

A Study on Distribution, Habitat Use and Conservation Status of Himalayan Musk Deer (*Moschus chrysogaster*) in Askot Wildlife Sanctuary, India

Kailash Chandra¹, Dinesh K.Sharma², Vijay Shridhar¹, Kusum Arunachalum^{1,*}

¹School of Environment and Natural Resources, Doon University, Dehradun, India-248001

²Department of Zoology, HNB Garhwal Central University Badshahithaul, Tehri Garhwal, India-249199

*Corresponding author: kusumdoon@gmail.com

Received January 02, 2021; Revised January 21, 2021; Accepted January 29, 2021

Abstract The population of Himalayan musk deer (*Moschus leucogaster*) synonym *Moschus chrysogaster* has declined in recent decades and reached an endangered status in its distribution range. The distribution of Himalayan musk deer is very restrictive to Himalayas of Northern India, Nepal, Bhutan and China hence has low population. Musk deer family is being hunted for their musk pod due to high demand in international markets specially in China and North East Asia for their cosmetic and pharmaceutical use. Due to its habitat loss and large scale poaching the species has become endangered. The species is nocturnal, crepuscular and elusive which makes it difficult to study its distribution and habitat use pattern. The present study was carried out in Dharchula range (about 100 sq. km) in Askot wildlife sanctuary (WLS), Uttarakhand, India from August 2017 to May 2019. We used trail sampling and silent drive count method to estimate the distribution, abundance, and habitat use pattern. A total 63 trail transects and 8 Silent Count Drive (SDC) walks were laid in fir mixed, temperate mixed, birch mixed and pure birch forest at different aspect, slope and elevation. We recorded 10 individuals and 39 pellet groups on 63 trail and 8 SDC walks totaling 169 km effort registering an overall encounter rate of 1.18 ± 0.20 individuals/km. We used mixed-effect models to characterize relationships between deer presence-absence data and habitat variables. The study confirmed that musk deer uses fixed defecation sites at higher elevations (3,000-4,300 m) throughout seasons and years. This species was found to use slope ranging between 20° and 55° and were found most abundant between 30° and 45° slope. The largest fraction of musk deer presence was observed in South west aspect and lowest in Northern aspect. The birch mixed forest recorded highest proportion of total musk deer followed by fir mixed forest. The distribution of musk deer was concentrated between 3,500 to 4,000 m a.s.l. A significant difference in density estimates of Himalayan musk deer was observed across the seasons. The encounter rate was higher 1.39 ± 0.13 during autumn and low 0.66 ± 0.22 during winter. It was observed that the species have suffered heavy decline in population in Askot WLS due to large scale collection of a medicinal fungus (*Ophiocordyceps sinensis*) locally called Keeda Jadi. Recently *Ophiocordyceps sinensis* also declared as vulnerable species by IUCN due to over exploitation of this fungus in this region. There is an urgent need for conservation plan for musk deer by strengthening the existing local institutional mechanism such as Van Panchayat and Gram Panchayat and integrating the interest of local community in sharing of benefits of the resources generated from the forest.

Keywords: habitat, transects, distribution, encounter rate, Community

Cite This Article: Kailash Chandra, Dinesh K.Sharma, Vijay Shridhar, and Kusum Arunachalum, "A Study on Distribution, Habitat Use and Conservation Status of Himalayan Musk Deer (*Moschus chrysogaster*) in Askot Wildlife Sanctuary, India." *Applied Ecology and Environmental Sciences*, vol. 9, no. 2 (2021): 193-202. doi: 10.12691/aees-9-2-11.

1. Introduction

The musk deer is a small member of primitive deer family named moschidae. It has been reported that musk deer population across the Indian Himalaya is under high risk due to anthropogenic pressures such as poaching for musk pods, habitat degradation and extensive habitat loss due to overgrazing patterns in recent past. The genus *Moschus* is distributed sporadically throughout the forest mountainous

parts of Asia from north of the Arctic Circle southward to the northern edge of Mongolia and to Korea [1]. The musk deer is found on the slopes of the Himalaya in China, Burma, India, and Nepal [1,2,3,4,5]. The over-exploitation and habitat destruction are the serious threats for their population decline in North Western Himalaya. Musk deer are poached to acquire their musk pods which have been used for traditional medicine and perfumes in China, India, and other countries since the 5th century [6,7,8].

Musk deer has been declared endangered by IUCN (A2cd ver3, 2016) [9] and also has been listed in

Appendix I of CITES. Shrinking distributional range, tremendous anthropogenic pressure on their preferred habitat has resulted in the loss of more than 50% their natural habitat. In Indian Himalayan region, five species of musk deer (i.e. Kashmiri musk deer [*Moschus cupreus*], Alpine musk deer [*Moschus chrysogaster*], Himalayan musk deer [*Moschus leucogaster*], Black musk deer [*Moschus fuscus*] and Forest musk deer [*Moschus berezovskii*] are strictly protected under the Indian Wildlife Protection Act-1972 [10]. The alpine musk deer endemic to the Tibet-Qinghai Plateau of China is distributed throughout the Plateau and within adjacent mountainous regions of western China [11,12].

The continuous distribution of the musk deer in past is now restricted to few isolated pockets in Himalaya due to large-scale poaching and extensive habitat destruction [1,13,14,15,16,17]. Musk deer habitats in the Himalayan range are under anthropogenic pressure due to intensive livestock grazing, fuel wood cutting, fodder collection, illegal medicinal fungus collection (*Cordyceps sinensis*), establishment of hydropower plants and road development [8,18,19,20]. Climate change is an additional factor affecting their population as they are very specific in habitat preference and have narrow distributional range. It has also been observed that the nocturnal, crepuscular behavior of the species and their preference to dense vegetation makes them prone to predators like common leopard (*Panthera pardus*), snow leopard (*Uncia uncia*), and golden jackal (*Canis aureus*). Askot wildlife sanctuary is probably the only Protected area network (PA) in India to possess habitats ranging from subtropical sal (*Shorea robusta*) to alpine meadows and covers three biomes, Eurasian High Mountain (Alpine and Tibetan) (Biome-5), and Sino-Himalayan temperate Forests (Biome-7) Sino-Himalayan Sub-Tropical Forests (Biome-8) [21]. This study is the first attempt to assess the

distribution and conservation status of musk deer in high altitude of Askot wildlife sanctuary, an ecologically significant protected area in the North western Himalaya.

