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DISTRIBUTION, RELATIVE ABUNDANCE AND HABITAT USE BY MOUNTAIN UNGULATES IN *PREK CHU* CATCHMENT, KHANGCHENDZONGA BIOSPHERE RESERVE, SIKKIM, INDIA

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Abstract

We assessed the distribution patterns and relative abundance of mountain ungulates in *Prek Chu* catchment of Khangchendzonga Biosphere Reserve (BR) during 2008-2009 by sampling trails/transects, vantage points and using camera traps. Presence of goral (*Naemorhaedus goral*), barking deer (*Muntiacus muntjac*), serow (*Naemorhaedus sumatraensis*), musk deer (*Moschus sp.*) and blue sheep (*Pseudois nayaur*) was confirmed through direct and indirect evidence. Presence of Himalayan tahr (*Hemitragus jemlahicus*) was confirmed only through camera traps. Blue sheep herds were readily detectable (n= 31) with the highest detection probability. Photo capture rate of goral (n= 156) was the highest. Differential use of elevation categories along with vegetation categories depicted blue sheep and musk deer as specialists for areas at (*Krummholtz* zone) and above treeline (>4000 m); and barking deer as specialist for lower elevation (>2500 m) wet temperate forested habitats. Goral and serow were generalists as they used all the forested areas of low altitude (<2000 m) subtropical forest, medium altitude (2000-3000 m) wet temperate forest and subalpine forests (3000-4000 m). Livestock grazing and pack animal presence in the study area along with garbage accumulation due to tourism are the main concerns for degradation of mountain ungulate habitats in *Prek Chu* catchment.

Key words: Distribution, detection probability, elevation categories, habitat degradation, photo capture rate.

Resumen

Distribución, abundancia relativa y uso del hábitat por los ungulados de montaña en la cuenca del Prek Chu, en la Reserva de la Biosfera de Khangchendzonga (Sikkim, India)

Se han evaluado los patrones de distribución y abundancia relativa de los ungulados de montaña en la cuenca del Prek Chu, en la Reserva de la Biosfera de Khangchendzonga durante 2008-2009 utilizando tanto transectos lineales y recorridos por senderos, puntos fijos y fototrampeo. Se ha confirmado a presencia del goral (*Nemorhaedus goral*), ciervo muntjac (*Muntiacus muntjac*), serow (*Nemorhaedus sumatraensis*), ciervo almizclero (*Moschus* spp.) y bharal (*Pseudois nayaur*) mediante evidencias directas e indirectas. La presencia del thar del Himalaya (*Hemitragus jemlahicus*) sólo se ha confirmado con el fototrampeo. Los rebaños de bharal fueron fácilmente detectables con la probabilidad más alta de detección. La tasa de fotocapturas de goral (n= 156) fue la más alta. El uso diferencial de los hábitats, pone de manifiesto que el bharal y el ciervo almizclero utilizan mayoritariamente áreas por encima de la línea de árboles superiores a 4000 metros (zona de Krummholtz), mientras que el ciervo muntjac ocupa áreas de menor elevación (> 2500 m) formadas por bosques húmedos templados. El goral y el serow fueron más generalistas ya que utilizan todas las áreas boscosas subtropicales de baja altitud (< 2.000 m), bosques templados húmedos de altitud media (2000-3000 m) y bosques subalpinos (3.000-4.000 m). El pastoreo del ganado doméstico, la presencia de animales de carga y la acumulación de basura debido al turismo son las causas principales de la degradación de los hábitats de montaña en la cuenca Prek Chu.

Palabras clave: categorías de elevación, degradación del hábitat, distribución, índice de foto captura, probabilidad de detección.

Introduction

The Khangchendzonga massif presides over the physiography of Sikkim. It has the world's third highest peak - Mt. Khangchendzonga (8,586 m), and its adjoining wilderness area hold an array of wildlife habitats that support rich biodiversity and forms an integral part of the people living in the region, providing life-support systems for several million people living in the hills and plains south of the region. In order to conserve and manage the rich biodiversity, the Khangchendzonga National Park (NP) was created in 1977 with an area of 880 km^2, which was later expanded to 1,784 km^2. The conservation and management efforts in the Khangchendzonga NP was further strengthened by an addition of 836 km^2 as buffer zones to the NP, to constitute the Khangchendzonga Biosphere Reserve (BR) in 2000 (Sharma & Lachungpa 2002).

Ungulates are a major constituent of the Himalayan mammalian fauna and are also the major prey base for the large mammalian predators. In total, 19 ungulate species belonging to four families *viz*., Moschidae, Cervidae, Bovidae and Equidae, inhabit the Himalaya (Bhatnagar 1993). The Himalaya and associated mountain ranges are home to 12 of 31 species (38.7%) of Caprinae found worldwide, the richest in any part of the world (Shackleton 1997). In total 14 species of ungulates are reported to occur in the Khangchendzonga BR (Sharma & Lachungpa 2002).

Over 10 major research studies and some surveys have been carried out in Khangchendzonga NP and BR, but all focusing on vegetation, habitats, birds and social studies. The most recent study in Khangchendzonga NP is by Tambe (2007) on the alpine vegetation ecology and livestock grazing. There have been no surveys or studies dealing with the aspects such as the distribution, abundance and ecology of mountain ungulates in Khangchendzonga NP and BR. Keeping this in view, this study was carried out in the *Prek Chu* catchment (*chu=river*) located in the western part of the BR, with the objective of assessing the mountain ungulates spatial distribution patterns, relative abundance and habitat use.

