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Cover Page Footnote

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HABITAT PREFERENCE BY HIMALAYAN MUSK DEER (*MOSCHUS LEUCOGASTER*) IN SHEY PHOKSUNDO NATIONAL PARK, NEPAL

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ABSTRACT

Himalayan Musk Deer (*Moschus leucogaster*) is distributed across the mid-mountainous region from the elevation of 3000 m to 4000 m. Shey Phoskundo National Park lies in western Nepal and Shey Phoksundo Rural Municipality serves as the prime habitat in this region. The main objective of this study was to find out the habitat preference of Himalayan Musk Deer and to evaluate all the suitable habitats. Transects survey were done to evaluate the preferred attributes of the species. Pellets were rarely found where the crown cover was more than 75 % but the resting sites were abundantly found there and forest of *Pinus wallichiana* and *Betula utilis* were found to be used mostly. Deforestation of temperate mixed forests and illegal poaching of musk deer for musk pods should be clamped down for the conservation of this endangered species.

Keywords: Deforestation, ecological behaviour, ivlev's electivity index, Himalayan Musk Deer, Nepal.

INTRODUCTION

The Himalayan Musk Deer (Moschus leucogaster; Hodgson, 1839) is one of the five musk deer species found around the world and in the case of Nepal, it is one of the six deer species (Khadka and James, 2016). Himalayan musk deer (hereafter musk deer) is commonly called *Kasturi Mirga* in the Nepalese language and *Lah* in the Tibetan language; by far spoken in the westernmost mountainous region of Nepal. Musk Deer is classified as Endangered in the IUCN Red List of Threatened Species, is listed in Appendix I of CITES and is also included as a protected priority species by the Department of National Park and Wildlife Conservation Act 1973 (Aryal and Subedi, 2011; Green, 1986; Maksimova et al., 2015; Singh et al., 2019). The population of the species has declined drastically due to poaching for musk and the degradation of available habitats of the species (Aryal et al., 2010; Khadka and James, 2016; Shrestha and Moe, 2015). Degradation of habitat is further accelerated by over-exploitation of available resources due to the dependence of local people on forests for their daily needs as the inhabitants of the Himalayas mostly depend upon livestock and agriculture followed by tourism i.e. hotels and lodges (Aryal et al., 2010). Shrinkage of the habitat leads to overlapping of the grazing area for the musk deer and their livestock (Aryal and Subedi, 2011) . The study of habitat preference allows conservationists and researchers to create suitable habitat conditions for the species in all the feasible habitats around the world.

At the elevation of 3,000 - 4,000 m above sea line this species is discontinuously distributed throughout the Himalayas (Shrestha and Moe, 2015) falling in Afghanistan, Bhutan, China, India, Nepal, Pakistan and Myanmar (Aryal and Status, 2014). In Nepal, the potential habitat of the species covers 30,177 km^2, of which 5815 km^2 falls

inside the protected area (Aryal and Subedi, 2011). Musk deer is shy and solitary species and is often seen during dawn and dusk (Maksimova et al., 2015). They are herbivorous, mainly feeding on grass, moss, plant leaves, shoots, lichen and twigs. Every individual of this species chooses a fixed place to defecate and covers the fresh pellets with mud, litter and even with the old pellets while some of them share the place for defecation (Green, 1987; Khadka and James, 2016; Singh et al., 2019). Their resting sites were usually seen near *Abies spectabilis*, *Betula utilis* and *Rhododendron* species (Aryal and Subedi, 2011).

The declining number of musk deer has necessitated the study of their habitat and distribution at both national and local levels. In Nepal, most of the musk deer related studies are concentrated in Sagarmatha National Park (SNP) as it is the prime habitat for the species (Aryal et al., 2010). Shey Phoksundo National Park (SPNP) also hold appreciable population of the species yet no study musk deer related study is available for the area. This research gap focused on the analysis of the habitat preference and availablity of musk deer in relation to SPNP's geography and habitat type.

