Ecological Separation between Ibex and Resident Livestock in a Trans-Himalayan Protected Area

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Abstract
The spatio-temporal overlap in resource selection by resident livestock and Asiatic ibex (*Capra ibex sibirica*) was studied in Pin Valley National Park, a Trans-Himalayan protected area important for conservation of the endangered snow leopard and ibex.

Approximately 350 resident livestock grazed in the 300 sq.km study area within the park between May and December every year. This relatively large livestock population could potentially compete with the estimated 250 ibex for space and food. In this paper we have tried to establish whether ibex and resident livestock compete at the level of habitat selection. Diet selection and possible pasture degradation were outside the purview of this paper. We located seven radio-collared ibex over one year and also recorded the location of any domestic animal on a 1:50,000 topographical map. Various habitat attributes were recorded for each sighting.

During summer ibex migrated to higher elevations (mean 4,400m) while most livestock continued to use the lower valleys (<4,100m). There was greater altitudinal overlap, during spring and autumn, however ibex primarily grazed on steeper slopes, closer to escape terrain. We suggest that ibex and resident livestock used the habitat differently throughout the period of overlap in the Park, and thus livestock did not interfere with ibex at this scale of resource selection. We note, however, that this situation resulted primarily from two factors: a) nearly all resident livestock were herded back to settlements at night and were thus mainly grazed near habitations; and b) livestock holdings were not increased because of the problem of collecting enough forage for winter stall feeding.

Introduction

In mountain pastures, livestock is widely regarded as competing with wild herbivores by depleting resources and degrading the pastures (Schaller 1977, Shah 1988, Rikhari *et al.* 1992). Further, studies indicate that such grazing can lead to loss of plant biodiversity, including rare and endemic plants (Kala *et al.* 1998). In recent years, there have been reports of increased pressure on the Himalayan rangelands and protected areas as a result of a rise in livestock populations in response to the shift from subsistence to market economies (Lal *et al.* 1991; Mishra 1997). Government agencies try to prohibit livestock grazing within wildlife protected areas in India as per the Indian Wildlife Protection Act - 1972 (GOI 1992). Our observations indicate that in the Trans-Himalayan regions pasturelands are at a premium, and livestock are an important resource for the primarily agro-pastoral community who may have no place other than in

a protected area to graze their livestock. Given this situation, it is important to assess whether livestock in a protected area are actually detrimental to the ecosystem, and only to prohibit grazing if they are. For this reason we quantified the extent of habitat separation between sympatric populations of ibex, the primary wild ungulate in Pin Valley National Park, and resident livestock.

Study Area

The Pin Valley National Park (675 sq.km) is located in the rain shadow of the Pir Panjal range in the Lahul and Spiti district of Himachal Pradesh, India. This region is characterised by a cold, arid climate with a short plant growth period between June and September. There are a total of 17 villages in Pin Valley with a human population of *ca.* 1,250 people (Bhatnagar 1996). All these villages are located in the 'buffer zone' to the east and south of the national park (Figure 8). Of these, only eight villages depend to varying degrees on the Parahio catchment that constitutes the northern portion and bulk of the national park (Bhatnagar 1996). People depend on the park for collection of fuelwood and fodder and for livestock grazing and agriculture. Pin Valley residents have a total livestock population of 2,360 animals, and the eight dependent villages a total of 1,270 animals with a mean livestock holding of 9.8 animals per family (Pandey 1991, Bhatnagar 1996). Based on a survey of 75 families (livestock holding 733) in the eight dependent villages, Bhatnagar (1996) reported that goats (27%) and sheep (24%) dominated the holding, followed by donkeys (15%), horses (12%), yak-cow hybrids (males are called dzo and females dzomo, 10%), yaks (8%), and cows (3%). People graze their livestock in the park between May and December every year. By the end of December, animals are herded back to the villages and are stall-fed till May or June.

Seventeen migratory herders from Shimla and Kinnaur districts, with *ca.* 8,000 sheep and goats, have been permitted to graze their stock in Pin Valley by the Forest Department (Pandey 1992). Every June, they enter the region from the Bhaba pass lying south of the national park and leave the park by mid August, spending 50 to 60 days in the region. Seven to eight groups with *ca.* 2,900 sheep and goats graze their stock in the upper Parahio watershed, in the Khamengar, Debsa, and Killung nalas. Since these animals were not grazed in the intensive study area as defined by the seven radio-collared ibex (Bhatnagar 1997), we limited our study to the possible competition posed by the resident livestock that remained in the area for about eight months.

Methods

Livestock Abundance and Distribution

Residents who brought in livestock from the dependent villages were interviewed to assess the numbers of various species being brought into the study area and the pastures where they were grazed. This information was cross-checked by actual counts in those areas to get an estimate of abundance and distribution.