Study area

The Khangchendzonga BR is one of the most significant biodiversity hotspots of India, having varying ecozones from temperate to arctic (1,220 - 8,586 m). The varying elevation of 1,220 to 8,586 m (Khangchendzonga summit) within an aerial distance of just 42 km makes this park a unique natural heritage hotspot in the world. The Khangchendzonga BR encompasses temperate, subalpine and alpine habitats (1,220 to 5,000 m) as well as rocky slopes, glacial moraines and permafrost areas (>5000 m) with diverse slope and aspect categories, along with a range of wildlife use. The area of Khangchendzonga BR has been divided into seven watersheds or river subsystems, namely, Lhonak (15%), Zemu (23%), Lachen (5%), Rangyong (36%), Rangit (6%), Prek (8%) and Churong (7%). For this study, *Prek chu* catchment area was selected as the study area because it represents all the habitats of the Khangchendzonga BR (Figure 1). The *Prek Chu* valley [27° 37'N, 88° 12E - 27°21N, 88° 17E] opens up in the upper reaches and the total area of this watershed is 182 km^2, which is about 8% of the total area of the Khangchendzonga BR. The highest elevation and the lowest elevation of the *Prek Chu* watershed are 6,691 m (summit of Pandim) and 1,200 m respectively, with a mean of 3,562 m (Tambe 2007). The following elevation classes are observed– 1,001-2,000 m (5%), 2,001-3,000 m (13%), 3,001-4,000 m (25%), 4,001-5,000 m (44%) and 5,001-6,991 m (13%) in the study area. The annual rainfall ranges from 1,750 mm to 2,250 mm, with the mean being around 2,230 mm (Tambe 2007). The *Prek Chu* watershed has a typical monsoon climate and can be divided into the following habitat classes– mixed sub-tropical and mixed temperate (17%), subalpine (24%), *krummholtz* (12%), alpine pastures (5%), rock and snow cover (41%) and water bodies (1%) [Figure 2].

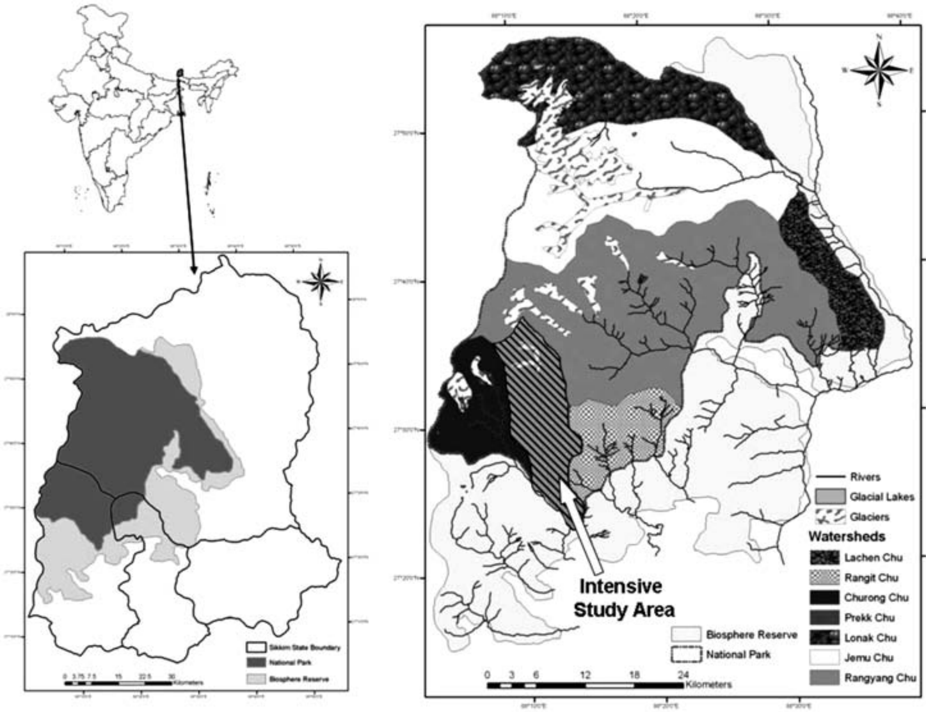


Figure 1. Location of Khangchendzonga Biosphere Reserve in Sikkim, India and different watersheds of Khangchendzonga National Park, showing the intensive study area of *Prek Chu* catchment.