MATERIALS AND METHODS

Study Area

Shey Phoksundo National Park (29°15'-29°45' NL and 83°08'- 83°31' E) spread over 3,555 km^2 with elevation range of 2130 - 6885 m above sea line, located at one of the most remote westernmost parts of Nepal (Dolpa District) though some part of it also falls under Mugu District. The Dolpa district consists of 6 rural municipalities (Shey Phoksundo, Jagadulla, Kaike, Mudkechula, Chharka Tangsong and Dolpo Budhha rural municipalities) and 2 municipalities (Thulobheri and Tripura Sundari Municipalities).

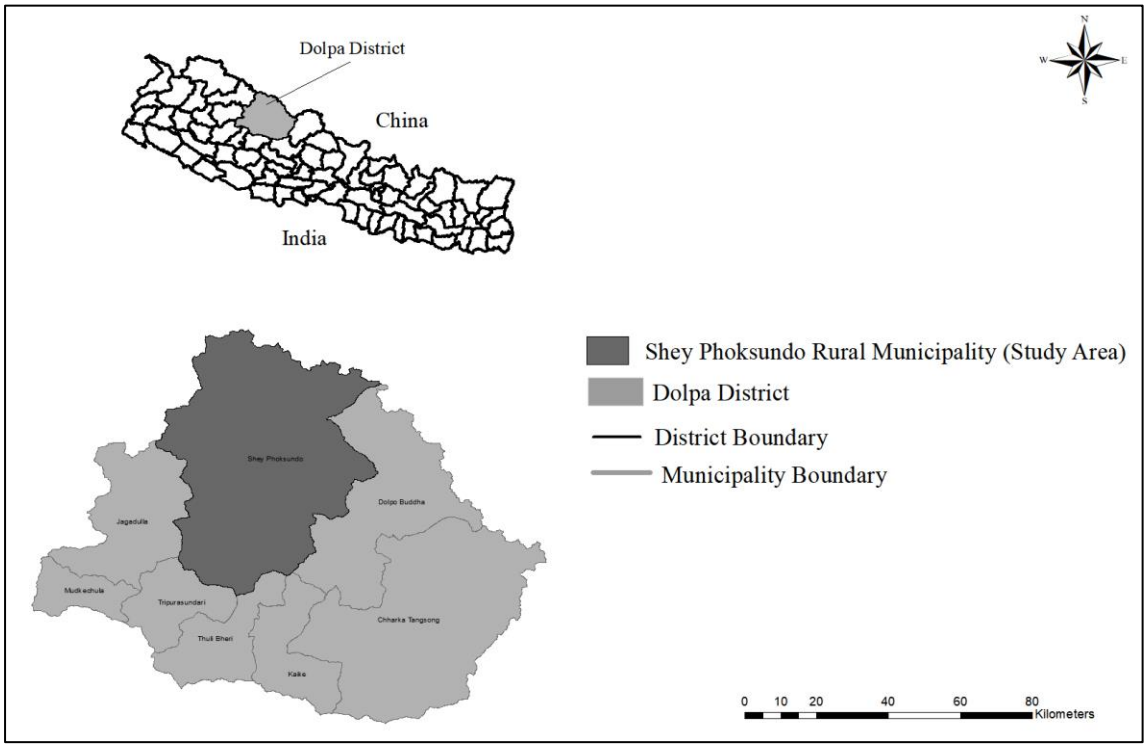

Figure 1: Map of the study area (Shey Phoksundo Rural Municipality) with seven other Municipalities of Dolpa district.

The study was carried out within the political boundaries of Shey Phoksundo Rural Municipality from February-July 2021.

There is a sharp seasonal difference in the rainfall and temperature in the region with the annual precipitation ranging from 500 mm to 1500 mm in northern and southern steeps respectively because of the rain shadow area. Vegetation within the area is highly diverse due to climatic and attitudinal variations. Temperate and sub-alpine vegetation dominate the Southern steep hills slopes whereas dense forests of *Pinus wallichiana* intermixed with *Cedrus deodar*, *Tsuga dumosa*, *Abies spectabilis* and *Picea smithiana* is dominant in the lower valley. The landscape of the upper tree line is dominated by *Betula utilis* and *Juniperus recurva*.

