



Distribution, status and aspects of ecology of mammalian species in Kedarnath Wildlife Sanctuary, Uttarakhand Himalayas, India

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Abstract

The study was conducted in Kedarnath wildlife sanctuary during 2012, a year before the major natural disaster took place in Himalayas. Kedarnath wildlife sanctuary is situated in Chamoli district of Uttarakhand Himalayas covering an area of 975 sq km. A total of 28 mammalian species were reported from this sanctuary. However, scientific information on many of these mammals are scanty and there is a gap of knowledge regarding their status, distribution and ecology. Considering this, an attempt was made to study sambar, alpine musk deer, himalayan tahr, asiatic black bear and red fox found in Shokharak area of Kedarnath WLS. Direct as well indirect methods were used to assess the population and habitat use. Twenty four trail-transect of different length were laid throughout the study area and monitored three times, covering 43 km in 124.50 hours. The overall encounter rate (group/km) among different species was recorded maximum for Himalayan Tahr (0.208 group/k.m) and Tugnath was the place where its density was maximum (31.83 ± 13.59). The pattern of habitat use by different species revealed that Himalayan Tahr, alpine musk deer and Asiatic black bear prefer high altitude areas therefore they are found in Shokhark, Tugnath and Chandrasila, whereas, sambar and red fox prefer middle altitude and because of this their presence was not recorded from above mentioned areas. A further investigation is needed to understand the post disaster impact on the abundance and habitat use of mammals in Kedarnath wildlife sanctuary. Findings of present study could be a best baseline data to make future strategy for the better management, conservation and habitat improvement of the species.

Key words: Himalayas, Kedarnath wildlife sanctuary, musk deer, habitat use

1. Introduction

Information on species distribution and diversity pattern is crucial for understanding the ecological and evolutionary determinants of spatial heterogeneity in biodiversity [1]. Spatial congruence of species distributions has been studied in several taxa [2-4], but it remains poorly understood in mammalian community especially in herbivores. India is very rich as far as biological diversity is concerned. Mammalian diversity is one of the most important attributes of that diversity. About 397 species of mammals are found in India, of which 18.4% are endemic and 10.8 % are threatened [5].

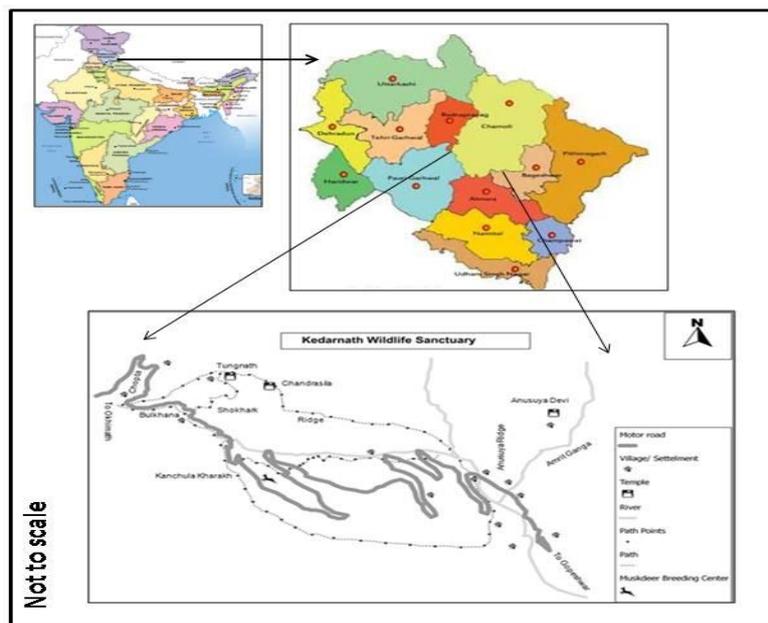
Large mammals by virtue of their bigger size and home range are relatively more prone to extinction as a consequence of fragmentation and degradation of habitat [6]. This leads to increase concern among scientist and researchers. Studies of mammals always fascinate scientist, researchers as well as common people because man himself belongs to this class. Studying leopards, bears, musk deer are more fascinating because they are key-stone species of jungle. Large carnivore predators like leopard (*Panthera pardus*), snow leopard (*Uncia uncia*), himalayan black bear (*Selenarctos thibetanus*) and their prey base mainly sambar (*Rusa unicolor*), barking deer (*Muntiacus muntjak*), Himalayan tahr (*Hemitragus jemlahicus*) and goral (*Nemorhaedus goral*) are extensively studied and their morphology, habitat, distribution and other attributes are accounted [6]. Out of ten recognizable bio-geographic zones [7] of India, Himalayas are less studied although it is more fragile and more diverse as far as flora and fauna are concerned [6]. Himalayan zone, in the far north, constituting 6.4 % of the total geographical area includes some of the highest peaks in the world and makes India one of the richest areas in terms of habitats and species. The steep slopes, unconsolidated soils and intense rainfall render the zone extremely fragile. The alpine and sub-alpine forests, grassy meadows and moist mixed deciduous forests provide diverse habitat for endangered species of bovids such as bharal (*Pseudois nayaur*), ibex (*Capra ibex*), markhor (*Capra falconeri*), Himalayan tahr (*Hemitragus jemlahicus*) and takin (*Budoreas taxicolor*). Other rare and endangered species restricted to this zone include zangul (*Cervus eldi eldi*) and musk deer (*Moschus moschiferus*). There are about 241 species (65%) recorded from the Himalaya and as many as 29 (37%) of mammalian species listed under Schedule I of Indian Wildlife Protection Act [8] occur in the Himalaya [9].

