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Research article

Population and demographic structure of blue sheep (*Pseudois nayaur)* and Himalayan tahr (*Hemitragus jemlahicus*) in Dhorpatan Hunting Reserve, Nepal

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Abstract

The blue sheep and Himalayan thar were counted using the vantage count method to obtain population and demographic status in Dhorpatan Hunting Reserve, western Nepal between April and May of 2021. We used binoculars (Olympus 10 × 50 and Nikon 10 × 42) and spotting scopes (Nikon 20–60 × 75 and Bushnell 20–60 × 65) for identifying the animals into class and sex categories. A total of 1290 blue sheep were counted in six hunting blocks of DHR with an apparent density of 2.2 animals/km² in 79 herds (mean heard size: 16.33 ± 1.53). Maximum numbers of blue sheep were recorded from Dogadi (n=361) and low numbers in Sundaha block (n=89). We found a significant difference in the average herd size of blue sheep among the six blocks, possibly due to human-induced disturbances as some blocks are relatively accessible and closer to human settlements. However, there was no significant difference in the average male and female sex ratio and density between hunting blocks. Similarly, a total of 744 Himalayan tahr were observed in six hunting blocks with an apparent density of 1.49 animal/km² in 50 herds (mean heard size: 14.88±2.29). Maximum numbers of tahr were recorded from Ghustung (n=387) and low numbers in Surtibang block (n=12). We found a significant difference in the average herd size of Himalayan tahr and male to female sex ratio, but not a significant difference in density between hunting blocks. Regular study of population dynamics in the context of trophy hunting is very crucial. Thus, annual surveys of these game species are recommended for designing sustainable game trophy hunting in the region.

Keywords: Density; Distribution; Herd size; Naur; Population structure; Sex ratio

1 | Introduction

The blue sheep (*Pseudois nayaur* Hogdson, 1833) locally known as naur, and Himalayan tahr (*Hemitragus jemlahicus* Smith, 1826) locally known as jharal, are closely tied to the rugged mountainous regions of the Himalayas (Jnawali et al. 2011). They are the important species in the alpine ecosystems, playing roles in maintaining vegetation dynamics and serving as prey for large carnivores such as snow leopards (*Panthera uncia*) and other predators (Chetri et al. 2019; DNPWC & DoFSC 2024; Filla et al. 2020). Blue sheep typically inhabits alpine meadows and steep, rocky slopes above the tree line, often at elevations ranging from 3,000 to 5,500 meters in the Nepal Himalayas (Aryal et al. 2013). Himalayan tahr, on the other hand, are found at slightly lower elevations, often between 2,500 and 5,000 meters (Shrestha 2006). Blue sheep are found in Bhutan, China, northern India, northern Myanmar, Nepal, and northern Pakistan (Harris 2014) and Himalayan tahr are found in the Himalayas of China, India and Nepal, spread over an estimated area of 44,200 km² (Ale et al. 2020). The blue sheep and Himalayan tahr are listed as Least Concern (LC) and Near Threatened (NT) in the IUCN Red List of threatened species (Harris 2014; Ale et al. 2020).

The blue sheep and Himalayan tahr are listed among eligible game species to participate in different categories of hunting awards provided by Safari Club International (SCI 2023). Thus, the popularity of hunting these wild animals is growing among international hunters due to this recognition. Many international adventurous tourists have enjoyed trophy hunting of blue sheep and Himalayan tahr in Dhorpatan Hunting Reserve (DHR) including the hunt of barking deer (*Muntiacus vaginalis*), and wild boar (*Sus scrofa*). DHR is the only hunting reserve in Nepal which was gazetted in 1987. The sustainable trophy hunting of game species was initiated in DHR in 1976 (Wegge 1976). The trophy hunting quota in DHR is being determined by the Department of National Parks and Wildlife Conservation (DNPWC) based on periodic surveys of five years intervals. To manage trophy hunting, the reserve has been divided into seven blocks and a specific quota is set for each block. Trophy hunting is allowed in only two seasons of the year, one in spring (March–April) and another in autumn (October-November). Trophy hunting is also the main source of revenue for the DHR. In the

Photo 1. Class III males of blue sheep (left) and Himalayan tahr (right) in their natural habitats. (Photo: Madhu Chetri)

year 2023/24, a total of USD 328,374.62 (1 USD=NPR 130) was collected as revenue from trophy hunting (DHR 2024).