Pseudois nayaur, Ochotona spp., *Lepus pistols*, *Marmota himalayensis*, *Moschus* spp. etc. are the major herbivores in the National Park area. The main predators of this ecosystem are *Canis himalayensis* and occasional spatial variation with *Panthera uncia* and a moderate probability of *Lynx lynx*.

Data Collection

The harsh terrain and erratic weather condition make it quite difficult, almost impossible to survey the whole area. Record the precise information about the habitat correlates of the species was discussed with the local groups, park staff and experts about the habitat areas of the species. This study focused on the habitat sites as suggested by them. The transect walk method was used for indirect sign survey (pellet, resting site, footprint) to record and collect information regarding the habitat correlates like elevation, slope, crown cover, etc. (Nandy et al., 2020; Yi et al., 2020; Yang et al., 2003).

i. Field Sampling and Data Collection

Musk deer's habitat area of the park was divided into three blocks; Pugmo, Rigmo and Bauligaad. The area was then plotted with a grid of 3*3 km with the help of the ArcGIS 10.2.1 version. At least two transects (1 km long and 10 m wide) in each grid having potential musk deer distribution placed at some 200 m gap between consecutive transects were surveyed. A signed survey was initiated with the slow walk of two people abreast on each transect (Shrestha and Meng, 2014). Habitat correlates were recorded within 10m radii for each sign encountered and termed those radii as "use plot". Also, random sampling was done 50-100 m away from each sign encountered as mentioned above within 10 m of radii and termed that radii as "available plot". If there was any presence of signs on the available plots then it was termed a "use plot".

ii. *Data Analysis*

Habitat correlates such as vegetation, slope, elevation and crown cover were considered for the analysis of the habitat preference of musk deer using Ivlev's electivity index (IV) which is expressed as IV = (U%− A%) / (U% + A%), where "A" indicates "availability plots" and "U" infers "use plots" (Agresti, 2007). The value of the index ranges from -1.0 to +1.0 where positive values refer to the preference of that particular habitat correlate whereas negative values imply the avoidance of that particular correlate and 0 indicates random use. And R Studio (version 4.1.0) was used to prepare the graph of different IV values of different correlates.

The habitat suitability map was prepared based on the preference of the habitat selection of the species i.e. slope, altitude and land cover using ArcGIS version 10.8. The Digital Model Elevation (DEM) of Shey Phoksundo Rural Municipality was clipped out from the DEM of the Dolpa district. The map of elevation, slope, and land use was made with the help of this DEM file and all of the rater files were reclassified using reclassify tool. The weighted overlay tool was applied for the suitable preference of the habitat correlates.

RESULTS

A total of 40 transects were surveyed and presence/absence data (signs of musk deer such as footprint, pellet, shelter, etc.) and habitat correlates (i.e. elevation, forest type, slope, etc.) of the species were recorded in each sub-block of phoksundo block as shown in Table 1. The transect length ranged between 600 m and 1410 m (average length = 820 m). The total survey effort was 32.82 km. These transects ranged between 3099 m and 3909 m elevation (average elevation= 3556 m). A total of 166 use plots and 45 available plots were recorded in the study area. The musk deer sign encounter rate was high in Rigmo-Rikhe sub-block (7.66/km) and the lowest in Pugmo-Punikha (4.4/km) (Table 1).