A total of 28 mammalian species are reported from Kedarnath wildlife sanctuary [10]. However, scientific information on many of these mammals is scanty. With the exception of a few ecological studies, most of the available information is based on status surveys [11-16] and short term studies [17-19]. Since very few informations are available on distribution and ecology of species found in Himalayas, it is utmost to consider them for detailed study. The present study is an attempt to fill the gap and try to record status and distribution of mammals found in Kedarnath wildlife sanctuary.

2. Materials and Methods

2.1. Study Area

The study was carried out in a part of Kedarnath wildlife sanctuary (KWLS) which is placed in IUCN - IV category (Managed Nature Reserve) and Bio geographical Province of 2.38.12 of India (Himalayan Highlands). The study area is located in the Garhwal region of Greater Himalaya in Uttarakhand (30°25'00"-30°45'N and 78°55'00"-79°22'00"E). The area covered by sanctuary is 9.752sq km. Perennial rivers such as Sone Ganga, Mandakini Ganga, Kali Ganga, Mandani Ganga, Madhmaheshwar Ganga, Balsurti and Amrit Ganga flow through this protected area. The intensive study area is located towards southern boundaries of the sanctuary around Shokhark, Tungnath and Chandrasila with the varying altitude of 3000 m to 3800 m a.s.l. The area was selected as it has wide altitudinal range, different habitat and vegetation types, diverse aspect and slope. Within the study area vegetation is represented by different zones of sub-alpine and alpine. The sub-alpine zones have oak (*Quercus spp.*), fir (*Abies pindrow*) *Rhododendron arborium*, *Rhododendron campanulatum* and associated species [20]. Alpine region is mainly dominated by meadows (*Bugiyal*) and scrub.



3. Methodology

3.1. Data collection

To assess the status and distribution of mammals the direct as well indirect evidences were recorded. For the direct sightings of the mammals the trail were monitored during dawn and dusk. Twenty four trail-transect of different length were laid throughout the study area and monitored three times. A total distance of 43 km was covered and 124.50 hours were spent on trails monitoring. A total of 164 sampling plots were established and between two consecutive plots an interval of 100 m was maintained. The elevation, latitude and longitude of each sampling plot were recorded using GPS (Gramin-72). On each sampling plot pellet group/scat of different mammalian species were counted within 10 m radius circular plots and the pellets/scats were identified on the basis of their shape, size and colour [21]. Same sample plots were also used for vegetation composition (habitat parameters) for investigating habitat utilization pattern of different mammalian species reported from the study area. Tree species density was assessed by plot method [21-26]. In this method a point was selected randomly and on that a circular plot was established with 10m radius. The distance between two points was kept 100 m. At every plot tree species and their individuals were counted in 10 m radius circular plot. The canopy cover was measured at four points at each sampling plot, using a grided mirror of 25x25 c.m. which is divided into 100 equal grids. The mirror was kept horizontally at 1.25m above the ground level, and grid squares covered by more than 50% of tree foliage were counted. Percentage canopy cover for each sampling plot was calculated from the number of grids covered by foliage.

Shrub species and their individuals were counted in 3m radius circular plots. Average shrub height was measured for each plot, using a measuring tape, and shrub cover was measured by ocular estimation.

For herbs and grasses four quadrates of 0.5x0.5 m were laid in each circular plot. In this way a total of 656 quadrates were laid for the purpose. Different grass and herb species encountered in samples were identified and their total number was recorded.

3.2. Data analysis

The sighting of different mammal species was used to calculate encounter rate (ER) with reference to distance and time.

ER is obtained as:

$$ER = n / l \text{ or } ER = n / t$$

where n is the number of animal sighted, l is the distance travelled and t is the total time spent.

Mammal density was estimated by pellet group or scats for each sample plots and later on data were pooled to calculate total density of animals in study area. The pellet group/ scat data for different mammalian species were also analysed by performing *t* test for mean values of different habitat variables in available and utilized plots. Kruskal Wallis One way analysis of variance and multiple comparisons (Scheffe's) were used to test for significant differences in mean density of mammal vis-à-vis habitat types and habitat factors. All statistical tests were performed using SPSS 10.0 [27].

3. Results and discussion

The study revealed that mammalian species are present in Kedarnath WLS and it is supported by the presence of indirect evidences of Himalayan tahr, musk deer, sambar, Asiatic black bear and red fox in Shokhark and its surrounding. Apart from this, direct sighting of common langurs; and Himalayan tahr, musk deer, goral, serow were recorded from Bhulkana and Shokhark respectively. Furthermore, direct sighting of golden jackal and indirect evidences of Himalayan tahr were recorded from Tungnath. However, no direct sighting of any mammal was observed from Chandrasila (Table 1).