Trophy hunting, when carefully managed, can play an important role in wildlife conservation by generating revenue that supports habitat preservation benefitting local communities (Aryal et al. 2015). However, to ensure such practices are sustainable, it is essential to conduct detailed population studies (Bajimaya et al. 1990). Population studies provide critical data on species demographic structure, population sizes, growth rates, and distribution, enabling wildlife managers to set appropriate hunting quotas that prevent overharvesting. By understanding the dynamics of target species, including their interactions with the environment and other species, reserve managers can ensure that trophy hunting contributes to the long-term health and genetic diversity of wildlife populations, aligning hunting practices with broader conservation goals. In our study, we assessed the population and demographic structure of blue sheep and Himalayan tahr in the DHR of Nepal.

2 | Materials and methods

2.1 | Study area

DHR is famous for trophy hunting. International hunters from different countries visit DHR for trophy hunts of blue sheep and Himalayan tahr. DHR extends between 28°15' N to 28°55' N latitude and 82°25' E to 83°35' E longitude, covering an area of 1325 km^2 in the Dhaulagiri range of Western Nepal (Fig. 1). The

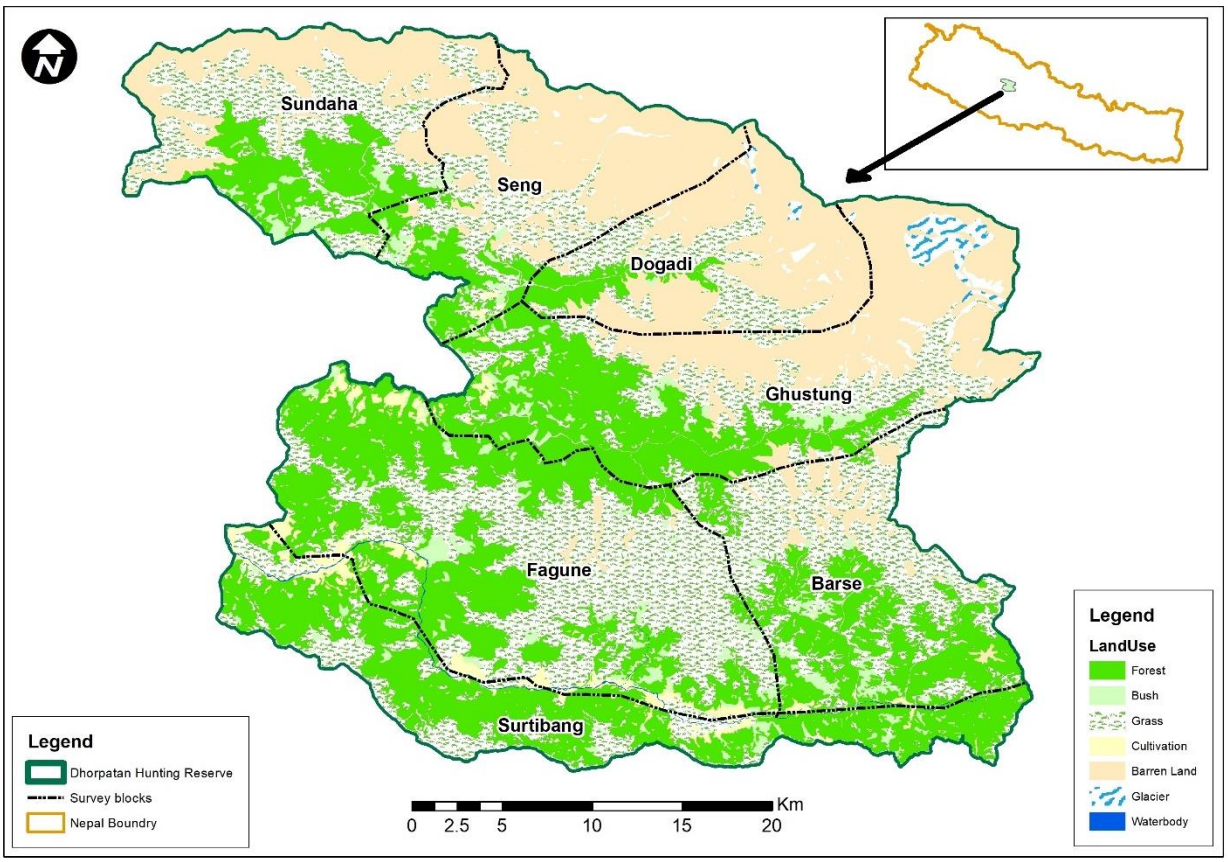

Figure 1. Map of the study area showing survey blocks and location of DHR in Nepal.

reserve falls within the Baglung and Myagdi districts of Gandaki Province and East Rukum of Lumbini Province.