Habitat Preference

i. Altitude Preference

Musk sign encounter rate was higher at the middle elevations (3500-3800 m asl.; IV = 0.75) decreasing in both decreasing (3200-3500 m asl, IV = 0.60; 2900-3200 m asl; IV= 0.08) and increasing (>3800 m asl; IV = 0.37) elevations. (Figure 2).

ii. Slope Preference

From 0 to >75º, the slope was divided into four categories with an interval of 25º. The species exhibited a higher sign encounter rate at 25- 50 º slope (IV = 0.74), which was followed by the slope range of 50 to 75 (IV=0.48) and 0-25 slope (IV= 0.32). Slope greater than 75º did not show any signs of musk deer (Figure 3).

iii. Crown Cover Preference

Musk Deer generally preferred 25-50% of the crown cover (IV=0.78). Comparatively, musk deer was found to prefer the less crown cover i.e. 0-25% (IV= 0.22) than dense forest i.e. >75% (IV= 0.18) (Figure 4).

Table 1: Survey efforts within sub-blocks of Phoksundo block with their respective number of signs and transects

SN	Block	Sub-block	Total transects	Total Signs	Sign Encounter rate/km	Use plots	Available plots
1	Phoksundo	Rigmo-Rikhe	18	138	7.66	86	23
2	Phoksundo	Pugmo-Punikha	20	88	4.4	70	18
3	Phoksundo	Bauligad	2	10	5	10	4