2. Material and Methods

2.1. Study Area

The conservation history of Askot Wildlife Sanctuary started in 1916 when most of the forested areas were protected as reserve forests. Askot Musk Deer Wildlife Sanctuary was setup in 1986 with the sole aim of protection of Musk deer. Because of higher valuable bio-diversity elements, the area was upgraded as Askot Wildlife Sanctuary in 2013 for better protection and conservation drive of all biodiversity in area spread over 600 km² as a sanctuary in Pithoragarh district, Uttarakhand, India. All the revenue villages and hamlets are kept out of the newly demarcated boundary of the sanctuary. It lies between 29°46'45" to 30°27'45"N latitude and 81°01'53" to 80°16'25"E longitude (central coordinate: 30°07'15"N 80°39'09"E) and covers almost 600 km² (230 sq miles). The River Kali forms the international boundary and separates it from Nepal in the East and to the West; it is bounded by West Almora Forest Division, to the North by Tibet and the South by Pithoragarh Forest Division. The Sanctuary covers three major watersheds of Goriganga, Kali and Eastern Dhauri. It comprises of the reserve forests of the Askot Range (289 km²), 225 km² of Civil and Van Panchayat areas and 85 km² of Agricultural lands. The various forest blocks, i.e. Rugling, Jyotigad, Hiragumarhi, Duk, Sobla, East Ghandhura, West Ghandhura, Majtham, Thakla, and Daphia are the biodiversity-rich habitats of the Sanctuary [22].

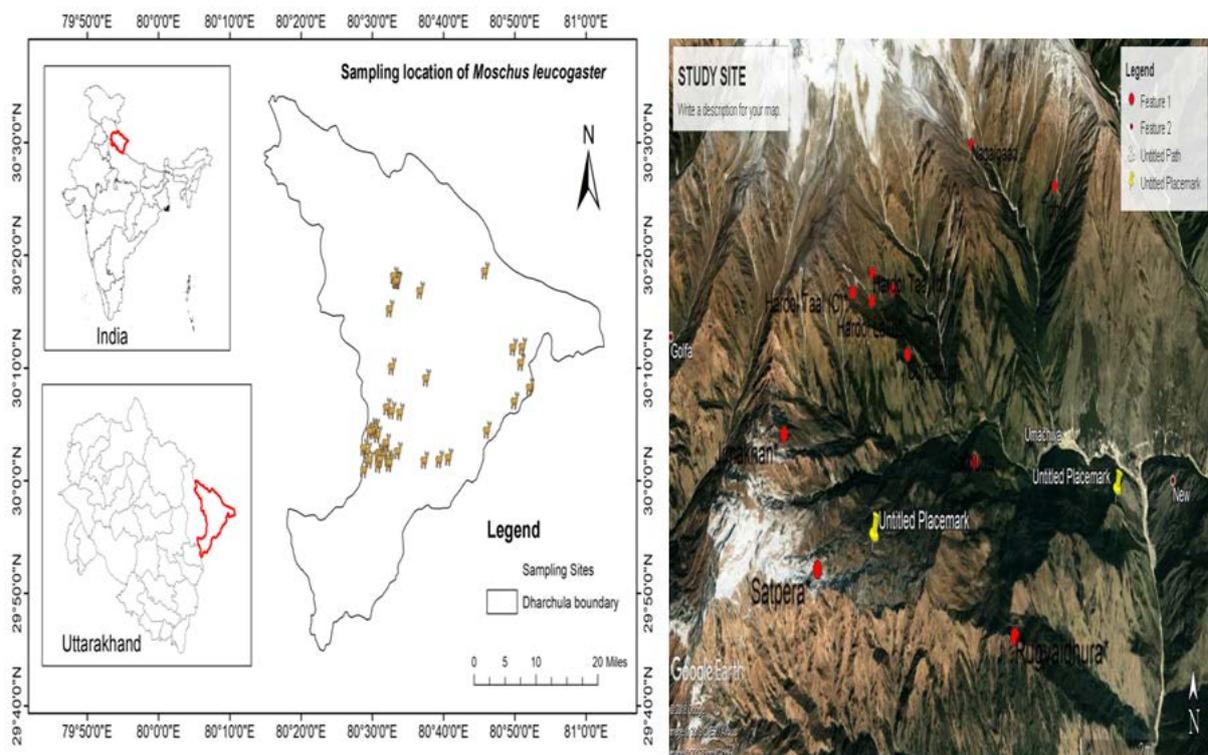


Figure 1. Map showing study site in Dharachula range, Askot wildlife sanctuary

2.2. Preliminary Survey

Askot wildlife sanctuary is divided into four major valleys: Gori valley (Gori Ganga valley), Darma valley, Chaudash valley and Byans valley based on the administrative boundary of the sanctuary. Within each valley forested areas are separated by natural features such as river, stream, ridges, and gullies, etc. Preliminary information on the occurrence of musk deer was obtained from informal interaction by questionnaire and discussion with concerned and knowledgeable people, villagers, herders, local leaders, and district forest staff. The distribution pattern was identified on the basis of direct observation, presence, and absence of pellets, hoof marks and tracks and other key informants.

2.3. Sampling Design and Data Collection

The data was collected from August 2017 to May 2019. A total of 63 trails transect and eight Silent Drive Count (SDC) walks varying in length from 1 km to 5 km were established at different elevation from 2500-4500 to cover the maximum area of the valley. The trails were walked early in the morning from 6:00 am to 10:00 am and evening from 3:30 pm to 5:00 pm. Direct and indirect evidence of Himalayan musk deer and other species were recorded. Forest types within the trails were divided into fir mixed, temperate mixed, birch mixed and pure birch forest. These forest types were located at different elevation range varying between 2700-3000 m a.s.l. (Temperate Mixed), 3000-3288 m a.s.l. (Fir Mixed), 3400-3500 m a.s.l. (Birch Mixed), 3000-3600 m a.s.l. (Birch Mixed), 3500-4500 m a.s.l. (pure Birch) and 3200-3600 m a.s.l. (Birch Mixed). On each trail running at different elevation from lower to higher elevation sampling was done at least two times every month except in the months of January and February due to heavy snowfall. During mid-June to mid-August study was suspended due to high rainfall, landslide and poor visibility. Record of direct sighting and indirect evidence (pellets group) of musk deer were made with respect to habitat attributes such as altitude, aspect, slope, and forest types during September to December which corresponds to autumn and winter season. Sampling for assessing the impact of anthropogenic factors was carried out along the transect at every 500-m intervals. A total of 130 plots of 10-m radius were established on either side of transects and were used to collect data on the presence and absence of Himalayan musk deer. Data on their preferred habitat structure, habitat variability and vegetation types were also collected. The plots were also studied for understanding the impact of disturbance factors such as tree felling (Number of cut tree/plot), lopping (number of lopped tree/plot), livestock grazing (number of goat and sheep/transect) and the impact of fire were also recorded. The poaching pressure, trade in animals' parts and collection of medicinal fungus (*Ophiocordyceps sinensis*) was assessed using questionnaire surveys in the villages located in and around the valleys. The general disturbances factors were estimated to assess the conservation threats to Himalayan musk deer.