Table-1: Status of different mammalian species in the Kedarnath wildlife sanctuary (2012)

Species	Bhulkana	Shokhark	Tungnath	Chandrasila
Himalayan Tahr	0	+, -	-	-
Alpine musk deer	0	+, -	0	0
Sambar	0	-	0	0
Goral	0	+	0	0
Serow	0	+	0	0
Common Langur	+	+	0	0
Asiatic black bear	0	-	0	-
Golden Jackal	0	0	+	0
Red fox	0	-	0	0

+: Direct sighting, -: Indirect sighting, o: No evidence

4.1. Encounter rate

The overall encounter rate (group/k.m) was maximum for Himalayan Tahr (0.208 group/k.m) followed by Alpine musk deer (0.069 group/k.m), golden jackal (0.0464 group/k.m), while serow, goral and langur showed the similar encounter rate as (0.0232 group/k.m). The encounter rate (groups/100 hr.) of Himalayan tahr, was recorded maximum (7.22 groups/100 hr.) followed by Alpine musk deer (2.41 groups/100 hr.) and golden jackal (1.6 groups/100 hr). The serow, goral and langur had the minimum encounter rate (0.8groups/100 hr) (Table-2).

Table-2: Average encounter rate per 100 hour/ k.m of different mammalian species in Kedarnath wildlife sanctuary (2012)

S.No	Species	ER/km	ER/100hr.
1	Musk Deer (<i>Moschus chysogaster</i>)	0.069	2.41
2	Himalayan Tahr (<i>Hemitragus jemlahicus</i>)	0.208	7.22
3	Serow (<i>Capricornis sumatraensis</i>)	0.0232	0.8
4	Goral (<i>Nemorhaedus goral</i>)	0.0232	0.8
5	Common Langur (<i>Presbytis entellus</i>)	0.0232	0.8
6	Golden Jackal (<i>Canis aureus</i>)	0.0464	1.6

4.2. Density estimation

The pellet group of alpine musk deer (AMD), sambar, and scat of red fox were recorded only from Shokhark, while Himalayan tahr pellet groups were recorded from all the three sites and it was found maximum at Tungnath (31.83 ± 13.59). However, on comparing density with reference to different sites, it was not found significant (F2 161 = 0.144, P > 0.05). The Asiatic black bear (ABB) dung pile were recorded from Shokhark and Chandrasila and it was recorded maximum at Chandrasila (1.67 ± 1.24) with an insignificant result (F2 161 = 0.507, P > 0.05) (Table 3).

Table 3: Mean pellet group/scat density (Density± SE) of different mammalian species at surveyed sites in Kedarnath wildlife sanctuary (2012)

S.No	Species	Mean density ± SE		
		Shokhark	Tungnath	Chandrasila
1	Alpine Musk deer	3.57 ± 1.26	0	0
2	Himalayan Tahr	25.47 ± 6.11	31.83 ± 13.59	24.57 ± 8.36
3	Sambar	12.73 ± 7.06	0	0
4	Asiatic black bear	0.7963 ± 0.7962	0	1.67 ± 1.24
5	Red fox	0.795 ± 0.558	0	0

In different altitudinal range the pellet group/scat/dung pile density were assessed. AMD were recorded maximum at 3000-3250 m (3.97 ± 1.50) and the results were found to be significant ($F_{2, 161} = 4.270, P < 0.05$). Himalayan tahr was also reported from all the three altitudinal range and the density was maximum at 3000-3250 m (28.85 ± 7.18), however the results were not significant ($F_{2, 161} = 0.101, P > 0.05$).

Sambar and Red fox were recorded only from 3000-3250 m altitudinal range while ABB were recorded from 3000-3250 m and 3501-3750 m altitudinal range and density was maximum at the highest altitudinal range (1.67 ± 1.24), however results were not found significant ($F_{2, 161} = 0.623, P > 0.05$) (Table 4).

Table-4: Mean pellet group/scat density (Density \pm SE) of different mammalian species along different altitudinal range of Kedarnath wildlife sanctuary (2012)

S.No	Species	Mean density \pm SE		
		3000 - 3250 m	3251-3500 m	3501- 3750 m
1	Alpine Musk deer	3.97 ± 1.50	0.739 ± 0.739	0
2	Himalayan Tahr	28.85 ± 7.18	24.43 ± 9.34	24.57 ± 8.36
3	Sambar	15.92 ± 8.80	0	0
4	Asiatic black bear	0.995 ± 0.995	0	1.67 ± 1.24
5	Red fox	0.993 ± 0.697	0	0

4.3. Habitat utilization

4.3.1. Use of Habitat

The mean pellet group density of musk deer was found maximum (5.02 ± 3.66) in sub-alpine habitat followed by Alpine meadows (3.10 ± 1.49) and minimum (2.27 ± 1.57) in mixed habitat however results were not significant ($F_{3, 160} = 2.738, P < 0.05$). The mean pellet group density of Himalayan tahr was maximum (55.30 ± 18.99) in sub-alpine followed by alpine scrub (28.06 ± 7.77), alpine meadows (23.29 ± 7.20) and minimum (5.68 ± 3.29) in mixed habitat and results were found to be significant ($F_{3, 160} = 2.705, P < 0.05$). Pellet group density of sambar was significantly higher (31.84 ± 19.58) in mixed habitat than alpine meadows (3.10 ± 2.43) ($F_{3, 160} = 3.995, P < 0.05$).