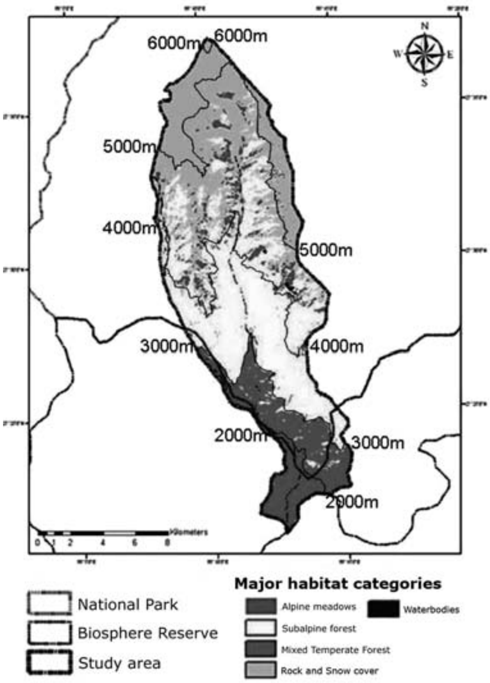
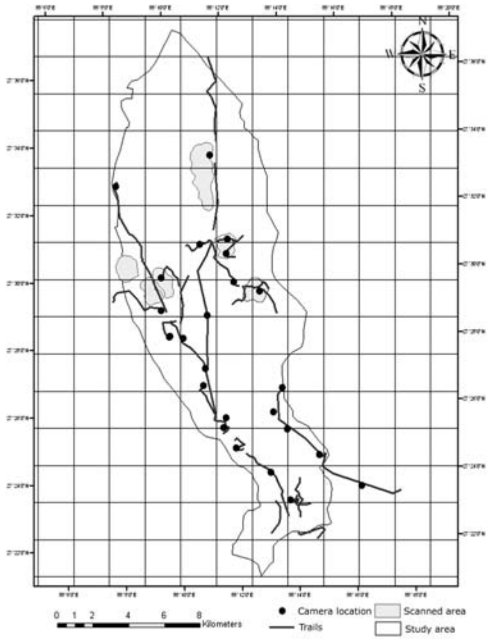


Figure 2. Major habitat categories and contours of *Prek Chu* Catchment, Khangchendzonga Biosphere Reserve, Sikkim, India.

Methodology

The study was conducted from 1 April 2008 to 31 July 2009 and all field activities were carried out in the form of field expeditions - camping in different areas of the *Prek chu* watershed. One field survey was usually of 8-7 days and all the sampling units were replicated after every 7-10 days. Based on available literature and field reconnaissance survey, the following techniques were adopted for the study.

1. Camera traps were used from 1 February 2009 to 31 July 2009 for the assessment of distribution and relative abundance of ungulates. The study area was divided into 2×2 km sampling grids/cells and camera traps were placed along trails or paths (Figure 3) that were actively used by study species. Twenty five cameras (Wildview/Stealthcam) were deployed in 22 cells, covering an area of 88 km^2 of 168 km^2 of accessible area in the study area. Since the study species are rare, the strategy was to survey more



sampling units less intensively rather than less sampling units more intensively (Mackenzie & Royle 2005).

Figure 3 Map of Intensive study area showing Trails, Scan areas and locations of Camera traps in 2×2 km grids in *Prek Chu* Catchment, Khangchendzonga Biosphere Reserve, Sikkim, India.

2. Transect and trail sampling (n= 22; 1.5 to 7 km) was used for abundance estimation and habitat use pattern of ungulates. In the Himalaya, curvilinear transect/trail sampling have been used to overcome the difficulties of working in steep, rugged and inaccessible terrain (Sathyakumar 1994, Vinod & Sathyakumar 1999). The characteristics of different transects/trails are given in Table 1. Length of each of transects/trails were calculated using ArcGIS version 9.3 (ESRI 2008). In case of sightings, data on time of sighting, number of individuals, sex of the individuals, sighting angle, sighting distance were recorded. For habitat description data on major vegetation types, elevation, aspect and slope were recorded.
3. Scanning method was used for abundance estimation and assessing habitat use patterns of blue sheep. This technique involves careful scanning from vantage points using spotting scope and/or binoculars (8×40) for a specified period of time. We used six vantage points in the study area and

the area of scan was measured using ArcGIS version 9.3. The scanning was done between 06:00h to 09:00h and 15:00h to 18:00h. Scan duration varied from one to three hours, depending on the weather conditions. The number of animals seen, their age, sex and activity pattern was recorded for every sighting. The various habitat parameters *viz.,* major vegetation types, elevation, aspect, slope categories and distance to escape terrain were also recorded around a 10 m radius of the animal sighted, whenever possible.

4. Dung counts were used for estimation of dung density of mountain ungulates in the study area. The dung counts were made within a 20×2 m belt transect laid at every 100 m interval along the trails and transects. The pellet groups were removed after every count in order to avoid double counting during the next sampling. During the reconnaissance survey, sample pellet groups of ungulates were primarily identified according to previous field experiences and collected for secondary validation by the locals. These sample pellet groups were then taken to Wildlife Institute of India and final identification and confirmation was done by experts with the help of reference photographs of species specific pellet groups (Sathyakumar *unpublished*).
5. For the assessment of the status of wildlife habitats, various habitat parameters were identified and enumerated along trails and transects, following standardized techniques (Hays *et. al.* 1981, Sale & Berkmuller 1988, Sathyakumar 1994) at different altitude zones. At every 100 m along transects and trails, one plot (10×10 m) was laid and in each plot, numbers of trees (> 31 cm DBH) were measured. Shrubs were counted inside a 5×5 m nested within the 100 m^2 plot. Grass/herb species were recorded in four 1×1 m plots randomly nested within the same plot. Percent tree, shrub, ground (herbs, forbs, grass, litter, barren) and rock cover categories were estimated. Other habitat parameters such as altitude, aspect, and slope were also recorded. The elevation, aspect and slope maps were generated from topographic maps through scanning and digitization. In case any direct/indirect evidence was observed between two sample plots, a presence plot was laid and the above parameters were recorded in the similar manner.

TABLE 1
Characteristics of Transects/Trails used for the Study in *Prek Chu* Catchment, Khangchendzonga Biosphere Reserve, Sikkim, India, April 2008 to July 2009.

