Seasonal patterns in habitat use of blue sheep *Pseudois nayaur* (Artiodactyla, Bovidae) in Nepal

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Summary. – Blue sheep *(Pseudois nayaur)* are the main prey of the endangered snow leopard *(Panthera uncia)* as well as an important game species in Nepal. A knowledge of how blue sheep utilize their habitat is essential for the scientific management of the sheep and for the conservation of the snow leopard, but we only have a limited understanding of this aspect of blue sheep ecology. I studied the habitat use pattern of blue sheep by direct observation in the Annapurna Conservation Area, Nepal where they occur sympatrically with the snow leopard. The sheep used grassland habitats more frequently during pre-parturition (spring) and post-parturition (autumn) than other habitat types, but scrub and grassland habitats were used equally frequently during the rut (winter). The sheep used smooth undulating slopes of medium steepness ($< 40°$) on southerly aspects within the elevation range of 4,200-4,600 m most frequently in all seasons, and there was no evidence of seasonal migration along the elevation gradient. When not in broken landforms (e.g., cliff, landslides), the sheep maintained proximity (≤ 150 m) to such features suggesting their importance as escape cover (i.e., from predators). The use of habitat components by blue sheep appeared to be related to the distribution of foraging areas and escape cover.

Résumé. – Les bharals sont d'importants gibiers au Népal en plus d'être les principales proies de la panthère des neiges, espèce en danger d'extinction dans ce pays. Il est donc essentiel d'avoir une certaine base de connaissances sur l'utilisation de son habitat par l'espèce pour en permettre une meilleure gestion scientifique, ainsi que la conservation de la panthère des neiges. Cependant nos connaissances sur cet aspect de l'écologie du bharal sont très limitées. J'ai étudié, par observations directes, le modèle d'utilisation de l'habitat du bharal dans l'aire protégée de la région de l'Annapurna, Népal, endroit où les bharals et les panthères des neiges partagent le même habitat. Pendant l'hiver, les bharals ont fréquenté autant les prairies herbeuses que les terrains broussailleux tandis qu'en automne, on les retrouvait majoritairement dans les prairies herbeuses. Ils avaient coutume de fréquenter les versants sud des terrains légèrement ondulés à pente douce (20-40°), et ce à une altitude allant de 4 200 à 4 600 m, indépendamment de la saison. De plus, nous n'avons trouvé aucune preuve de migration saisonnière le long du gradient d'altitude. Lorsqu'ils ne s'y trouvaient pas, les bharals gardaient toujours une certaine proximité (150 m) d'un terrain assez escarpé (e.g., falaise, éboulis), suggérant ainsi l'importance de ces éléments de l'habitat comme protection (contre les prédateurs). On peut donc conclure que leur répartition dans l'habitat serait liée à la disponibilité de la nourriture et à la possibilité de fuir en cas de danger.

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INTRODUCTION

Blue sheep *(Pseudois nayaur)* are medium-sized goats with sheep-like affinities, and their main geographic distribution is restricted to Qinghai-Tibet Plateau and adjacent ranges (Schaller 1977, Wang and Hoffmann 1987). In Nepal, they occur along the southern slope of the greater Himalayas, bordering Tibet where an estimated 10,000 sheep occupy 15,000 km^2 habitat area (Schaller 1977, Wegge and Oli *in press*).

Blue sheep are an important prey of the endangered snow leopard *(Panthera uncia)* in the Himalayas and adjacents ranges (Chundawat and Rawat 1994, Oli *et al.* 1993, Schaller *et al.* 1987, 1988). They also are the most important game species in Nepal, generating a significant proportion of revenue from sport hunting (53.8 % in 1988-89, 57.6 % in 1989-90 ; hunting records of Dep. Natl. Parks and Wildl. Conservation, Nepal). A knowledge of the habitat use pattern of blue sheep is essential for the scientific management of the sheep and for the conservation of the remaining snow leopard populations. However, in Nepal, this information is available only from an area with little predation but substantial hunting pressure (Wegge 1979, Wilson 1981). Here, I report on habitat use of blue sheep in Manang, Nepal, where the sheep are not hunted but are subjected to substantial predation by snow leopards (Oli 1994 a).

STUDY AREA

This study was conducted in the upper Marsyangdi valley of Manang district within the Annapurna Conservation Area, Nepal (28°30' to 28°50' N, 83°50' to 83°5' E). The study area consisted of rugged terrain with slopes of variable steepness. Altitude ranged from 3,600 to over 6,000 m. The study area was situated in the rain shadow of the Annapurna mountain range, and the climate was dry and cold.

The vegetation corresponded to the steppe vegetation type, and consisted of grassland interspersed with scrub. The scrub community on gentle slopes was dominated by *Juniperus squamata,* whereas broken and steeper slopes were dominated by *Caragana gerardiana, C. brevispina, Artemisia* spp., *Lonicera* spp., *Berberis angulosa, Rosa* spp., and *Ephedra gerardiana.* Above 4,800 m, the vegetation was sparse and was dominated by *Rhododendron anthopogon, Potentilla biflora,* and *Saxifraga* spp.