The mean faecal density of Asiatic black bear was found maximum (2.27 ± 2.27) in mixed habitat and minimum (1.25 ± 0.93) in alpine scrub, however results were not significant ($F_{3, 160} = 0.664, P > 0.05$). The red fox scat was only recorded in sub-alpine region (3.34 ± 2.30) with a significant result ($F_{3, 160} = 5.548, P < 0.05$), (Table 5).

Table-5 Mean Density \pm SE of different mammalian species in different habitat of Kedarnath wildlife sanctuary (2012)

S.No	Habitat	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	Alpine meadows	3.10 ± 1.49	23.29 ± 7.20	3.10 ± 2.43	0	0
2	Alpine scrub	0	28.06 ± 7.77	0	1.25 ± 0.93	0
3	Mixed	2.27 ± 1.57	5.68 ± 3.29	31.84 ± 19.58	2.27 ± 2.27	0
4	Sub- alpine	5.02 ± 3.66	55.30 ± 18.99	0	0	3.34 ± 2.3

4.3.2. Use of Aspect

In general musk deer prefer two aspects of north east where its density was more (3.88 ± 1.98) and minimum in south east where its density was (3.85 ± 1.83), however results were not found significant ($F_{6, 1} = 1.586, P > 0.05$). Tahr was found in five aspect out of which maximum in west (84.91 ± 34.57) followed by south west (51.75 ± 43.37), north east (37.27 ± 10.42), south east (21.22 ± 7.92) and minimum in north west (15.91 ± 5.63). However results were insignificant ($F_{6, 1} = 2.011, P > 0.05$). Sambar was reported from three aspects out of which maximum in north east (13.98 ± 12.48) followed by south east (12.54 ± 7.45) and minimum in north west (0.441 ± 0.441), however results were not found significant ($F_{6, 1} = 0.572, P > 0.05$).

Asiatic black bear was reported from south west (7.96 ± 7.96) and north west (1.32 ± 0.98) and red fox was only found in north east (1.55 ± 1.08). However results were insignificant ($F_{6, 1} = 1.477, P > 0.05$ & $F_{6, 1} = 1.006, P > 0.05$), (Table 6).

4.3.3. Use of slope

The mean pellet group density of musk deer was significantly higher (80.00 ± 80.00) in 76-100 degree slope followed by 0-25 degree slope (10.60 ± 10.60), 26-50 degree (1.63 ± 0.988) and minimum in 51-75 degree (1.57 ± 0.77) slope ($F_{3, 160} = 63.28, P = 0.000$). The mean pellet group density of Tahr was found maximum (116.76 ± 116.76) in 0-25 degree of slope followed by 26-50 degree (28.16 ± 7.46) and minimum in 51-75 degree (19.65 ± 4.56) of slope. Results were found significant ($F_{3, 160} = 2.863, P < 0.05$). Likewise the mean pellet group density of sambar was found to be maximum (79.60 ± 47.80) in 76-100 degree of slope followed by 51-75 degree (8.25 ± 6.42) and minimum (4.49 ± 3.0) 26-50 degree of slope however results were not found significant ($F_{3, 160} = 1.849, P > 0.05$).

Table -6 Mean Density of different mammalian species in different aspects of Kedarnath wildlife sanctuary (2012)

S. N.	Aspect	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	North east	3.88 \pm 1.98	37.27 \pm 10.42	13.98 \pm 12.48	0	1.55 \pm 1.08
2	North	0	0	0	0	0
3	North west	0	15.91 \pm 5.63	0.441 \pm 0.441	1.32 \pm 0.98	0
4	South east	3.85 \pm 1.83	21.22 \pm 7.92	12.54 \pm 7.45	0	0
5	South	0	0	0	0	0
6	South west	0	51.75 \pm 43.37	0	7.96 \pm 7.96	0
7	West	0	84.91 \pm 34.57	0	0	0
8	East	0	0	0	0	0

The mean scat density of black bear was found maximum (1.17 \pm 0.87) in 51-75 degree of slope and minimum (0.816 \pm 0.816) in 26-50 degree of slope, however results were not found significant (F3 160= 0.060, P > 0.05). The mean scat density of red fox was significantly higher (10.60 \pm 10.60) in 0-25 degree of slopes than 51-75 degree (0.392 \pm 0.392) of slopes (F3 160= 10.35, P = 0.0000), (Table 7).

Table- 7 Mean Density of different mammalian species along different slopes of Kedarnath wildlife sanctuary (2012)

S.No	Slope	Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	0-25°	10.6	116.76	0	0	10.6
2	26-50°	1.63	28.16	4.49	0.816	0
3	51-75°	1.57	19.65	8.25	1.17	0.392
4	76-100°	80	0	79.6	0	0

4.3.4. Use of vegetation cover

4.3.4.1. Use of tree cover

The mean pellet group density of musk deer was found to be significantly higher (10.60 \pm 5.30) in middle tree cover followed by low tree cover (2.70 \pm 1.62) and minimum (0.58 \pm 0.41) in no tree cover (F2 161 = 7.384, P < 0.05). The mean pellet group density of Tahr was found maximum (28.30 \pm 17.95) in medium tree cover followed by low tree cover (27.09 \pm 8.82) and minimum (25.64 \pm 5.87) in no tree cover and results were not found significant (F2 161 = 0.015, P > 0.05). Likewise the mean pellet group density of sambar was found to be maximum (18.97 \pm 11.88) in low tree cover followed by medium tree cover (10.61 \pm 7.50) and minimum (0.29 \pm 0.29) in low tree cover with a significant result (F2 161 = 3.008, P = 0.05).