Habitat Utilisation by Livestock

Data on the habitat utilisation (Table 11) by livestock were collected along the trails while monitoring the radio-collared ibex (Bhatnagar 1997). In the process,

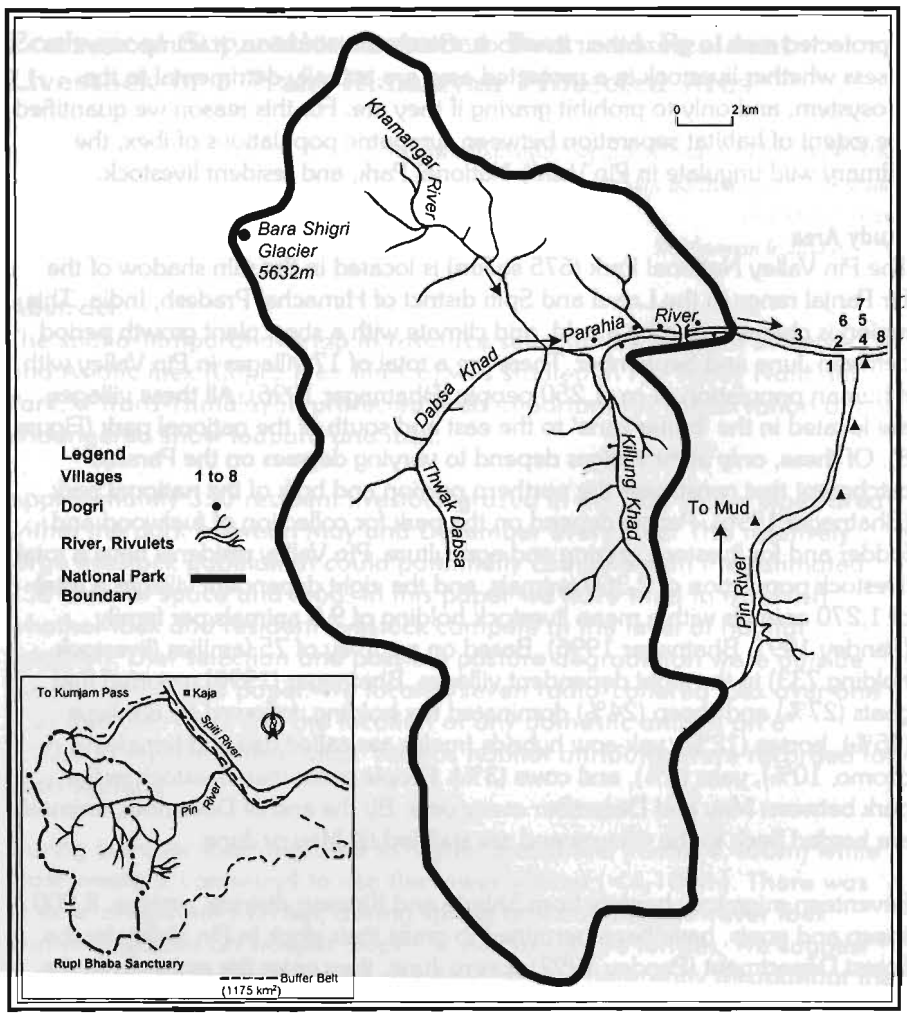

Figure 8. **Map of Pin Valley National Park (675 sq.km) showing the study area in the Parahio watershed. Note that villages are primarily located around the eastern periphery of the park and the summer settlements are inside the park**

approximately 10 km in the Kidul Chu Valley and 8 km in the Parahio-Kocho Valley were surveyed three to five times every week. We obtained 296 sightings of livestock and 237 of ibex covering spring (15 April to 30 June), summer (1 July to 15 September), and autumn (16 September to 30 November). This included the major period of overlap (May to December).

Habitat variables that determine use by ibex and livestock may differ. For example, the value of distance to escape terrain (ET) for ibex is not the same for horses or other livestock species, except goat and possibly sheep. The variables were, however, recorded for livestock to differentiate between usage by ibex and livestock, not for studying habitat use by livestock *per se*.

Table 11. **Habitat variables and their categories used in quantifying habitat use by ibex in Pin Valley National Park**

Habitat Variable	Categories/Description
Terrain type	1. **Interspersed Rocky Slopes (IRS) I**: steep (usually >40°), broken areas, usually below large rocky slabs & cliffs. 2. **Rocky slabs**: parallel rock slabs with occasional plant patches. 3. **Cliffs**: rocky slopes > 50° 4.**Rocky slopes**: slopes with an exposed rock cover of >20%, usually stony fields 5.**Smooth slopes**: smooth slopes with rock cover < 20%, usually good vegetation cover. 6. **Scree**: loose rocky slopes fanning out below rocky slabs and cliffs. 7. **Old moraine**: steep unstable high bank, often bordering the valley bottom. 8. **Valley bottom**: usually rocky, flat land at the base of the valley; has occasional shrubby patches. 9. **Glaciers**.
Aspect	North (338° to 23°), North-East (24° to 68°), East (69° to 113°), South-East (114° to 158°), South (159° to 203°), South-West (204° to 248°), West (249° to 293°), North-West (294° to 337°).
Slope	Angle estimated in degrees intervals of 5°
Closest dist. to cliffs (escape terrain)	Estimated in units of 5 m
Altitude	Elevation in metres

Analysis

Since the data were not normally distributed, only nonparametric tests were used. Seasonal differences in the use of various habitat categories by livestock were tested based on a Chi square test of independence (Sokal and Rohlf 1995). For nominal variables, differences between ibex and livestock were tested based on a Chi square test of independence, while differences between continuous variables were tested using the Kruskal Wallis Oneway ANOVA test (Sokal and Rohlf 1995). To study seasonal differences in the use of altitude between ibex and livestock, we subtracted each of the observed records of altitude of ibex with that of livestock to obtain a distribution of all possible differences. We repeated the same for distance to escape terrain, but here we subtracted the observed figures of use by livestock with use by ibex. If the values of differences were grouped closely around zero, this would indicate a minimal difference in use by the two groups; if positive, it would mean ibex used higher altitudes than livestock or in the case of distance to escape terrain, that livestock grazed farther from escape terrain than ibex. Negative values would imply the opposite.