Snow leopards, blue sheep, and red fox *(Vulpes vulpes)* were the only large wild mammals present in the area. All accessible parts of the study area were extensively grazed by local livestock. The sheep in the study area have not been hunted for $\geq$ 15 years, following a hunting prohibition imposed by the local Monastery.

METHODS

Blue sheep were observed during pre-parturition or spring (13 April to 9 may 1990), post-parturition or autumn (10-25 September 1990), and rut or winter (2 January to 28 February 1991). I scanned mountain slopes with 10 x 50 binoculars. Once located, blue sheep groups were observed with a variable magnification (15-60 x) spotting-scope mounted on a tripod. Habitat type, landform type, and slope were determined

through observation. Altitude and aspect were estimated using an altimeter and a hand held compass, respectively.

Three major habitat types were recognized : grassland (smooth to moderately steep slopes with ≥ 20 % grass cover and little rock coverage), scrub (habitats of varied steepness with ≥ 20 % shrub cover and < 20 % grass cover), and barren (habitats with < 20 % vegetation cover regardless of steepness).

Landform features varied considerably within each habitat type. Thus, I recognized 5 landform types based on rock coverage and steepness : smooth undulating slopes (SUS ; slopes of gradient < 45° and rock coverage < 25 %), moderately broken slopes (MBS ; slopes of 25-45° with < 50 % rock coverage), distinctly broken slopes (DBS ; slopes of gradient > 25° and ≥ 50 % rock coverage), scree/landslide (slopes with rock-falls and landslides, gradient generally > 45°), and cliff (steep rock-face, steepness > 45°, and rock coverage ≥ 70 %).

Habitat and landform types, altitude, slope, and aspect were noted for each group of blue sheep observed. When a group was observed in two adjacent habitats, the assigned habitat was that where the majority of the sheep were seen. Frequency distribution of sheep groups in different habitat features was used to determine the habitat use pattern in the 3 seasons of the study. Log-likelihood ratio or G-test was used to test for seasonal differences in the use of habitat features. Categories of habitat features were combined if > 1 cell had expected frequencies of < 5. Statistical analyses were performed with Statistical Analysis System (SAS Institute, Inc. 1988), and results were considered significant at $\alpha = 0.05$. Lack of data on the availability of habitat components made it impossible to perform preference analyses or to identify habitat features that are critical to blue sheep survival and reproduction.

An estimated 697 to 1,071 sheep occupied the 105 km² study area, a density of 6.6 to 10.2/km² (Oli 1994 a). Other aspects of blue sheep population ecology are reported by Oli (1991).

RESULTS

Blue sheep used grassland more frequently than scrub or barren habitats during pre-parturition and post-parturition, but grassland and scrubs were used equally frequently during the rut. Thus, there was a significant seasonal variation in the use of habitat types (Table 1). The use of habitat during the rut differed from that in pre-parturition ($G = 8.772$, 2 df, $p = 0.012$) and post-parturition ($G = 13.644$, 2 df, $p = 0.001$), but the pattern of habitat use during pre-parturition was similar to that in post-parturition ($G = 1.733$, 2 df, $p = 0.420$).

Over 37 % of blue sheep groups were observed on smooth undulating slopes in all seasons, making it the most frequently used landform type (Table 1). The use of landform types did not vary seasonally (Table 1), nor did any season differ from others with respect to landform use (pre-parturition vs. post-parturition : $G = 2.725$, 4 df, $p = 0.605$; pre-parturition vs. rut : $G = 0.382$, 4 df, $p = 0.984$; post-parturition vs. rut : $G = 3.474$, 4 df, $p = 0.482$).

The mean (± S.E.) elevation of sheep distribution was 4,423.7 m (± 26.7), 4,499.5 m (± 22.7), and 4,463.1 m (± 19.6) during pre-parturition, post-parturition, and rut, respectively. Elevations between 4,200-4,600 m were most frequently used ; > 53 % of blue sheep groups were observed within this range in all seasons. There was no significant seasonal variation in the use of elevation (Table 1). The use of elevation

during pre-parurition was similar to that in post-parturition (G = 1.442, 4 df, $p = 0.837$) and the rut (G = 9.34, 4 df, $p = 0.053$) ; the pattern was different between the rut and post-parturition (G = 12.884, 4 df, $p = 0.012$).

The sheep used moderately steep slopes ($< 40^{o}$) most frequently during pre-parturition (55.4 %) and post-parturition (60.0 %), but the use of steeper slopes (40-60°) increased during the rut (47.2 %). Although the seasonal variation in the use of slope was not significant (Table 1), pair-wise comparison detected differences between rut and pre-parturition (G = 6.414, 2 df, $p = 0.040$), and rut and post-parturition (G = 6.354, 2 df, $p = 0.042$). The use of slope during pre-parturition and post-parturition did not differ (G = 0.201, 2 df, $p = 0.904$).

