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ESTIMATING RELATIVE ABUNDANCE AND HABITAT USE OF HIMALAYAN BLUE SHEEP *Pseudois nayaur* IN GANGOTRI NATIONAL PARK, WESTERN HIMALAYA, INDIA

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Abstract

Himalayan Blue sheep *Pseudois nayaur* is the most abundant wild ungulate in the Gangotri National Park in Western Himalaya, India. We conducted surveys from April 2008-November 2008, to estimate relative abundance, population structure and habitat use of the blue sheep in Gangotri National Park, Uttarakhand, India. We used 11 hill trails to estimate abundance parameters in Gangotri National Park. Sampling area ranges from an altitude of 2,600-5,000 m a.s.l. in Gangotri and Nilang valley of Gangotri National Park. We recorded a total of 120 groups (1,184 individuals) with an average encounter rate (individuals/km, SE ±) of 9.07 (SE ± 1.65), across three seasons *viz*, spring, summer and autumn. Blue sheep group sizes ranged from 1 to 65 individuals and the average group size was 9.87 (SE ± 1.24). We classified 302 males, 518 females and 137 yawns (<2 years) also with 227 unidentified individuals (19%) during the study period. Blue sheep observed largely using grassland habitats and smooth undulating slopes of medium steepness (41°-50° (39.17%) and 31°-40° (31.66%)), largely on southerly aspects within the elevation range of 3,000-4,000 m most frequently in all seasons. When not in broken landforms, the blue sheep maintained proximity (<170m) to such features suggesting their importance as escape covers from predators. Blue sheep in Gangotri valley appeared to be habituated to human presence, as many of the groups were found to be unmindful of the movement of large number of pilgrims during April-October, a religious practice that has been going on for centuries. Livestock grazing, large tourism activities, poaching, developmental activities and military activities have been identified as threats for the conservation and management of blue sheep populations in the protected area.

Keywords: Blue sheep *(Pseudois nayaur),* Gangotri National Park, Group size, Habitat utilization, Nilang valley.

Resumen

*Estimación de la abundancia relativa y del uso del hábitat del bharal (*Pseudois nayaur*) en el Parque Nacional de Gangotri, Himalaya Occidental. India*

El bharal (*Pseudois nayaur*) es el ungulado mas importante en el Parque Nacional de Gangotri, en la región de Uttarakhand (India). Se realizo un seguimiento desde abril hasta noviembre de

2008 (130,5 km y 32 días de trabajo de campo). Se utilizaron recuentos por barrido visual y observación en 11 itinerarios en zonas con una altitud entre 2.800 m y 5.000 m en el valle del Gangotri. Se registró un total de 120 grupos (1.189 individuos) con una tasa media de encuentro (individuos/km ± SE) de 9,07 (±1,65). Se observaron 364 machos, 627 hembras y 192 crías durante el período de estudio. El tamaño de los grupos de bharal osciló entre 1 y 65 individuos y el tamaño medio de los grupos fue de 9,87 (±1,24). Además, se compararon los resultados en tres estaciones: primavera, verano y otoño. Se observó una disminución en la tasa de encuentro entre las estaciones: 12,96 (±1,94) en primavera, 11,05 (±2,90) en verano y 4,43 (±0,71) en otoño. El mayor tamaño medio de los grupos se observó en otoño (20,71 ±10,33), seguido de la primavera (10,22 ± 1,77) y el verano (7,9 ± 1,30). En el valle del Gangotri, el bharal parece estar acostumbrado a la presencia humana, dado que los grupos eran indiferentes al movimiento de un gran número de peregrinos entre mayo y octubre, algo que se lleva realizando desde hace siglos. En el valle del Nelong, se encontraron ejemplares en grupos más pequeños y con baja abundancia, lo cual podría deberse a que la topografía y composición de la vegetación es distinta de la del valle del Gangotri, ya que la zona corresponde más al Transhimalaya (una prolongación de la cordillera Zanskar) mientras que el valle del Gangotri pertenece al Gran Himalaya. Además, el valle del Nelong está sometido a un mayor grado de perturbación ocasionada por el pastoreo de ganado y otras actividades humanas. Se presentarán y debatirán cuestiones sobre conservación.