Transect	Length (km)	Altitude (m)	Aspect	Slope (°)	Habitat	No. of walks
Yuksom-Sachen	4.49	2000-2500	W	15-30	Temperate	40
Sachen up-Sachen down	1.7	2300-2350	SW	30-45	Temperate	16
Bakhim-Tsokha	1.8	2300-3000	SW	30-45	Temperate	39
Yuksom-Bakhting	2.1	2000-2300	NW	15-30	Temperate	22
Labdang-Kasturi	6.66	2300-3000	N	15-30	Temperate	13
Dzongri-Jamling	1.7	3700-3900	W	30-45	Sub alpine	13
Kasturi-Phedi	4.09	3000-3900	SW	30-45	Sub alpine	7
Tsokha-Deorali	3.93	3000-3900	SW	15-30	Sub alpine	32
Dzongri-Kokchurong	2.8	3700-3900	NE	15-30	Sub alpine	5
Phedang-Kokchurong	7.24	3700-3800	NE	15-30	Sub alpine	11
Tsokha-Ghunsa	1.94	3000-3200	SW	15-30	Sub alpine	16
Kiniya-Basecamp	5.94	4400-4500	NW	0-15	Alpine	4
Thansing-Pokhrital	1.8	4000-4100	E	30-45	Alpine	5
Thansing-Neerpokhri	1.6	4000-4200	W	15-30	Alpine	8
Lampokhri-Jaireni	1.9	3900-4200	SW	15-30	Alpine	5
Dzongri-Sukhapokhri	3.73	4000-4100	NW	0-15	Alpine	13
Dzongri-Deorali	1.96	3900-4000	N	0-15	Alpine	28
Dzongri-Kiniya	1.99	3900-4500	NW	0-15	Alpine	13
Dzongri-Laxmipokhri	1.96	4200-4500	NE	15-30	Alpine	10
Thansing-Lampokhri	3.06	4000-4200	SW	15-30	Alpine	11
Lampokhri-Chamre	1.77	4200-4300	NW	15-30	Alpine	8
Thansing-Somiti	3.66	4000-4200	N	0-15	Alpine	8

Analytical methods

Site occupancy and detection probability

Site occupancy is a reliable method for estimating the distribution of a species in a given area. Site occupancy is the total number of sites/sampling units that a species occupies on a spatial scale while detection probability is the chance of any species being detected in that particular sampling area. Direct and indirect signs recorded on transects/trails were entered in the form of 1-0 matrix for each transect/trail taking five sampling occasions/replicates. The sampling occasions were chosen such that they were distributed temporally throughout the study period. Generation of presence/absence data was based on the detection in each camera trap deployed and indirect evidence or direct sighting in a sampling unit. Presence was counted as 1 while absence was taken as 0. Consequently, the matrix which was generated was used to calculate site occupancy (and its standard error), along with the detection probability (along with its standard error), using the Program PRESENCE version 2.3 (Hines 2006) computer package.

Relative abundances

Based on camera trap photographs, photo-capture rate, an index of relative abundance (RAI) as the number of days required for obtaining a photo capture of a species (Carbone *et al*. 2001) was calculated. Only independent pictures of a particular species were counted as valid to estimate RAI. Independence was defined following O'Brien *et al.* (2003) as each photo identified species and rated as a dependent or independent event. An ‘independent capture event’ (Datta *et. al.* 2008) was defined as (1) consecutive photographs of different individuals of the same or different species, (2) consecutive photographs of individuals of the same species taken more than 1 minute apart and (3) non-consecutive photos of individuals of the same species.

Encounter rates (n/L, where n= Number of sightings and L= the length of transect/trail walked) based on transect and trail sampling were obtained. Density of animals was obtained using DISTANCE 5.0 (Thomas *et al.* 2002). Relative density of blue sheep through scanning was calculated as n/A (n= number of animal and A= scanning area). The dung density was estimated as follows: D= n/A; where 'n' is the total number of pellet groups counted and 'A' is the area of the sample plots or belt transects.

Habitat use

Use of different altitudes by different ungulates was compared by using box-plots and the differences were tested through Kruskal-Wallis test by using SPSS 16 (Nourusis 1990). The modified χ^2 (Sokal 1994): log-likelihood Chi-square statistic (χ_L^2) was used to statistically test for significant use of different habitat variables such as slope categories and vegetation cover classes, by ungulates. Availability of altitude, slope, aspect and major vegetation categories were calculated from the data generated from the random plots along transects and trails. Availability and use of altitude, aspect, slope and major vegetation categories were compared, using Bonferroni confidence intervals (95%) computed according to Neu *et al.* (1974) to determine preference for habitat categories in terms of those used more than availability (UMA), used proportional to availability (UPA), and used less than availability (ULA).

Results

Twenty-two transects and trails (Table 1) were surveyed over a period of one and a half years (1 April 2008 to 31 July 2009). Twenty five camera traps were deployed (from February 2009 to July 2009) in three different habitat zones. Total camera trap nights in the temperate zone were 1200 (8 cameras), that in sub-alpine 1200 (8 cameras) and in alpine 1350 (9 cameras). Total camera trap nights in the study period were 3750 nights.

Distribution

Amongst the mountain ungulates, presence of goral (*Naemorhaedus goral*), barking deer (*Muntiacus muntjac*), serow (*Naemorhaedus sumatraensis*), musk deer (*Moschus sp.*) and blue sheep (*Pseudois nayaur*) was confirmed through direct and indirect evidence. Presence of Himalayan tahr (*Hemitragus jemlahicus*) in the study area was confirmed only through camera traps. Distribution of mountain ungulates in different habitat and elevation categories in the study area is given in Figure 4.