The habitat preferences of livestock were investigated for comparison with ibex based on Marcum and Loftsgaarden's (1980) 'non-mapping technique'. Availability of the habitat attributes was estimated using 200 random points in the study area. The proportionate use of habitat categories was then compared with the availability to assess which habitat categories were used more than their

proportional availability ('preferred'), less than their proportional availability ('avoided'), and in proportion to availability.

Results

Livestock abundance and distribution

The resident livestock in Pin Valley can be grouped into two categories.

1. *Species dependent on human settlements*: sheep, goats, donkeys, and cows/dzomo that were directed to pastures every morning, and herded back into pens in the evening. Their distribution was quite predictable and close to settlements.
2. *Species' independent of human settlements*: free-ranging (yaks) and partially free-ranging species (adult horses) which may be herded back into pens but were essentially kept in pastures far from settlements.

The dependent villages had a livestock holding of 1,266 animals, but only *ca.* 350 of these (28%) (Table 12) were grazed within the national park and adjacent tracts that formed the study area. The remainder in the first category were grazed close to the villages, and those in the second category were grazed further downstream along the Pin River. Sheep and goats constituted roughly half of the livestock that grazed in the study area (Table 12).

Table 12. **Species-wise population estimates of livestock in the eight villages dependent on the Parahio catchment, Pin Valley National Park, and which actually graze in or in the vicinity of the study area. The overall population estimates are from Pandey (1991) and the estimates for Parahio are based on counts and interviews with locals**

Species	Dependent villages	Study area (Parahio)	Livestock type wise proportion in study area
Settlement Dependent			
Sheep & Goat	529	145	67%
Cows, Dzomo	149	40	
Donkeys	243	45	
Settlement Independent			
Horse	134	60	33%
Yak, Dzo	211	60	
Total livestock	1266	350	

Habitat and spatial separation

The livestock showed seasonal differences in the use of terrain type (c^2 test, $p<0.0001$), aspect ($p<0.0001$), distance to escape terrain ($p<0.0001$), and

altitude ($p=0.0004$), but not in the use of slope categories ($p=0.33$). Since ibex also showed seasonal differences in habitat use (Bhatnagar 1997), the three seasons, spring, summer, and autumn, were considered separately.

There was a high degree of spatial overlap between ibex and resident livestock in spring (Figure 9). In summer, however, ibex moved to higher elevations, while most livestock remained along the valley bottom, resulting in spatial separation (Figures 10, 11).

The ibex choice of terrain type, aspect (c^2 test, $p<0.001$), slope, distance to escape terrain, and altitude (Kruskal Wallis test, $p<0.05$) differed from that of livestock in all seasons except spring, when the use of aspect did not differ (c^2, $p>0.05$) (Table 13). Altitudinal separation was at a minimum during spring, with a median difference of 160m, and at a maximum during summer, with a median difference of 540m (Figure 11, Table 14). Over 75% of the ibex sightings were above livestock during spring, and this was even greater during summer (92%) and autumn (89%). Settlement independent livestock had some amount of altitudinal overlap with ibex but this was minimal for the settlement dependent livestock (Figure 11). Compared to ibex, livestock used gradual slopes and occurred farther from escape terrain (Kruskal Wallis test, $p<0.05$) (Figure 12, 6). The median difference in the use of distance to escape terrain by livestock and ibex was 60m in spring, and increased to 160m in summer. Over 90% of livestock sightings were further from escape terrain than ibex in each season (Table 14).

Table 13. **Frequency distribution (%) showing difference between ibex and livestock in the use of altitude and distance to escape terrain (ET) in Pin Valley National Park. Differences refer to the difference between all possible pairs of values of these variables used by livestock and ibex based on their sightings in spring, summer, and autumn. For altitude the difference was (altitude ibex – altitude livestock) and for distance to ET, it was (ET livestock – ET ibex)**

	Spring	Summer	Autumn
Altitude (m)	(n = 3355)	(n = 17490)	(n = 5928)
Median altitude difference (m)	160	540	400
- 800 to 0m	22	08	11
1 to 500m	66	39	52
501 to 1,000m	12	47	28
1,001 to 1,400m	00	06	09
Distance to ET	(n = 3355)	(n = 16072)	(n = 5928)
Median difference in ET (m)	60	160	150
-200 to 0m	10	07	04
1 to 50m	26	09	15
51 to 100m	38	20	18
101 to 150m	11	11	14
> 150m	15	53	49

