Towards snow leopard prey recovery: understanding the resource use strategies and demographic responses of bharal Pseudois nayaur to livestock grazing and removal



Final project report submitted by Kulbhushansingh Suryawanshi Nature Conservation Foundation, Mysore Post-graduate Program in Wildlife Biology and Conservation, National Centre for Biological Sciences, Wildlife Conservation Society –India program, Bangalore, India To

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1. Executive Summary:

Decline of wild prey populations in the Himalayan region, largely due to competition with livestock, has been identified as one of the main threats to the snow leopard Uncia uncia. Studies show that bharal *Pseudois nayaur* diet is dominated by graminoids during summer, but the proportion of graminoids declines in winter. We explore the causes for the decline of graminoids from bharal winter diet and resulting implications for bharal conservation. We test the predictions generated by two alternative hypotheses, (H1) low graminoid availability caused by livestock grazing during winter causes bharal to include browse in their diet, and, (H2) bharal include browse, with relatively higher nutrition, to compensate for the poor quality of graminoids during winter. Graminoid availability was highest in areas without livestock grazing, followed by areas with moderate and intense livestock grazing. Graminoid quality in winter was relatively lower than that of browse, but the difference was not statistically significant. Bharal diet was dominated by graminoids in areas with highest graminoid availability. Graminoid contribution to bharal diet declined monotonically with a decline in graminoid availability. Bharal young to female ratio was three times higher in areas with high graminoid availability than areas with low graminoid availability. No starvation-related adult mortalities were observed in any of the areas. Composition of bharal winter diet was governed predominantly by the availability of graminoids in the rangelands. Since livestock grazing reduces graminoid availability, creation of livestock free areas is necessary for conservation of grazing species such as the bharal and its predators such as the endangered snow leopard in the Trans-Himalaya.

2. OBJECTIVES

2.1 Introduction

Increasing human population and human disturbance are well understood to be key drivers of declining large carnivore populations across the world (Weaver *et al.* 1996). But, Implementation of proper management policies can make conservation of large carnivores possible even in areas with high human densities (Linnell *et al.* 2001). Declining wild prey populations is the other important factor affecting numbers of large carnivores (Karanth *et al.* 2004). Decline of wild prey populations in the Himalayan region, largely due to competition with livestock, has been identified by the SLSS as one of the main threats to the snow leopard (McCarthy and Chapron 2003). Though there are numerous studies examining prey-predator relationship, very few of these have paid attention to the dependence of carnivore densities on their prey densities. Facilitation of wild prey recovery is the only solution to the problem of declining wild prey populations.

In most regions of the world, livestock is found sympatric with wild ungulates (Prins 1992). Co-existence of ungulates that depend on similar resources has puzzled ecologists for a long time. Owing to the long term nature of such studies and the logistic difficulties in measuring competition between sympatric herbivores, the issue has however received little attention. Close interactions between wild herbivores and domestic cattle also fueled ecological research examining the effects of livestock grazing on plant communities and other sympatric wild herbivores (Bokdam & Gleichman 2000; Hobbs *et al.* 1996). Studies often measured resource overlap between different herbivores but failed to explain whether competition or resource sharing was occuring. It is thus difficult to

establish the nature of interaction between livestock and wild herbivores. The evidence suggesting decline in reproductive performance of herbivores due to density dependant forage decline (Guinness & Albon 1982 in Mishra *et al.* 2004) and the data suggesting decline in forage availability for wild herbivores because of high densities of domestic livestock is often ignored.

Recent research from the tropical forests of south India shows that exclusion of livestock facilitates rise in wild herbivore population (Madhusudan 2004). Recent studies on Tibetan argali *Ovis amon hodgsoni*, Himalayan ibex *Capra sibirica* and bharal *Pseudois nayaur* from the Indian Trans-Himalaya have examined various facets of livestock and wild herbivore competition. Argali showed behavioral responses to presence of livestock by moving to higher and steeper slopes with poor forage quality, indicating competitive displacement (Namgail *et al.* 2006). There is also empirical evidence indicating competition between Himalayan ibex and four out of seven livestock species for forage (Bagchi *et al.* 2004).

Recent research concludes that the decline of important prey species such as the bharal (Oli 1994) and ibex is due to competition with livestock (e.g. Mishra *et al.* 2004, Bagchi *et al.* 2004). Bharal populations in areas with high densities of livestock also showed show poor infant to female ratios (Mishra *et al.* 2004). Wild prey declines also have a cascading effect, intensifying human-snow leopard conflicts by increasing carnivore dependence on livestock (Bagchi & Mishra 2006). Facilitating wild prey recovery is

therefore an important management priority for snow leopard conservation, and the SLSS underscores the need for supporting relevant research to achieve this.

Wild prey recovery in the Himalaya is complicated by the pastoral activities of communities living in the snow leopard's range. Can the population recovery of wild mountain ungulates be achieved alongside some amount of livestock grazing? If so, to what extent? Can domestic grazing strategies be modified to enhance snow leopard conservation without compromising people's livelihoods? To answer these questions, it is important to understand whether or not, and how, the bharal and ibex are able to cope with forage limitation imposed by livestock. What kind of resource-use strategies do they employ to mitigate the effects of disturbance and the reduced availability of forage due to livestock, particularly in winter which is the lean season for forage availability? As four fifths of the rangelands in the Spiti valley of Himachal Pradesh are overstocked (Mishra, Prins & Van Wieren 2001), understanding bharal foraging strategies in the presence and absence of livestock gains additional importance. In this light I propose this study to examine overwintering strategies that bharal employ to meet their resource requirements during the resource lean period and its effects on demography of bharal.