The majority of the land in the reserve is covered by forest area (34.20%), grassland (33.63%) and barren land (24.25%). The rest is covered by shrubland (3.58%), settlement and agricultural land (2.18%) and water bodies including sand area (2.16%). The elevation of the reserve ranges from approximately 2000–7243 m (DHR 2024).

DHR is rich in biodiversity. The reserve supports 14 ecosystem types representing the mid-hill to higher Himalayan ecosystem (Shrestha et al. 2002) and is characterized by alpine, sub-alpine and high-temperate vegetation. The reserve has several alpine pastures (locally known as *Patan*) which are very important for blue sheep and Himalayan tahr. Other important species in the reserve are snow leopard, wolf (*Canis lupus*), goral (*Naemorhedus goral*), serow (*Capricornis sumatraensis*), Himalayan black bear (*Ursus thibetanus*), barking deer (*Muntiacus vaginalis*), wild boar (*Sus scrofa*), and rhesus monkey (*Macaca mulatta*). Likewise, musk deer (*Moschus leucogaster*), red panda (*Ailurus fulgens*), cheer pheasant (*Catreus wallichii*) and Himalayan monal (*Lophophorus impejanus*) are a few other important species that are also found in the reserve (DHR 2024).

There are around 56 settlements inside and in the proposed buffer zone area of Rukum, Baglung and Myagdi District. The settlements (villages) are mostly inhabited by Dalit, Magar, Chantyal, Brahmin, Chhetri, Thakali, Nauthar and Tibetan refugees (DHR 2024). The majority of them rely on the reserve to meet their requirements of timber, firewood, fodder, and pasture. Local people take their cattle to graze in the different pastures of the reserve for seasonal grazing mainly in the summer season. It has been estimated that around 80,000 to 100,000 livestock enter the reserve for grazing every year from villages in and around the reserve (DHR 2019).

2.2 | Methods

Before the start of field survey, several consultation meetings were done with focal persons of DNPWC, DHR and representatives of professional hunting companies working in the Dhorpatan Area. The seven blocks, which are divided for management and to regulate hunting in DHR were taken as reference survey blocks for this study. Three survey teams (five members of the survey team including game scouts from DHR and a student on each team) were formed to cover the entire study area. Team 1 covered three survey blocks: Barse, Fagune and Surtibang; Team 2 covered two blocks: Dogadi and Ghustung; and Team 3 covered two blocks: Sundaha and Seng respectively (Fig. 1). Before the initiation of the surveys, all members of survey team were oriented on survey methods and data recording to make the count uniform.

The population of blue sheep and Himalayan tahr were estimated based on direct observation using the vantage point count method. The method is widely used for counting blue sheep and tahr populations (Wegge 1976; Jackson & Hunter 1996; Chetri & Pokharel 2006; Aryal et al. 2010; Karki & Thapa 2011; Aryal et al. 2014). The survey team was positioned opportunistically on a high vantage point along ridgelines from where there is likely a high chance of animal observation. All the sites of DHR were scanned using binoculars and spotting scopes. Powerful spotting scopes (Nikon 20–60×75 and Bushnell 20–60×65) and binoculars (Olympus 10×50, Nikon 10×42) were used during the survey to find the herds and classify them according to the age class group (Table 1). The sex and age classification of blue sheep and tahr were classified based on the snow leopard monitoring guideline (Thapa 2007). Depending on the terrain and slopes, the observation distance varied from 200 m to 1.5 km. The blue sheep and Himalayan tahr which could not be classified on sex and age categories were recorded as unidentified (UN).