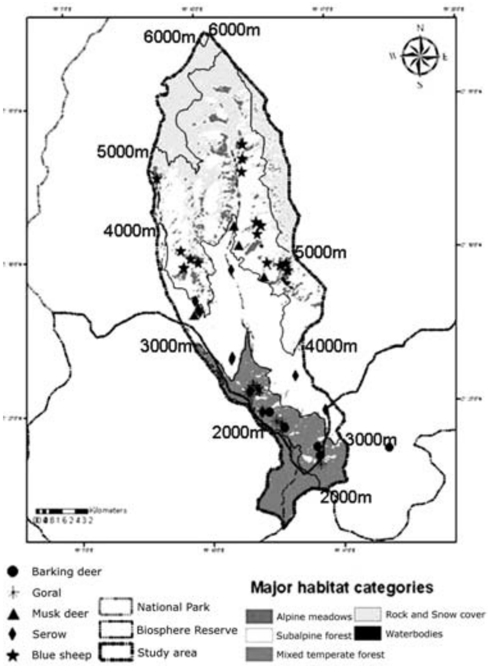


Figure 4. Distribution of Ungulate evidences in *Prek Chu* catchment, Khangchendzonga Biosphere Reserve, Sikkim, India, April 2008 to July 2009.

The proportion of site utilization for serow was highest and it decreased in the following order: serow>Himalayan tahr>goral>blue Sheep>barking deer>musk deer (Figure 5). Blue Sheep had the highest detection probability (0.55±0.09) among all the ungulates. Serow had low detection probability (0.27±0.23), but the highest proportion of sites occupied.

Relative abundance

Encounter rates and density based on transects/trails and scans were calculated. Encounter rate of blue sheep from scan sampling was estimated as 2.99±0.56 animal/hr (n= 31). Estimated encounter rate (animal/km) of other ungulates from trail/transect sampling were as follows: barking deer (n= 11, 0.15±0.05/km) > goral (n= 8. 0,11±0.05/km) > serow (n= 4, 0.05±0.03/km) > musk deer (n= 2, 0.03±0.02/km).

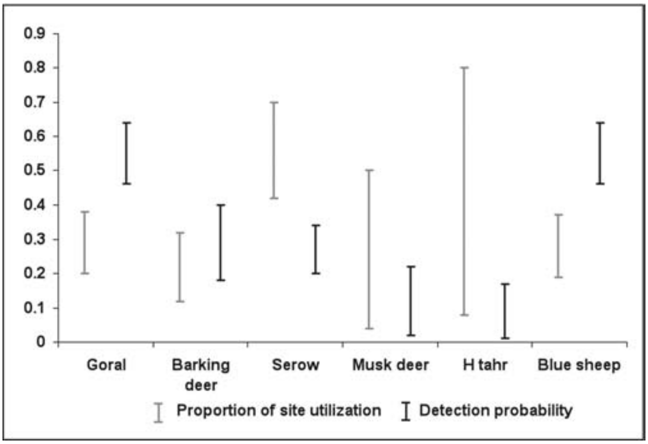


Figure 5. Proportion of site utilization and detection probability of ungulates in *Prek Chu* catchment, Khangchendzonga Biosphere Reserve, Sikkim, India.

Relative density for blue sheep was estimated as 3.67±0.78/km^2. Density of other species also followed the same order: Barking deer (0.35±0.14/km^2), goral (0.23±0.1/km^2), serow (0.12±0.06/km^2) and musk deer (0.06±0.05/km^2). Relative density of blue sheep varied significantly (Kruskal-Wallis χ^2=12.16, df= 3, p= 0.01) between autumn (5.68±1.08/km^2) and summer (1.12±0.73/km^2). Dung density (Number of pellet groups/ha) of barking deer (Kruskal-Wallis χ^2=13.03, df= 3, p= 0.01), musk deer (Kruskal-Wallis χ^2= 13.31, df= 3, p= 0.00) and blue sheep (Kruskal-Wallis χ^2=80.94, df= 3, p= 0.00) changed significantly during different seasons, whereas dung densities of goral and serow did not vary significantly in different seasons (Table 2). In summer, the dung density of the blue sheep decreased to 12.32±5.45 from 59.56±8.48 of spring, while no pellets of musk deer were recorded during the period.

Based on 3,750 camera trap nights, goral had the highest capture and corresponding capture rate (n= 156, 5.20±2.68/100 days) [Figure 6], followed by serow (n= 39,1.27±0.57/100 days). Other species had a capture rate of less than 1. Thus, the capture rates (# photographs/100days) for the ungulates increases in the following order: musk deer (n= 3, 0.10±0.05) > Himalayan tahr (n= 7, 0.17±0.08) > barking deer (n= 13, 0.43±0.40) > blue sheep (n= 25, 0.83±0.50) > serow (n= 39, 1.27±0.50) > goral (n= 156, 5.20±2.68).

TABLE 2
Dung density of mountain ungulates in different seasons in the *Prek Chu* catchment, Khangchendzonga Biosphere Reserve, Sikkim, India, April 2008 to July 2009.

Season	Goral	Barking deer	Serow	Musk deer	Blue sheep
Winter	24.75±4.15	6.65±2.44	7.15±1.93	15.11±5.57	56.37±12.26
Spring	18.69±3.31	6.62±2.25	6.71±1.56	1.29±0.74	59.56±8.48
Summer	23.73±7.07	7.01±7.01	4.81±2.99	0.00±0	12.32±5.45
Autumn	8.51±3.95	22.18±8.10	10.26±3.55	12.99±6.43	145.71±23.04
χ^2	5.05	13.03	5.57	13.31	80.94
p	0.17	0.01*	0.14	0.00*	0.00*

* Difference is significant

Figure 6. Capture rate (#/ 100 days) for ungulates *Prek Chu* Catchment, Khangchendzonga Biosphere Reserve, Sikkim, India.