2.4. Data Analysis

Habitat variability and topographical attributes with reference to presence and absence of the Himalayan musk deer in the study site were analyzed using comparative habitat parameters. Encounter rate was calculated using the formula $ER=n/L$, where N is the number of individuals recorded L is the effort (Kilometers). Density $D=n/2L$ (D = number of individuals recorded and L =total length). Data was pooled for both the years and Kruskal-Wallis test was performed to find out the significance of differences between habitat variability the observation using R.3.6.1.software. χ^2 tests were performed for confirming the significant difference in the habitat use pattern of the studied Himalayan musk deer species [23].

2.5. Modeling Musk Deer Presence-absence

Musk deer presence-absence was modeled as a binary distribution using “logit” function in multilevel mixed-effect model with “glmer” function using “lme4” package [8] in R software. We fitted the full model with all potential candidate variables and backward stepwise selection method was used to select the model with the best covariates having the smallest Akaike Information Criteria (AIC) value. The selected covariates were fitted using a mixed-effects model where the model structure used two random effects—one associated with site-level and another associated with transect nested within the site as multiple transects were sampled within a site. We also compared the selected model with the null model (without covariates) fitted as a multilevel mixed model using likelihood ratio test [8]. Performance of the best model was evaluated using a receiver-operating characteristics (ROC) curve as compared to the null model using “pROC” package [8] in R. The ROC plot provides area under the curve as a useful indicator of model performance in evaluating presence-absence in ecology [8,24]. The significance of each variable in the model predicting musk deer presence-absence was also evaluated by plotting predicted values (probability) against response (musk deer presence-absence) based on model fit.

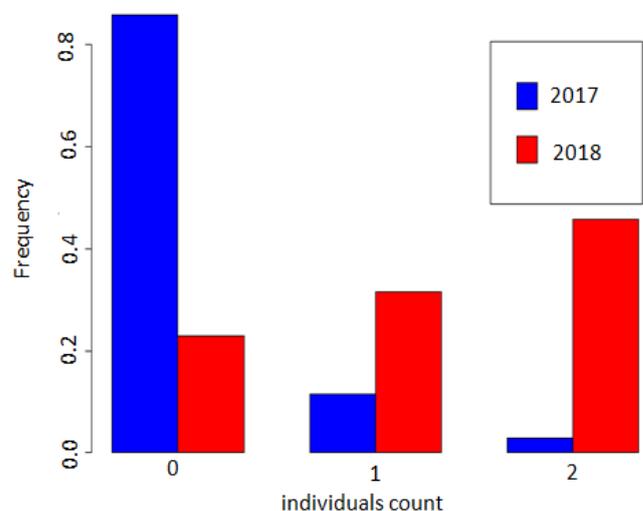


Figure 2. Frequency of musk deer based on individuals count (Direct and indirect)

3. Results

3.1. Abundance

The encounter rates were expressed as number seen per km walk. We incorporated indirect evidence (pellet groups) along with direct sighting on the trails to calculate the encounter rates. We have recorded 10 individuals and 39 pellet groups of the Himalayan musk deer on 63 trail walks totaling 169 km effort. The overall encounter rate was 1.18 ± 0.20 individuals/km. There was a distinct seasonal variation in encounter rate of the Himalayan

musk deer with 1.39 ± 0.13 individuals/km in autumn and 0.66 ± 0.22 individuals/km in winter, respectively (Figure 4a). Significant difference ($P > 0.05$) in density estimates were also observed across seasons (Figure 4b).

3.2. Distribution of Musk Deer Based on Aspect, Elevation and Forest Type

The distribution of musk deer individuals was independent of the years ($\chi^2=0.15886$, $df=2$, $p\text{-value}=0.9236$) (Figure 2). Average musk deer distribution was studied with respect to aspect elevation and forest types.

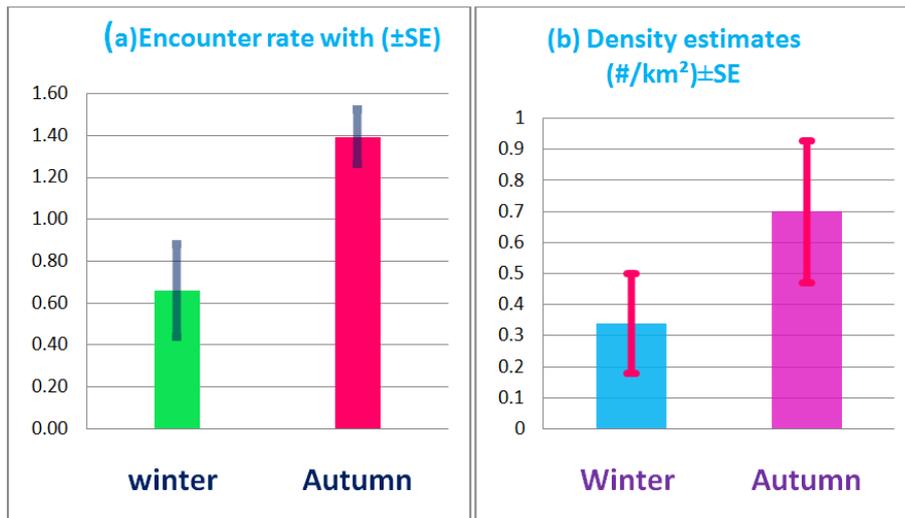


Figure 3. Seasonal variation in the (a) encounter rate (b) density estimates of the Himalayan musk deer (August 2017 to May 2019)