The survey was conducted between April to May 2021. Collected data were analyzed using SPSS and Excel whereas maps were produced using ArcMap. For density estimation, we considered the methods used by Karki and Thapa (2011). The actual area inhabited by blue sheep and Himalayan tahr was far less than the total area of the reserve. Thus, 50% of the area was used to calculate the apparent density of blue sheep and Himalayan tahr in DHR. We estimated the recruitment rate based on young to 100 female ratios.

3 | Results

3.1 | Distribution of blue sheep and Himalayan tahr

During the survey, blue sheep were recorded in all the survey blocks except the Surtibang. Similarly, Himalayan tahr were recorded in all the survey blocks except the Barse area (Fig. 2).

3.2 | Population structure, herd size and density of blue sheep

A total of 1290 blue sheep were observed, in six survey blocks (Fig. 3). Out of the total blue sheep (n=1290) observed 476 were females, 432 were males (Class I: 142; Class II: 160; and Class III: 130), 174 were yearlings and 177 were young.

Table 1. Age and sex classification of blue sheep and Himalayan tahr (adopted from Thapa 2007).

Species	Age and Code	Description	Remarks
Blue sheep	Young (Y)	< 1 year	Male and female
	Yearling (Yr)	1–2 years	Male and female
	Adult Female (AF)	2 + years	Female
	Class I Male (CL-I)	2–4 years;15-30 cm horns	Young male
	Class II Male (CL-II)	4–7 years, 30-45 cm horns that curve backward	Sub-adult male
	Class III Male (CL-III)	7 + years, 45+ cm horns curved	Trophy age male
Himalayan tahr	Young (Y)	< 1 year	Male and female
	Yearling (Yr)	1–2 years	Male and female
	Adult Female (AF)	2 + years	Female
	Class I Male (CL-I)	2–3 years male	Young male
	Class II Male (CL-II)	3–5 years male	Sub-adult male
	Class III Male (CL-III)	5 + years	Adult male

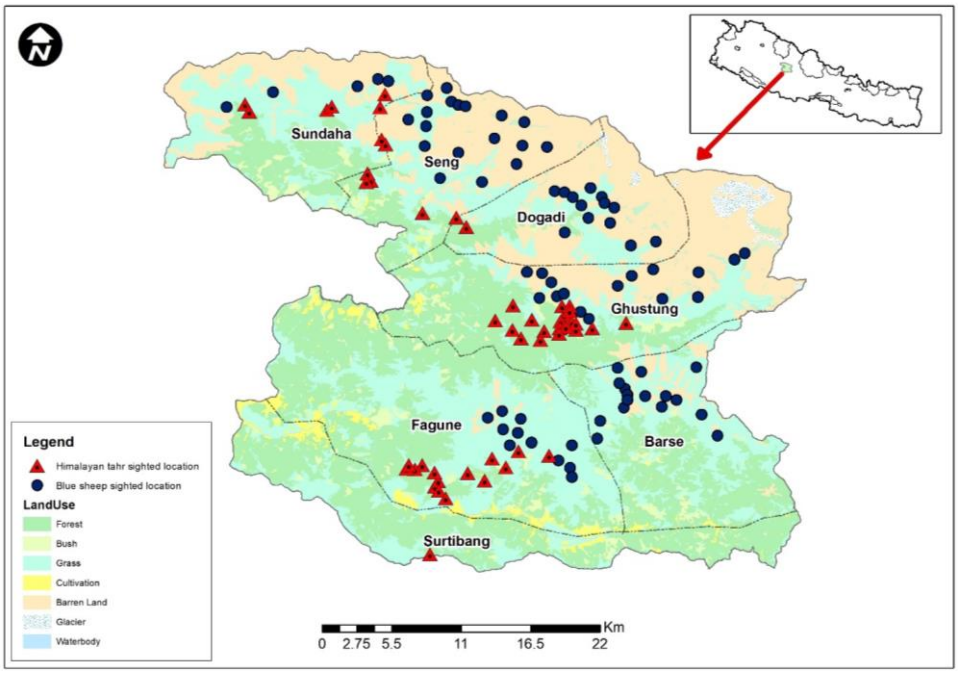

Figure 2. Distribution of blue sheep and Himalayan thar in DHR.

Table 2. Herd size and density of blue sheep.