Habitat use and selection

Ungulates significantly differ with each other in their use of different elevation categories (Kruskal-Wallis χ^2= 261.11, df= 4, p= 0.00). Box plots (Figure 7) showed that barking deer (n= 27) used lower elevations (2,000-2,500 m) and goral (n= 95) used both lower and middle altitudes (2,000-3,500 m). Serow (n= 57) used a wide range of altitude classes (2,500-4,000 m), whereas the musk deer (n= 16) and blue sheep (n= 130) both used exclusively high altitude category (> 4,000 m).

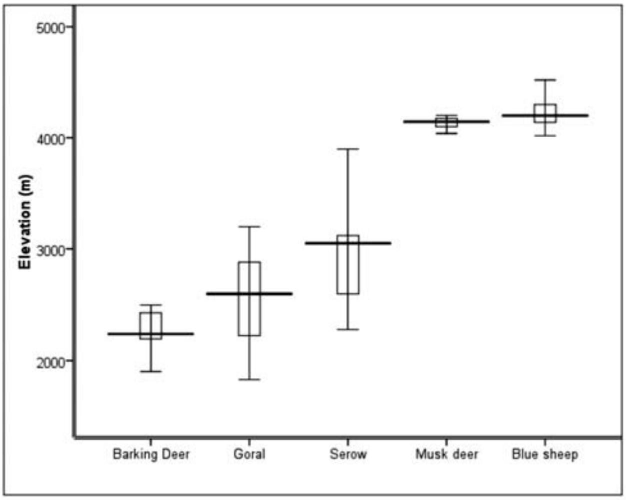


Figure 7. Boxplots showing the use of Elevation by different ungulates in *Prek Chu* Catchment, Khangchendzonga Biosphere Reserve, Sikkim, India.

Ungulates used the steep slope of 30°-40° without any significant difference (χ_L^2= 2.11, df= 16, p= 0.99). Blue sheep evidence was found in flat (10°-20°), moderately steep (20°-30°) and steep (30°-40°) slope categories. Most of the musk deer (75%) evidences were found in steep (30°-40°) slope categories. Very little evidence of (goral, barking deer and serow) was found in steeper slopes of > 40° (Table 3).

Direct or indirect evidence of blue sheep were never found below the tree line zone. Musk deer mostly used areas without tree cover (0-25%) whereas the other ungulates (goral, barking deer and serow) used all the tree cover categories with no significant difference (Table 3).

TABLE 3
Percentage use of different habitat variables by ungulates in *Prek chu* Catchment Khangchendzonga Biosphere Reserve, Sikkim, India, April 2008 to July 2009.

Variable	Categories	Goral	Barking deer	Serow	Musk deer	Blue sheep	χ_L^2	df	p
Slope (°)	10-20	9.80	5.26	4.21	0.00	25.31	56.44	12	0
	20-30	42.16	43.86	37.89	25.00	39.88	2.11	12	0.99*
	30-40	47.06	43.86	55.79	75.00	16.87	92.56	12	0
	40-50	0.98	7.02	2.11	0.00	0.00	22.56	12	0.12*
Tree cover (%)	0-25	0.00	0.00	8.42	91.67	-	110.47	9	0.00
	25-50	30.39	26.32	23.16	4.17	-	8.25	9	0.76*
	50-75	56.86	49.12	49.47	4.17	-	25.00	9	0.51*
	75-100	12.25	24.56	20.00	0.00	-	12.16	9	0.20*
Shrub cover(%)	0-25	38.24	8.77	35.79	4.17	54.75	56.55	12	0.00
	25-50	41.67	47.37	33.68	45.83	40.34	2.02	12	0.99*
	50-75	19.12	40.35	30.53	37.50	4.91	92.71	12	0.00
	75-100	0.98	3.51	0.00	12.50	0.00	25.53	12	0.01
Ground cover (%)	0-25	47.06	89.47	64.21	12.50	36.20	45.76	12	0.00
	25-50	20.10	10.53	9.47	50.00	52.45	97.96	12	0.00
	50-75	15.20	0.00	25.26	37.50	11.35	32.76	12	0.00
	75-100	17.65	0.00	1.05	0.00	0.00	112.30	12	0.00
Rock cover (%)	0-25	96.57	98.25	91.58	79.17	37.88	125.81	12	0
	25-50	2.94	1.75	8.52	12.50	55.83	232.47	12	0
	>50	0.49	0.00	0.00	8.33	5.37	25.62	12	0.01

* Difference is not significant

Medium (25-50%) shrub cover was used by all ungulates without significant difference among them (χ_L^2= 2.20, df= 12, p= 0.99). Serow evenly used all the shrub cover categories (Table 3). Musk deer used medium to high cover (25-100%) of stunted *Rhododendron* and *Juniperus* scrub of *Krummholtz* zone whereas the blue sheep evidence was found mostly in low to medium (0-50%) cover of *Krummholtz* vegetation.

Ungulates differ significantly in use of different ground cover classes (Table 3). Most of the evidence of goral, barking deer, serow and blue sheep was found in low to medium (0-50%) ground cover category, whereas musk deer evidence was found in medium to high (25-75%) ground cover category.

