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DISTRIBUTION AND RELATIVE ABUNDANCE OF MOUNTAIN UNGULATES IN PINDARI VALLEY, NANDA DEVI BIOSPHERE RESERVE, UTTARAKHAND, INDIA

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Abstract

We assessed the distribution and relative abundance of mountain ungulates in Pindari Valley (*ca.* 110 km^2), Nanda Devi Biosphere Reserve, Uttarakhand, India, from June, 2007 to July, 2009. We used trail sampling, and scan counts to estimate the distribution and relative abundance of mountain ungulates such as Blue sheep (*Pseudois nayaur*) and Himalayan tahr (*Hemitragus jemlahicus*). For Himalayan musk deer (*Moschus chrysogaster*), we used indirect evidences also to determine presence/absence and relative abundance. We prepared habitat maps of the study area on the GIS domain and plotted the locations of sightings and signs to show the distribution pattern of mountain ungulates. Data on presence of human, livestock and other disturbances were also recorded and analyzed to investigate their effects on ungulate distribution. While Blue sheep and Himalayan tahr were mostly encountered in the alpine regions, the Himalayan musk deer were often sighted in the *krummholtz* region. The overall encounter rates (#/hr±SE) for blue sheep and Himalayan tahr were 4.13/hr±1.00 and 1.38/hr±0.45 respectively. The overall encounter rate (#/km±SE) for Himalayan musk deer based on trail walks was 0.26±0.04. The overall relative density estimates (#/km^2±SE) for blue sheep and Himalayan tahr were 0.35±0.09 and 1.38±0.45 respectively. There was seasonal variation in the encounter rates for blue sheep and Himalyan tahr. Most of the mountain ungulates were sighted between 3,500 m and 4,500 m, but Blue sheep were sighted up to 5,500 m. Eastern, south-eastern and western aspects of mountain slopes were mostly used by these mountain ungulates. Most of the sightings of Blue sheep and musk deer were in 30º-40º slope, whereas for Himalayan tahr, it was 50º-60º slope. We compare the relative abundance estimates of mountain ungulates of the Pindari region with the estimates from the Nanda Devi National Park, (Core Zone) and other localities in the buffer zones of Nanda Devi Biosphere Reserve. Livestock grazing and anthropogenic pressures are the main concerns for the conservation and management of these mountain ungulates and their habitats in the Pindari Valley region.

Keywords: Blue Sheep, distribution, Himalaya, Himalayan musk deer, Himalayan tahr, Nanda Devi, relative abundance.

Resumen

Distribución y abundancia relativa de ungulados de montaña en el valle del Pindari, Reserva de la Biosfera de Nanda Devi, Uttarakhand, India

Evaluamos la distribución y abundancia relativa de los ungulados de montaña en el Valle del Pindari (ca. 110 km^2), en la Reserva de la Biosfera de Nanda Devi, Uttarakhand, India, entre junio 2007 y julio de 2009. Utilizamos el recorrido de senderos y recuentos por barrido visual para estimar la distribución y abundancia relativa de ungulados de montaña como el bharal (*Pseudois nayaur*) y el thar del Himalaya (*Hemitragus jemlahicus*). En el caso del ciervo almizclero de montaña (*Moschus chrysogaster*), utilizamos también evidencias indirectas para determinar la presencia/ausencia y la abundancia relativa. Confeccionamos mapas de hábitat en el área de estudio utilizando SIG y trazamos los lugares de los avistamientos y otros indicios para mostrar el patrón de distribución de los ungulados de montaña. Los datos relacionados con la presencia humana, de ganado y otras perturbaciones fueron registrados y analizados para determinar su impacto sobre la distribución de ungulados. Mientras que el bharal y el thar del Himalaya se encontraron principalmente en las regiones alpinas, el ciervo almizclero de montaña se observó con mayor frecuencia en el área de krumholtz. Las tasas globales de encuentro (número/hr+ES) del bharal y el thar del Himalaya fueron 4,13/hr±1,00 y 1,38/hr±0,45 respectivamente. Las tasas globales de encuentro (número/km+ES) obtenidas en recorridos de senderos, para el ciervo almizclero de montaña fueron 0,26+0,04. Las estimaciones globales de densidad (número/km^2+ES) del bharal y del thar del Himalaya fueron 0,35±0,09 y 1,38±0,45 respectivamente. No hubo variación estacional en la tasa de encuentro para el bharal y el thar del Himalaya. La mayoría de los avistamientos de ungulados fueron entre los 3.500 y 4.500 metros, aunque el bharal fue avistado a alturas de hasta 5.500 metros. Las vertientes más utilizadas por estos ungulados eran las orientadas al este, sudeste y oeste. La mayoría de los avistamientos de bharal y de ciervo almizclero fueron en pendientes de 30º-40º, y los del thar del Himalaya en pendientes de 50º-60º. Comparamos las estimaciones de abundancia relativa de ungulados de montaña en la región del Pindari con las del Parque Nacional de Nanda Devi (zona central) y otros lugares de las zonas amortiguadoras de la Reserva de Biosfera de Nanda Devi. El pastoreo de ganado y las presiones antropogénicas son los principales factores de preocupación en cuanto a la conservación y manejo de estos ungulados de montaña y de sus hábitats en la región del Valle del Pindari.