Block	Number of herds observed	Average herd size (Mean ± SE)	Herd size range (Min-Max)	Number of blue sheep observed	Area used to calculate the apparent density (km²)	Apparent density (animals/km²)
Sundaha	5	17.8 ± 4.07	9 - 32	89	72.5	1.23
Seng	18	11.94 ± 2.04	3 - 36	215	69.0	3.12
Dogadi	13	27.77 ± 5.09	3 - 75	361	99.5	3.63
Ghustung	16	20.19 ± 4.38	4 - 65	323	83.5	3.87
Fagune	11	9.91 ± 1.59	2 - 17	109	162.5	0.67
Barse	16	12.06 ± 1.74	5 - 25	193	100.5	1.92
Total	79	16.33 ± 1.53	2 - 75	1290	587.5	2.20

Altogether 79 herds were observed with a maximum herd (groups) distributed in Seng (18 herds) and a minimum in the Sundaha area (5 herds) (Table 2). One of the large herds of blue sheep was observed in the northern part of the Dogadi area with 75 individuals. We found a significant difference in the average herd size of blue sheep in all blocks (χ^2=13.76, p=0.02, df=5).

The density of blue sheep was estimated to be 2.20 animals/km². The highest density was found in Ghustung, Dogadi and Seng i.e. 3.87, 3.63 and 3.12 animals/km² respectively while low density was observed in the Fagune i.e., 0.67 animals/km². There was no significant difference in population density among the blocks (χ^2=3.65, p=0.66, df=5).

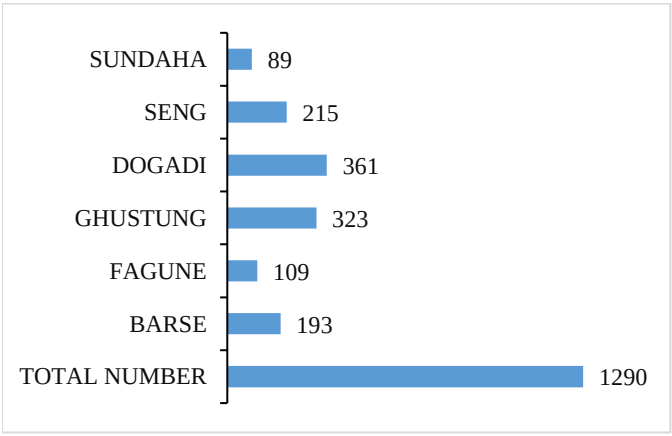

Figure 3. Numbers of blue sheep observed according to survey blocks.

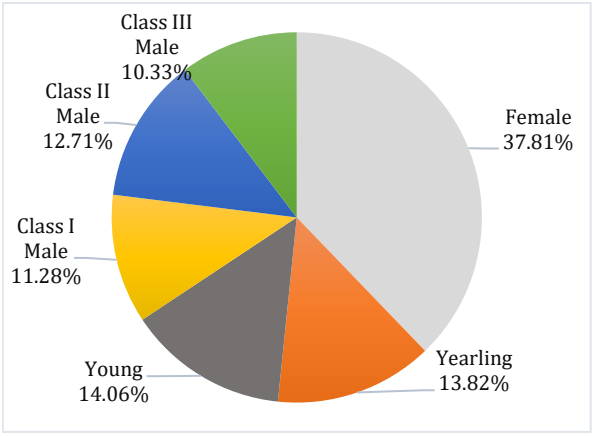

Figure 4. Sex and age structure of blue sheep.

Table 3. Population structure and sex ratio of blue sheep.

Block	Y	Yr	F	Cl-I	Cl-II	Cl-III	M	UN	Total	Y/100 F	Yr/100 F	M/100 F
Sundaha	11	11	33	13	12	7	32	2	89	33	33	97
Seng	25	33	81	26	26	22	74	2	215	31	41	91
Dogadi	51	45	133	29	51	52	132	0	361	38	34	99
Ghustung	44	41	124	41	42	31	114	0	323	35	33	92
Fagune	19	19	39	12	12	8	32	0	109	49	49	82
Barse	27	25	66	21	17	10	48	27	193	41	38	73
Total	177	174	476	142	160	130	432	31	1290	37	37	91

3.3 | Population composition and sex ratio of blue sheep

Out of the total classified blue sheep (n=1259), the number of females was observed to be higher (37.81% of the population) followed by total males (34.31%), young (14.06%) and yearlings (13.82%) (Fig. 4). Out of the total male, the number of Class I males was 32.87%, Class II was 37.04% and Class III was 30.0%. While categorizing male groups separately, the number of Class I males was 32.87%, Class II was 37.04% and Class III was 30.09% out of the total male classified population.