Habitats on southerly aspects (90-270° azimuth) were most frequently used ; 69.2 %, 81.6 %, and 80.3 % of blue sheep groups were observed on southerly aspects during pre-parturition, post-parturition, and rut, respectively. The pattern of habitat use with respect to aspect varied seasonally (Table 1). The use of aspect during pre-parturition differed from that in post-parturition (G = 11.424, 3 df, $p = 0.010$). No difference in the use of aspect was detected between rut and pre-parturition (G = 6.811, 3 df, $p = 0.078$), and rut and post-parturition (G = 2.705, 3 df, $p = 0.439$). Northerly aspects was less frequently used in all seasons (Table 1).

DISCUSSION

The relatively high frequency of use of grassland habitats on smooth undulating slopes of medium steepness within the elevational range of 4,200-4,600 m appeared to be associated with the distribution of foraging areas ; most grasslands in the study area were located within the limits of these parameters. The low frequency of use of lower elevations was likely because of human disturbance (e.g., firewood and wild garlic collection, grazing, and trekking) ; the avoidance of habitats at higher elevations (> 4,800 m) was apparently because of little vegetation. The increased use of scrub habitat during rut was probably a response to a decreased availability of foraging areas in grassland habitats due to the presence of snow. Scrubs were only partially covered by snow and on steeper slopes, they were exposed by wind relatively quickly compared to grasslands. Durings such periods, shrubs, particularly *Caragana* spp., *Rosa* spp., and *Ephedra* spp., were the only food sources available to the sheep, and this explains an increased use of scrubs during winter. The use of grassland increased, however, when snow melted or grassy slopes were exposed by wind. A consistently large proportion of mixed groups in all seasons indicated that sexes did not segregate during this study (Oli 1991), and there was no evidence of sex-dependent differential use of habitat components.

Qualitative field observations suggested that blue sheep maintained proximity (≤ 150 m) to broken landforms (e.g., cliffs, landslides, boulders) when they were not observed in such features. Similar observations were reported by Chundawat (1992) from the Hemis National Park, India. I infer from these observations that broken landforms are an important habitat component and are probably used as escape cover by blue sheep. This inference is further augmented by the observation that blue sheep seldom used some extensive grasslands with little or no rock coverage. Wegge (1979) reported that blue sheep group size increased with an increasing distance from the nearest escape cover, and a similar trend was detected from casual observations in this study. Living in larger groups when not in proximity to adequate escape cover may

TABLE 1. – Frequency distribution of blue sheep groups by habitat features in Manang, Nepal, 1990-91. Values of G-statistic (G), degrees of freedom (df), and observed significance level (p) also are given for each habitat feature.

Habitat features*	Pre-Parturition	Post-parturition	Rut	G	df	p
A. Habitat type				16.87	4	0.002
Grassland	37	23	28			
Scrub	11	3	28			
Barren	18	12	16			
B. Landform type				4.24	8	0.835
Smooth undulating slope	26	15	27			
Moderately broken slope	18	10	23			
Distinctly broken slope	8	4	10			
Scree/landslide	8	3	8			
Cliff	4	6	4			
C. Altitude (m)				14.99	8	0.059
<4,200	10	6	11			
4,200-4,400	17	7	28			
4,400-4,600	19	13	23			
4,600-4,800	15	8	10			
>4,800	4	4	0			
D. Slope (°)				9.18	4	0.057
<40	36	21	25			
40-60	23	11	34			
>60	6	3	13			
E. Aspect (°)				14.27	6	0.027
0-90	9	7	11			
90-180	24	14	26			
180-270	21	17	31			
270-360	11	0	3			

* See text for definitions.

minimize the predation risk on individual sheep through an increased vigilance and alertness, and dilution effect (Treisman 1975 a, Treisman 1975 b, Vine 1971).

In Dhorpatan, Nepal, blue sheep preferred habitats equivalent to grasslands in smooth undulating slopes of medium steepness in this study (Wegge 1979, Wilson 1981). Wilson (1981) reported that blue sheep in Dhorpatan, Nepal, moved to higher elevations between October and December, whereas Chundawat (1992) found that the sheep in the Hemis National Park, India, moved to higher elevations in summer. I found no evidence of seasonal shift in the use of elevation. Site-specific differences in habitat characteristics and human activities may explain observed discrepancies. Nonetheless, all studies of blue sheep habitat use concur in that the pattern is determined by

the distribution of foraging areas and escape cover (Chundawat 1992, Harris and Miller 1995, Wilson 1981, this study) which may vary between sites depending upon local habitat conditions, juxtaposition, and human disturbance.

Depletion of blue sheep and other wild ungulate populations has adversely affected snow leopards in many parts of the leopard's range (e.g., Schaller *et al.* 1988, Schaller *et al.* 1994). This also has resulted in an increased predation of domestic livestock by snow leopards thereby fueling the conflict between livelihoods of local pastoral communities and snow leopard conservation goals (Oli 1994 b, Schaller *et al.* 1994). The success of a snow leopard conservation programme in many parts of the leopard's range will, therefore, largely depend on the effective management of blue sheep populations for which an adequate understanding of their habitat requirements is a prerequisite.

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