The mean scat density of Asiatic black bear and red fox was found maximum (1.35 \pm 1.35 & 0.67 \pm 0.67) in low tree cover and minimum (0.88 \pm 0.65 & 0.29 \pm 0.29) in no tree cover, respectively, However results were insignificant (F2 161 = 0.146, P > 0.05 & F2 161 = 0.251, P > 0.05), (Table 8).

Table- 8- Mean Density \pm SE of different mammalian species in different tree covers of Kedarnath wildlife sanctuary (2012)

Low = 1-30 %, Medium = 31-60 % and High = more than 60 %

S.No	Tree cover	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	No cover	0.58 \pm 0.41	25.64 \pm 5.87	0.29 \pm 0.29	0.88 \pm 0.65	0.29 \pm 0.29
2	Low	2.70 \pm 1.62	27.09 \pm 8.82	18.97 \pm 11.88	1.35 \pm 1.35	0.67 \pm 0.67
3	Medium	10.60 \pm 5.30	28.30 \pm 17.95	10.61 \pm 7.50	0	0
4	High	0	0	0	0	0

4.3.4.2. Use of shrub cover

The mean pellet group density of musk deer and sambar was found maximum (1.92 \pm 0.76 & 7.71 \pm 5.29) in low shrub cover and minimum (1.91 \pm 1.41 & 5.09 \pm 4.49) where shrub cover was entirely absent respectively, however results were not found significant (F2 161 = 0.383, P > 0.05 & F2 161 = 0.217, P > 0.05). The mean pellet group density of Tahr was found maximum (40.75 \pm 10.95) in no shrub cover followed by medium shrub cover (29.72 \pm 14.73) and minimum (18.33 \pm 4.90) in low shrub cover, however results were insignificant (F2 161 = 2.375, P > 0.05).

The mean scat density of black bear (1.60 \pm 0.95) and red fox (1.27 \pm 0.89) was reported from low and no shrub cover respectively, however results were not found significant (F2 161 = 0.921, P > 0.05 & F2 161 = 0.921, P > 0.05), (Table 9)

4.3.4.3. Use of herb cover

The mean pellet group density of sambar and mean scat density of red fox was found maximum (18.78 \pm 14.12 & 0.81 \pm 0.81) in medium herb cover and minimum (2.51 \pm 1.19 & 0.27 \pm 0.27) in low herb cover respectively, however results were not found significant (F2 161 = 2.088, P > 0.05 & F2 161 = 0.410, P > 0.05). The mean pellet group density of Tahr was maximum (31.84 \pm 19.68) in no herb cover followed by medium herb cover (29.38 \pm 10.02) and minimum (24.57 \pm 5.55) in low herb cover, however results were insignificant (F2 161 = 0.143, P > 0.05).

Likewise mean pellet group density of musk deer was found maximum (1.95 ± 0.71) in low herb cover and minimum (1.63 ± 1.63) in medium herb cover, however results were not found significant ($F_{2, 161} = 0.295, P > 0.05$). The Asiatic black bear was only reported in low herb cover and the mean scat density was (1.39 ± 0.83), showing insignificant result ($F_{2, 161} = 0.613, P > 0.05$), (Table 10).

Table-9- Mean Density \pm SE of different mammalian species in different shrub covers of Kedarnath wildlife sanctuary (2012)

S.N.	Shrub cover	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	No cover	1.91 ± 1.41	40.75 ± 10.95	5.09 ± 4.49	0	1.27 ± 0.89
2	Low	1.92 ± 0.76	18.33 ± 4.90	7.71 ± 5.29	1.60 ± 0.95	0
3	Medium	0	29.72 ± 14.73	0	0	0
4	High	0	0	0	0	0

Low = 1-30 %, Medium = 31-60 % and High = more than 60 %

Table- 10- Mean Density \pm SE of different mammalian species in different herb covers of Kedarnath wildlife sanctuary (2012)

S.N.	Herb cover	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	No cover	0	31.84 ± 19.68	0	0	0
2	Low	1.95 ± 0.71	24.57 ± 5.55	2.51 ± 1.19	1.39 ± 0.83	0.27 ± 0.27
3	Medium	1.63 ± 1.63	29.38 ± 10.02	18.78 ± 14.12	0	0.81 ± 0.81
4	High	0	0	0	0	0

Low = 1-30 %, Medium = 31-60 % and High = more than 60 %

4.3.4.4. Use of grass cover

The mean pellet group density of musk deer was significantly higher (31.85 ± 31.85) in no grass cover followed by medium grass cover (1.51 ± 1.51) and minimum (1.39 ± 0.55) in low grass cover ($F_{3, 160} = 11.17, P < 0.05$). Likewise the mean pellet group density of Tahr was significantly higher (159.25 ± 159.25) in no grass cover followed by medium grass cover (42.45 ± 14.12), high grass cover (23.87 ± 15.24) and minimum (21.84 ± 4.68) low grass cover ($F_{3, 160} = 4.252, P < 0.05$). The mean pellet group density of sambar was maximum (7.95 ± 7.95) in high grass cover followed by low grass cover (6.50 ± 4.09) and minimum (4.54 ± 4.54) in medium grass cover, however results were not found significant ($F_{3, 160} = 0.026, P > 0.05$). The Asiatic black bear and red fox were only reported in low grass cover with mean scat density of (1.16 ± 0.69 & 0.46 ± 0.32) respectively, however result were not significant ($F_{3, 160} = 0.182, P > 0.05$ & $F_{3, 160} = 0.130, P > 0.05$), (Table 11).