2.2 Objectives

Five of the six previous studies on bharal have shown that graminoids form the dominant forage type in bharal diet in summer (see Shrestha, Wegge & Koirala 2005). While all these studies suggest that bharal are adapted for a graminoid diet type, studies also reported that the graminoid contribution to bharal diet drops to 50% during winter

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(Mishra *et al.* 2004). Two questions emerge: (I) why do bharal, seemingly adapted to a graminoid diet include large amounts of browse in their winter diet? Is it due to competition with livestock for graminoids or is it because of the seasonal change in the chemical composition of plants? And (II) what are the consequences of this shift in diet for bharal population dynamics?

In this study I explore the causes of the decline in graminoids and increase of browse in the bharal diet during winter. I examine two alternate hypotheses to explain the decline of graminoids in bharal diet - H1: Low graminoid availability due to competition with livestock causes bharal to include browse in their diet, and H2: Bharal include browse, with relatively higher nutrition, to compensate for the poor quality of graminoids during winter. H1 predicts that in areas where graminoid availability is relatively high in winter, bharal will continue to be grazers. On the other hand, H2 predicts that bharal diet will have a high proportion of browse even in areas with high graminoid availability to compensate for the poor graminoid quality. H1 also predicts that bharal populations in areas with high graminoid availability will perform better. In contrast the latter predicts that bharal populations will perform better in areas where bharal can optimise diet quality.

I tested these predictions by comparing bharal diet composition in areas with varying graminoid availability in a semi-experimental framework. Chemical composition of all plant species contributing to bharal diet during winter was also analysed to determine nutrient content of available forage species.

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Map showing boundaries of the three grazing treatments. Inset shows the location of the Kibber Wildlife Sanctuary in India (top right).

Google Earth URL: <u>http://earth.google.com/intl/en/GooleEarth4.3</u>. 2008. GeoEye TerraMetrics (image taken on 7th January 2007) (Accessed on 30th June 2008)

3. Methods

3.1. Study Area: The study was carried out in the Kibber Wildlife Sanctuary (32°15′-32°22′ N, 78°02′-78°13′ E), Spiti district, Himachal Pradesh, India. The Sanctuary is located along the plateau on the northern banks of the Spiti river. The intensive study area had an altitudinal range from 3800 m to 5000 m. The terrain was mainly rolling hills broken occasionally by rocky cliffs and outcrops. During winters the temperature drops to -35° C. Summer has mean maximum temperatures around 25° C. Precipitation is mainly in the form of winter snow, which starts to melt around late March.

The vegetation is 'dry alpine steppe' (Champion & Seth 1968). Very few shrubs exceed a height of one meter. The vegetation is mainly dominated by shrubs such as *Caragana brevifolia* and *Lonicera spinosa*. Graminoids are represented by species of *Stipa, Carex, Kobresia, Elymus,* and *Festuca* etc. Botanical nomenclature in this paper follows Aswal & Mehrotra (1994).

The people of the region are mainly agro-pastoralists. Green peas, black peas and barley form the main agricultural crops. Domestic livestock include goats, sheep, horses, donkeys, cows, and yak and cow-yak hybrids. Sympatric wild herbivores of the region include ibex *Capra sibirica* and hare *Lepus oiostolus*. Predators of bharal include large carnivores such as snow leopard *Uncia uncia*, Tibetan wolf *Canis lupus chanco* and Golden Eagle *Aquila chrysaetos*.

The study area consisted of three levels of livestock grazing intensity; ungrazed, moderately grazed and heavily grazed. The ungrazed area consisted of a relatively large village reserve (15-20 km²) established as part of a conservation program (led by the Snow Leopard Trust and Nature Conservation Foundation) and protected from livestock grazing since 2005 (two-thirds of the village reserve area) and 1999 (one third of the reserve area), with bharal being the only wild ungulate therein. Among the livestock grazed areas I identified two similar adjoining pastures that differed by at least 50 % in

their livestock density (Table 1). The less grazed of the two areas was used as moderately livestock grazed treatment while the other was intensely livestock grazed treatment. The treatments were adjoining each other. Because of the large size of the treatments I expected the bharal populations to have distinct identities across the treatments.

Livestock grazing pressure	Altitude (m)	Livestock grazing pressure kg km ⁻²		Total area (km²)
-		Summer	Winter	
None	3800-5000	Nil	Nil	20
Moderate	3900-4900	1326	337	34
Intense	3800-4700	2163	721	16

Table 1. Stocking densities of livestock in three grazing treatments in the study area

3.2. Methods:

3.2.1. Estimating forage availability: I estimated forage availability from biomass of grass and herbs and ground cover, during early winter between 5th and 30th December 2007. Above ground graminoid and herb biomass was clipped from 87 randomly laid plots, each 3 m x 3m (n=40 in un-grazed, n=30 in moderately grazed and n=17 in intensely grazed treatment). Graminoids and herbs were separated, weighed fresh and oven dried. Shrubs were not clipped. Plant height was expected to affect forage availability after events of snowfall, so I measured the tallest height of all plant species in reserve and moderately grazed treatments. A similar system of systematic plots with a random start was followed. The height of the tallest plant of each species within the plot was measured. Ground cover was recorded from 30 to 50 points at 50 cm intervals along 210 transect lines, Plant species, bare ground or rock touching each point along the transect line was recorded. The lines were systematically placed with a random start.