Palabras claves: Himalaya, Nanad Devi, Bharal, Thar del Himalaya, ciervo almizclero de montaña, abundancia relativa, distribución.

Introduction

The state of Uttarakhand lies in the Western Himalaya. Western Himalaya is the only region in entire Indian Himalaya that has a combination of perpetual snow, glaciers, alpine meadows and forests (Rodgers *et al.* 2000, MoEF and

Kalpvriksh 2004)). Larger ranges in altitude, latitude and moisture regime in the region form wide ecological avenues. The region harbours more than 33% of mammals and 40% of endemic species of the Indian subcontinent (MoEF & Kalpavriksh 2004). Anthropogenic activities such as collection of fuel wood, fodder, litter and livestock grazing are degrading the mountain ecosystem gradually influencing nearly 50% of the geographical area of the region (MoEF & Kalpavriksh 2004). To counteract this 12% of forest area has been protected under various national parks and wildlife sanctuary in the state. One of such protected areas is Nanda Devi Biosphere Reserve which is globally known for its two World Heritage Sites - Valley of Flowers and Nanda Devi National Park which are also the core zones of the reserve. These sites are among the least disturbed forest areas due to ban on any kind of human activities except limited eco-tourism (Sathyakumar 2004). These core zones are rich in biodiversity and are naturally protected due to high mountain peaks encircling them. The buffer zone of the Biosphere Reserve has 47 villages and shows varying degrees of anthropogenic pressures. The study area, Pindari Valley is an adjacent valley to Nanda Devi National Park in the buffer zone and is one of the identified areas for mini core by National Biodiversity Strategy and Action Plan (MoEF & Kalpavriksh 2004). So, there is a need for mapping the biodiversity of the region quantitatively and qualitatively.

This study is the first attempt to assess the distribution and relative abundance of the high altitude mountain ungulates in Pindari valley viz., Blue sheep (*Pseudois nayaur*), Himalayan tahr (*Hemitragus jemlahicus*) and Himalayan musk deer (*Moschus chrysogaster*). In India, Himalayan tahr and Himalayan musk deer are distributed along the southern side of the Greater Himalaya between 2,000 to 4,400 m and 2,500 to tree line (ca. 3,300 m in western Himalaya) respectively. Blue sheep is distributed in the arid tracts in the Trans-Himalaya and also in some high alpine meadows on the southern slopes of the Greater Himalaya (Sathyakumar & Bhatnagar 2002). The conservation status of Himalayan tahr is NT, of Himalayan musk deer is EN and of Blue sheep is LC according to the IUCN Red List 2010 (downloaded on 22 September, 2010).

The study area

The Upper Pindari catchment of *ca.* 117.8 km^2 is located in the southern part of Nanda Devi BR (30º19'N-30º10'N and 79º57'E-80º4'E). The study area encompasses elevation ranging from 1,700 m to 7,500 m with diverse aspect and slope (Figure 1, Table 1). Timberline lies around 3,500m. The upper reaches of the Pindari Valley has two main glaciers - Pindari and Nandakot which are the sources of River Pindari. The majority of annual precipitation occurs as snow. Temperature descends below 0^0 C in peak winters and reaches maximum to 30^0 C in the summer. The study area experiences four seasons, *viz.*, winter (Jan-Mar), spring (Apr-Jun), summer (Jul-Sep) and autumn (Oct-Dec).