The sex ratio of blue sheep was estimated to be 91 male/ 100 female on average (Table 3). The highest male to female ratio was observed in Dogadi followed by Sundaha, Ghustung, Seng and Fagune. Barse had the lowest male to female ratio (73 male/ 100 female) in comparison to other blocks. However, there was no significant difference in the average male to female sex ratio in all six blocks (χ^2=5.41, p=0.37, df=5). The young and female ratio was observed to be 37 young/ 100 female.

3.4 | Population structure, herd size and density of Himalayan tahr

A total of 744 Himalayan tahr were observed in six survey blocks (except Barse) of DHR (Fig. 5). The maximum number of tahrs was recorded from Ghustung (n=387) followed by Sundaha (n=139) and Fagune (n=116) while the low number of tahrs was observed in the Surtibang area (n=12).

Altogether 50 herds of Himalayan tahr were observed with a maximum herd number in Ghustung (20 herds) and a minimum in Surtibang (1 herd) (Table 4). During the survey, one of the large herds (n=92 individuals/ herd) was observed in the Gyawa pass of the Ghustung area. We found a significant difference in the average herd size of Himalayan tahr in all blocks (χ^2=11.14, p=0.05, df=5).

The density of Himalayan tahr was estimated to be 1.49 animals/km^2. The highest density of tahr was observed in Ghustung (4.63 animals/km^2) while the lowest density was observed in Surtibang (0.16 animals/km^2). There was no significant difference in the density of tahr in the entire study blocks (χ^2=9.12, p=0.15, df=5).

3.5 | Population composition and sex ratio of Himalayan tahr

Out of the total classified Himalayan tahr (n=732), the number of females was higher (37.30% of the population) followed by total males (36.89%), young (11.75%) and yearlings (14.07%) (Figure 6). While categorizing male groups separately, the number of Class II males was 36.30% out of the total classified male population followed by Class III (34.44%) and Class I (29.26%).

The sex ratio of Himalayan tahr was estimated to be 99 male/ 100 female on average (Table 7). There was a significant difference in average male to female sex ratio between the blocks (χ^2=12.76, p=0.01, df=4). The male to female sex ratio was observed to be higher in Ghustung (112 Male/100 Female) and Seng (110 Male/100 Female). During this survey period, 86 young and 103 yearlings were observed with 273 females. No males were recorded from the Surtibang peak area during this survey.

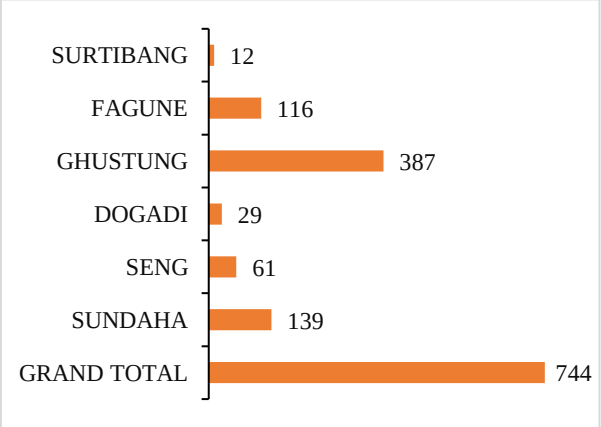

Figure 5. Number of Himalayan tahr observed according to survey blocks.

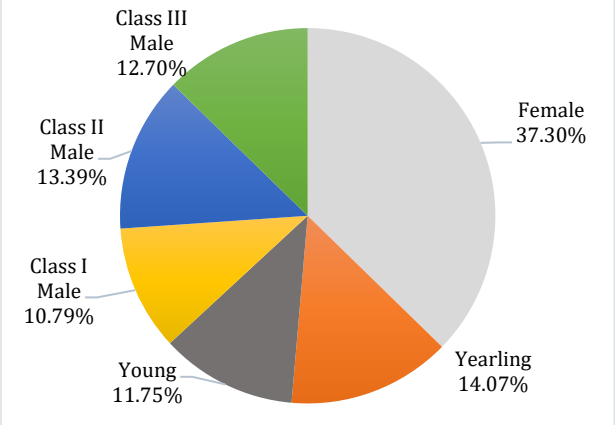

Figure 6. Proportions of sex and age structure of Himalayan tahr.