3.2.2. Estimating diet of bharal: Bharal were located and observed from a distance of about 50 m with a pair of 8×32 (Olympus) binoculars and a 20-60×60 spotting scope (KONUSPOT 60s). After the bharal had moved away, the feeding site was examined for fresh feeding signs. A 3×3 m plot was laid at the intensive feeding site. Any species covering >10% of ground and with >50% feeding was given a score of 2, and species covering <10% of the feeding area with most individuals been fed on or species with abundant cover but with only few individuals been fed on were scored as 1. Species that were not fed on were scored 0, following Mishra *et al.* (2004) (n=81 in reserve, n=122 in moderately grazed and n=170 in intensely grazed).

3.2.3. Sampling for chemical composition of plant species: Samples of each species that was fed on by bharal were clipped from four randomly selected locations every month from each of the three treatments. These samples were oven dried, homogenised and analysed for: 1. Total Ash; 2. Crude fat; 3. Crude protein (Kjeldahl nitrogen \times 6.25); 4. Crude fibre; 5. Acid detergent fibre (ADF); 6. Acid detergent lignin (ADL) following AOAC (1990). Neutral detergent fibre (NDF) was calculated following Van Soest, Robertson & Lewis (1991).

3.2.4. Population estimation: I did a total count to assess bharal population structures across the three treatments. The census was conducted on 2^{nd} April 2008. Each treatment was thoroughly searched by two teams of two persons independently. The census was conducted from horseback, on foot and from all terrain vehicles. After encountering a

group their location and structure was recorded. Bharal were classified as per Mishra *et al.* (2004).

3.3. Data Analysis: Each clipped plot was used as a sampling unit to calculate mean above ground forage biomass across treatments. I used each feeding site of bharal as a sampling unit to assess bharal diet. Scores for each plant species were added and divided by the sum of all the scores across all species which gave me the proportionate contribution of each plant species to bharal diet following Mishra *et al.* (2004). The 95% confidence limits for mean above ground biomass and bharal diet composition were calculated through Monte-carlo simulations. I carried out 1000 permutations with repeated draws from the observations with replacement (Krebs 1989) to calculate the parameter of interest. The percent nutrient content of bharal diet was assessed as a product of bharal diet composition and nutrient content of each plant species in bharal diet. The 95% confidence limits were calculated by assessing the nutrient content of the 1000 permutations obtained from repeated draws of bharal diet composition with replacement from the observations.

Analysis of variance (ANOVA) was used to asses the difference in the number of plant species in the diet among various treatments. Welch two sample t-test was used to asses the differences in plant heights across moderately grazed and reserve treatments.

I grouped food species into graminoids, herbs, sub-shrubs (shrubs < 50 in height) and shrubs. The groups comprised of the following species:

Graminoids: *Stipa orientalis, Elymus longe-aristatus, Carex sp.* and *Leymus secalinus.*

Herbs: *Astragalus grahamiana*, unidentified herb A (unid A), *Cousinia thomsonii, Lindelophia anchusoides*, unidentified herb B (unid B), *Bupleurum candollei, Ephedra gerardiana*, unidentified herb C (unid C) and *Hieracleum thomsonii*.

Shrubs: Ribes orientale, Rosa webbiana.

Sub-shrubs: Caragana brevifolia, Eurotia ceratoides.

I assessed the suitability of plant species for bharal by examining their foraging preferences following Vanderploeg & Scavia (1979). The electivity index E^* was calculated as:

$$E_i^* = [W_i - (1/n)]/[W_i + (1/n)],$$

where *n* is the number of plant species

$$W_i = (r_i / p_i) / \sum (r_i / p_i),$$

The proportion of i^{th} plant species in the diet is denoted by r_i and the proportion available is denoted by $p_{i.}$

Electivity index value for any forage species close to zero indicated that bharal fed on the species in proportion to its availability, while negative values indicated avoidance and positive values indicated preference for the species. For the electivity analysis, I converted the data into a presence/absence and fed/not fed format. If a particular plant species was present at a feeding site it was scored one for presence in the sample. If a species was present and had been fed on by bharal then it was scored one for feeding in the sample. The proportional availability (p_i) of a particular species *i* was calculated as:

$$p_i = x_i / y$$

Where x_i is the number of sites where i^{th} plant species was present and y is the sum of x for all i

The proportion of the species *i* in the diet (r_i) was calculated as:

$$r_i = v_i / w$$

Where v_i is the number of sites where i^{th} plant species was foraged upon by bharal and y is the sum of v for all *i*

The data were pooled within plant types to calculate the electivity index for each plant type.

The difference across treatments in the ratio of yearlings to adult females (an indirect measure of population performance or fecundity) was tested through repeated sampling. I bootstrapped the census data with each herd as a sampling unit. 1,00,000 permutations of sample sizes equal to those observed in the field were drawn with replacement from the pool of all the bharal herds encountered in the census across all the three treatments. The number of times the yearling to female ratio from these randomly drawn samples showed a difference as large as the one observed in the field was recorded. These were the chance events, and their proportion in the 1,00,000 permutations was the probability of observing the difference due to random chance alone.

4. Results

4.1. Forage availability and vegetation structure: The mean above ground dry graminoid biomass was 15.6 kg ha⁻¹ (95% confidence interval 10.6-22.3 kg ha⁻¹), 18.4 kg ha⁻¹ (14.8-22.7 kg ha⁻¹) and 7.1 kg ha⁻¹ (5.6-9.1 kg ha⁻¹) in the reserve, moderately grazed and intensely grazed treatments respectively (Fig. 1.a). The mean above ground dry herb biomass was 26.4 kg ha⁻¹ (19.6-33.7 kg ha⁻¹), 36.1 kg ha⁻¹ (23.7-51.9 kg ha⁻¹) and 22.1 kg ha⁻¹ (17.7-26.7 kg ha⁻¹) in the reserve, moderately grazed treatments

respectively (Fig 2). The ground cover was dominated by bare soil and rock in all the three treatments. Vegetation cover was highest in the Reserve (31.2%) followed by moderately grazed (28.37%) and intensely grazed (11.09%) treatments. Sub-shrubs dominated vegetation cover with over 90% of vegetation representation in the reserve, 76% in moderately grazed and only 26% in intensely grazed (Fig. 1.b).