Palabras clave: Abundancia, Pseudois nayaur, Parque Nacional de Gangotri, tamaño de grupo, valle del Nelong

Introduction

The Himalayas are part of the world largest mountain complex and a buffer to major realms *viz.,* Oriental, Palearctic and Ethiopian (Mani 1974), they are rich repository of unique biodiversity. In the Himalayas, ecosystem face great conservation challenges under the mounting threats of ill-planned developmental activities, unlimited resource use and uncontrolled grazing by domestic livestock (Kala & Rawat 1999) and has led to the degradation of remaining wildlife habitats. Ungulates are a major constituent of the Himalayan mammalian fauna and they 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 1994). The Himalaya and associated mountain ranges form the home to 12-31 species (38.7%) of Caprinae found worldwide, the richest in any part of the world (Shakleton 1997). The Western Himalaya is home to five species of mountain ungulates.

It includes Goral (*Nemorhaedus goral*), Serow (*N. sumatrensis*), Himalayan tahr (*Hemitragus jemlahicus*), Blue Sheep (*Pseudois nayur*) and the Himalayan musk deer (*Moschus chrysogaster*).

Blue sheep *Pseudois nayaur* is the most abundant wild ungulate in the Gangotri National Park (GNP) in the Western Himalaya, India other than Himalayan tahr (*Hemitragus jemlahicus*) and the Himalayan musk deer (*Moschus chrysogaster*). Blue sheep (*Pseudois nayaur*) or bharal are medium sized goats with sheep like affinities; their main distribution is restricted to Central Asian Mountains – from Kunjereb in Pakistan west to Sichuan and Gansu province of China in east, through large Tibetan plateau, along Greater Himalayan chain in India, Nepal and Bhutan as southern limit. In India, it is distributed from Ladakh, Lahul-Spiti, Himachal Pradesh, Uttarakhand, Sikkim and the western Tawang region of Arunachal Pradesh (Bhatnagar 2002). Blue sheep is protected under Schedule I of Indian Wildlife Protection Act (1972). Blue sheep are an important prey of the endangered snow leopard (*Uncia uncia*) (Chundawat & Rawat 1994; Schaller *et al.* 1987, 1988) and usually occur between elevation range 2,500 and 5,500 m inhabiting moderate to steep slopes in the cold and arid regions of the trans-Himalaya (Bhatnagar 2002). Knowledge of the distribution, habitat use pattern is essential for the management of blue sheep and for the conservation of remaining snow leopard populations.

The landscape immediately north of main central thrust (MCT) in the state of Uttarakhand, India represents a unique cold, arid ecosystem that has largely escaped the attention of ecologists, geographers and natural resource managers, owing to remoteness, harsh climatic conditions and inaccessibility owing to security reasons as Indian Army has occupied the area and entry of visitors, tourists etc. is prohibited in the Nilang valley. Along with part of Gangotri glacier (Greater Himalaya), the area is under protection as Gangotri National Park (GNP). This area forms a narrow strip (50-80 km wide) between the crest of Greater Himalaya and water divide between Satluj and Yarlung-Tsangpo that also forms the international boundary between India and Tibet (Valdiya 2001, Mazari 2007, Chandola *et al.* 2008). This area exhibits close affinities with Tibetan plateau both in terms of topography and species composition.

The Current study is the part of broader Gangotri landscape biodiversity project started in April 2008. The present study examined relative abundance, population structure and habitat use by the blue sheep across various habitat types, landform types and under habitat categories (altitude, aspect and slope) in the area. We also compare abundance parameters across seasons to look at seasonal pattern of relative abundance in GNP.