Table 4. Herd size and density of Himalayan tahr.

Block	Number of herds observed	Average herd size (Mean ± SE)	Herd size range (Min-Max)	Number of H. tahr observed	Area used to calculate the apparent density (km^2)	Apparent density of H. tahr (animals/km^2)
Sundaha	6	23.17 ± 2.10	18 - 30	139	72.50	1.92
Seng	6	10.17 ± 3.74	2 - 26	61	69.00	0.88
Dogadi	2	14.50 ± 3.50	11 - 18	29	99.50	0.29
Ghustung	20	19.35 ± 5.15	2 - 92	387	83.50	4.63
Fagune	15	7.73 ± 1.25	1 - 16	116	100.50	1.15
Surtibang	1	12.00 ± 0.00	12 - 12	12	74.00	0.16
Total	50	14.88 ± 2.29	1 - 92	744	499.00	1.49

Table 5. Population structure and sex ratio of Himalayan tahr.

Sites	Y	YR	F	CL-I	CL-II	CL-III	UN	M	Total	Y/100 F	YR/100 F	M/100 F
Sundaha	17	18	48	15	17	13	11	45	139	35	38	94
Seng	9	7	21	10	9	4	1	23	61	43	33	110
Dogadi	4	4	12	0	3	6	0	9	29	33	33	75
Ghustung	43	45	141	43	55	60	0	158	387	31	32	112
Fagune	11	25	45	11	14	10		35	116	24	56	78
Surtibang	2	4	6	-	-	-	-	-	12	33	67	-
Total	86	103	273	79	98	93	12	270	744	32	38	99

4 | Discussion

We assessed the population and demographic structure of blue sheep and Himalayan tahr in the only hunting reserve of Nepal. The finding reveals that blue sheep were distributed in most of the alpine pastures of DHR except the Surtibang area. Similarly, Himalayan tahrs were distributed in all hunting block areas except Barse, but more concentrated in Ghustang, Fagune, and Sundaha. The average population density of blue sheep in reserve was recorded to be 2.6–2.7 animals/km^2 in 1981 (Wilson 1981), 1.45 (ranging from 0.38–3.60) animals/km^2 in 2007 (Karki & Thapa 2011) whereas the density blue sheep was recorded to be 1.8 animals/km^2 in the Fagune and Barse blocks of DHR in 2008 (Aryal et al. 2010). In this study, we found the average apparent density of blue sheep to be 2.20 animals/km^2 with the highest in Ghustung (3.87 animals/km^2) and the lowest in Fagune block (0.67 animals/km^2). Similarly, the average herd size of blue sheep was also higher, i.e., 16.33±1.53 than the previous records of 2007 (11.7 individuals/herd) and 2011 (15 individuals/herd) (Karki & Thapa 2011; Kandel et al. 2011). However, the average herd size showed no significant difference when compared to those previous studies (χ^2=0.79, p=0.68, df=2).

The larger average herd size of blue sheep was observed in Dogadi and Ghustung whereas lower average herd size was observed in Fagune, Barse and Seng blocks. This could be due to the remoteness of the Dogadi and Ghustung blocks. Fagune and Barse blocks are relatively accessible and closer to human settlement (Wegge, 1997). We observed human disturbances in Seng and Sundaha blocks during the survey period which might have caused the splitting of larger herds. Group size of blue sheep varied seasonally and mixed groups were most numerous in all seasons (Oli & Rogers 1996). Similarly, the density of Himalayan tahr was estimated to be 1.49 animals/km^2 with the highest in Ghustung (4.64 animals/km^2) and lowest in the Surtibang block (0.16 animals/km^2). However, we found no significant difference in average density across the blocks. The average herd size of thar was recorded to be 14.88±2.29 during this survey. One of the largest herds (n=92 animals) was observed in Gyawa pass of Ghustung block. Dhakal et al. (2023) recorded up to 77 individuals in one herd during May in Langtang National Park.