Plant height data were collected on the four commonest plant species (one graminoid, one herb and two sub-shrubs) from two treatments (reserve & moderately grazed) that had similar above ground biomass. Height of *S. orientalis* (graminoid) was significantly different between reserve and moderately grazed treatments while there was no difference in the height of sub-shrubs. The mean height of *S. orientalis* (graminoid) was 10.8 and 5.5 cm in reserve and moderately grazed treatments respectively, the differences grass height across the two treatment was statistically significant (t = -3.08, P = 0.009) (Fig. 3). The differences were not significant for any other plant species, *C. brevifolia* (t = -0.94, P = 0.36), *E. ceratoides* (t = -1.49, P = 0.14), *B. candollei* (t = -0.63, P = 0.58). As a result of the taller grass (*S. orientalis*) in reserve treatment I expect the availability of graminoids to be higher in reserve treatment than in moderately grazed treatment and the least in the intensely grazed treatment.



Fig.1. (a) Mean winter graminoid biomass, and (b) Percent ground cover in livestock ungrazed (reserve), moderately grazed and intensely grazed treatments during winter in Sipti, India. Error bars in (a) represent asymmetric 95% confidence limits, based on clipped plots as sampling units.



Fig.2. Mean winter herb biomass in livestock ungrazed (reserve), moderately grazed and intensely grazed treatments during winter in Sipti, India. Error bars represent asymmetric 95% confidence limits, based on clipped plots as sampling units.



Fig.3. Mean plant height in livestock un-grazed (Reserve) and livestock moderately grazed (Moderate) treatments. White and shaded represent reserve and moderately grazed respectively. Error bars represents \pm one standard error.

4.2. Chemical composition of forage plant species (Nutrients available):

Bharal winter forage plant species were analysed for seven nutritional parameters. Subshrubs had highest amount of crude protein but the differences were not significant. Herbs had higher ash content than shrubs and sub-shrubs but only marginally higher than graminoids. The crude fat content of all types of plants was relatively similar. Crude fibre and NDF content of shrubs was lower than other plant types. There were no significant differences among the ADF and ADL content of the four plant types (Table 2 & 3). Welch two sample t-test was used to test for significance of differences. None of the plant types differed significantly in any of the seven parameters. Altogether there was no significant difference in the nutritional quality of any of the four plant types.

Table 2. Various nutritional parameters of plants that contributed more than one percent to bharal winter diet in Spiti, Himachal Pradesh, India. Figures in the table are percent content of the particular parameter (column) per unit dry matter of the species (row). In the first column capital letter(s) following plat species name inside parenthesis denote G, Graminoids; H, Herbs; S, Shrubs; SS, Sub-shrubs.

Plant species	Total	Crude	Crude	Crude	Neutral	Acid	Acid
	ash	fat	fibre	protein	detergent	detergent	detergent
					fibre	fibre	lignin
					(NDF)	(ADF)	(ADL)
Lindelophia	23.2	1.38	18.81	5.22	42.9	37.33	17.52
anchusoides.(H)							
Stipa orientalis (G)	7.18	2.80	27.66	2.44	68.75	36.84	16.03
Caragana brevifolia (SS)	5.93	2.19	34.25	7.64	66.3	46.52	11.20
Elymus longe-aristatus (G)	3.97	0.75	38.26	1.62	78.99	45.59	17.08
Unidentified herb B	3.97	0.25	36.79	0.80	80.30	63.78	22.82
Eurotia ceratoides (SS)	4.05	1.02	30.80	3.65	80.56	57.99	23.72
Bupleurum candollei (H)	2.52	1.61	36.60	4.43	76.73	57.26	16.90
Astragalus grahamiana (H)	4.31	1.06	27.13	2.41	69.94	52.08	17.62
Cousinia thomsonii (H)	11.77	1.17	30.91	4.43	52.14	40.95	13.94
Leymus secalinus (G)	8.31	0.97	37.35	1.62	75.83	48.63	09.69
Rosa webbiana (S)	3.78	1.07	30.15	2.80	53.73	41.46	22.64
Ribes orientale. (S)	5.65	1.17	25.33	2.03	52.59	45.51	15.07
Ephedra gerardiana (H)	6.06	0.35	31.04	1.63	44.04	27.17	23.08
Unidentified herb A	6.58	2.00	32.49	4.02	65.37	41.92	14.22
Hieracleum thomsonii (H)	4.67	2.36	37.73	2.81	70.98	52.78	15.84
Unidentified herb C	13.35	2.18	33.93	1.62	70.65	41.01	10.20
Carex sp. (G)	3.03	1.94	36.45	2.85	73.48	56.03	25.59

	Total ash	Crude fat	Crude	Crude	NDF	ADF	ADL
			protein	fibre			
Graminoids	5.6 (1.1)	1.6 (0.4)	2.1 (0.2)	34.9 (2.1)	74.3 (1.8)	46.8 (3.4)	17.1 (2.8)
Shrubs	4.7 (0.6)	1.1 (0.03)	2.4 (0.2)	27.7 (1.7)	53.2 (0.4)	43.4 (1.4)	18.9 (2.6)
Sub-shrubs	4.9 (0.6)	1.6 (0.4)	5.6 (1.4)	32.5 (1.2)	73.4 (5.0)	52.3 (4.0)	17.5 (4.4)
Herbs	8.5 (2.1)	1.4 (0.2)	3.0 (0.5)	31.7 (1.9)	63.7 (4.3)	46.0 (3.5)	16.9 (1.2)

Table. 3. Nutritional parameters of plants types during winter in Spiti, Himachal Pradesh, India. Figures in the table are percent dry weight content (one standard error) of the particular parameter (column) for every plant type (row).