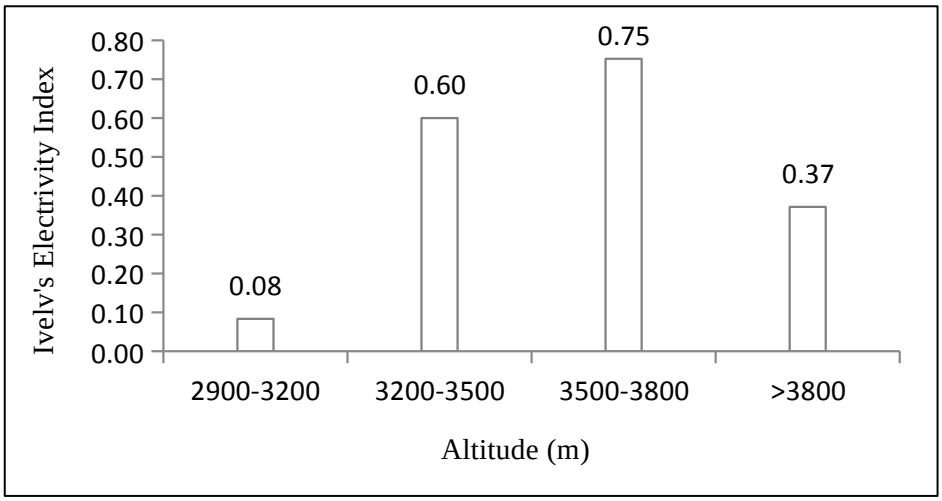

Figure 2: Preference of habitat by the species with respect to altitude

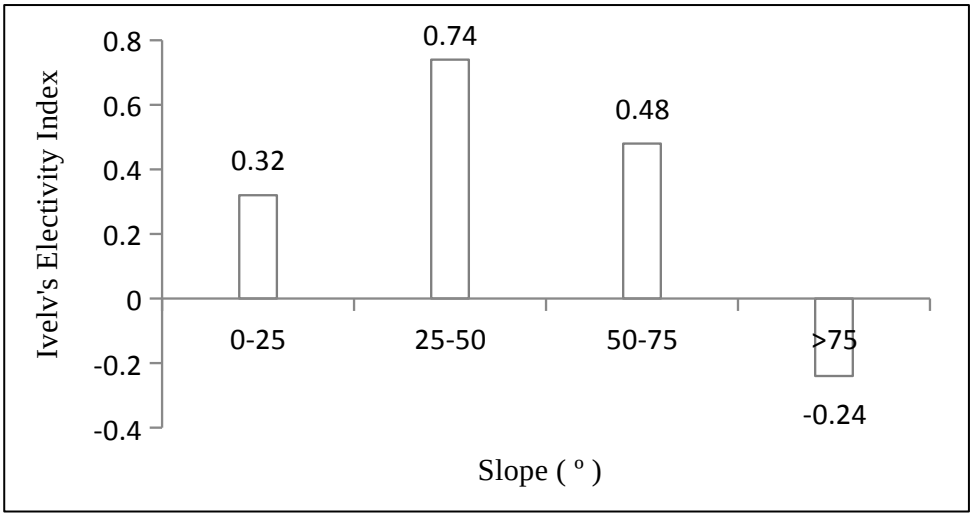

Figure 3: Preference of habitat by the species with respect to slope

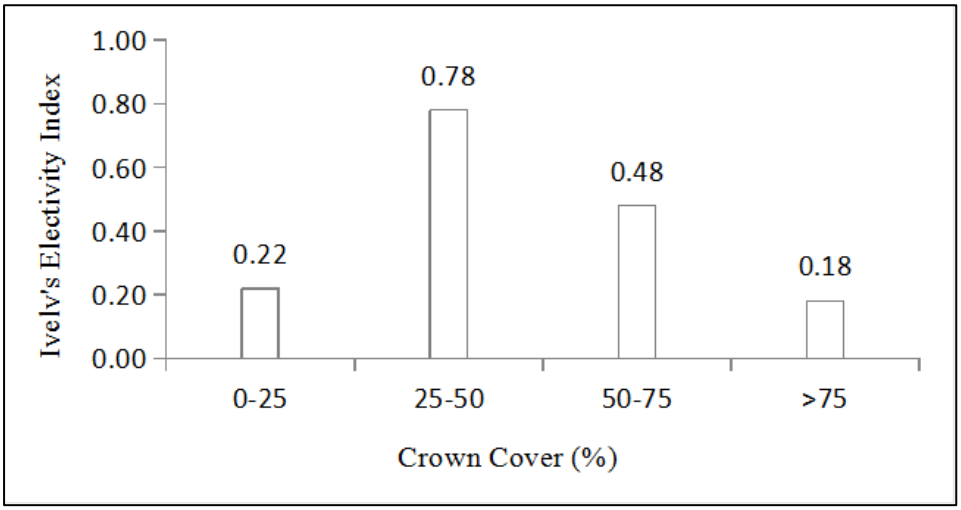

Figure 4: Preference of habitat by the species with respect to crown cover

iv. Forest Type Preference

Seven different forest types were recorded from the study area within the habitat of Himalayan Musk Deer. The forest dominated by *Pinus wallichana* was found to be mostly preferred by the species (IV=0.54) which was followed by the dominant forest of *Betula utilis* (IV = 0.53). The species were found to use forest type of *Cupressus spp.* randomly (Table 2).

Table 2: IV value of forest type concerning the preference of habitat by the species

Forest type	Ivlev's electivity index (IV)
Pinus wallichiana dominant	*0.54*
Pinus wallichiana and *Tsuga dumosa* mixed	*0.48*
Tsuga dumosa dominant	*0.18*
Betula utilis dominant	*0.53*
Betula utilis and *Picea smithiana* mixed	*0.33*
Picea smithiana dominant	*0.30*
Cupressus spp.	*0.00*

Potential Habitat

Following the landcover map of Shey Phoksundo Rural Municipality (Figure 5) and based on the preference of the habitat correlates by the species, a suitability map was prepared (Figure 6) which shows the potential habitat of musk deer within the SPNP region. The suitability was divided into two categories: highly suitable (the only potential habitat) and unsuitable habitat.