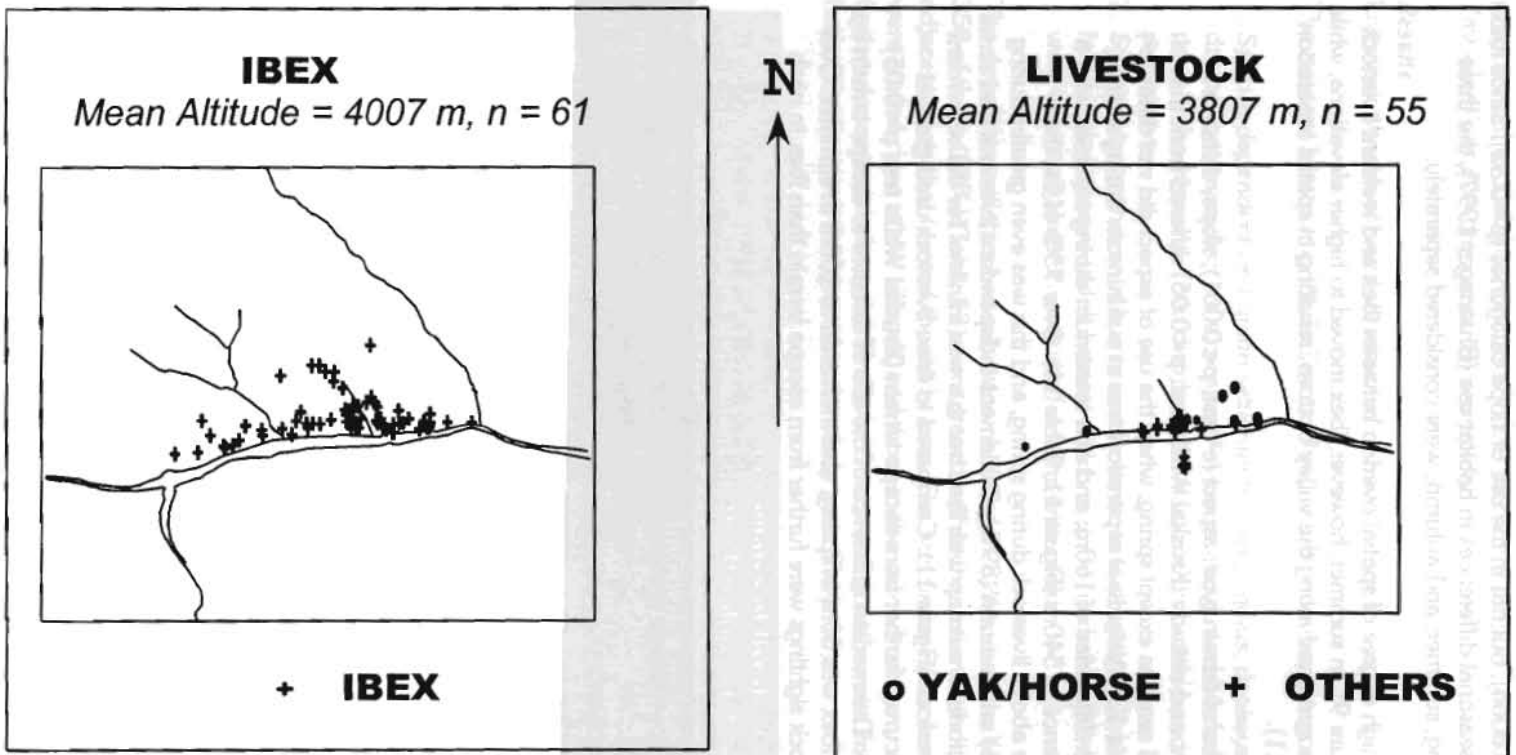

Figure 9. **Distribution of ibex and livestock during spring (1994, 1995). Note the spatial overlap between ibex and livestock near the valley bottom**