4.3. Winter diet of bharal: During the study, 34 plant species were recorded from bharal feeding sites. Twenty seven of these had been fed on at least once. Only 16 plant species contributed more than one percent each to the winter diet, which consisted of 46.2% graminoids, 17.8% sub-shrubs, 32.3% herbs and 4.4% shrubs. Graminoid contribution was highest in the reserve (74.3%), 49.7% in the moderately grazed treatment and 36.6% in the intensely grazed treatment (Fig. 4.). The proportion of herbs was equal in the reserve and in the moderately grazed area at 10%, but over 50% in intensely grazed treatment; (40%). In the reserve a single species of grass, *S. orientalis* formed 56% of the diet.

ANOVA (unequal n) for number of species available per feeding site as dependant variable and grazing treatments as fixed factors showed significant differences (d.f. = 2, F = 5.21, p = 0.005). Plants species available per feeding site were highest in the intensely grazed treatment followed by the moderately grazed treatment and reserve treatment. Similar analysis for number of species in bharal diet per sample also differed significantly (d.f. = 2, F = 2.23, p < 0.0001). Bharal fed on greater number of species in the intensely grazed treatment.



Fig.4. Winter diet composition of bharal in reserve, moderately grazed and intensely grazed treatments in Spiti, India. Error bars indicate 95% confidence limits, based on each feeding site examination as a sampling unit.

Table 4. The contribution (%) of different plant species which formed 95% of the winter diet of bharal in the livestock ungrazed reserve, moderately grazed and intensely grazed treatments in Spiti, India. G, Graminoids; H, Herbs; S, Shrubs; SS, Sub-shrubs. a- absent from the habitat

Plant species	Overall winter	Reserve	Moderately	Intensely
			grazeu	grazeu
Ribes orientale. (S)	0.6	0.0	А	1.8
Astragalus grahamiana (H)	0.7	А	1.8	0.4
Unidentified herb A (H)	0.7	А	A	2.2
Cousinia thomsonii (H)	1.2	А	1.2	2.6
Lindelophia anchusoides (H)	1.4	А	0.6	3.6
Unidentified herb B (H)	1.6	1.2	0.3	3.5
Bupleurum candollei (H)	2.3	3.8	0.9	2.2
Ephedra gerardiana. (H)	2.3	0.6	0.9	5.5
Rosa webbiana (S)	2.4	А	А	7.5
Unidentified herb C (H)	3.5	А	А	10.8
Carex sp. (G)	3.6	А	7.4	3.5
Elymus longe-aristatus (G)	5.7	10.2	4.7	2.2
Leymus secalinus (G)	7.4	5.7	6.2	10.4
Caragana brevifolia (SS)	7.8	8.3	15.1	0.2
Hieracleum thomsonii (H)	8.0	1.9	5.0	17.2
Eurotia ceratoides (SS)	10.8	9.0	21.0	2.6
Stipa orientalis (G)	35.1	56.4	28.7	20.3
Others	4.2	2.6	6.2	3.8

Electivity index calculated following Vanderploeg and Scavia (1979) was positive for all the four species of graminoids and four species of herbs, namely Unid C, *H. thomsonii, L. anchusoides* and *E. gerardiana*, indicating selective preference for these species. All other herbs, shrubs and sub-shrubs had negative values, and thus were eaten less in proportion to their availability *E. ceratoides* one of the sub-shrub had an index very close to zero (electivity index $E^* = -0.03$) indicating feeding in proportion of availability of the species.

Among plant types, the index was positive only for graminoids ($E^* = 0.28$), while it was negative for shrubs ($E^* = -0.30$) and sub-shrubs ($E^* = -0.27$) and close to zero ($E^* = -$ 0.003) for herbs (Fig 5). Electivity indices for herbs, sub-shrubs and shrubs in presence of graminoids at the feeding site were $E^* = 0$, $E^* = -0.31$ and $E^* = -0.27$ respectively which increased to $E^* = 0.04$, $E^* = -0.14$ and $E^* = 0.05$ respectively in absence of graminoids (Fig 6). The change in electivity index for sub-shrub from $E^* = -0.31$ to $E^* = 0.05$ indicates that sub-shrubs were the most preferred plant types for bharal in absence of graminoids. The electivity index (E^*) remained constant in presence and absence of herbs, sub-shrubs and shrubs from the feeding site. This result indicates that presence/absence of graminoids affected bharal foraging decisions disproportionately compared to the presence absence of other plant types.



Fig.5. Electivity indices (E*) calculated following Vanderploeg and Scavia (1979) for plant groups contributing more than one percent to bharal diet. Positive values indicate preference for a species while negative values indicate avoidance. Values closer to zero indicate feeding in proportion to availability.



Fig.6. Electivity indices (E*) calculated following Vanderploeg and Scavia (1979) for plant groups a) using sites with graminoid presence b) using areas with graminoid absence. Positive values indicate preference for a species while negative values indicate avoidance. Values closer to zero indicate feeding in proportion to availability. G, Graminoids; H, Herbs; S, Shrubs; SS, Sub-shrubs.