Study area

The study was conducted in Gangotri National Park (GNP) (30°50'-31°12'N, 78°45'-79°02'E) is located in the Uttarkashi District of northern Indian state of Uttarakhand, is the largest (2,390 km^2) protected area in the state. The northeastern park boundary is located along the international boundary with Tibet. The altitude varies from 1,800 to 7,083 m a.s.l. It falls under the Biogeographical zone –2B Western Himalaya (Rodgers & Panwar 1988) (Figure 1), including a considerable stretch of snow-clad mountains and

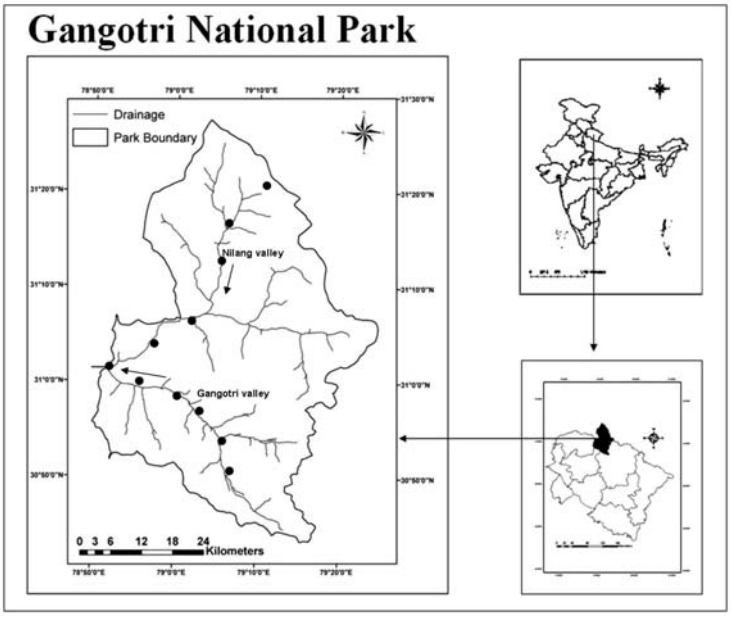

Figure 1. Map of study Area showing 11 location of sampling trails in Gangotri and Nilang valley in GNP.

glaciers. The Gangotri, after which the park has been named, is one of the holy shrines of Hindus and located inside the Park. The park area forms a viable continuity between Govind National Park and Kedarnath Wildlife Sanctuary of Uttarakhand state. High ridges, deep gorges and precipitous cliffs, rocky craggy glaciers and narrow valleys characterize the area.

The GNP is accessible through two major river valleys *viz.,* Gangotri and Nilang valley. Gangotri valley runs through entire catchment of Bhagirathi (Ganges) River inside GNP. The river originates from the place Gaumukh (approx 19 km from Bhaironghati), which is one of the largest glacier in Himalaya and also very important holy shrine of Hindus. It attracts a large number of tourists throughout the year. Due to variation in the altitude and aspect, a high diversity of vegetation exists in the park. So far, 15 species of mammals and 150 birds species are documented in the park (Parmanand *et al.* 1994). Forests of the Gangotri valley are Himalayan moist temperate type with dry alpine scrub at higher elevation (Champion & Seth, 1968). Nilang valley forms the entire catchment of river Jahnavi or Jadh Ganga and its tributaries. The area is dissected broadly by snow fed tributaries of the Jadh Ganga, which drains the area to meet the Bhagirathi river at Bhaironghati (an entry point to park). Although, entire region (GNP) had been categorized under Western Himalaya (2B) by Rodgers & Panwar (1988) but the Nilang valley and the surrounding region can be safely categorized into Trans-Himalaya (Zone 1) (Chandola *et al.* 2008). Historical account of the Nilang valley has been given by Atkinson (1981 *Rep.*). Very few research studies or surveys have been conducted in the area. Naithani (1988) provide botanical account with 170 species of flowering plants from some part of the GNP. Negi (2002) presented status of seven mountain ungulate species in the area. Uniyal & Ramesh (2004) assessed the status of wildlife in Gangotri valley of GNP. Chandola *et al.* (2008) studied the floral diversity and status of livestock grazing in some parts of the GNP. Bhardwaj & Uniyal (2009) documented status of wildlife in Nialng valley.