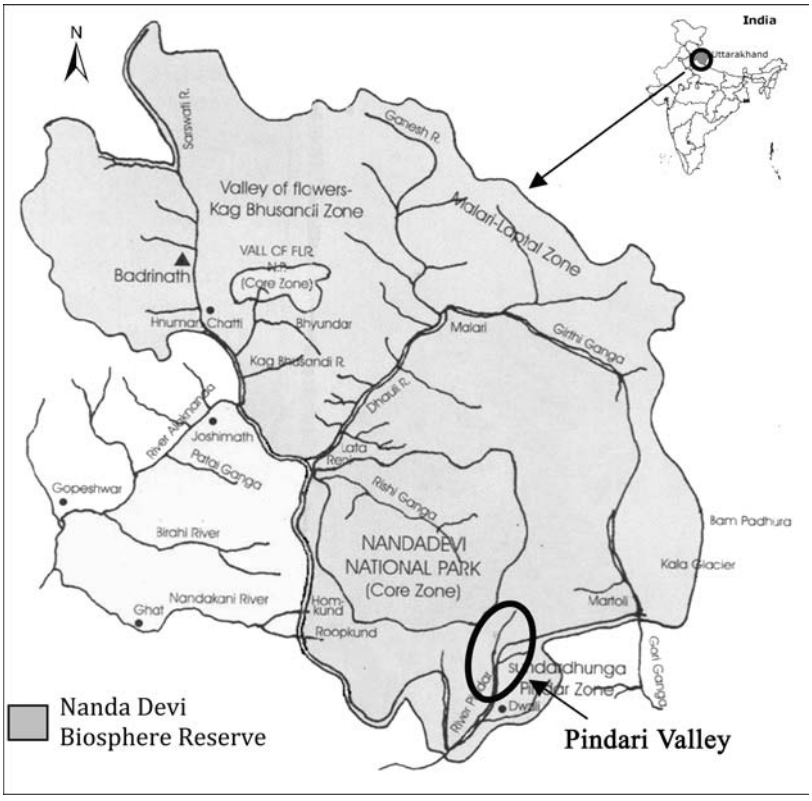

Figure 1. A Map showing the location of Pindari Valley in the Nanda Devi Biosphere Reserve, India.

TABLE 1
Percentage availability of topographical categories in Pindari valley, Nanda Devi Biosphere Reserve.

Parameter	S. no.	Category	Availability (%)
Altitude (m)	1.	< 2500	0.04
	2.	2500-3000	2.69
	3.	3000-3500	6.87
	4.	3500-4000	15.02
	5.	4000-4500	19.74
	6.	4500-5000	24.28
	7.	5000-5500	20.03
	8.	5500-6000	8.23
	9.	>6000	3.09
Aspect (°)	1.	N (337.5-22.5)	6.15
	2.	NE (22.5-67.5)	8.19
	3.	E (67.5-112.5)	18.11
	4.	SE (112.5-157.5)	20.73
	5.	S (157.5-202.5)	8.33
	6.	SW (202.5-247.5)	12.35
	7.	W (247.5-292.5)	16.67
	8.	NW (292.5-337.5)	9.48
Slope (°)	1.	0-10	3.91
	2.	10-20	17.75
	3.	20-30	24.67
	4.	30-40	25.15
	5.	40-50	19.86
	6.	50-60	7.23
	7.	60-70	1.41
	8.	>70	0.03
Habitat type	1.	Snow	61.09
	2.	Rocky area	8.30
	3.	Alpine meadow	22.49
	4.	Krummholtz	4.43
	5.	Temperate forest	3.66

In the study area, *Betula utilis* along with *Rhododendron campanulatum* forms an important community in the subalpine region. Temperate mixed forests are dominated by species such as *Quercus* spp. *Rhododendron barbatum*, *Acer Caesium* and *Prunus* spp. Alpine and subalpine meadows are dominated by *Salix* spp., *Bistorta* spp., *Anaphalis* spp. and *Rhododendron anthopogon* and *Juniperus recurva* respectively. The entire area falls under reserve forest land and there are no permanent human habitations or agricultural lands in the study area. Although the closest village is located 11 km from the study area, some anthropogenic pressures such as livestock grazing (ca. less than 5500), collection of medicinal plants were seen in the study area. Fuel wood collection by local people for their sustenance during above mentioned activities inside the study area and for catering to the needs of trekkers/ tourist was another form of interference. Other human activities include mountaineering and pilgrimage.

Methods

The field study was carried out from June 2007 to July 2009. Six trails and three scan points were selected so as to cover the maximum area of the valley for observing the selected mountain ungulates (Figure 2). Trails of length between 1.46-7.1 km were used in order to cover the area ranging between the elevations 2,500 m to 4,200 m and all the major habitats (Table 2). Scans were carried out during early morning (06:00 to 08:00) and late evening (17:00 to 19:00). The areas scanned

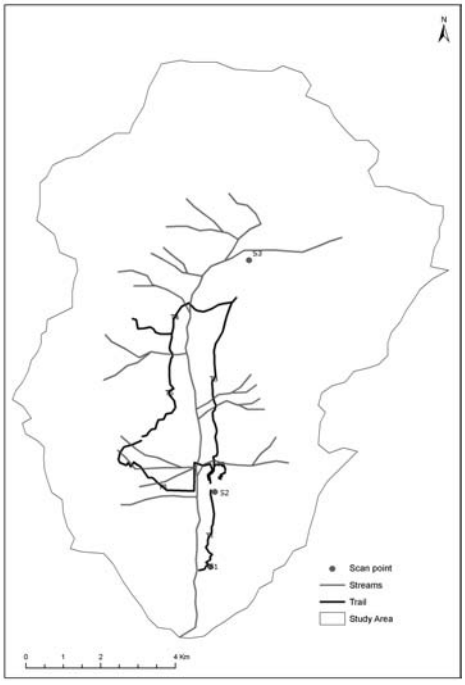

Figure 2. A map of the Pindari Valley showing the transects/trails and scan stations used during the study.