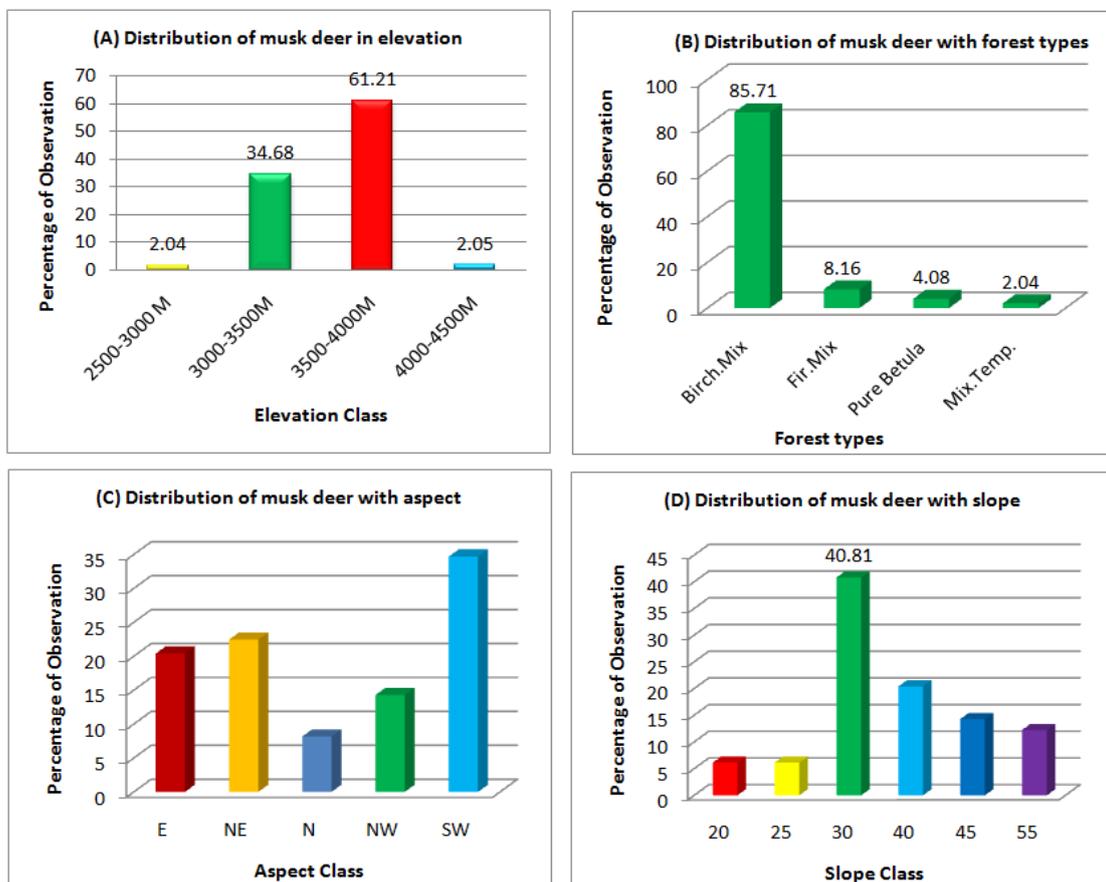


Figure 4. Frequency of musk deer based on Elevation (a), Forest types (b), Aspect (c) and Slope categories (d)

3.2.1. Aspect

The distribution of the musk deer based on topographical aspect is shown in (Figure 4c). The largest fraction of musk deer presence was observed on the SW aspect (34.69%), followed by the NE aspect (22.44%), E aspect (20.4%), NW aspect (14.28%) and thereafter N aspect (8.16%). However, when the slopes were grouped just into north versus south, greater percentage of musk deer was present on the north-facing slopes (44.88%) as compared to the south (34.69%). Although, high frequency of musk deer response was observed on SW, NE and E aspect the difference was not significant. The distribution of musk deer based on slope is shown in (Figure 4d). The species was found to use slopes ranging between 20° and 55° and were found most abundant between 30° and 40° slope. The musk deer presence was lowest on 20° (5%) and gradually increased with increase in slope angle with highest presence observed on 30° slope (40.81%) after which there was a gradual decline in musk deer presence with increase in slope angle.

3.2.2. Forest types and Elevation

The average high proportion of total musk deer observed by direct count and palette group count was in birch mixed forest (85.71%) followed by fir mixed forest (8.16%), pure birch (4.08%) and mixed temperate forest (2.04%). The frequency observation of musk deer based on direct count and palette group count category were dependent on forest types ($\chi^2=7.62$, $df=3$, $p\text{-value} = 0.05$). In the sanctuary, musk deer presence was recorded within the altitudinal range of 2,500 m to 4,500 m covering almost all the forest types. The data also revealed that musk deer was highly concentrated between 3,500 m to and 4000 m (above 65.29%) followed by 3,000 m to 3,500 m (34.68%) (Figure 4a). However, the percentage observation of musk deer was significantly low (2.0 %) both at 2,500 to 3,000 and 4,000 to 4,500 m.

3.3. Effect of Habitat Variables on Occurrence of Musk Deer: Prediction through Modeling of Variables

Musk deer presence and absence as binary response with generalized linear mixed effect model [8] recorded that habitat variables such as aspect, forest types, and elevation had a significant effect on the probability of musk deer presence (Table 1). The selected mixed-effect model was significantly different from the null model (without covariates [8]) fitted with a mixed effect approach in likelihood ratio test ($\chi^2=68.082$, $p\text{-value}<0.001$). The model indicated that variability due to random effects in predicting musk deer presence from trails within site was larger than the sites across.

Table 1. Parameter estimates and standard errors of the mixed-effects model to predict musk deer presence and absence based on habitat sites

	Estimate	Std. Error	t value	p-value
(Intercept)	0.70732	0.15517	4.558	0.000927
Forest. Types	0.43902	0.19915	2.205	0.029268
Elevation	-0.27642	0.19067	-1.450	0.92552
Aspect	0.05691	0.19067	0.298	0.386648
Random:				
sig01	0.5650382			
Sigma	0.5199037			
AIC	21.6.			

DeLong's test paired ROC curve indicated that the area under the curve (AUC) [8] of the selected model was (83.2%) significantly larger ($z = -4.472$, $p\text{-value} < 0.001$) than that of the null model (72.6%) (Figure 5). The selected covariates were highly appropriate to predict musk deer presence and absence.