Table-11- Mean Density \pm SE of different mammalian species in different grass covers of Kedarnath wildlife sanctuary (2012)

S.N.	Grass cover	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	No cover	31.85 ± 31.85	159.25 ± 159.25	0	0	0
2	Low	1.39 ± 0.55	21.84 ± 4.68	6.50 ± 4.09	1.16 ± 0.69	0.46 ± 0.32
3	Medium	1.51 ± 1.51	42.45 ± 14.12	4.54 ± 4.54	0	0
4	High	0	23.87 ± 15.24	7.95 ± 7.95	0	0

Low = 1-30 %, Medium = 31-60 % and High = more than 60 %

4.3.5. Use of tree density

The mean pellet group density of musk deer was maximum (6.36 ± 4.24) in high tree density followed by medium tree density (2.65 ± 2.65) and minimum (1.37 ± 0.63) in low tree density with an insignificant result ($F_{3, 160} = 1.29, P > 0.05$). The mean pellet group density of Tahr was maximum (29.09 ± 5.45) in low tree density followed by high tree density (12.74 ± 8.49), very high tree density (10.60 ± 10.60) and minimum in medium tree density (7.95 ± 5.71), however results were not significant ($F_{3, 160} = 0.705, P > 0.05$). The mean pellet group density of sambar was significantly higher (60.50 ± 50.34) in high tree density followed by medium tree density (23.88 ± 18.85) and minimum (0.91 ± 0.72) in low tree density ($F_{3, 160} = 6.96, P < 0.05$).

The mean scat density of black bear was significantly higher (21.23 ± 21.23) in very high tree density than low tree density (0.68 ± 0.51) ($F_{3, 160} = 8.74, P < 0.05$). Red fox was only reported in low tree density and the mean scat density was (0.45 ± 0.32), however results were not significant ($F_{3, 160} = 0.119, P > 0.05$), (Table 12).

4.3.6. Use of shrub density

The mean pellet group density of musk deer was found maximum (2.54 ± 0.97) in low shrub density and minimum (1.22 ± 1.22) in medium shrub density however results were not found to be significant ($F_{4, 159} = 0.711, P > 0.05$). Mean pellet group density of Tahr was maximum (52.44 ± 23.00) in very high shrub density followed by low shrub density (29.29 ± 6.16), high shrub density (15.91 ± 10.69), extremely high shrub density (10.60 ± 10.60) and minimum (6.12 ± 3.54) in medium shrub

density, however results were not significant ($F_{4, 159} = 1.81, P > 0.05$). Likewise the mean pellet group density of sambar was maximum (23.27 ± 19.63) in medium shrub density and minimum (4.13 ± 2.50) in low shrub density, showing insignificant result ($F_{4, 159} = 1.20, P > 0.05$).

Table-12- Mean Density \pm SE of different mammalian species in different tree density of Kedarnath wildlife sanctuary (2012)

S.N	Tree density	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	Low	1.37 ± 0.63	29.09 ± 5.45	0.91 ± 0.72	0.68 ± 0.51	0.45 ± 0.32
2	Medium	2.65 ± 2.65	7.95 ± 5.71	23.88 ± 18.85	0	0
3	High	6.36 ± 4.24	12.74 ± 8.49	60.50 ± 50.34	0	0
4	Very High	0	10.60 ± 10.60	0	21.23 ± 21.23	0

Low = 0-250 ind/hac, Medium = 251-500 ind/ha., High = 501-750 ind/ha. And Very High = 751-1000 ind/ha.

The mean scat density of black bear was found maximum (5.61 ± 4.08) in very high shrub density and minimum (0.63 ± 0.63) in low shrub density, however results were not significant ($F_{4, 159} = 1.964, P > 0.05$). The red fox was only reported in low shrub density and the mean scat density was (0.63 ± 0.44), showing an insignificant result ($F_{4, 159} = 0.317, P > 0.05$), (Table 13).

Table- 13- Mean Density \pm SE of different mammalian species in different shrub density of Kedarnath wildlife sanctuary (2012)

S.N.	Shrub density	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	Low	2.54 ± 0.97	29.29 ± 6.16	4.13 ± 2.50	0.63 ± 0.63	0.63 ± 0.44
2	Medium	1.22 ± 1.22	6.12 ± 3.54	23.27 ± 19.63	0	0
3	High	0	15.91 ± 10.69	0	0	0
4	Very High	0	52.44 ± 23.00	0	5.61 ± 4.08	0
5	Extremely high	0	10.60 ± 10.60	0	0	0

Low = 0-1500 ind/hac, Medium = 1501-3000 ind/ha., High = 3001-4500 ind/ha. , Very High = 4501-6000 ind/ha. and Extremely High = 6001-7500 ind/ha.