ranged between 2,500-6,000 m. Each trail and scan point was sampled at least three and six times respectively every month except in the months of January, February and December due to heavy snowfall. In late July and August study was suspended due to high rainfall and poor visibility due to low clouds. Monitoring of the trails and scan points were largely dependent on the weather conditions and logistics. Scan counts were primarily done for Blue sheep and Himalayan tahr, whereas trail walks were used for Himalayan musk deer. Records of direct sighting and indirect evidences (pellets groups were dissembled from the trails every time on sighting) were made on time, species, number of individuals and habitat attributes such as altitude, aspect, slope, and vegetation type.

TABLE 2
Characteristics of the trails/transects and scan points selected for the study.

Trail/ Scanpoint	Vegetation type	Length/Area	Altitude
T 1	*Quercus-Prunus-Rhododenron*	2.6 km	2600-3200
T 2	*Betula-Rhododendron*	1.46 km	3200-3500
T 3	*Danthonia-Rhododendron*	7.1 km	3200-4000
T 4	*Danthonia-Rhododendron, Bistorta-Anaphalis*	2.5 km	4000-4500
T 5	*Danthonia-Rhododendron*	6.44 km	4000-4200
T 6	*Danthonia-Betula-Rhododendron*	5.33 km	4200-3200
S 1	*Quercus-Prunus-Rhododenron*	0.6 km^2	2500-2800
S 2	*Betula-Rhododendron-Danthonia*	15.57 km^2	3500-5000
S 3	*Danthonia-Rhododendron, Bistorta-Anaphalis*	27.55 km^2	4000-6000

Encounter rates were calculated using the formula ER = N/E where N is the number of individuals recorded and E is the effort (hours or kilometers). Density (#/km^2) was calculated using the formula D = N/A where N is the number of individuals recorded and A is the area that was scanned from the vantage points. Boundaries of the scanned areas were drawn on the topographic sheet

of the region and area was calculated separately (Table 2) for three scanned sites corresponding to three vantage points using ArcGIS 9.1 (Kittur *et al*. 2009) using ArcGIS version 9.3.

Statistical analysis

Density (DE = no. of individuals recorded/ area scanned) and encounter rates (ER = no. of individuals/ scan hours) were calculated for each sampling effort separately using MS Office Excel 2003. With pooled data for all the years, Kruskal – Wallis test was done to find out the significance of differences between the seasonal observations using SPSS 15. χ^2 test was done for confirming the significant difference in the habitat use pattern of the three studied ungulate species (Zar 2007).

Results and discussion

Abundance of Blue sheep, Himalayan tahr and Himalayan musk deer

Scanning was found to be the best method for surveying blue sheep and Himalayan tahr as these species inhabit open mountain slopes with sparse vegetation and highly rugged terrain such as cliffs (Caughley 1970, Schaller 1973, Green 1978, Sathyakumar 1994). Trail walk was considered to be an appropriate method for surveying the Himalayan musk deer (Sathyakumar 1993, 2004). Therefore, the encounter rates were expressed as number seen per hour and number seen per km walk for Himalayan tahr and Himalayan musk deer respectively.

A total of 1,150 individuals of blue sheep were recorded in 41 observations made in a total effort of 168 scan counts (316 hours). Similarly, a total of 526 individuals of Himalayan tahr were recorded in 56 observations made in a total effort of 193 scan counts (386 hours). We recorded 11 individuals and 69 pellet groups of the Himalayan musk deer on 135 trail walks totalling 474 km effort (Table 3).

In Pindari Valley, the encounter rate (ind/hr) of Blue Sheep was highest (4.13±1.00 individuals/hr) when compared to Himalayan tahr (1.97±0.37 individuals/hr) and Himalayan musk deer (0.26±0.04 individuals/km). However, the sightings of Himalayan tahr were more frequent than the other two species.

Encounters rates ranged between 0 and 82.33 individuals/hr for Blue sheep, 0 and 18 individuals/hr for Himalayan tahr, and 0 and 2.73 individuals/hr for Himalayan musk deer. Average group sizes of Blue sheep and Himalayan tahr were 30.95±7.23 individuals (2 to 247 range) and 10.82±1.87 individuals (1 to 42 range) respectively. Therefore, in Pindari valley, the most frequently encountered ungulate was Himalayan tahr in small groups. Blue sheep was encountered in large groups at times and Himalayan musk deer was encountered rarely.