The current study was carried out from April 2008 to October 2008 in two valleys of GNP. The area was only accessible area inside the park and mentioned to hold good populations of blue sheep (Uniyal & Ramesh 2004). The Nilang

valley habitat is under large livestock grazing pressure during spring to autumn (Chandola *et al.* 2008). Out of four seasons identified, three seasons were sampled: spring (15 March to 15 June), summer (16 June to 15 September) and autumn (16 September to 28 October). The study was discontinued in autumn due to high snowfall and failure in getting study permissions.

Material and methods

Data collection

A number of 11 hill trails (n=35) with a mean trail length of 3.7 km (SE ± 0.25) (Table 1) were identified, marked and sampled to obtain information on relative abundance, population structure and habitat use across three seasons: six trails in Gangotri valley (sampling altitude ranged from 2,600 to 4,500 m a.s.l.) and five in Nilang valley (2,600 to 5,000 m a.s.l.) (Figure 1). Trails were walked at a uniform pace (Mean 1.96 km/hr). The primary considerations in establishing transects (randomly laid) were adequate coverage of the accessible area, and representation of the habitat types in which blue sheep densities could be expected to differ.

Table 1
Details of sightings, individuals, effort and sampling days for Blue sheep in the GNP during April 2008-November 2008.

	Sightings	Blue sheep Indiv.	Trails	Effort km)	Effort (hr)	Sampling days	Encounter rate (Indiv./km)	Average Group size
Spring	63	644	15	51	26.5	15	12.63 (± 1.9)	10.22 (± 1.77)
Summer	50	395	15	45.5	24.5	15	11.68 (± 2.9)	7.9 (± 1.30)
Autumn	7	145	5	12	15.5	5	12.08 (± 6.7)	20.71 (± 10.33)
Total	120	1184	35	108.5	66.5	35	9.07 (± 1.2)*	9.87 (± 1.24)*

*Average encounter rate/group size of blue sheep (data pooled for all seasons).

Trails were walked between 06:00 h - 10:00 h as well as between 14:00 h - 16:30 h. Whenever a herd of blue sheep was sighted the time was recorded and then surrounding area was scanned for more individuals using a pair of binoculars (8 X 42) and further the cluster was identified as one. We recorded group size, total individual present, as well as its sex and age composition, whenever possible (i.e., if we were close enough and the group remained within visual contact). Blue sheep were sexed and aged according to age-classes modified from Schaller (1977) and Wilson (1981). The following age groups were used fawns (<2 years), adult male and adult female. Criteria for aging used were (1) Body size, (2) Horn length and shape, (3) Intensity of the black markings on the legs and chest and (4) Behaviour.

We recorded information on habitat utilization by recording habitat type, landform type, altitude, aspect (direction to which the mountain slope faces) and slope class was recorded. When a group was observed in two adjacent habitats, the assigned habitat was that, with the majority of sheeps were seen. Three major habitat types were recognized: (1) Grassland (smooth to moderately steep slopes with ≥ 20% grass cover and little rock coverage), (2) Scrub (habitat of varied steepness with ≥ 20% shrub cover and < 20% grass cover), and (3) Rock (land with < 20% vegetation cover regardless of steepness).

Landforms features varied considerably within each habitat type. Thus landform types were recognized based on rock cover and steepness: (1) Smooth undulating slopes (with slopes < 45° and rock cover < 25%), (2) Moderately broken slopes (with slopes 25-45° and < 50% rock cover) (3) Distinctly broken slopes (slopes > 25° and ≥ rock cover (4) Scree (slopes with landslides with slopes generally > 45°) and (5) Cliff (steepness > 45° and rock coverage ≥ 70%). The altitude, aspect and slope in the study area were broadly stratified into five, eight and five categories respectively (Table 2).

The GPS coordinates and altitude information for mountain tops, ridges and important locations was recorded using a Global Positioning System (Garmin GPS) and altimeter. Slope was estimated using a clinometer and bearing were recorded using liquid filled hand held compass. All the observations were taken by single observer to avoid inter-observer bias.