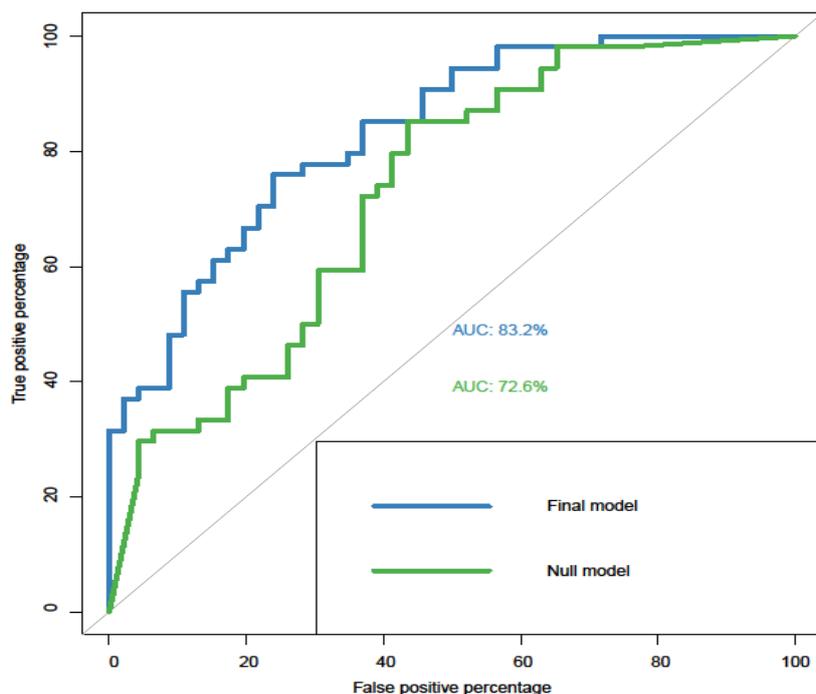


Figure 5. Comparing receiver-operating characteristic (ROC) curves between null and final model. The area under the curve (AUC) of the final model was significantly higher than the null model fitted as multilevel mixed-effects model. The random variance component of the null model provided the power to make 72.6% correction

Table 2. Disturbances recorded and threat score at different study sites of Askot wildlife sanctuary (AWLS)

Trail/Sites	cutting	Loping	% grazing	Fire	Poaching pressure
Site1	2.36±0.83	2.48±0.87	16.6±1.82	O	2
Site2	0±0	3.04±1.07	20.37±4.90	S	2
Site3	2.88±1.17	3.58±1.4	12.13±4.21	O	3
Site4	0±0	0±0	3.2±5	O	3
Site5	0±0	0±0	0±0	O	4
Site6	0±0	4.58±1.8	12.31±5	S	4
Site 7	0±0	0±0	0±0	S	4
Site8	0±0	0±0	0±0	S	4
Site9	2.04±0.88	0±0	0±0	O	4
SDC A Site	1.15±0.5	0±0	10.52±2.5	O	1
SDC B Site	5.71±2.85	0±0	24.89±1.2	O	1

Note: Poaching pressure: 1 = nil, 2 = low, 3 = medium, 4 = high
Site: SDC (Silent Drive Count), Fire: S=Seasonal, O=Occasional.

3.4. Threat

Tree felling was recorded maximum at trail site 3 (2.88±1.17, Table 2) followed by site 1 (2.36±0.83) and site 9 (2.04±0.88), respectively. However, in rest of the trail sites no tree felling was recorded. In Silent Drive Count (SDC) site A, tree felling was higher (5.71±2.85) than all the trail sites. Whereas, tree lopping was maximum at trail site 6 (5.58±1.8) followed by trail site 3 (3.58±1.4), 2 (3.04±1.07) and 1 (2.48±0.87), respectively. Contrary to this, no tree lopping was recorded both at SDC site A and B in Askot Wildlife Sanctuary. Maximum grazing pressure was recorded from SDC B Site (24.89±1.2) followed by trail site 2 (5.71±2.85) trail site 1 (16.6±1.82), respectively. Occasional fire was recorded from all the trail sites and SDC sites, whereas, in trail site 2, 6 and 7 the fire was seasonal. Questionnaire surveys in the villages and other key information revealed that poaching and hunting pressure was maximum at study site 5,6,7,8 and 9 and least in SDC site A and B for Askot Wildlife Sanctuary (Table 2).

Another important and significant anthropogenic pressure in Askot wildlife sanctuary is the collection of medicinal fungus locally called “keedajadi” or “Yartsa Gumbo” (*Ophiocordyceps sinensis*). It is found in mountainous regions of India, China, Nepal, Bhutan and Tibet at an altitude between 3,000 and 5,000 m a.s.l. Its habitat is limited to the alpine meadows and shrub lands of the Himalaya. The stalk-like dark brown to black fruiting body grows out of the head of the dead caterpillar and emerges from the soil in alpine meadows by early spring. The important medicinal mushroom has a long history of traditional use in Chinese and Tibetan medicine. Due to its high medicinal properties and global market demand, the *Ophiocordyceps sinensis* having high economic values with local market price in range of Rs 10-12 lakh per kg. [25]. The price of *Ophiocordyceps sinensis* is reported to have increased dramatically about 900% between 1990s and 2014. Every year number of families living in and around the Askot wildlife sanctuary migrates to higher altitudes for collection of Keeda Jadi. It has been found that it contributes up to 40- 60% of total household income of these families. The interviews with the collectors of *Ophiocordyceps sinensis* also revealed

that about that 60% of the people collecting medicinal fungus are also involved in poaching.

4. Discussion

4.1. Encounter Rate and Density Estimate

The study on distribution and abundance is an essential and foremost step to assess the population size in order to plan a successful management and conservation strategy. Previous study by Groves et al. [26] has reported the presence of all the five species of Musk deer in Indian Himalayan range from Arunachal Pradesh in the east to Kashmir in the west. This being the first study on distribution and habitat-use of musk deer in Askot wildlife sanctuary gains significance for conserving the endangered species in the Himalaya. The encounter rate recorded from direct observation and the pellet group count in the present study for Himalayan musk deer was 1.18±0.20 individuals/km which is higher than the encounter rate recorded in Pindari valley 0.26±0.04 individuals/km [23] and Bedni-Ali 0.01±0.01 individuals/km [27], respectively. However, the density estimate of musk deer 0.7/km², recorded in the present study is significantly lower than the musk deer density of 3.33/ km² recorded from Dhela range in Great Himalayan National Park (GHNP) [15]. The overall musk deer density estimated by the Silent Drive Count method (N=8) in the present study is 0.63±0.3133 musk deer/km², which is lower as compared to the estimate given by Green, in 1985 (3.2/km²) and Sathyakumar, 1994 (3.7/km²) using Silent Drive Count method in Kedarnath wildlife sanctuary. The lower abundance estimates in Askot WLS in comparison to Kedarnath WLS could be attributed to high human disturbances such as tree cutting, lopping, grazing and poaching in general and wide scale collection of *Ophiocordyceps sinensis*, a medicinal fungus in the vicinity (Plate 1) in particular. There was a marked seasonal variation in the density estimate; the higher 0.70±0.23 individuals/km² was recorded in autumn in comparison to 0.34±0.16 individuals/km² in winter (Figure 3). This may be attributed to the availability of sufficient food after the rains and the season is also being the mating period of the musk deer.