TABLE 3
Total number of observations, number of individuals, sampling days and sample sizes in different seasons for each species in Pindari valley, Nanda Devi Biosphere Reserve, June 2007 to July 2009.

Species	Season	Observations (clusters)	Individuals	(n= Sample size)	Sampling days
				Scans	
Blue sheep	Winter	0	0	12	8
	Spring	21	306	74	53
	Summer	8	199	42	27
	Autumn	12	645	30	18
	Total	41	1150	158	106
				Scans	
Himalayan tahr	Winter	3	4	15	9
	Spring	38	452	98	75
	Summer	6	20	45	30
	Autumn	9	50	35	23
	Total	56	526	193	137
				Trails	
Himalayan musk deer	Winter	2	0* 9**	10	7
	Spring	18	5* 28**	58	46
	Summer	11	3* 19**	46	34
	Autumn	9	3* 13**	21	18
	Total	40	11* 69**	135	105

* visual encounter, ** pellet groups

The encounter rates, density estimates, and group sizes were significantly different in different seasons for Blue sheep and Himalayan tahr but not in case of the Himalayan musk deer (Table 4). Blue sheep encounter rate (9.37±3.38 individuals/hr), density estimate (0.90±0.37 individuals/km^2) and group size (53.75±19.41 individuals) were highest during autumn and lowest during winter (Table 4). The *p*-values obtained for ER, DE and GS based on Kruskal-Wallis test were 0.016, 0.007 and 0.000 respectively indicating significant differences in different seasons. Himalayan tahr encounter rate was highest (3.35±0.69 individuals/hr) in spring and lowest (0.26±0.15 individuals/hr) in winter. Correspondingly the density estimate was highest (2.18±0.81 individuals/km^2) in spring and lowest (0.22±0.15 individuals/km^2) in winter. Similarly, the group size of tahr was highest (11.89±1.66 individuals) in spring and lowest (1.33±0.33 individuals) in winter. Kruskal-wallis test resulted in *p*-values of 0.002, 0.024 and 0.003 for encounter rate, density estimate and group size respectively indicating significant differences in different seasons. The calculated p-value for Himalayan musk deer was 0.487 showing no significant difference in encounter rates obtained for different seasons.

Comparison of the status of mountain ungulates in Pindari valley with other areas

There is not much information on the abundance of Blue sheep, Himalayan tahr and Himalayan musk deer in the western Himalayan region (Table 5). The studies done in Kedarnath and Bedni Ali were yearly whereas the studies done in Nanda Devi National Park (NP) and Chenab valley were in the months of May, June and July. The mean encounter rate of Blue sheep in Pindari Valley was lower than the encounter rate estimated in Bedni-Ali, the other area in the buffer zone of Nanda Devi Biosphere Reserve (BR). In Pindari Valley, the encounter rate was 4.13±1.0 individuals/hr and in the Bedni-Ali it was 10.2±1.2 individuals/hr. But the range of encounter rate was remarkably higher in the Pindari Valley as compared to any other site in the core zone and buffer zone of Nanda Devi BR. Density estimated in the Pindari Valley was 0.35±0.09 individuals/km^2 which was lower than the density obtained in the Bedni-Ali as 6.95±0.82 individuals/km^2. Mean

TABLE 4
Seasonal variation in the (a) encounter rates (b) density estimate and (c) group sizes of Blue sheep, Himalayan tahr and Himalayan musk deer in Pindari Valley, Nanda Devi Biosphere Reserve, India, June 2007 to July 2009.

(a) Encounter rates (#/hr) & (#/km for musk deer) ±S.E

Species	Winter	Spring	Summer	Autumn
Blue sheep	0 (n=12)	2.05 ± 0.76 (n=74)	3.43 ± 1.78 (n=42)	9.37 ± 3.38 (n=30)
Himalayan Tahr	0.26 ± 0.15 (n=15)	3.35 ± 0.69 (n=98)	0.31 ± 0.13 (n=45)	1.00 ± 0.38 (n=35)
Himalayan Musk deer	0.32 ± 0.22 (n=10)	0.30 ± 0.07 (n=58)	0.19 ± 0.08 (n=46)	0.27 ± 0.10 (n=21)