Fig.7. Electivity indices (E*) calculated following Vanderploeg and Scavia (1979) for plant species contributing more than one percent to bharal diet. Positive values indicate preference for a species while negative values indicate avoidance. Values closer to zero indicate feeding in proportion to availability. G, Graminoids; H, Herbs; S, Shrubs; SS, Sub-shrubs.

4.4. Nutrient contents of bharal winter diet:

Nutrient content of bharal diet was calculated as the product of the nutrient content of each plant species and the contribution of the plant species to bharal diet in each of the three treatments. Nutrient (total ash + crude protein) content of bharal diet did not show any difference across the treatments (Fig.7 & 8). The percent NDF, ADF, ADL and crude fibre content of bharal diet also did not show any significant differences across the treatments. These results show that the nutrition available to bharal across the three treatments was constant.



Fig.8. Percent nutrient (total ash + crude protein) content of bharal diet during winter across livestock ungrazed, livestock moderately grazed and livestock intensely grazed treatments in Spiti, Himachal Pradesh. Error bars represent 95% confidence limits calculated based on each feeding site as a sampling unit.



Fig.9. Crude fibre, Neutral detergent fibre (NDF), Acid detergent fibre (ADF) and Acid detergent lignin (ADL) content in bharal diet during winter in Spiti, Himachal Pradesh. Error bars represent \pm one standard error.

4.5 Population structure: The yearling to adult female ratio was 0.9, 0.24 and 0.28 in the reserve, moderately grazed and intensely grazed treatments respectively. The difference between the reserve and other two treatments was significant (p < 0.0001; bootstrap, 100,000 permutations). The difference between the yearling to female ratio across moderately grazed and intensely grazed treatments was not significant (Table 5).

Table 5. Population structure of bharal *Pseudois nayaur* in livestock ungrazed, moderately grazed and intensely grazed rangeland in Spiti, Indian Trans-Himalaya. Figures in parenthesis in the first row are the number of herds of bharal recorded in the respective treatment.

	Reserve (7)	Moderately grazed (7)	Intensely grazed (6)
Adult females	21	21	36
Yearlings	19	5	10
Class I to IV male	17	31	48
Yearling 100 females ⁻¹	90	24	28
Total	57	57	94

5. Discussion

In this study I tested the predictions of two alternative hypotheses to explain the decline of graminoids in bharal diet during winter. Our results were in agreement with the hypothesis that low graminoid availability due to competition with livestock causes bharal to include browse in their diet, as bharal diet in winter continued to be dominated by graminoids in areas with higher graminoid availability and low livestock pressure. In rangelands where graminoid availability was lower, bharal tended to include more browse in the diet. The selection of graminoids by bharal in spite of their relatively lower crude protein, and moderate ash content indicates that nutritional levels of plant types had little influence on bharal winter diet selection. These results suggest that the availability of graminoids determines bharal diet composition, and the quality of non-graminoids does not have a significant effect in determining the winter diet of bharal. The high positive electivity index for graminoids and the influence of graminoid presence on the electivity index for other plant types also indicate that bharal preferred graminoids to any other forage type, (Mishra *et al.* 2004; Shrestha *et al.* 2005). Craniodental adaptations of the species (Tempel and Vriji 2008) also suggest that bharal are grazers.

Chemical analyses show that the differences in the nutrient quality across plant types during winter were not significant. Selection of graminoids in such a scenario indicates the importance of adaptation for a particular diet type, in this case, for a grazing diet. Yet, the nutrient quality of all plant species (except C. brevifolia; sub-shrub and L. anchusoides; herb) was below maintenance level (<5% crude protein; estimated for Ovis canadensis [Hebert 1976 in Goodson, Stevens & Bailey 1991]). Our study thus underscores the role of fat accumulation during summer (productive season) in temperate and alpine species such as the bharal. Fat reserves acquired during summer, together with winter diet and nutrition, are presumably the major factors determining the body weight of bharal during winter (the gestation period). Female weight during pregnancy (winter for bharal) is known to be an important determinant of the birth weight of the young, born just at the end of winter; late April- early May (Illius & Gordon 1999). As the survival of young through the first year is related to weight at birth (Clutton-Brock et al. 1987; Loison et al. 1999), winter nutrition available for females is expected to be a key factor in determining the first year survival of infant bharal.

Our results show that bharal, while remaining dependent on graminoids, also have the plasticity to be able to utilise other forage types in areas where preferred forage is unavailable. Such plasticity has been observed in other herbivores such as the mountain hare that live in similar seasonal environments and do not hibernate during winter (Iason & Van Wieren 1999). Feeding plasticity could be important for herbivores in areas with unpredictable weather affecting forage availability. High snowfall even over short durations usually covers up most graminoids, making them inaccessible for species like the bharal. This plasticity to include other plant types in the diet in such conditions can thus positively affect survival. Since I did not observe any starvation related adult mortality in bharal, which has not been reported by other studies either (Mishra et al. 2004), I expect feeding plasticity to be important for adult survival in areas with unpredictable weather affecting forage availability. However, our results also hint that diet plasticity may have a cost in terms of reduced population recruitment. The young to female (Y:F) ratio (population performance) in the livestock ungrazed treatment was three times higher than the livestock intensely grazed treatments. This indicates high fecundity and first year survival for bharal in the ungrazed areas. These results, while being consistent with our hypothesis that low graminoid availability causes bharal to include non-graminoid in their diet, are also consistent with previous studies showing suppression of fecundity (Mishra et al. 2001; Mishra et al. 2004) and survival of young of bharal due to reduced forage availability in areas with high livestock densities (Gaillard et al. 1998). This result suggests the potential importance of graminoid availability in influencing fecundity and first year survival of bharal.