Use of rock cover was also significantly different among ungulates (Table 3). Goral, barking deer and serow used low (0-25%) rock cover category, whereas musk deer used low to medium (0-50%) rock cover. Most of the blue sheep evidence was found in medium (25-50%) rock cover.

On examining the availability and utilization of the elevation categories, barking deer used the lower elevation categories (1,000-2,000 m and 2,001-3,000 m) more than availability, whereas blue sheep and musk deer both used the high (> 4,000 m) elevation category more than the availability. Goral and serow used the medium elevation zones (2,000-4,000 m) more than their availability [Figure 8a.]. South-west was the most used aspect by ungulates except for blue sheep [Figure 8b.]. Musk deer mostly used the eastern aspect, whereas blue sheep used the north, northeast and northwest aspects to a larger extent. All ungulate species except blue sheep used the 30°-40° slope category positively. Blue sheep preferred flat areas under 0°-10° slope category and proportionately used the available area under 10°-20° slope category [Figure 8c]. Figure 8d illustrates the availability and the utilization patterns of different habitat types by mountain ungulates. Barking deer, goral and serow used the wet-temperate habitat more than its availability. Barking deer also proportionately used the available subtropical habitat; whereas serow used the fir-birch-rhododendron dominated subalpine habitats more than their availability. Blue sheep and musk deer both used the Alpine-scrub habitat more than its availability, but the musk deer used the stunted *Rhododendron* and *Juniperus* scrub habitat according to its availability.

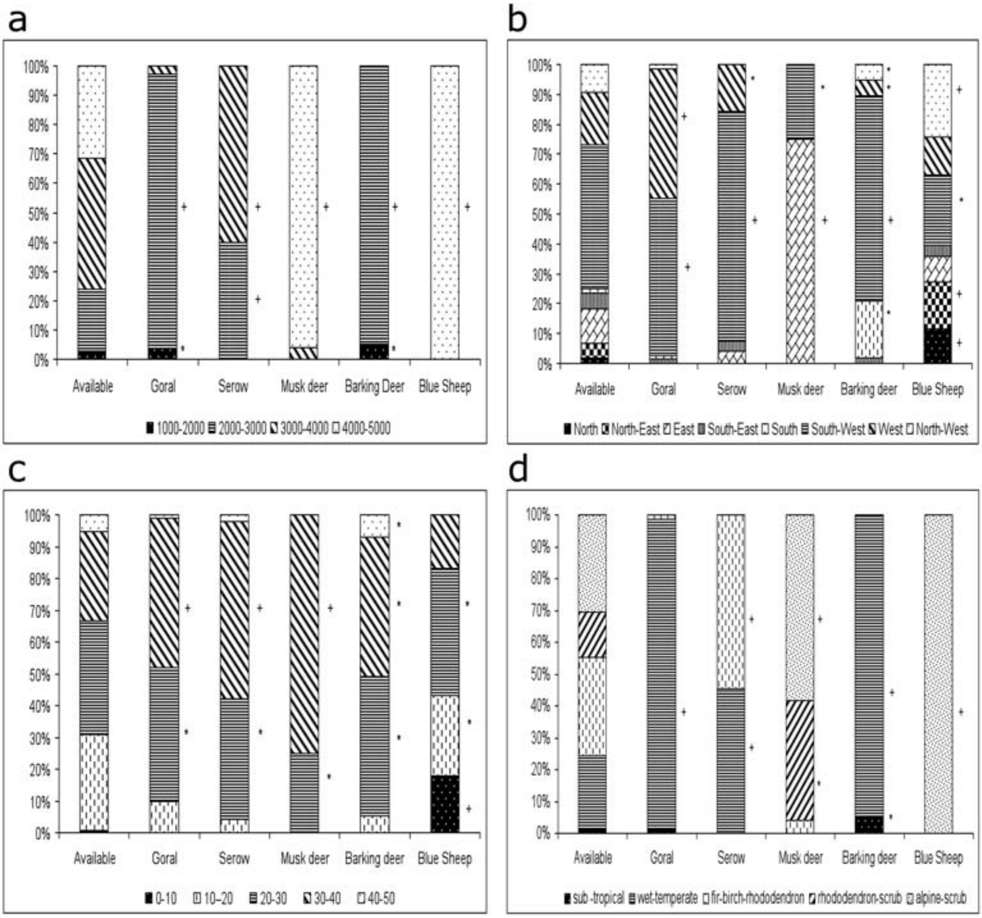


Figure 8. Availability and use of (a) altitude, (b) aspect, (c) slope and (d) major habitat types by ungulates in KBR, based on the Bonferroni confidence intervals calculated according to Neu *et al.* (1974). Plus sign denotes the used more than availability and asterisk denotes the used in proportion to availability; not marked are used less than availability (Significance level maintained 0,05).

Discussion

Confirmation of the presence of six mountain ungulates in the *Prek Chu* catchment area proved that the area has a diverse prey base for large carnivores. Presence of Endangered Himalayan musk deer, Vulnerable serow and Near Threatened Himalayan tahr (IUCN 2010) made this area important from the conservation aspect. Himalayan tahr may be distributed in the most inaccessible parts of the study area where trail sampling was not carried out. It appears that they are using only small portions along the eastern boundary of the study area. It is reported to occur in the adjacent catchment area, Rangit chu. Non-detection of Himalayan tahr pellet groups confirms that the species was absent from most of the study area for most of the time, because Himalayan tahr pellets are very conspicuous in morphology and easily distinguishable from pellet groups of other ungulates present in the study area (Sathyakumar *unpublished*). Spatial distribution pattern of direct and indirect evidence of ungulates in the *Prek Chu* catchment area showed a clear distinction between two groups: blue sheep and musk deer distributed over 4,000 m altitude in alpine and *krummholtz* zone and goral, barking deer, serow and Himalayan tahr distributed below 4,000 m in forested areas of wet temperate and subalpine vegetation.