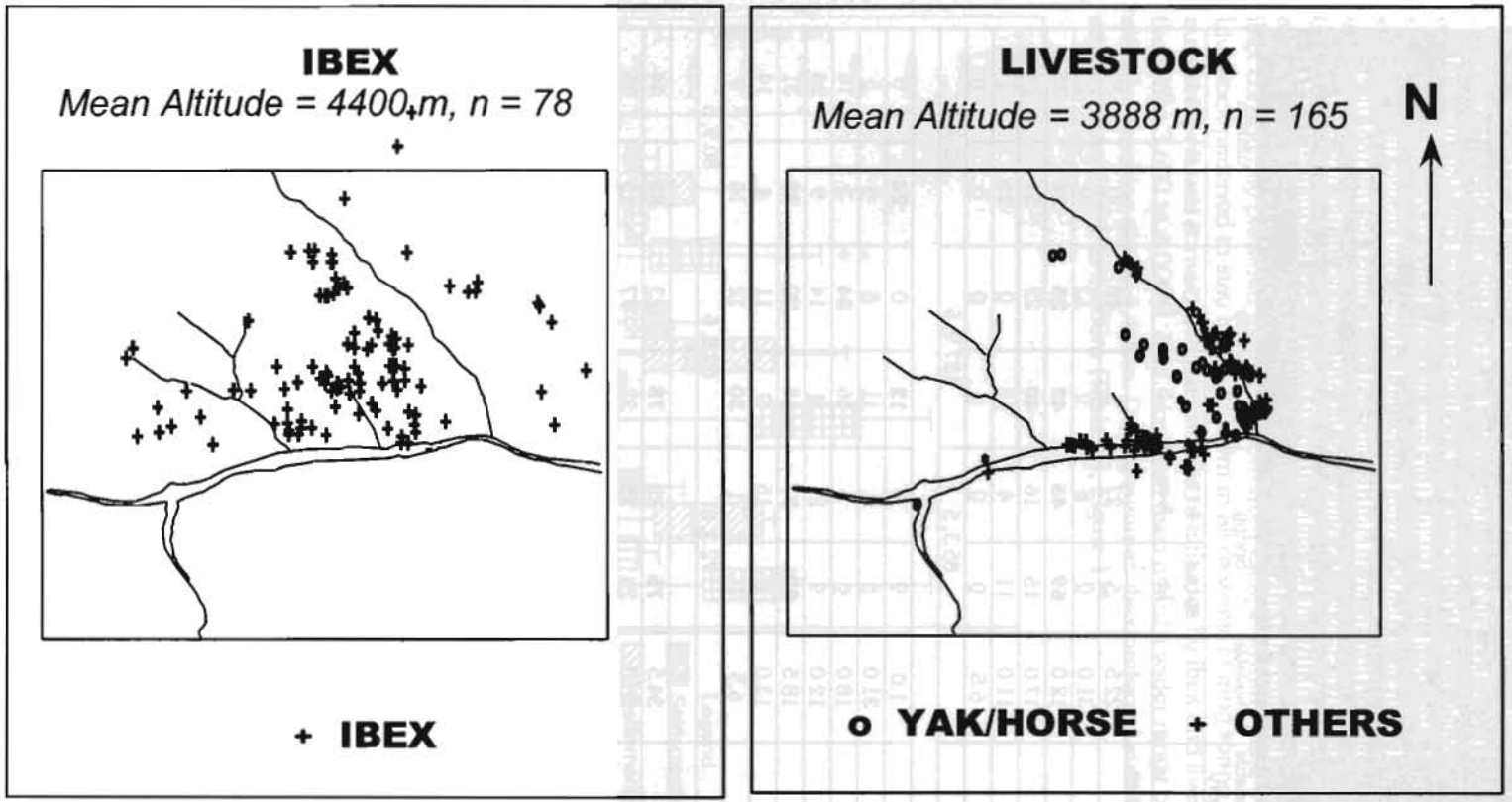

Figure 10. **Distribution of ibex and livestock during summer 1994. Note that while most livestock continue to use the lowest slopes, ibex move to higher elevations, thus minimising spatial overlap**

Table 14. **Seasonal habitat selection by livestock (LS) compared to use by ibex during the three seasons of overlap (May 1994 to December 1994; spring, includes May 1995) in the intensive study area. Preferences are calculated based on Marcum and Loftsgaarden's (1980) Bonferroni confidence intervals. Preference (bold), avoidance (underline), and usage in proportion to availability (normal text) must be treated in a relative sense. χ^2 values are for differences in the use and availability of LS only (all p<0.0001). See Bhatnagar (1997) for more details**

Habitat variable & category	% Available	Spring		Summer		Autumn	
		% Use LS	% Use Ibex	% Use LS	% Use Ibex	% Use LS	% Use Ibex
Terrain type							
IRS	22.5*	5	27	5	**40**	0	30
SI/CI.	31.0	0	8	0	13	0	10
RS	12.0	**69**	**45**	**42**	**25**	**24**	**35**
SS	17.0	15	16	**40**	22	**51**	24
Other*	11.0	11	4	13	0	**25**	1
Glacier	6.5	0	0	0	0	0	0
		85.3, 5		127.9, 5		82.3, 5	
Aspect							
Flat	1.0	9	0	**12**	0	**24**	0
N,NE,NW	31.0	5	1	11	8	6	5
E	18.0	6	5	16	**34**	3	16
SE	12.0	9	21	4	14	9	**25**
S	18.5	**69**	**57**	18	20	**38**	31
SW	13.0	2	15	9	11	4	14
W	6.5	0	1	**30**	12	16	9
		72.3, 6		69.8, 6		80.9, 6	
SL (°)							
00-30	34.5	**76**	25	**78**	23	**85**	44
31-60	55.0	24	**75**	22	**77**	15	55
61-90	10.5	0	0	0	0	0	1
		31.9, 2		74.0, 2		58.2, 2	
DTET (m)							
0	32.5	0	8	1	12	00	6
01-50	33.0	14	**82**	7	**64**	17	**90**
51-100	16.0	**53**	10	23	21	17	3
101-150	4.0	15	0	**13**	1	**16**	1
>150	14.5	18	0	**56**	2	**50**	0
		55.3, 4		136.3, 4			
Altitude (m)							
3600-3800	11.5	**66**	17	**41**	3	**70**	12
3801-4000	11.0	**31**	**48**	**41**	7	21	13
4001-4200	17.0	2	22	10	15	4	30
4201-4400	13.0	1	6	6	23	5	23
4401-4600	13.0	0	4	2	**25**	0	4
4601-4800	11.0	0	3	0	17	0	13
>4801	23.5	0	0	0	10	0	5
		103.0, 6		144.6, 6		118.0, 6	

* Terrain type 'other' includes scree, valley bottom, and old moraine.

We analysed preferences for all the livestock categories pooled together because of the sample size needed for a chi square test. Ibex and resident livestock showed similarities in the selection trends for terrain type, aspect, and to some extent altitude during spring (Table 14). Both groups of animals preferred rocky slopes during all seasons, but the use of interspersed rocky slopes by ibex and smooth slopes and 'other' terrain types by livestock was high during summer and autumn. While ibex preferred slopes with an inclination between 31° and 60°, livestock consistently preferred slopes $\leq$ 30° (Table 14). Livestock used areas farther than 100m from escape terrain during summer and autumn, while ibex consistently preferred areas 1 to 50m from escape terrain (Table 14). Livestock preferred to stay below 4,000m in all seasons. During spring and autumn there was some overlap in the use of altitudes by ibex and livestock in the range 3,600 to 4,000m. Ibex, however, used a much wider range of altitudes reaching above 4,400m. During summer, ibex preferred even higher regions, from 4,401 to 4,600m (Table 14, Figure 11).