The male to female ratio of blue sheep was observed to be 91 males/100 females which is higher than the previous records of 2007 (86 males/100 females) and 2011 (82 males/100 females) (Karki & Thapa 2011; Kandel et al. 2011) but lower than the previous records of 1979 (104 males/100 females) and 1981 (102 males/100 females in autumn survey and 69 males/100 females in spring survey) (Wegge 1979; Wilson 1981). However, there was no significant difference in male to female ratio among these studies (χ^2=9.62, p=0.09, df=5). In the case of tahr, we found a significant difference in the average male to female sex ratio in between the blocks. The male to female sex ratio was observed to be higher in the Ghustung, Seng and Sundaha blocks. The male population was observed more than the female population in Ghustung and Seng blocks and in other blocks male population was observed to be less than female population. We observed only one group in the Surtibang area where the male population was absent. These findings suggest to control hunting activities in the Surting area until the recovery of the species to a viable population.

The ratio of observed young to 100 females was taken as the annual recruitment rate being young as a new population added in a year. The annual recruitment rate of blue sheep was observed to be 37 on average in hunting blocks with the highest recruitment rate of 49 young/100 females in the Fagune block during this survey. Karki and Thapa (2011) and Kandel et al. (2011) reported the recruitment rate of 13 and 43 according to the survey of 2007 and 2011 respectively. The study by Wegge (1979) indicated a recruitment rate of 81, whereas Wilson (1981) recorded rates of 93.2 in autumn and 77.3 in spring

observations, respectively. This shows that the reproductive rate or young survival rate in recent days is relatively lower. This could be due to predation as we encountered fresh pugmarks and scats of snow leopard and Himalayan wolf during the survey period. A higher recruitment rate in a population targeted for trophy hunting has implications for management and conservation. It allows for potentially increased or sustained hunting quotas without adversely affecting the overall population, as more individuals reach maturity.

During the survey, we observed high human disturbance in some pastures (herders and local people for Yarsagumba *Cordyceps sinensis* collection) which might have some implications on the actual population estimate and their composition. However, we believe long-term periodic and regular monitoring would yield more robust data. Direct observation through the vantage point count method has several advantages and limitations (Nichols et al. 2000; Singh & Milner-Gulland 2011). On the positive side, it provides a relatively cost-effective and efficient way to survey large areas and monitor wildlife populations over time, particularly in difficult terrain. This method allows for consistent and repeatable observations, reducing the likelihood of observer bias and offering valuable data on animal status and distribution. However, the method also has limitations. It may not account for animals hidden by vegetation or terrain, leading to potential underestimation of population sizes. Additionally, it relies on the observer's ability to detect and accurately record and classify animals from a distance, which can be affected by weather conditions, time of day, and observer experience. Consequently, while vantage point counts are useful for broad surveys, they may need to be complemented with other methods to ensure comprehensive data collection. To address the limitations, employing the double-observer method (Nichols et al. 2000; Suryawanshi et al. 2012) combined with other cutting-edge technologies like camera traps, drones, and thermal imaging can improve accuracy. It will provide a more comprehensive data and compensate for potential missed detections. Furthermore, use of citizen scientist also can help to generate long-term data on the population dynamics of game species in the region. These strategies collectively help to mitigate the method's limitations and ensure more reliable data collection.

5 | Conclusions

In DHR, we observed that blue sheep were distributed in all the hunting blocks except the Surtibang and Himalayan tahr in all hunting blocks except the Barse area. Only a few Himalayan tahrs were found in the Surtibang Peak area of Surtibang block, thus it is recommended to stop hunting activities in this area until the recovery of the species to a viable population. The average herd size of blue sheep recorded in the present study was comparatively higher compared to earlier records. The annual recruitment rate was low for both blue sheep and Himalayan tahr which could be probably due to predation. With regular updates on population growth, decline, and interaction with their environment, wildlife managers can set appropriate hunting quotas that avoid overharvesting and maintain the genetic diversity and health of the species. Thus, annual surveys and regular monitoring of game species are crucial in the context of trophy hunting to ensure that hunting practices are sustainable and contribute positively to conservation efforts.

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Authors' contributions

B.S.T., S.K.T., B.K.D. and N.S. designed the research. B.S.T. and A.T. involved in data collection. B.S.T. and M.C. analyzed the data and prepared a draft manuscript. All authors contributed to the manuscript and gave final approval for publication.

Conflicts of interest

The authors declare no conflict of interest.

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