistent with the results obtained in other studies on these wild ungulates (Wilson, 1989; Bhatnagar, 1997; Longva, 1998; Namgail *et al.*, 2004). Such preferences reflect the importance of cliffs as escape terrain, and perhaps a high predation pressure in the area, as indicated by a relatively high abundance of snow leopard signs such as scrapes, spray marks and droppings (Namgail, Unpubl. data). The high affinity of these ungulates toward cliffs may also make them relatively less vulnerable to disturbance associated with livestock grazing, as such terrain types are used less frequently by livestock herders (pers. obs.). The relatively higher number of these species in Ladakh (Fox *et al.*, 1991) could be due to a low level of competition with domestic livestock, which has the capability of outcompeting ibex and blue sheep as shown by theoretical (Mishra *et al.*, 2002) as well as empirical studies (Bagchi *et al.*, 2004; Mishra *et al.*, 2004).

The overlap in habitat use by ibex and blue sheep suggests a high potential for competition between them, as habitat overlap can lead to exploitation as well as interference competition (Begon *et al.*, 1996). But comparative data from both sympatric and allopatric populations, encompassing all seasons need to be collected to demonstrate competition. However, given the relatively higher density of blue sheep in ladak, it is possible that this species negatively influences the population and distribution of ibex in the Zangskar Mountains and other areas where they come together.

7. Conclusion

There was substantial overlap in habitat use by ibex and blue sheep, which is in contrast to the prediction of competition theory. Such high overlap in habitat use by the two species in a region with inherently low plant productivity, especially in the resource-limited winter months, suggests a high potential for competition. A thorough understanding of resource selection of both sympatric and allopatric populations of ibex and blue sheep is desirable to assess the level of competition.

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