TABLE 2
Frequency distribution of blue sheep by habitat features (habitat type, landform type, Elevation range, slope and aspect categories) during study period (2008) in GNP.

	Habitat features*	No. of groups observed	Percent of group observed
2 (a) Habitat type	Grassland	68	56.66
	Scrub	23	19.16
	Barren	29	24.16
2 (b) Landform type	Smooth undulating slope	52	43.33
	Moderately broken slope	28	23.33
	Distinctly broken slope	14	11.66
	Scree	7	5.83
	Cliff	19	15.83
2 (c) Altitude (m)	2500-3000 m	16	13.33
	3001-3500 m	30	25.0
	3501-4000 m	47	39.17
	4001-4500 m	18	15.0
	4501-5000 m	9	7.5
2 (d) Slope (°)	0-10°	0	0
	11-20°	5	4.17
	21-30°	15	12.5
	31-40°	36	31.66
	41-50°	43	39.17
	51-60°	21	12.5
	60-70°	0	0
2 (e) Aspect	North	5	4.17
	Northeast	0	0
	East	2	1.67
	Southeast	10	8.33
	South	20	16.67
	Southwest	43	35.83
	West	15	12.5
	Northwest	25	20.83
	Total	n=120	100%

Analytical methods

To assess pattern of group size and relative abundance (Mean, SE ±) across seasons mean and SE was used and the differences were tested using Kruskal-Wallis Test. For habitat use assessment, mean and SE was calculated for different altitude, slope and aspect categories used by blue sheep. All above analysis was conducted using statistical software R (R Development Core Team, 2005 ver. 2.9.2).

RESULTS

Relative abundance and population structure

One hundred twenty groups of blue sheep, totaling 1184 individuals, were sighted during the 35 days of field study across three seasons (Table 1). The size of groups ranged between lowest one (n=34) to highest 65 (n=1). The most commonly encountered herds consisted of 1-2 animals (n=51) followed by 3-5 (n=12) and 11-19 (n=11) contributing 42.5%, 20% and 10% respectively of the total (n=120) observations (Figure 2). As Figure 2 indicates, few herds of more than 30 individuals were encountered during the study period. Of the 120 groups observed across three seasons, the average group size was 9.87 (SE ± 1.24) individuals/group (Figure 3). We found a significant difference in group size across seasons (Kruskal-Wallis Test: χ^2= 5.9, P= 0.05).We observed a decrease in average group sizes across seasons *viz.*, it was recorded highest for autumn (20.71 SE ± 10.33) followed by spring (10.22 SE ± 1.77) and summer (7.9 SE ± 1.30) (Table 1).

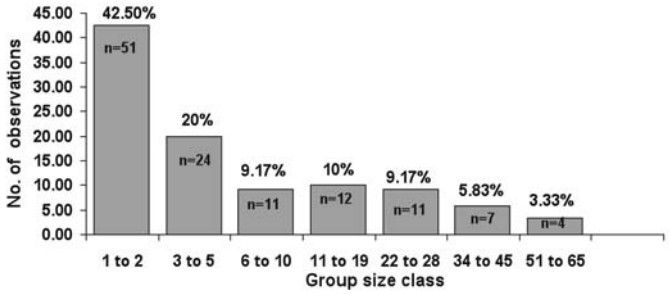

Figure 2. Group size observations and percentage of blue sheep under different classes during study period (2008) in GNP.

Out of 1184 animals observed, 297 (19.17%) were either too distant or escaped too quickly to be classified into sex and age class. The remaining 957 individuals consisted of 302 males, 518 females and 137 young ones (<2 years) in age-sex class category during the study period. Males comprised 25.51%, females 43.75% and young ones 11.57% (<2 years) out of total 1184 individuals observed (Figure 3).