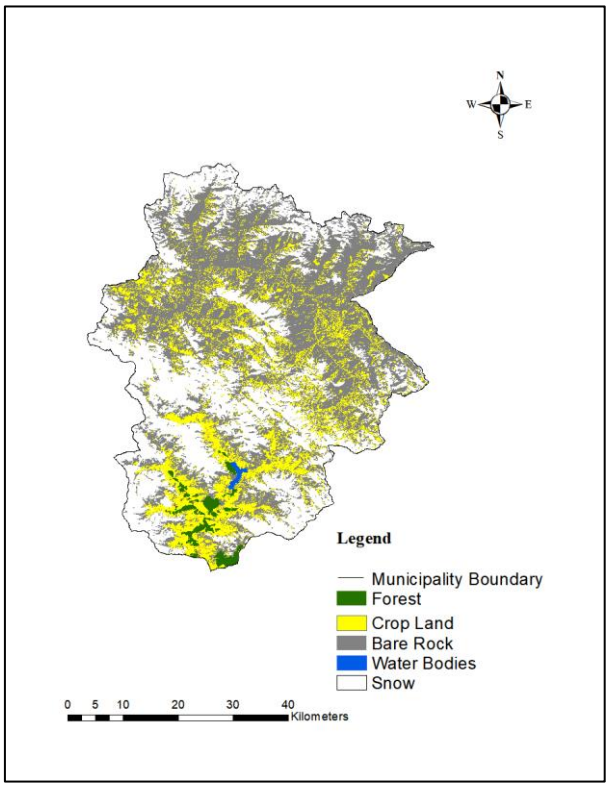

Figure 5: Land cover map of Shey Phoksundo Rural Municipality

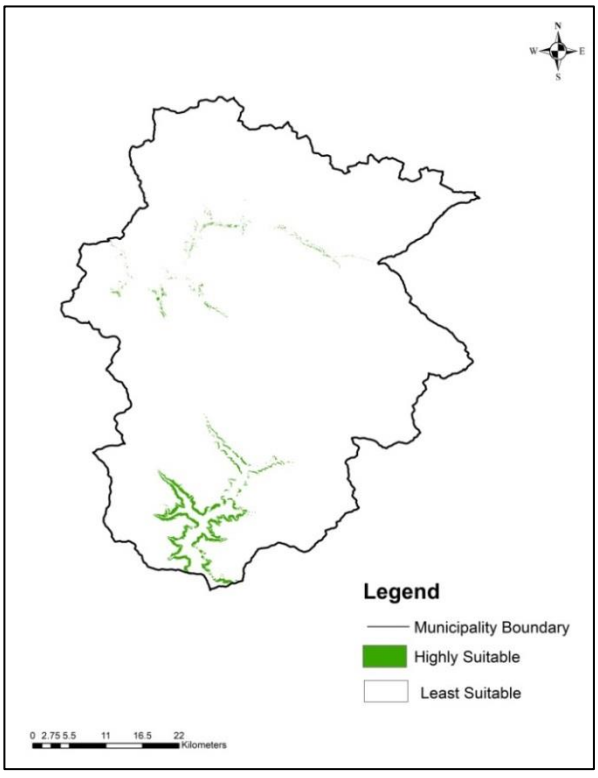

Figure 6: Map of potential habitat of musk deer in Shey Phoksundo Rural Municipality

DISCUSSION

The signs of the species were not found at an altitude greater than 3900m. Despite similar habitats in Indian Himalayas, mainly in Uttrakhand, the signs of species were found at an altitude of 4200 m (Khadka et al., 2017) because of the availability of the forest type preferred by the species at that altitude. On the contrary, Aryal and Subedi (2011) found that the musk deer avoid a habitat greater than 4000 m in Manaslu Conservation Area. This research showed that the species tend to prefer the altitude range from 3500 to 3800 m mostly and the preference of habitat by the species increases gradually from 3200m to 3800m which somehow supported the findings of Aryal et al. (2010) in Sagarmatha National Park. This may be due to the presence of suitable forest types and preferred plant mostly recorded from the forest of *Pinus wallichiana* as it is a highly dominant forest in the study area followed by *Betula utilis*; but Aryal and Subedi (2011) found that the species avoid *Pinus wallichiana* forest in Manaslu Conservation Area. Despite the same habitat type, the study done in Uttarakhand, India by Ilyas (2013) found the signs of the species abundantly in the forest of *Quercus* spp. even at an altitude of 4500 m. This variability indicated that Musk Deer tends to adapt to every forest type as long as the habitat supported its survival irrespective of altitude and dominant plant species.