4.3.7. Use of herb density

The mean pellet group density of musk deer was maximum (7.95 ± 7.95) in very high herbs density followed by medium herbs density (2.48 ± 1.28), high herbs density (2.27 ± 1.57) and minimum (0.46 ± 0.46) in low herbs density with insignificant result ($F_{3, 160} = 1.590, P > 0.05$).

The mean pellet group density of Tahr was maximum (40.93 ± 15.35) in high herbs density followed by low herb density (30.90 ± 7.39), medium herb density (15.91 ± 6.01) and minimum (7.95 ± 7.95) in very high herbs density. However results were not significant ($F_{3, 160} = 1.456, P > 0.05$).

The mean pellet group density of sambar was significantly higher (29.57 ± 19.71) in high herbs density followed by medium herbs density (1.99 ± 1.39) and minimum (0.93 ± 0.65) in low herbs density ($F_{3, 160} = 3.242, P < 0.05$).

The mean scat density of red fox was maximum (1.13 ± 1.13) in high herbs density and minimum (0.49 ± 0.49) in medium herbs density with an insignificant result ($F_{3, 160} = 0.738, P > 0.05$).

The Asiatic black bear was only reported in low herb density and the mean scat density was (2.34 ± 1.38). However results were not found significant ($F_{3, 160} = 1.329, P > 0.05$), (Table 14).

4.3.8. Use of grass density

The musk deer, sambar and red fox were only reported in low grass density and the mean pellet group and scat density was found (2.15 ± 0.77 ; 7.66 ± 4.27 & 0.47 ± 0.33) respectively, however results were not found significant ($F_{2, 161} = 0.891, P > 0.05$; $F_{2, 161} = 0.370, P > 0.05$ & $F_{2, 161} = 0.232, P > 0.05$). The mean pellet group density of Tahr was found maximum (95.52 ± 85.25) in high grass density followed by medium grass density (38.91 ± 15.70) and minimum (21.54 ± 4.15) in low grass density, however results were found significant ($F_{2, 161} = 3.781, P < 0.05$).

Table-14- Mean Density \pm SE of different mammalian species in different herbs density of Kedarnath wildlife sanctuary (2012)

S.N.	Herb density	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	Low	0.46 ± 0.46	30.90 ± 7.39	0.93 ± 0.65	2.34 ± 1.38	0
2	Medium	2.48 ± 1.28	15.91 ± 6.01	1.99 ± 1.39	0	0.49 ± 0.49
3	High	2.27 ± 1.57	40.93 ± 15.35	29.57 ± 19.71	0	1.13 ± 1.13
4	Very High	7.95 ± 7.95	7.95 ± 7.95	0	0	0

Low = 0-150 ind/meter squire, Medium = 151-300 ind/meter squire, High = 301-450 ind/meter squire and Very High = 451-600 ind/meter squire

The mean scat density of black bear was maximum (2.35 ± 2.35) in medium grass density and minimum (0.71 ± 0.53) in low grass density. However results were not significant ($F_{2, 161} = 0.581, P > 0.05$), (Table 15).

Table-15- Mean Density \pm SE of different mammalian species in different grass density of Kedarnath wildlife sanctuary (2012)

S.N.	Grass density	Mean Density \pm SE				
		Musk deer	Himalayan Tahr	Sambar	Asiatic black bear	Red fox
1	Low	2.15 ± 0.77	21.54 ± 4.15	7.66 ± 4.27	0.71 ± 0.53	0.47 ± 0.33
2	Medium	0	38.91 ± 15.70	0	2.35 ± 2.35	0
3	High	0	95.52 ± 85.25	0	0	0

Low = 0-100 ind/meter squire, Medium = 101-200 ind/meter squire and High = 201-300 ind/meter squire

Table-16 represents the mean values of habitat variables between available and utilised plots for different mammalian species in Kedarnath wildlife sanctuary. Musk deer preferred the area with high tree density, low shrub density, high herb density and low grass density. However results were not significant for tree, shrub and grass ($t = -1.821, P > 0.05$; $t = -1.509, P > 0.05$ and $t = 1.776, P > 0.05$ respectively), but contrary to this for herbs ($t = -2.139, P < 0.05$). Himalayan Tahr preferred the area with low tree density, low shrub density, low herbs density and high grass density however results were not found significant ($t = 0.622, P > 0.05$; $t = 0.391, P > 0.05$; $t = 0.472, P > 0.05$; and $t = -1.884, P > 0.05$ respectively). Sambar preferred the area with high tree density, low shrub density, high herb density and low grass density. However results were not significant for shrub, herbs and grass ($t = 0.537, P > 0.05$; $t = -1.518, P > 0.05$ and $t = 1.699, P > 0.05$ respectively), but when we considered it with respect to trees only then it was found significant ($t = -4.092, P < 0.001$).

Asiatic black bear preference was on area with high tree density, high shrub density, low herb density and low grass density. However results were found to be significant for trees, shrubs and grass ($t = -1.468, P > 0.05$; $t = -1.521, P > 0.05$ and $t = 0.506, P > 0.05$ respectively), but it was significant for herbs ($t = 2.348, P < 0.05$). Red fox preferred the area with low tree density, low shrub density, high herb density and low grass density. However results were not significant for trees, shrubs, herbs and grasses ($t = 0.476, P > 0.05$; $t = 1.187, P > 0.05$; $t = -1.207, P > 0.05$; $t = 0.213, P > 0.05$ respectively).