5.1 Conservation implications

The Trans-Himalayan and Tibetan grassland system are one of the largest grazing systems of the world (the Tibetan rangeland being over 130 million ha; Miller 2002). This region supports over 12 species of wild ungulates and is also the centre of snow leopard range, making it an extremely important conservation area. This area also

supports a large number of people that are mainly pastoralists (for example, the rangelands of the Tibetan plateau alone support over 39 million people that are predominantly pastoralist; Miller 2002).

Out of the 12 species of wild ungulates of this region at least six are predominantly grazers (Miller & Schaller 1996). While three of the seven species of livestock of the region are also mainly grazers, the other four are intermediate feeders (at least 50% graminoids in diet) (Mishra *et al.* 2004). Thus, livestock, which heavily outnumbers wild ungulates in these areas, seem to severely limit the availability of graminoids for wild ungulates. The findings of our study emphasise the need for enhancement of graminoid availability in key areas for wild grazing ungulates such as the bharal. Removal of livestock grazing pressure from such key conservation areas is thus likely to lead to increase in wild grazing ungulate populations, by improving fecundity and recruitment. Increased wild prey population should thus help conserve viable population of snow leopard in this landscape.

References:

AOAC. (1990) *Official methods of analysis*. 15 edn. Assiciation of Official Analytical Chemists, Arlington, Virginia, USA.

Aswal, B. S. & Mehrotra, B. N. (1994) *Flora of Lahaul-Spiti*. Bishen Singh Mahendra Pal Singh Publishers, Dehradun, India.

Bagchi, S. & Mishra, C. (2006) Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). *Journal of Zoology* **268**:217-224.

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

Bokdam, J., Gleichman, M. J. (2000) Effects of grazing by free-ranging cattle on vegetation dynamics in a continental north-west European heathland. *Journal of Applied Ecology* **37**, 415–431.

Champion, F. W. & Seth, S. K. (1968). *A revised survey of the forest types of India*. Nasik, India: Manager, Government of India Press.

Clutton-Brock, T.H., Major, M., Albon, S.D. & Guinness, F.E. (1987) Early development and population dynamics in red deer. I. Density-Dependent effects on juvenile survival *Journal of Animal Ecology*, **56**, 53-67.

Gaillard, J., Festa-Bianchet, M. & Yoccoz, N.G. (1998) Population dynamics of large herbivores: variable recruitment with constant adult survival. *Trends in Ecology and Evolution*, **13**, 58-63.

Goodson, N.J., Stevens, D.R. & Bailey, J.A. (1991) Effects of Snow on Foraging Ecology and Nutrition of Bighorn Sheep. *Journal of Wildlife Management*, **55**, 214-22.

Gordon, I.J. (2003) Browsing and grazing ruminants: are they different beasts? *Forest Ecology and Management*, **181**, 13-21.

Hobbs. N. T., Baker, D. L., Bear, G. D., and Bowden, D. C. (1996) Ungulate grazing in sagebrush grassland: Mechanisms of resource competition. *Ecological Applications*, **6**, 200-217.

Iason, G.R. & Van Wieren, S.E. (1999) Digestive and ingestive adaptations of mammalian herbivores to low-quality forage. In *Herbivores: Between Plants and Predators, Proceedings of the Symposium of the British Ecological Society* (ed H. Olf, Brown, V.K. & Brent, R.), pp. 337-69. Blackwell Scientific Publications, Oxford.

Illius, A.W. & Gordon, I.J. (1999) Scaling up from functional response to numerical response in vertebrate herbivores. In *Herbivores: Between Plants and Predators, Proceedings of the Symposium of the British Ecological Society* (ed H. Olf, Brown, V.K., & Brent, R), pp. 337-69. Blackwell Scientific Publications, Oxford.

Karanth, K. U., Nichols, J. D., Kumar, N. S., Link, W. A. & Hines, J. E. (2004). Tigers and their prey: predicting carnivore densities from prey abundance. Proceedings of. *The National Academy of Sciences USA* **101**: 4854–4858.

Krebs, C.J. (1989) *Ecological Methodology*. Harper & Row Publishers, New York.

Linnell, J. D. C., Swenson, J. E. and Andersen, R. (2001) Predator and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation*, **4**, 345-349.

Loison, A., Langvatn, R. & Solberg, E.J (1999) Body mass and winter mortality in red deer calves: disentangling sex and climatic effects. *Ecography*, **22**, 20-30.

Madhusudan, M. D. (2004) Recovery of wild large herbivores following livestock decline in a tropical Indian wildlife reserve. *Journal of Applied Ecology* **41**, 858-869.

Mautz, W.W. (1978) Sledging on a bushy hillside: the fat cycle in deer. *Wildlife Society Bulletin*, **6**(2), 88-90.

McCarthy, T. M. and Chapron, G., (2003) *Snow Leopard Survival Strategy*. ISLT and SLN, Seattle, USA.

Miller, D. (2002) The Importance of China's Nomads. *Rangelands*, **24**, 22-24.

Miller, D.J. & Schaller, G.B. (1996) Rangelands of the Chang Tang Wildlife Reserve in Tibet. *Rangelands*, **18**, 91-96.

Mishra, C., Prins, H.H.T. & van Wieren, S.E. (2001). Overstocking in the Trans-Himalayan rangelands of India. *Environmental Conservation*. **28**, 279–283.

Mishra, C., Van Wieren, S., Ketner, P., Heitkonig, I.M.A. & Prins, H.H.T. (2004) Competition between domestic livestock and wild bharal *Pseudois nayaur* in the Indian trans-Himalaya. *Journal of Applied Ecology*, **41**, 344-54.