Plate 1. Base camp for medicinal fungus collectors (*Cordyceps sinensis*) in Darma valley, Askot WLS

4.2. Relationship with Topography and Forest Types

Some studies have shown that musk deer prefer southern aspect due to their warmer climatic conditions in the Himalaya [13,14]. The similar results were found in the present study as the higher evidence of musk deer were found in southwest aspect (Figure 4c) which are the steeper and warmer slopes in Askot WLS. On contrary, high numbers of musk deer latrines in north, northeast and northwest aspects were recorded in Neshyang valley, Mustang, Nepal by Singh et al. [8]. The species was found to use slope ranging between 20° and 55° and were most abundant between 30° and 45° (Figure 4d). The musk deer prefers these slopes categories because these slopes were steeper and are used as an anti-predatory strategy to protect them from the predators like common leopard (*Panthera pardus*), snow leopard (*Uncia uncia*), and golden jackal (*Canis aureus*) in Askot WLS. It may also be said that preference of aspect and slope are rather a matter of habitat availability in relation to animal's ecological requirement than topographical attributes [8]. The musk deer are generally found in elevation range 2,000 -5,000 m [4]. In our study, musk deer were found highly concentrated between 3,400-4,000 m (above 65.29%) (Figure 4a), which indicates the suitability of site to the musk deer at a higher elevation. This is because musk deer prefer birch mixed forest, which occurs at higher elevation range and are without human disturbances. The musk deer presence was found in birch mixed, fir mixed, and temperate mixed and pure birch forest in the present study (Figure 4b). However, about 85.71% of musk deer was found in birch mixed forest consisting of *Betula utilis* and *Rhododendron campanulatum* in Askot WLS. The other studies in the Himalayan ranges of Nepal and India have reported that musk deer preferred a wide range of forest types found between 2,500 and 4,200 m such as fir-birch forest, mixed forest of birch, dwarf rhododendron scrub, birch-rhododendron forest, fir and rhododendron and oak (*Quercus semecarpifolia*) forest [17,28,29]. Our study revealed that in Askot WLS musk deer has very narrow

distributional range and specific preference for the habitats as it was found concentrated only in birch mixed forest. This is in contrast to the earlier studies in Kedarnath WLS [13,14,17] where it was observed that musk deer had wide distribution and habitat preference range. The narrow distribution range observed in the present study could be attributed to tremendous anthropogenic pressure such as livestock grazing, tree felling and lopping in temperate mixed forest and fir mixed forest located at lower altitude forcing the species to move to higher elevation. Moreover, the rhododendron shrub in birch mixed forest had a dense growth of "reindeer moss" (*Cladonia rangiferina*) which is the most preferred food of the musk deer and the bushy shrub cover of the rhododendron in birch mixed forest is also an anti-predatory approach to hide and take shelter by the species. The other possible reason could be the overall rises in temperature due to climate change making species to move to higher altitudes as the species has very limited tolerance for temperature fluctuations. The similar observations have been made by Jiang et al. [30] who reported that the musk deer would move to higher elevation and the suitable habitat area of musk deer would decrease over the next 30 to 50 years in China owing to climate change.

4.3. Effect of Habitat Variables on Occurrence of Muskdeer: Prediction through Modeling of Variables

Analysis of the ROC curve returning the point with the sum of sensitivity and specificity showed that the best model had a discrimination threshold of 0.55 to classify binary response as musk deer absence because this threshold minimized the classification errors of the model (Figure 5). The true positive rate (sensitivity) was 80% and true negative rate (predicting actual musk deer absence) was 61%, which indicated that the model predicted a better number of actual musk deer presence trails than actual musk deer absence trails. From the modeled habitat suitability (AUC=0.832), musk deer distribution is predicted to be concentrated in the northeastern and northwestern part of the study area (Figure 5). Both linear models and ordination method indicate that stand

attributes such as forests types, aspect, and elevation are important attributes for determining the presence of musk deer in forest located between 3,000 and 4,500 m.

We understand that this study will provide baseline information which will be useful for preparing species conservation action plan for Askot wildlife sanctuary. Using the approach based on musk deer distribution and identifying the threats we hope that future studies can be designed to investigate the response of musk deer to ecological correlates, livestock grazing, and human disturbances. This study will also provide a foundation for designing more comprehensive study on the territorial claims by different sexes and individuals of musk deer and predator escape behavior. The use of an advanced technology such as molecular genetic analysis, camera trapping, and GPS collars can play an important role to achieve the objectives in future studies.

4.4. Threat

The maximum livestock presence (About 67.34% grazing pressure) was recorded in the habitat lying between elevations of 3,000m to 4,000m in Askot WLS. These are the areas which are more suitable for the musk deer and are found being under the tremendous grazing pressure for the livestock of people living in the nearby villages. Because of this the natural habitat of musk deer is severally affected. Occasional and seasonal forest fire in the month of September- October by the local people also affects the breeding of musk deer as these months also represent the mating season of musk deer.

The presence of anthropogenic disturbance is also known to effect musk deer and other ungulates. In the present study, effect of human activity such as collection of medicinal fungus, livestock grazing, tree cutting, lopping varied between different study sites. Severe anthropogenic disturbances on the Himalayan musk deer population and its habitat were recorded from areas that were close to the vicinity of the reserve forest boundary. Of all the protected areas surveyed and studied for musk deer population in western Himalayan region such as Kedarnath wildlife sanctuary, Nanda Devi Biosphere Reserve and Govind Pashu Vihar, Askot wildlife sanctuary is the most threatened study site. Questionnaire surveys in the villages and interview of the people residing in the camps for the collection of *Ophiocordyceps sinensis* (without disclosing identity) revealed that poaching pressures was found in whole Askot wildlife sanctuary area. The poaching pressure was maximum at Darma valley followed by Chaudash valley and Byans valley for Askot WLS. Moreover, Darma valley (Both Reserve and Civil Forest patches) is visited by large number of people every year in the month of May to July for the collection of Keeda Jadi (*Ophiocordyceps sinensis*) causing great disturbance as these months are also the breeding season of musk deer affecting their population adversely. Out of three valleys in Askot WLS the most threatened valley was Darma, where locals from nearby villagers and outsiders were involved in practice of killing the species for musk pod and also consuming the meat as food. The interviews with the collectors of *Cordyceps sinensis* revealed that more than 60% of them are involved in poaching. This gains significance because the

maximum presence of musk deer was observed in Darma valley of Askot WLS.