The findings of this study regarding the preference for slope by the species in this region haven't coincided with any other research within the national territory. This may be due to the difference in geography and available habitat in the study area. The current study showed that the slope of 25º to 50º is mostly preferred by the species but avoids the habitat with a slope greater than 75º. The pellets were also recorded from the plain site i.e. lower forest trail and even from the dense forest area near the village where the slope is less than 25º. This may be due to the only water source available in that area i.e. Rikhe River which is at 500 m distance from the village. But Wandi et al. (2019) found the highest encounter rate of the pellets at more than 75º slope in the Fir forest of Sakteng Wildlife Sanctuary of Bhutan. By far, the research on the distribution and habitat preference of the musk deer in Nepal set the fine line about the avoidance of a slope greater than 50º but our research (a pioneer) on the SPNP region shows the use of habitat by the species up to 75º slope. Globally, the signs of the species were found even at more than 75º slope which suggested that the species could prefer the highly steep slope depending on the geography and suitable habitat.

The findings of this study showed that the species tends to prefer the crown cover between 25-50 %. Pellets were rarely found where the crown cover was more than 75 % but the resting sites were abundantly found there. They prefer the shelter on the upper base surface of the tree where the crown cover is more than 50 % and sometimes up to 75% or even more. Resting sites of different sizes were found below dense crown cover which could be of the young ones. The dense crown cover was significantly correlated with choosing a habitat for musk deer. Because of the olfaction communication, these particular characteristics of musk deer help to confine the latrine scents for a longer period than the exposed sites and the confined scent of the latrine help to establish communication with other individuals (Khadka et al., 2017; Thapamagar et al., 2019).

Each time, musk deer individuals defecating in the same place favours the poaching strategy but we didn't record any snare on-site during the survey. Besides poaching, feral dogs in the areas could be a reason behind declining in the

number of Himalayan Musk Deer. The loss of habitat could be another main cause of the decline in the number which might be aided by the forest fire and the extraction of timber from the areas near the village. The presence of livestock or their dung wasn't found to directly affect the habitat preference and distribution of musk deer as per the survey because the study recorded the presence of pellets from the site where there is the presence of livestock's dung but the overlap at the grazing site by the livestock affect the habitat.

CONCLUSION

Comparing it with national and global findings has provided the ecological character of the species in the context of habitat preference. The altitudinal range and steep slope didn't affect the distribution and preference of the habitat for the species. However, preference was affected by the presence of vegetation and suitable crown cover irrespective of the vegetation type. They are likely to choose different vegetation for different purposes i.e. ambush, resting site and grazing but can also adapt to the availability of choice. Small villages barely take part in the fragmentation of the habitat but this could affect the distribution of the species. Illegal extraction of timber, encroachment for cultivation, illegal poaching of musk deer for musk pods and overlapping of the grazing area should be clamped down for the conservation of this endangered species.

AUTHOR'S CONTRIBUTION

I, Rishi Ram Paudel am the author of this manuscript. This is the research project of my undergraduate thesis. The whole manuscript i.e. maps, graphs and tables are designed by me. I have done the field work and related data analysis using R along with the interpretation of the result.

Aman oli is the co-author of this manuscript. He is my research assistant during the field survey. He helped me during the process of data entry and its analysis. He has contributed a lot to the process of interpretation and presentation of the result in front of the park staff and DNPWC.

Pramod Ghimire is the advisor of this project. Training before the field survey given by him helped us to collect the data precisely in the field. He guided us throughout the project and helps to manage every obstacle during the field survey with his good relationship with the park staff. Above all this, he helped us to revise the manuscript thoroughly and went through interpretation of the result and better execution of this project.

CONFLICT OF INTEREST

There is no conflict of interest among the author, co-author and funding agency regarding this paper.

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