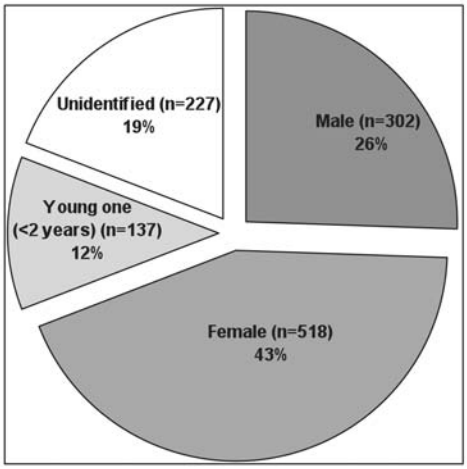

Figure 3. Sex and age composition of Blue sheep classified (n=927) during study period (2008) (out of 1184 sighted) in GNP.

Out of 1,184 animals observed, seasonal abundance was higher in spring (644) followed by summer (395) and autumn (145) (Table 1). The average encounter rate was 9.07 (SE ± 1.24) individuals/km for all seasons. We observed a decrease in average encounter rates across seasons *viz.*, spring 12.62 (SE ± 1.94), summer 8.68 (SE ± 2.90), and autumn 4.26 (SE ±0.71) (Table 1).

Habitat use

Blue sheep were observed largely using grassland (56.66%) and rock habitat types (26.16%) across all seasons. In landform types the major observations were recorded under smooth undulating slopes (43.33) and moderately broken slopes (33.33). Considerable amount of observations were also recorded under cliff (15.83) category. While very few observations were recorded under scree landform categories.

Blue sheep observed to use mean elevation of 3644.77 m (SE ± 48.13), throughout study period. Most number of sightings (n=47) occurred in elevation class of 3,501-4,000 m contributing 39.16% of total. While, 25% (n=30) and 15% (n=18) observations were under 3001-3500 m and 4001-4500 m elevation class respectively (Table 2c).

Out of total group sightings 39.17% of sightings (n=43) consisted of herds utilizing slopes class 41°-50°. Slope class 31°-40° and 51°-60° contributes 31.66% and 12.5% of groups observed (Table 2d) respectively. In aspect class, blue sheep were observed to utilize (35.83%) southwest category. Northwest and south aspects 20.83% and 16.66% respectively were also utilized broadly during study period (Table 2e).

Discussion

Abundance of blue sheep is well studied in Trans-Himalayan and Himalayan region of both western and eastern Himalayas (Mishra *et al.* 2004, Fox *et al.* 1988). Blue sheep or bharal was the only most commonly seen species in the alpine areas of GNP other than Himalayan tahr and Himalayan musk deer. The encounter rates of blue sheep (individuals/km) in present study were lower (9.07/km SE ± 1.24), compared to Nanda Devi National Park (26.4/km) (Sathyakumar 1993), in Gangotri valley of GNP (17.3/km) (Uniyal & Ramesh 2004) and in buffer zone of Nanda Devi Biosphere Reserve (14.17/km) (Bhattacharya *et al.* 2007) in previous studies in Western Himalayan region (Zone 2B). The low individual encounter rates can be attributed to the reason that the GNP is less productive with broken terrain, consists deep gorges, high gradient slopes (>45°) and narrow valleys (relatively colder and dry for most of the year), with less visible area, compared to Nanda Devi National Park. The differences in blue sheep encounter rates in GNP seems quite low compared to previous study by Uniyal & Ramesh (2004), as it was a six days survey in October 2004 . A relatively higher mean encounter rate and group size of blue sheep was observed for autumn seasons as with snowfall at higher elevations, blue sheep group were found moving towards lower elevations (Obs. Pers.). Few sampling occasions (n=5) in autumn season are due to the fact that study was discontinued after heavy rainfall and failure

in getting study permissions and thus explaining high standard error on mean encounter rate and group size in autumn. The unequal male to female sex ratio is may be because of about 19% (n=227) of unidentified individuals during study.