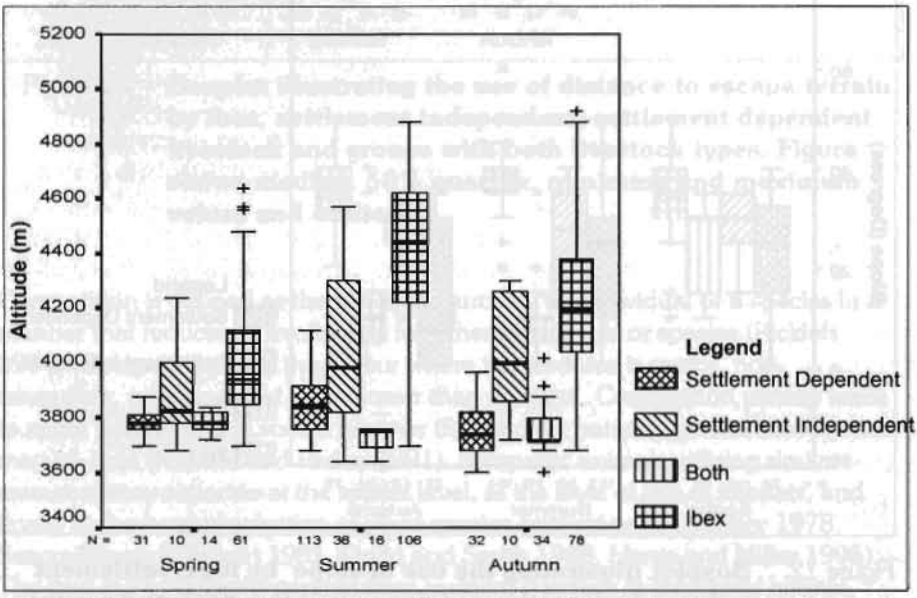

Figure 11. **Boxplot illustrating the use of altitude by ibex, settlement independent, settlement dependent livestock and groups with both livestock types. Figure shows median, 50 % quartile, minimum and maximum values and outliers.**

Discussion

We estimated that there were 200 to 250 ibex in the Parahio watershed (Bhatnagar and Manjraker, unpubl. data) sharing the area with *ca.* 350 resident livestock between May and December each year. There are no comparative figures from other areas, but with over 1.4 livestock for every ibex, the pressures imposed by them on the area could be substantial. However, the results show that concentrated use of areas by livestock during all three seasons was limited primarily to the lowest slopes near the valley bottom (Figures 9, 10).

Habitat Separation between Ibex and Resident Livestock

There was some overlap in the use of altitudes, terrain types, and aspect by ibex and livestock during spring and autumn (Figure 11, Table 14). However, the separation between the two was clear during all seasons in terms of use of slope and distance to escape terrain (Figures 12 and 13). The separation between ibex and livestock was highest during summer when they differed in the use of altitude and terrain type as well as in other variables. Ibex and livestock are thus most likely to compete for resources during spring and autumn, while during summer the possibility of either 'exploitation' or 'scramble' competition is excluded by the spatial separation. Ibex were seen foraging in the vicinity of and also in the same group as livestock during spring and autumn on about 10 occasions, without any overt antagonism. This shows that the chance of interference competition was minimal even during the period of overlap.

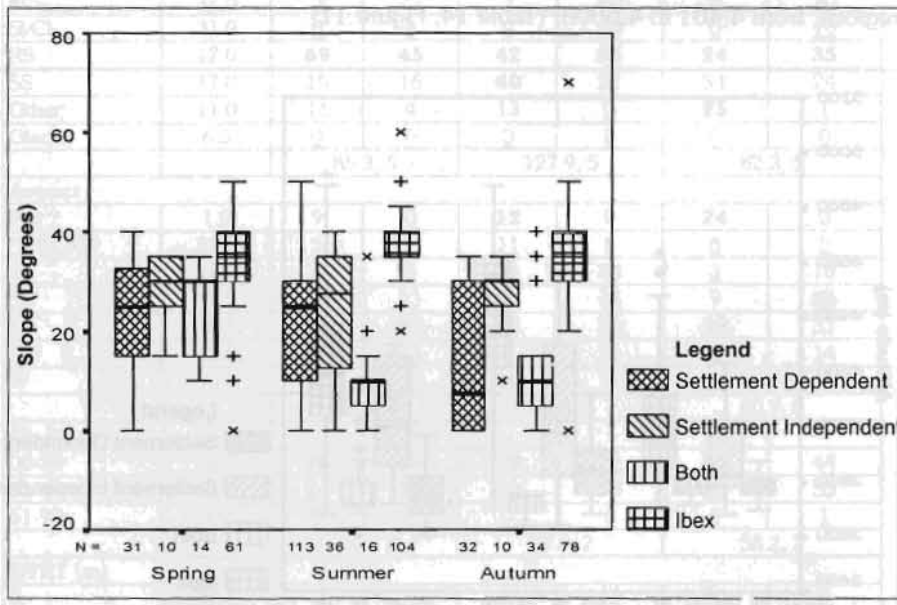

Figure 12. **Boxplot illustrating the use of slope by ibex, settlement independent, settlement dependent livestock and groups with both livestock types. Figure shows median, 50 % quartile, minimum and maximum values and outliers.**

Before analysing the competition between ibex and livestock further, we will look at human intervention in the use of habitats by the resident livestock. Approximately, 66% of the 350 resident livestock (settlement dependent) were directed daily by the owners into pastures selected on a rotation basis and were left to forage for three to twelve hours. Some of these animals were herded back into pens at mid-day for a few hours. Proximity to settlements was an important consideration in the choice of pastures, and usually all animals from this category were located within two kilometres of settlements along the lower valley. A large proportion of livestock were left to graze in fields after harvesting in August, to manure the fields. There was thus a decline in altitudinal use by livestock in September-October (Bhatnagar 1997).