Morgantini LE, Hudson RJ (1985) Changes in diets of wapiti during a hunting season. *Journal of Rangeland management*, 38:77-79.

Mysterud, A. (2000) Diet overlap among ruminants in Fennoscandia. *Oecologia*, **124**, 130–137.

Namgail, T., J. L. Fox and Y. V. Bhatnagar (2006) Habitat shift and time budget of the Tibetan argali: the influence of livestock grazing. *Ecological Research* **22**, 25-31.

Oli, M. K. (1994) Snow Leopards and Blue Sheep in Nepal: Densities and Predator: Prey Ratio. *Journal of Mammalogy*, **75**, 998-1004.

Prins, H.H.T. (1992) The pastoral road to extinction: competition between wildlife and traditional pastoralism in East Africa. *Environmental Conservation*, **19**, 117–123.

Shrestha, R., Wegge, P. & Koirala, R.A. (2005) Summer diets of wild and domestic ungulates in Nepal Himalaya. *Journal of Zoology*, **266**, 111-19.

Tempel Cvd, Vriji Md (2008) Cranial and appendicular morphologies functionally related to feeding type and habitat of Trans-Himalayan Caprinae. M.Sc. Dissertation, Wageningen Agriculture University, Wageningen

Van Soest, P.J., Robertson, J.B. & Lewis, B.A. (1991) Method for dietary fibre, neutral detergent fibre and non starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, **74**, 3583-97.

Van Wieren, S.E. (1996) *Digestive strategy in ruminants and nonruminants*. PhD, Wagningen Agriculture University, Wageningen.

Vanderploeg, H.A., & Scavia, D. (1979) Two Electivity indices for feeding with special reference to zooplankton grazing. *Journal of Fisheries Research Board of Canada*, **36**, 362-65.

Weaver, J. L., Paquet, C. P. and Ruggiero, L. F. (1996) Resilience and conservation of large carnivores in the rocky mountains. *Conservation Biology*, **10**, 964-976.

Nutritional	Represents	Importance for	Method of estimation
parameter		ungulate foraging	
Total Ash	Macro minerals required in relatively large amounts by ungulates. Include calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), chlorine (Cl), sulphur (S) and sodium (Na). Micro (or Trace) Minerals: Minor minerals required in very small amounts. Includes manganese (Mn), copper (Cu), zinc (Zn), selenium (Se), iron (Fe), cobalt (Co), iodine (I) and fluorine (FI).	Total ash represents the sum of all the different minerals present in the forage. Herbivores, like all organisms, need a certain amount of these minerals for various metabolic functions.	AOAC (1990)
Crude fat	Measured as ether extract, it represents the total amount of fat in the plant	One of the sources of energy for herbivores.	AOAC (1990)
Crude protein	An estimate of the total protein content of forage; calculated as the product of Total nitrogen (N) and 6.25; Crude protein includes true protein and other nitrogen-containing substances such as ammonia, amino acids, nitrates.	N being the most important component animal tissue forms the most important component of forage. Herbivores are limited by minimum levels of crude protein below which they spend more energy trying to digest the small quantity N and lose weight in the process.	(Kjeldahl nitrogen × 6.25) AOAC (1990)
Crude fibre	Represents the total amount of fibre present in the forage	Fibre content is negatively related to digestibility.	AOAC (1990)
Neutral detergent fibre (NDF)	Complex carbohydrates including cellulose, hemicellulose, lignin and pectin that form the plant cell wall. Non-lignified cellulose can be digested by the gut microbial flora. Hemicellulose is partially digestible. Lignin is completely indigestible.	Total forage intake is negatively related to NDF. Most ungulates can consume only up to 1.2% NDF of their total body weight.	Van Soest, Robertson & Lewis (1991)
Acid detergent fibre (ADF)	Primarily cellulose, lignin and variable amounts of silica	Acid detergent fibre (ADF) is the less digestible fibre portion of the forage. The higher the ADF	AOAC (1990)

		level, the lower the	
Acid detergent lignin (ADL)	Represents the total lignin content of the plant sample. Lignin is a polyphenolic component of cell walls that impart mechanical strength to the plant tissue	Lignin is the prime factor influencing the digestibility of plant cell wall material. Increase in lignin usually causes decrease in digestibility, intake, and animal performance.	AOAC (1990)

6. Photographs:

SLT Pics 1: An adult male ibex (*Capra sibirica*). Ibex form an important prey species of the snow leopard.

SLT Pics 2: Two adult male bharal (*Pseudois nayaur*). Bharal are an important prey species of the snow leopard.

SLT Pics 3: Ibex kid. This study showed that reduced forage availability for bharal due to competition from domestic livestock depressed their population recruitment.

SLT Pics 4: Members of the research team heading towards the field site. The study site remained covered with over two feet snow throughout the study duration with temperatures dipping to - 35° C.

SLT Pics 5: Members of the research team at one of the field site.

SLT Pics 6: Ibex kid. Depressed population recruitment due to competition from livestock could also be affecting ibex.

SLT Pics 7: A snow leopard. I was lucky to see the snow leopard on multiple occasions during the field work of the project. This lone snow leopard was seen at one of the intensive study site.

SLT Pics 8: Two snow leopards. On one lucky day during the field work we saw three snow leopards together. The animals in the photo are a mother and a cub from the trio.

SLT Pics 9: Two snow leopards. On one lucky day during the field work we saw three snow leopards together. The animals in the photo are a mother and a cub from the trio.

SLT Pics 10: A snow leopard peeping from a cave hideout.

All the photographs were captured during the field work of the project by Kulbhushansingh Suryawanshi.











-Kulbhushan