N = number of scans/walks, #- number of individuals

(b) Density Estimates (#/km^2)±SE

Species	Winter	Spring	Summer	Autumn
Blue sheep	0 (n=12)	0.24 ± 0.11 (n=63)	0.20 ± 0.10 (n=33)	0.90 ± 0.37 (n=26)
Himalayan Tahr	0.22 ± 0.15 (n=15)	2.18 ± 0.81 (n=83)	0.46 ± 0.26 (n=30)	0.49 ± 0.30 (n=24)

n- number of scans, #- no. of individuals

(c) Group size (individuals/group)±SE

Species	Winter	Spring	Summer	Autumn
Blue sheep	0 (n=0)	14.57 ± 4.74 (n=21)	24.87 ± 8.96 (n=8)	53.75 ± 19.41 (n=12)
Himalayan Tahr	1.33 ± 0.33 (n=3)	11.89 ± 1.66 (n=38)	3.33 ± 0.66 (n=6)	5.55 ± 0.98 (n=9)
Himalayan Musk deer	0 (n=0)	1 (n=5)	1 (n=3)	1 (n=3)

n- number of groups

group size in Pindari Valley was markedly higher than any area in the buffer or core zone of Nanda Devi BR. The maximum number of individuals of Blue sheep seen in a herd was 247 in Pindari Valley, whereas not more than 61 individuals in a group were seen in any of the other sites - Nanda Devi NP (61 individuals) and Bedni-Ali (37 individuals). The reason of lower encounter rates in Pindari Valley in comparison to Bedni-Ali could be the difference in the intensity of anthropogenic pressures in the two study areas. The anthropogenic pressure in Bedni-Ali was higher (Bhattacharya *et al.* 2007) as compared to Pindari Valley which restricts the movement of the wild animals to certain localities. Whereas, in Pindari Valley due to lower anthropogenic pressure the movements of wild animals could be larger. Encounter of an animal would be decreased if its movement is spread across a vast area and increased if the movement of animal is confined to a smaller area, such as tops and cliffs of mountains and encounter rate could be higher in that particular area. Higher mean group size of the Blue sheep in Pindari Valley shows that the area is less disturbed and the quality of the habitat is good.

Stockley (1928) has observed a herd of 200 individuals of blue sheep in India and Schaffer (1937) has seen a herd of 400 in Tibet. Population density in Nepal was found to be 0.9-2.7 individuals/km^2, increasing to 8.8-10.0 individuals/km^2 during the winter (Schaller 1977, Wang & Hoffmann 1987). An animal's food habits influence its group size. Species which browse on small, high quality items, items which grow scattered and are wholly removed when eaten, generally do not congregate into herds (Jarman 1974). At the other extreme are grazers, whose abundant food resources in a typically open environment enable them to forage in herds of hundreds and even thousands. Aggregations of Blue sheep are often a result of locally abundant food source (Schaller 1977).

Similar trend was seen in the case of the Himalayan tahr and Blue sheep. The encounter rate and density for Himalayan tahr in Pindari Valley were lower than the encounter rate and density found in the other sites in buffer and core zone of the Nanda Devi BR. But the mean group sizes were higher than the other areas. The encounter rate obtained for Himalayan tahr in Pindari Valley was 1.97±0.37 individuals/hr. In Kedarnath Wildlife Sanctuary (WS) the encounter rate was 20.8±2.9 individuals/hr during 1989-91 (Sathyakumar 1994) and 9.78±0.56

TABLE 5
Overall encounter rates, densities and group sizes of Blue sheep, Himalayan tahr and Himalayan musk deer in Pindari valley and their comparison with other areas of Western Himalaya.

	Parameter	Pindari	NDNP[1] (1993)	NDNP[2] (2004)	KWLS[3] (2004)	KWLS[4] (1994)	Chenab valley[5]	Bedini Ali[6]
Blue sheep	ER	4.13±1.0 (0-82.33)	- (0-26.40 ind/km)	- (0-3)[#]	-	-	-	10.2±1.2
	DE	0.35±0.09 (0-8.96)	- -	- -	-	-	-	6.95±0.82
	GS	30.95±7.2 (2-247)	- -	8.96 ± 7.50 (1-32)	-	-	-	14.17±1.5 (2-60)
Himalayan tahr	ER	1.97±0.37 (0-18)	- -	-	9.78±0.56	20.8±2.90 (17.9-23.8)	7.37	-
	DE	1.38±0.45 (0-53.33)	- -	-	10.4	7.56*	-	-
	GS	10.82±1.8 (1-42)	- -	-	6.1±0.3 (1-46)	13.7±2.30 3.63-13.54	7.88	(2-16)
Himalayan musk deer	ER	0.26±0.04 (0-2.73)	- (0-0.20 ind/km)	- (0-2.22)	-	-	-	0.01±0.01
	DE		-	4[##]	-	3.7 ± 0.20**	-	0.56±0.34