Site occupancy and detection probability for mountain ungulates depend upon their habitat and behavior. Therefore, blue sheep had the highest detection probability among all the ungulates owing to its gregarious nature inhabiting alpine areas having no tree cover, hence aiding its detection. Serow had highest proportion of site utilization but low detection probability due to the fact that it inhabits dense areas ranging from sub-tropical to sub-alpine habitats and is solitary and shy, making its detection difficult.

Relative abundance of blue sheep was higher in terms of number of animal seen/hr which did not indicate it as the most encountered species in the study area. The time specific relative abundance may be the function of the longer time spent on point scans than in trail walks, moreover, the open alpine habitat also made the blue sheep detection easier in comparison with other ungulates living under dense forest cover.

Very few studies or surveys had been carried out for blue sheep abundance in moist Alpine areas (with high rainfall and less snow cover) in the eastern part of the Greater Himalaya that can be compared with the findings of the present study. Blue sheep density in Bhutan [4-6/km^2 - Fox & Jackson 2002], in Helan Mountain China [3.63- 4.64 /km^2 - Zhensheng *et al.* 2008] were comparable with the present density [3.67±0.78/km^2]. Density of musk deer (3.4 to 4.5/km^2) in the Annapurna Conservation Area in Nepal (Aryal 2005) was much higher in comparison with the musk deer density estimated for this study area.

For ecological studies, an understanding of habitat use patterns by any species is essential. Specific habitat use pattern is the basic requirement for the conservation and management of wildlife species. Mountain ungulates used and preferred different major vegetation types which are distributed in different elevation zones. Differential use of elevation categories along with vegetation categories depicted blue sheep and musk deer as specialists for high altitudes of above treeline (> 4000 m) alpine and tree-line *Krummholtz* zones and barking deer as a specialist for lower elevation (> 2500 m) wet temperate forested habitat. Goral and serow are generalists because they used all the forested areas of low altitude (< 2000 m) subtropical forest, medium altitude (2,000-3,000 m) wet temperate forest and below treeline subalpine forest (3,000-4,000 m). Southwestern aspect had open grassy slopes interspersed with *Rhododendron* shrub that provided ideal foraging and resting habitat for goral, serow and barking deer. North and north-eastern aspects were preferred by blue sheep, as these aspects had more open grassy meadows with nearby cliffs as escape terrain. Eastern aspects had dense stunted *Rhododendron* forest with *Juniperus* scrub and scattered grassy openings, which provided ideal cover for musk deer. Alpine flat terrain (10°-30°) with medium (0-50%) ground cover were preferred by blue sheep, but as an anti-predation strategy they also selected steep (30°-40°) rocky slopes with *Juniperus* scrub. On the other hand, musk deer preferred steep slopes (30°-40°) with medium to high (25-75%) ground and shrub cover (*Juniperus* scrub and stunted *Rhododendron* spp.) and thus differs from blue sheep in terms of habitat preferences, though they occupy the same elevation and vegetation categories. Barking deer preferred low elevation (< 2,500 m) wet temperate forests with steep slope (30°-40°) and medium to high % shrub cover, which provide both foraging and escape cover. Both goral and serow preferred similar habitat types with steep slopes, good forest cover with undergrowth and low to medium ground cover, but differ in selection of elevation classes. Goral primarily used wet temperate forests below 3,000 m, whereas serow used a fir-birch-rhododendron dominated subalpine (3,000-4,000 m) habitat.

Before 2003, the *Prek Chu* catchment area of Khangchendzonga NP was subjected to a high degree of livestock grazing through the practice of domestic yak herding in the Alpine zone along with cattle and goat-sheep grazing in all the habitats. Due to a ban imposed by the Sikkim Government on yak herding and cattle grazing in 2003 and a joint venture of Forest Department, Local NGOs and villagers against yak herding in 2006 (Tambe 2007), such practices were reduced considerably. In the absence of yak herders and their livestock, blue sheep presence may have increased in its habitat, as indicated by the distribution depicted in this study (Tambe *pers. com.*), though confirmation of this trend could be made after further observations and analysis. In the present scenario, goat and sheep grazing (300-400 animals) is still in practice in the Alpine zone during summer. Presence of shepherd dogs (8-10) in the Alpine and treeline zone is a direct threat to the endangered musk deer as well as blue sheep young, which may have resulted in no or low dung density of these species in summer. Pack animal grazing (horses and *dzo*s) in forested as well as in the Alpine zone along with deposition of non-biodegradable waste material by hikers (48 sacks of waste material was collected by *Yuksam* school children during a recent campaign in this area in May 2009) may also lead to the problem of habitat degradation in future. Presently, proper management intervention through the joint endeavor of villagers, NGOs and the Forest Department are needed to maintain and improve the status of mountain ungulates as the major prey base for carnivores in Khangchendzonga BR. The habitats of mountain ungulates should be protected from degradation by aforementioned causes of livestock grazing and tourism practices in *Prek Chu* catchment area of the Khangchendzonga BR.

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