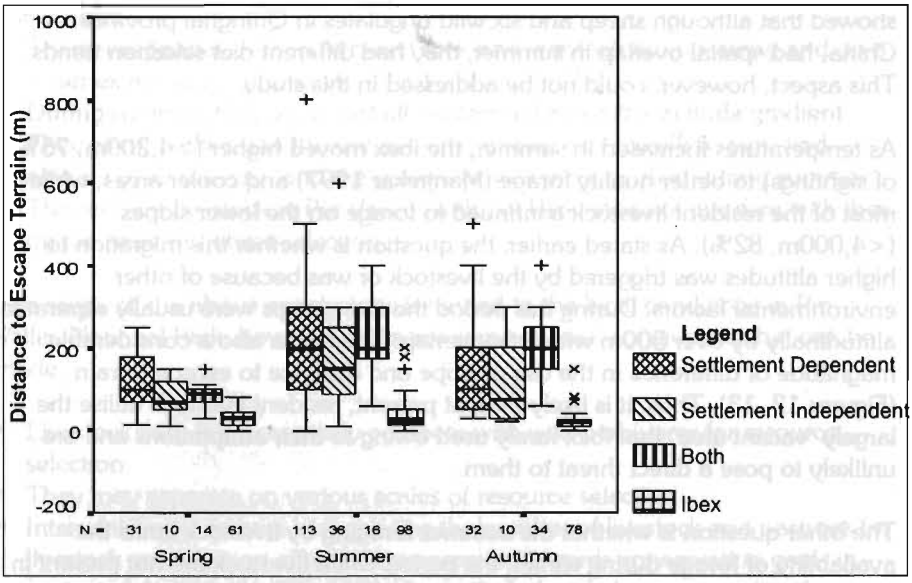

Figure 13. **Boxplot illustrating the use of distance to escape terrain by ibex, settlement independent, settlement dependent livestock and groups with both livestock types. Figure shows median, 50% quartile, minimum and maximum values and outliers.**

Competition is defined as the use of resource by an individual or a species in a manner that reduces its availability for other individuals or species (Ricklefs 1974). Competition may thus occur where the resource is scarce, non-renewable, or renewed at a rate lower than demand. Competition usually leads to niche partitioning in such a manner that in most natural communities species may co-exist (Milinski and Parker 1991). Sympatric animals utilising similar resources may separate at the spatial level, at the level of use of habitats, and finally at the level of selection of plant species or plant parts (Dunbar 1978, Seegmiller and Ohmart 1981, Dodd and Smith 1988, Harris and Miller 1995). The ibex in Pin Valley separated from resident livestock in the use of habitat. They used steeper areas and areas closer to escape terrain and, during summer, higher altitudes. It is important, however, to consider whether ibex separate into such areas as a result of, or independent of, competition from livestock.

During spring, the period of high spatial overlap, both groups used the lowest altitudes where the snow had thawed and fresh sprout was available. During this period, ibex had little choice as the upper-slopes were snow bound and plants had not sprouted. During May and June ibex were often attracted by the green pastures developed by the residents at Gechang barely 50m from their houses (by thawing snow early by dusting soil on the snow). Both, ibex and livestock primarily fed on *Lindelofia anchusoides* and some grasses which sprouted early (Manjrekar 1997). The extent of overlap in the diets, however, needs to be quantified. 'Exploitation competition' between ibex and livestock during this period is thus quite likely, but is probably minimised by separation in terms of use of steeper slopes and proximity to escape terrain. Harris and Miller (1995)

showed that although sheep and six wild ungulates in Quinghai province, China, had spatial overlap in summer, they had different diet selection trends. This aspect, however, could not be addressed in this study.

As temperatures increased in summer, the ibex moved higher (>4,200m, 75% of sightings) to better quality forage (Manjrekar 1997) and cooler areas, while most of the resident livestock continued to forage on the lower slopes (<4,000m, 82%). As stated earlier, the question is whether this migration to higher altitudes was triggered by the livestock or was because of other environmental factors. During this period the two groups were usually separated altitudinally by over 500m with little overlap. There was also a considerable magnitude of difference in the use of slope and distance to escape terrain (Figures 12, 13). Thus, it is likely that, at present, resident livestock utilise the largely 'vacant area' that ibex rarely used owing to their adaptations and are unlikely to pose a direct threat to them.

The other question is whether the summer foraging by livestock limits the availability of forage during winter, the period when livestock are not present in the area? The habitat usage by ibex in winter showed a clear avoidance of areas with excessive snow and a preference for rugged areas with easier accessibility to forage and escape terrain (Bhatnagar 1997). These never or rarely descend to areas as low as 3,800m, the median altitude of livestock usage (see Bhatnagar 1997 for more details). Thus summer grazing by resident livestock probably doesn't deplete winter forage for ibex because most of the livestock grazing areas remain under heavy snow during winter and are not used by ibex anyway. Thus, even during this period, resident livestock would not adversely impact forage availability to ibex.

Potential Threats to Ibex by Resident Livestock

The previous paragraphs suggest that the resident livestock are unlikely to have an adverse impact on ibex. This statement has to be taken with caution, as the primary reason for it is the more or less stable resident livestock population in Pin Valley (Bhatnagar 1996) and the manner in which people restrict usage by their livestock too near their settlements. Residents said that, although they may like to own more livestock, a restriction on this was imposed by the amount of fodder they can collect for the winter stall feeding (Bhatnagar 1996). If extra fodder is made available, there is a likelihood that livestock holdings will grow and have an adverse impact on ibex usage. The impact can be higher during spring when their ranges overlap, the resources are scarce, and ibex are in a poor body condition after the long winter.