Blue sheep were observed largely using grassland habitats, smooth undulating slopes and moderately broken terrains of medium steepness (<45°), largely on southerly aspects within the elevation range of 3,000-4,000 m (69.17%) most frequently in all seasons. The relative high frequency of use of grassland habitats on smooth undulating slopes of medium steepness within 3,000-4,000 m elevation range appeared to be associated with the distribution of foraging areas, as most grassland in the study area was located mostly within limit of above parameters. The low frequency of use lower elevations was likely because of human disturbance (e.g., large number of pilgrims, firewood collection and trekking). While, at higher elevation (> 4000m) the area is under immense pressure of military camps, developmental activities in Nilang valley and adventure tourism activities in Gangotri Valley. We observed differences in aspect used by blue sheep in two valleys; In Gangotri valley blue sheep were observed to use medium steep slopes in southeast and southwest aspects because it receives more sunshine. While in Nilang valley, which is more of Trans-Himalaya, blue sheep was observed to use lesser steep slopes with moderately broken terrain in northwestern and northern aspects as it is available and productive (receives more sunshine).

Quantitative field observations suggests that blue sheep maintained proximity (< 170 m) to broken landforms suggesting their importance as escape covers from predators. Similar observations were also reported by Chundawat (1992) and Oli (1996). These observations infer that broken land forms are an important habitat component and are probably used as escape cover by blue sheep. We also observed that blue sheep group size increased with an increasing distance from nearest escape cover, which seems to be supported by the fact that living in larger groups when not in proximity to adequate escape cover may minimize the predation risk on individuals through increased vigilance, alertness and dilution effect (Treisman 1975a,b, Oli 1996). Some of the major factors that affect habitat use by ungulates in the Himalaya includes distribution of foraging areas, escape terrain, escape cover and cover against extreme of weather and biotic pressures (Schaller 1977, Wilson

1981, Green 1985, Chundawat 1992, Sathyakumar 1994, Harris & Miller 1995, Oli 1996, Bhattacharya *et al.* 2007) and vary between sites depending upon local habitat conditions and human disturbance.

Gangotri valley promises a high potential of carrying good populations of blue sheep, Himalayan musk deer and Himalyan tahr, despite of the fact that thousands of pilgrims visits the valley during April-October each year. A large number of tourists also visit the area for trekking, camping and adventure mountaineering activities. It was observed that these tourists and pilgrims cause invaluable harm to the habitat. At many places, heaps of used bottles, cans, plastic, camping remains can be seen. We also record nine adult and two fawn mortalities (natural and predated) and one hunting case (with bullet marks in skin in Nilang valley) during our study. The blue sheep in Gangotri valley appeared to be habituated to human presence, as many of the groups were found to be unmindful of the movement of large number of pilgrims, a practice that has been going on for centuries. While Nilang valley blue sheep were observed in low abundance and smaller groups which may be attributed to the fact that this area differs in its topography and vegetation composition from Gangotri valley as it is more of Trans Himalaya (an extension of Zanskar ranges) while, Gangotri Valley falls in Great Himalayan ranges and presence of military camps and immense grazing pressure. The Nilang or Jadh Ganga valley is important as it is used by large herds of goats and sheeps and mules assisted by herders during spring to autumn. An estimated 30,000 sheeps, goats and mules graze these pastures intensively (Chandola *et al.* 2008). Nilang valley is also exposed to military camps, higher disturbance activities such as livestock grazing and other development human activities (road construction for military).

The current study dealing with abundance status and habitat use will be helpful in protection and management of the blue sheep and its habitat. This can be achieved by checking large livestock grazing, limiting numbers of tourists, providing guidelines to the visitors and by keeping vigilance, regular patrolling inside the park. Military is also need to be directed towards conservation (as military dogs were seen chasing blue sheep and other wildlife in the area). Poaching and intense grazing can easily eliminate wild ungulates (Holmes 1970,

Schaller 1977, Green 1978, Sathyakumar *et al.* 2009). GNP seems to provide good habitat for blue sheep and other ungulates populations and attendant predators in GNP in proximity of one of the (Gangotri) Himalayas largest and dynamic glacier. Successful conservation of wild ungulate populations, largely depends on the effective management, for which an adequate understanding of their distribution, habitat requirement and maintaining local community support is a prerequisite.

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