Out of five studied species, Himalayan tahr, alpine musk deer and Asiatic black bear were recorded from high altitude areas of Shokhark, Tungnath and Chandrasila. This result is in compliance with the study conducted by Green and Sathyakumar, where they suggested that these species always prefer high altitude areas [10, 28]. The other two species sambar and red fox whose distributions overlap in low and middle altitude area have not been recorded from Tungnath and Chandrasila. Himalayan Tahr seems to be least affected species as for as disturbances are concerns, therefore, its indirect evidences were recorded from all the three sampling sites Shokhark, Tungnath and Chandrasila where as Asiatic black bear indirect evidences were recorded from two sites Shokhark and Chandrasila. The reason could be that Tungnath is highly disturbed area due to its pilgrimage importance. The indirect evidences of alpine musk deer were only recorded from Shokhark where disturbances were comparatively less than Tungnath and Chandrasila. It is reported that altitudes play a greater role in the distribution of species in space and time [10]. Out of all five species from the study area, except Asiatic black bear, most of them were found along 3000-3250 m. Probably this is due to least disturbed and favourable environmental condition along these altitudinal gradients. In general, very few direct sighting of Himalayan tahr, Alpine musk deer and sambar were reported from different areas while there was no direct sightings of Asiatic black bear and red fox, suggesting extremely low abundance for all these species.

Mean pellet group density of musk deer and mean scat density of red fox were found maximum in sub-alpine region suggesting that musk deer and red fox preferred the area with high herb density. For Himalayan Tahr it was found that they preferred the area with low tree density although their mean pellet group density were maximum in Sub-alpine where tree density was found to be low as compare to mixed habitat. The reason could be that the Sub-alpine region is least disturbed among other three habitat type, mixed, alpine meadows and Alpine scrub. Likewise sambar and Asiatic black bear prefer area with high tree density and probably due to this, presence of sambar and Asiatic black bear was recorded maximum in mixed habitat which is largely inhabited by trees. Another reason could be that they get proper escape from danger under high tree density.

In the present study it was observed that musk deer preferred north east and south east aspects. It seems that both aspects provide favourable habitat to the animal. Green [10] reported that musk deer prefer the north western, southern, south western and western aspect more, whereas, Sathyakumar [15] reported that the musk deer use southern and south west aspects. Results shows that Himalayan tahr prefer west, south west, north east, south east and avoided north west, contrary to this, Tahr it has been documented that they prefer mostly eastern and south eastern aspects [15]. The reason could be that they get proper and favourable environment by preferring the sun facing slopes in the morning hours, when monitoring was carried out.

Results revealed that sambar use north east and south east and at the same time avoided North West aspect. This differential use of aspect by different species of mammals may be due to other factors such as difference in food availability and quality, cooler or warmer slopes and presence of shelter from adverse weather condition [20].

Contrary to this, Green [10] has reported that sambar prefer southern and south western aspect more.. Bhatnagar [29] suggested that sambar prefers southern and avoids northern aspect in winter and summer. f shelter from adverse weather condition [20].

Musk deer, sambar and Himalayan Tahr preferred steep slopes (more than 51°). The reason could be that the use of steep slope is an anti-predatory strategy and their preferences for habitats have steep slopes which offer excellent escape terrain [20].

Tree cover plays an important role in the distribution of all the mammalian species. The surveyed area is dominated mainly by scrubby vegetation, as the area is at timber-line, therefore trees were sparsely distributed. Most of the pellets/scat density was found in medium to low tree cover categories. Musk deer and Himalayan Tahr prefer open area (alpine meadows) close to thick canopy cover [30].

Sambar were mostly encountered in low tree and shrub cover (less than 30%) which is similar to the observation made by Bhatnagar in the Shiwaliks [29]. During the present study, it was found that sambar avoids closed canopy forest. Whereas, Johnsingh & Sankar, Green, and Khan et al. [31-33] have documented occurrence of sambar in closed canopy forest.

Asiatic black bear and red fox also show its preference to low to no categories as far as tree cover; shrub cover, herb cover and grass cover are concern. The study on sloth bear [34] shows that the bear avoided open and cropland and preferred high tree cover. The variation in results could be due to the difference in the study areas and availability of different canopy cover.

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Table-16- Mean values of habitat variables between available and utilized plots for different mammalian species in Kedarnath wildlife sanctuary (2012)

Variables	Musk Deer			Himalayan Tahr			Sambar			Asiatic Black Bear			Red Fox		
	Available	Utilized	<i>t</i>	Available	Utilized	<i>T</i>	Available	Utilized	<i>T</i>	Available	Utilized	<i>t</i>	Available	Utilized	<i>t</i>
Tree density	92.26	222.92	-1.821	104.79	83.33	0.622	85.79	386.69	-4.092	95.53	265.39	-1.468	99.46	31.85	0.476
Shrub density	1653.5	605.09	1.509	1639.71	1509.36	0.391	1619.43	1219.3	0.537	1571.29	3269.64	-1.521	1622.14	0	1.187
Herb density	184.79	283	-2.139	192.58	182.12	0.472	186.39	261.14	-1.518	192.74	20	2.348	188.24	298	-1.207
Grass density	59.51	26	1.776	53.16	70.26	-1.884	59.33	25.14	1.699	58.16	42.66	0.506	57.97	50	0.213

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