NDNP- Nanda Devi National Park, KWLS- Kedarnath Wildlife Sanctuary, [#]based on transect, [##] maximum density in an area, *based on transect walk, **based on silent drive count method 1- Sathyakumar, 1993; 2- Sathyakumar, 2004; 3-Kittur *et al.* 2004; 4- Sathyakumar, 1994; 5- Bhattacharya, *et al.* 2008; 6- Bhattacharya, *et al.* 2007.

individuals/hr in 2006 estimated by Kittur *et al.* (2006). Bhattacharya *et al.* (2008) estimated the encounter rate of Himalayan tahr in Chenab Valley, which is outside the Nanda Devi BR, as 7.37 individuals/hr. Density of Himalayan tahr calculated for Pindari Valley was 1.38±0.45 individuals/km^2 whereas for Kedarnath WS, it was 10.4 individuals/km^2 in 2004 (Kittur *et al.* 2006) and 7.56 individuals/km^2 during 1989-91 (Sathyakumar 1994). No abundance estimates were made during the scientific expeditions conducted in 1993 and 2004 in Nanda Devi NP, because of very few sightings of the species. In the year 1983, in a field survey of 50 days, 38 individuals of Himalayan tahr were seen in 10 sightings. Whereas in 2003 expedition only 3-5 Himalayan tahr were seen on an occasion. Mean group sizes of Himalayan tahr in Pindari Valley were estimated to be 10.82±1.8 individuals which are higher than the mean group sizes estimated in Kedarnath WS as 6.1±0.3 individuals by Kittur *et al.* (2006) and Chenab Valley as 7.88 individuals by Bhattacharya *et al.* (2008). But the average group sizes were lower than as found in the Kedarnath WS (13.7±2.3 individuals) by Sathyakumar (1994). The reason of lower abundance estimates of Himalayan tahr in Pindari Valley remains same as that for Blue sheep that the intensively studied area is larger (largest area studied in this study 27.55 km^2) as compared to the area studied in Kedarnath WS (9.6 km^2).

Vinod & Sathyakumar (1999) reported an encounter rate of 2.38±0.41 individuals/km and a density of 2.81± 0.49 individuals/km^2 in the Great Himalayan NP, Himachal Pradesh, which is higher than that in Pindari Valley. Schaller (1973) recorded the mean group size for Himalayan tahr as 6.5 individuals in eastern Nepal, whereas Green (1978) recorded mean group size of 14.8 individuals in Langtang NP. Mean group size of 5.14 to 13.7 individuals was observed by Vinod and Sathyakumar (1999) in the Great Himalayan NP.

Encounter rate obtained in Pindari Valley for Himalayan musk deer was 0.26±0.04 individuals/km which is higher than the encounter rate obtained in Bedni-Ali as 0.01±0.01 individuals/km (Bhattacharya *et al.* 2007). The range of the encounter rate obtained in the Nanda Devi NP in 1993 was 0-0.2 individuals/km (Sathyakumar 1993) which was almost consistent till 2003 (Sathyakumar 2004). Whereas the range of encounter rate obtained in Pindari Valley was 0-2.73 individuals/km, which was marginally higher than the core

zone estimates. Density was not calculated for the species because of inability to delineate the appropriate area. Green (1985) and Sathyakumar (1994) estimated density of Himalayan musk deer to be 3.2 and 3.7 individuals/km^2 using Silent Drive Count method in Kedarnath WS. Density estimated for Himalayan musk deer in Bedni-Ali region was 0.56±0.34 individuals/km^2 (Bhattacharya *et al.* 2007). The higher abundance estimates in Pindari Valley is due to less human disturbances in the area.

Habitat use pattern of Blue sheep, Himalayan tahr and Himalayan musk deer

Maximum sightings of Blue sheep were in the areas ranging between 4,500-5,000 m and were sighted up to the height of 5,500m on ice layers and as low as 3,500 on the sub-alpine livestock grazed lands (Figure 3a). Bigger group sightings were recorded mainly at heights between 3,500 and 4,500 m. Blue sheep used south-eastern, eastern and western slopes which were exposed to sun light for at least half of the day (Figure 3b). About 70% of the sighting of Blue sheep falls under the 30^0- 40^0 slopes and rest 30% were in the gentle slope category of 20^0-30^0 (Figure 3c).

Himalayan tahr was fairly distributed between the elevations of 2,500 to 4,500 m with maximum sightings between 3,000-4,000 m. Himalayan tahr was not sighted above 4,500 m (Figure 3a). Himalayan tahr was found distributed in the eastern, south-eastern, south-western and western slopes. More than 60% sightings were in the eastern slopes and near about 30% sightings were in south-eastern slopes. Less than 10% of the total sightings were in the south-western and western slopes (Figure 3b). Himalayan tahr was found to use all the slope categories but was mainly sighted in the steeper slopes of 50^0-60^0 (Figure 3c).