5. Conclusion

This study is the first attempt to assess the distribution and conservation status of musk deer in high altitude of Askot wildlife sanctuary, an ecologically significant protected area in the North western Himalaya. The dense and undisturbed forest of the higher Himalayas, dominated by birch and rhododendron provides the most suitable habitat for the Himalayan musk deer because of their unique behavior and timid nature. The population of musk deer in the Himalayas is being threatened due to habitat degradation causing forest fragmentation, depletion of tree and shrub cover, and reduction of floral diversity which in turn results in reduction of escape cover and food resources available to the musk deer. Few studies have been conducted on understanding the distribution, habitat use pattern and ecological behavior of musk deer in Hindu-Kush Himalaya, the natural habitat of musk deer (Table 3). Most of the studies conducted have focused on the general pattern of distribution of musk deer along with the other ungulates.

Askot wildlife sanctuary was set up in 1986 with the sole aim of protection of Musk deer. The sanctuary because of its uniqueness, biological representativeness, naturalness and presence of valuable bio-diversity elements is a potential habitat for the conservation of highly endangered musk deer. This species has suffered heavy decline in population in Askot wildlife sanctuary, due to the trapping, poaching, and habitat loss (Plate 2). It was observed that anthropogenic activities are the main cause of their population decline and poses tremendous pressure on existing population of ungulates especially musk deer and Himalayan goral as they have to share habitat with thousands of livestock. Large scale collection of medicinal fungus "Keedajadi" is another concern in the Askot WLS. During the months of May-July, nearly fifty camps and more than five thousand people including local villagers and outsiders were found to be involved in the collection of medicinal fungus (*Ophiocordyceps sinensis*) in the habitat used by Himalayan musk deer (Plate 1). The issue of Keeda Jadi collection by the large number of people is a matter of serious concern and need to be addressed on an urgent basis for conserving the existing population of the species in the Askot WLS. It is suggested that the collection of medicinal fungus should be regulated by limiting the issuance of passes and strengthening the existing local institutional mechanism such as Van Panchayat and Gram Panchayat and integrating the interest of local community in sharing of benefits of the resources generated from the forest on 90:10 basis (Ninety percent share of the income generated from the resources should go to Van Panchayat or Gram Panchayat and ten percent as revenue to the state government). Reducing the dependence on non timber forest produce (NTFPs) by strengthening alternative livelihood means such as traditional agriculture, horticulture and animal husbandry would also help in conserving the musk deer population in Askot WLS.

Table 3. Distribution, habitat use pattern and conservation status of musk deer in different protective areas in Hindu-Kush Himalaya (HKH)

Study Area	year	Major Finding	Reference
Kedarnath WLS, India	1985	Musk deer prefer southern aspects due to their warmer climatic conditions in the Himalaya. The western Himalaya region of India also showed a high frequency of latrines between 2,700 and 4,500 m.	[13]
(GHNP), India	1999	The density estimates for musk deer in Gumtharao and Dhela area were 3.33 ± 0.29 and 0.72 ± 0.49 / Km ² respectively.	[15]
Pindari Valley, India	2010	The overall encounter rate (#/km \pm SE) for Himalayan musk deer based on trail walks was 0.26 ± 0.04 .	[23]
Kedarnath WLS, India	2014	The relative abundance of AMD in terms of Encounter rate (groups/km) and pellet groups density (pellet groups/ha) was highest in Saukherk (1.3 groups/km and 58.8 ± 8.9 pellet groups/ha, respectively).	[17]
Gilgit Balistan, Pakistan	2015	Musk deer are widely distributed over the southern mountains of GB in areas with adequate forest cover.	[31]
Sagarmatha (Mt. Everest NP) Nepal	2010	Musk deer prefer altitudes of 3300 - 3700m and 36-45% slopes with N, NW aspects.	[32]
Manaslu Conservation Area, Nepal	2012	Musk deer are distributed within the altitudinal range of 3128-4039m, and the highly preferred altitudes between 3601-3800m, with a 21°-30° slope.	[33]
Annapurna Conservation Area, Nepal	2018	The musk deer use latrines in forests located at higher elevations (3,200-4,200 m) throughout multiple seasons and years.	[8]
Sakteng WLS Bhutan	2018	Intensive competition from unregulated grazing, Non-Timber Forest Products (NTFP) collection and poaching were observed as major threats to conservation.	[34]
China	2019	The suitable habitat area of musk deer would decrease over the next 30 to 50 years in China. The area with suitable climate for the Siberian musk deer will migrate to the southwest (to higher elevations) while areas suitable for the Alpine musk deer, the Himalayan musk deer, and the Anhui musk deer would all migrate to the northeast (To higher latitudes).	[30]
Askot Wildlife Sanctuary, India	2020	The distribution of musk deer was concentrated between 3,500 to 4,000 m a.s.l. The overall encounter rate was 1.18 ± 0.20 individuals/km. A significant difference in density estimates of Himalayan musk deer was observed across the seasons. The musk deer density estimated by the Silent Drive Count method (N=8) is 0.63 ± 0.3133 musk deer/km ² .	Present Study

**Plate 2.** The firstaid given after rescue of sub-adult male (6-7-month-old) musk deer from poachers

Acknowledgments

We acknowledge Ministry of Environment, Forest and Climate Change (MoEF & CC), Govt of India for providing the necessary financial support via National Mission on Himalayan Studies (NMHS) project. We also thank Dr. S. Sathyakumar (Scientist-G / Professor Wildlife Institute of India) for providing his ceaseless guidance on the academic front and research methodologies. We thank Divisional forest officer, Sub-Divisional forest officer Pithoragarh forest department and forest department staff of Askot wildlife sanctuary for their immense support during field visit. We want to acknowledge the field assistants, Rajendra Singh Bisht, Anoop Singh Rawat, Ram Singh Bahadur and Jaman Singh Dattal for their assistance and company during the field work, without their support it would not have been possible to conduct the field study.

References

- [1] Green MJ (1986) The distribution, status, and conservation of the Himalayan musk deer *Moschus chrysogaster*. *Biological Conservation* 35(4): 347-375.
- [2] Flerov, C.C. (1930). On the classification and the geographical distribution of the genus *Moschus* (Mammalian, *Cervidae*), *Ann. Mus.Zool.Acad.Sci.USSR*, 31, 1-20.
- [3] Flerov, C.C. (1951). Fauna of the USSR, I, Mammals: musk deer and deer; Moscow, USSR Academy of Sciences (Translated from Russian by Israel Program for Scientific Translation, 1960).
- [4] Timmins, R. J., & Duckworth, J. W. (2015). *Moschus leucogaster*. The IUCN Red List of Threatened Species 2015: e.T13901A61977764. [Online]. Retrieved from <http://www.iucnredlist.org/details/13901/0>. Accessed 20 October 2017.
- [5] Wilson, D. E. M., & Russell, A. (2011). *Handbook of the mammals of the World. Volume 2: Hoofed Mammals*. Barcelona, Spain: Lynx Edicions.
- [6] Feng, W., You, Y., Yong, H., Li, G., & Gu, Q. (1981). A historical examination on the musk gland of *Moschus chrysogaster*. *Journal of Zoology*, 2, 33-35.