Resident livestock may pose a threat to ibex through transmission of contagious diseases. People in the area occasionally reported cases of foot-and-mouth disease (FMD) and pneumonia among their livestock. However, during the course of the study, when over 8,000 ibex were classed in over 1,000 groups, only on one occasion was a limping ibex with a possibility of FMD observed.

A separate study on the habitat use by migratory livestock and the impact of fuelwood removal from the park may be necessary to ensure the long-term conservation of ibex in the PVNP.

Conclusions

1. There was spatial overlap between ibex and livestock during spring and, to a lesser extent, during autumn.
2. During summer, they were spatially separated along the altitude gradient.
3. They clearly differed in the use of slope, distance to escape terrain, and altitude in all seasons, and the difference was most marked during summer
4. The resident livestock in Pin Valley National Park does not interfere with ibex on the scale of habitat selection

The scope of the above conclusions is limited to the local conditions in Pin Valley National Park; however, there are some general conclusions that can be made.

- Livestock may not necessarily compete with wild herbivores for resource selection
- They may separate on various scales of resource selection
- Intervention by owners in regulating the number of livestock and pastures for livestock grazing is an effective compromise towards conservation goals in protected areas in the Trans-Himalayas that already have a scarcity of pastures
- The methods used in this paper can be used as a first step in assessing the impacts of livestock in a protected area

References

Bhatnagar, K. (1996) *A Study on People's Dependence and Attitudes in the Pin Valley National Park.* Report submitted to World Wide Fund for Nature-India: New Delhi

Bhatnagar, Y.V. (1997) *Ranging and Habitat Utilization by the Himalayan Ibex (Capra ibex sibirica) in Pin Valley National Park.* Ph.D. Thesis submitted to Saurashtra University, Rajkot

Dodd, N.J. and Smith, R.H. (1988) *Habitat and Spatial Relationships of Sympatric Desert Bighorn Sheep and Cattle.* Final Report submitted to Arizona Game and Fish Department Project W-78-R

Dunbar, R.I.M. (1978) 'Competition and Niche Separation in a High Altitude Herbivore Community in Ethiopia'. *E. Afr. Wildl. J.*, 16: 183-199

GOI (1992) *The Indian Wildlife (Protection) Act, 1972.* Dehradun: Natraj Publishers

Harris, R.B. and Miller, D.J. (1995) 'Overlap of Summer Habitats and Diets of Tibetan Plateau Ungulates'. *Mammalia* 59 (2): 197-212

Kala, C.P.; Rawat, G.S.; and Uniyal, V.K. (1998) *Ecology and Conservation of the Valley of Flowers National Park, Garhwal Himalayas.* RR-98/003. Dehradun: Wildlife Institute of India

Lal, J.B.; Gulati, A.K.; and Bist, M.S. (1991) 'Satellite mapping of alpine pastures in the Himalayas'. *Int. J. Remote Sensing,* Vol. 12 (3): 435-443

Manjrekar, N. (1997) *Feeding Ecology of Ibex (Capra ibex sibirica) in Pin Valley National Park*. Ph.D. Thesis submitted to the Saurashtra University, Rajkot

Marcum, C.L. and Loftsgaarden, D.O. (1980) 'A Non-mapping Technique for Studying Habitat Preferences'. *J. Wildl. Manage,* 44 (4): 963-968

Milinski, M. and Parker, G.A. (1991) 'Competition for resources'. In. Krebs, J.R. and Davis, N.B. (eds) *Behavioural Ecology: An evolutionary approach*. Oxford: Blackwell Scientific

Mishra, C. (1997) 'Livestock Depredation by Large Carnivores in the Indian Trans-Himalaya: Conflict Perceptions and Conservation Proposals'. *Environmental Conservation,* 24 (4): 338-343

Pandey, S. (1991) *Management Plan for Pin Valley National Park (1990-91 to 2000-01)*. Shimla: Himachal Pradesh Forest Department

Pandey, S. (1992) 'Estimation of Density of Ibex *Capra ibex Linn.* in Pin Valley National Park, Himachal Pradesh'. *J. Bombay Nat. His. Soc.,* 89 (3): 361-363

Ricklefs, R.E. (1993) *Ecology*. London: Nelson

Rikhari, H.C.; Negi, G.C.S.; Pant, G.B.; Rana, B.S.; and Singh, S.P. (1992) 'Phytomass and Primary Productivity in Several Communities of a Central Himalayan Alpine Meadow, India'. *Arctic and Alpine Research*, 24 (4): 344-351

Schaller, G.B. (1977) *Mountain Monarchs: Wild Sheep and Goats of the Himalaya*. Chicago: Chicago University Press

Seegmiller, R.F. and Ohmart, R.D. (1981) 'Ecological Relationships of Feral Band Desert Bighorn Sheep'. *Wildlife Monographs*. No. 78. Place and Publisher not found

Shah, M.H. (1988) 'Role of Nomads in the Destruction of Alpine and Subalpine Pastures and Future Strategies'. In: Singh, P. and Pathak, P.S. (eds) *Rangelands: resource and management,* pp.148-52 Jhansi: Range Management Society of India

Sokal, R.R. and Rohlf, F.J. (1995) *Biometry: The Principles and Practice of Statistics in Biological Research*. New York: W.H. Freeman