The Himalayan Musk deer was found restricted between 3,000 m and 4,500 m and were sighted maximum times in 3,500 m to 4,000 m (Table 3a) which is *Krummholtz* zone. It was observed in maximum categories of the aspect. This may owe to the factor that we incorporated indirect evidences (pellet groups) along with direct sighting on the trails to calculate the encounter rates. Maximum encounters of musk deer were in the east and west facing slopes which are warmer and exposed to sun light for longer periods of time. This species was found to

use slopes ranging between 20^0 and 60^0 and majority of the sightings were in the slopes of 30^0 to 40^0 (Figure 3c).

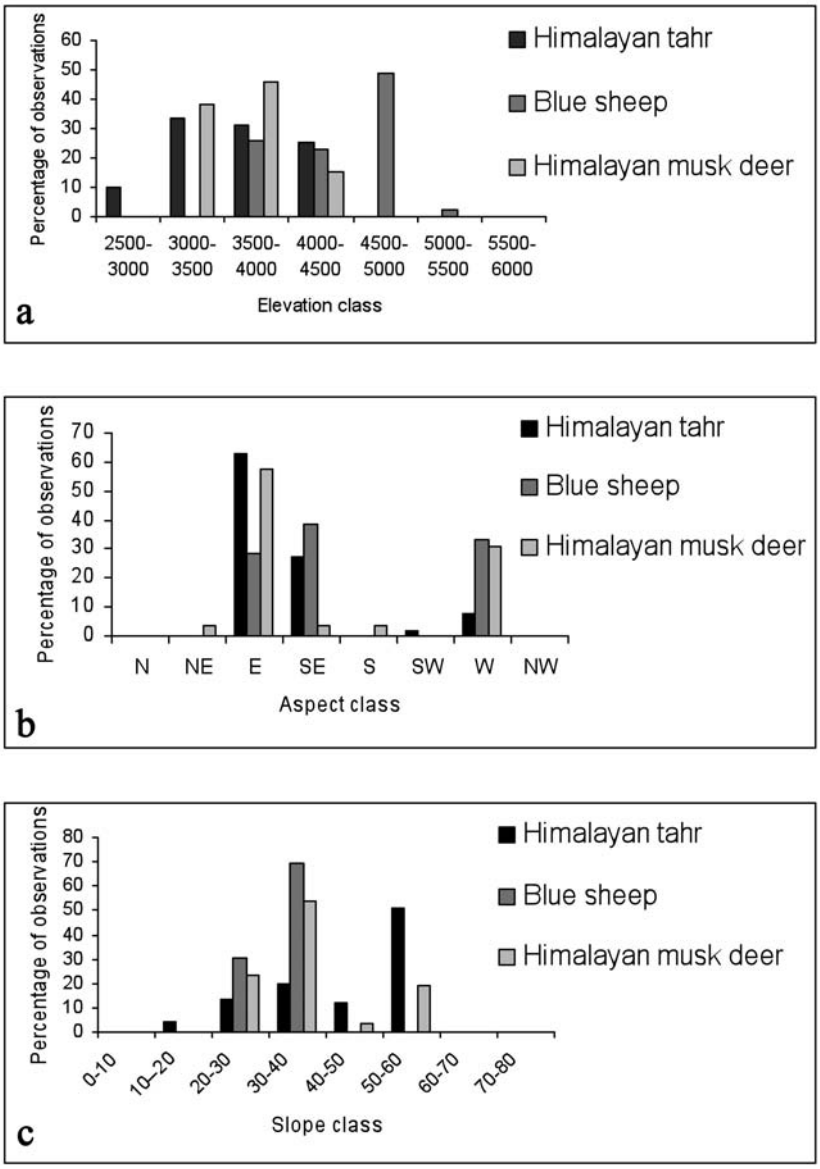

Figure 3. Use of (a) altitude, (b) aspect and (c) slope by mountain ungulates in Pindari Valley, Nanda Devi Biosphere Reserve, June 2007 to July 2009.

Habitat use pattern was compared among these three sympatric species using χ^2 test and was found to be highly significant in all the respect. The *p*-value for the aspect, elevation and slope was 0.001, 0.001 and 0.000 respectively.

Management

Pindari Valley harbours good populations of wild ungulates. Large group sizes of ungulates indicate that much part of the valley remains inviolate and has low anthropogenic pressure. So it becomes imperative to protect the area to conserve its biological diversity. The current levels of resources use by people and livestock appear to be within the sustainable levels, but need to be monitored so that these pressures do not increase. Poaching for meat is another threat to mountain ungulates in this area which needs to be controlled by adequate intelligence gathering, patrolling and through community participation. Education and awareness of local communities in the area and establishment of self help groups and community based ecotourism for alternate livelihood needs to be strengthened.

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