- [7] Jiang, Z., Meng, Z & Wang, J. 2002. Report for the Musk market survey. Endangered Species Scientific Commission of the People's Republic of China. Beijing.
- [8] Singh, P. B., Shrestha, B. B., Thapa, A., Saud, P., & Jiang, Z. (2018). Selection of latrine sites by Himalayan musk deer (*Moschus leucogaster*) in Neshyang Valley, Annapurna Conservation Area, Nepal. *Journal of Applied Animal Research*, 46, 920-926.
- [9] Harris, R. *Moschus chrysogaster*. *The IUCN Red List of Threatened Species 2016*:e. T13895A61977139.
- [10] Sathyakumar Rawat, Johnsingh (2015) Order Artiodactyla Family Moschidae Evolution, Taxonomy and Distribution.
- [11] Meng, Q., Li, H., & Meng, X. (2012a). Behavior pattern as the indicator of reproductive success of Alpine musk deer. *Iranian Journal of Veterinary Research*, 13, 276-281.
- [12] Yijun ZHOU, Xiuxiang MENG, Jinchao FENG, Qisen YANG, Zuojian FENG, Lin XIA and Luděk BARTOS. *Review of the distribution, status and conservation of musk deer in China*. *Folia Zool.* - 53(2): 129-140, 2004.
- [13] Green MJB (1985) Aspects of the ecology of the Himalayan musk deer (Doctoral dissertation, University of Cambridge).
- [14] Sathyakumar, S. 1994. Habitat ecology of major ungulates in Kedarnath Musk Deer Sanctuary, Western Himalaya. Ph.D. Thesis, Saurashtra University, Rajkot. 242 pp.
- [15] Vinod, T., & Sathyakumar, S. (1999). Ecology and conservation of mountain ungulates in the great Himalayan national park, western Himalaya. An ecological study of the conservation of biodiversity and biotic pressures in the Great Himalayan National Park Conservation Area—an eco-development approaches. FREEP-GHNP, 3.
- [16] Ilyas (2007). Status, conservation and aspect of ecology of musk deer 9 *Moschus chrysogaster*) in Kumaon and Garhwal Himalayas, Uttaranchal, India. Final technical report of DST funded project, AMU, Aligarh, India.
- [17] Ilyas O. (2014). Status, habitat use and conservation of Alpine musk deer (*Moschus chrysogaster*) in Uttarakhand Himalayas, India. *Journal of Applied Animal Research* 43(1): 83-91.
- [18] Dorji, S., Vernes, K., & Rajaratnam, R. (2011). Habitat correlates of the red panda in the temperate forests of Bhutan. *PLoS ONE*, 6, 6-11.
- [19] Grumbine, R. E., & Pandit, M. K. (2013). Threats from India's Himalaya dams. *Science*, 339, 36-37.
- [20] Thapa, A., Hu, Y., & Wei, F. *The endangered red Panda (Ailurus fulgens): Ecology and conservation approaches across the entire range*. *Biological conservation*, 220, 112-121, 2018.
- [21] Dhar U & Rawal R. S. *Protected area network in the Indian Himalayan region: Need for recognizing values of low profile protected areas*. *Current Science*, 175-184, 2001.
- [22] Samant S. S, Dhar U and Rawal R. S (1998). Biodiversity status of a protected area in West Himalaya: Askot Wildlife Sanctuary. *The International Journal of Sustainable Development & World Ecology*, 5(3), 194-203.
- [23] Kandpal V & Sathyakumar S (2010) Distribution and relative abundance of mountain ungulates in Pindari Valley, Nanda Devi Biosphere Reserve, Uttarakhand, India. *Galemys* 22(1): 277-294.
- [24] Manel, S., Williams, H. C., & Ormerod, S. J. (2001). Evaluating presence-absence models in ecology: The need to account for prevalence. *Journal of Applied Ecology*, 38, 921-931.
- [25] Yadav N., Down to Earth., & Grubb P. 2019. Himalayan 'gold rush': Growing livelihood reliance on lucrative and vulnerable trade., <https://www.downtoearth.org.in/blog/wildlife-biodiversity/himalayan-gold-rush-growing-livelihood-reliance-on-lucrative-and-vulnerable-trade-68453>.
- [26] Groves C. P., Wang Y. & Grubb P. 1995. The taxonomy of *Moschus*. *Acta Theriologica Sinica* 15(3) 181-197 (in Chinese with English abstract).
- [27] Bhattacharya T. & Sathyakumar S. *Studies on animal-habitat interactions in the buffer zone of Nanda Devi Biosphere Reserve*. Report Wildlife Institute of India, 2007.
- [28] Kattel, B. (1993). Ecology of the Himalayan musk deer in Sagarmatha National Park, Nepal. Ph.D. thesis, Colorado State University, USA.
- [29] Shrestha, B. B., & Meng, X. (2014). Spring habitat preference, association and threats of Himalayan musk deer (*Moschus leucogaster*) in Gaurishankar Conservation Area, Nepal. *International Journal of Conservation Science*, 5, 535-546.
- [30] F. Jiang, J. Zhang, H. Gao, Z. Cai, X. Zhou, S. Li, T. Zhang (2019). Musk deer (*Moschus* spp.) face redistribution to higher elevations and latitudes under climate change in China, *Science of the Total Environment* (2019).
- [31] Abbas, F., Rooney, T. P., Mian, A., Bhatti, Z. I., & Haider, J. (2015). The Distribution, Population Status, and Wildlife Product Trade of Himalayan Musk Deer in Gilgit-Baltistan, Pakistan, *Journal of Bioresource Management*, 2 (3).
- [32] Aryal, A., Raubenheimer, D., Subedi, S., & Kattel, B. (2010). Spatial habitat overlap and habitat preference of Himalayan Musk Deer ("*Moschus chrysogaster*") in Sagarmatha (Mt. Everest) National Park, Nepal. *Current Research Journal of Biological Sciences*, 2, 217-225.
- [33] Subedi et al. (2012). Habitat ecology of Himalayan Musk Deer (*Moschus chrysogaster*) in Manaslu Conservation Area, Nepal. *International Journal of Zoological Research*, 8, 81.
- [34] Wangdi et al. (2018). The distribution, status and conservation of the Himalayan Musk Deer *Moschus chrysogaster* in Sakteng Wildlife Sanctuary, *Global Ecology and Conservation*.

