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Research Article

Habitat preference of Himalayan musk deer (*Moschus leucogaster* Hodgson, 1839) at Lapchi of Bigu Rural Municipality, Gaurishankar Conservation Area

Narayan Prasad Koju[1,2,*], Bijay Bashyal[3], Satya Narayan Shah[1,4]

1 Center for Post Graduate Studies, Nepal Engineering College, Pokhara University, Nepal
2 Department of Psychology, University of Washington, Seattle, USA
3 Central Department of Environmental Science, Tribhuvan University, Kathmandu
4 Gaurishankar Conservation Area Project, National Trust of Nature Conservation

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Abstract

The Himalayan musk deer *(Moschus leucogaster)* is an endangered species listed in the IUCN Red List and Appendix I of CITES. It is widely but discontinuously distributed in Nepal. A Pellet sign survey was carried in April 2019 in Lapchi valley of Gaurishankar Conservation Area (GCA) in Nepal to assess the habitat preference of Himalayan musk deer. A total of 11 transects of 16348 m length and 10 m wide was surveyed. Seven Parameters: Elevation, Aspect, ground cover, distance from the water source, crown cover, rock exposure, and distance from settlement/cow sheds were recorded from the location where pellet (toilet) of musk deer were recorded to extrapolate the probable habitat map. We recorded a total of 157 musk deer pellet groups in the study area14.27 ± 2.91. The study concluded that the 38.4% (26.5 km^2) area of Lapchi valley is the probable habitat of musk deer. The χ^2 – test suggested that the distribution of musk deer is significantly associated with elevation and aspect of the location. Musk deer mostly preferred habitat between 3600-4000 m elevations, with North-West aspect, ground cover less than 25%, and canopy cover between 25%-50%. Musk deer signs were recorded in areas with rock exposure ranging from as low as less than 25%. Distance from the water source and human settlement affect the distribution of musk deer. The indirect signs were higher near water sources and far from human settlement.

Keywords: Endangered species, human settlements, pellet group, threat, water sources

Introduction

Musk deer is an ecologically and economically important species native to Asia. Four species of musk deer are reported in Nepal: Alpine musk deer *(Moschus chrysogaster)*, Himalayan Musk deer *(M. leucogaster),* black musk deer *(M. fuscus),* and Kashmir musk deer (*M. cupreus*) (Jnawali et al., 2011; Singh et al., 2019). The habitat of Himalayan musk deer and Alpine musk deer are overlapped in Nepal ((Jnawali et al., 2011). They are widely but discontinuously distributed in Nepal Himalayas, inhabiting subalpine and alpine scrubs (Green, 1986). All species of musk deer are listed under Appendix I of CITES and endangered by IUCN. In Nepal, they are protected species under Nepal's National Park and Wildlife Conservation Act (1973); and also occupy the Endangered (EN) category under Nepal's Red List national assessment (Jnawali et al., 2011).

Nepal is one of the important range countries of Himalayan musk deer distribution. It is widely distributed in Nepal across the Himalayan region, with a potential habitat of 5815.08 Km^2 inside protected areas (Aryal & Subedi, 2011). Himalayan musk deer are found in the Api Nampa Conservation Area (ANCA), Khaptad National Park (KNP), vation Area (ACA), Kanchenjunga Conservation Area (KCA), Sagarmatha National Park (SNP), Langtang National Park (LNP), Gaurishankar Conservation Area (GCA), Shey Phoksundo National Park (SPNP), and Makalu Barun National Park (MBNP) and Manaslu Conservation Area (MCA) (Aryal et al., 2010; Aryal & Subedi, 2011; Shrestha et al., 2019).

In these areas, they are distributed in Alpine forest with vegetation: oak, fir, rhododendron, blue pine, juniper, grass, lichens and scrub between elevations of 2,200 to 4,300 meters on the eastern and southern edge of Tibet and the southern slopes of the Himalayas. Musk deer usually lives in forests with moderate to steep slopes (Green, 1978, 1986; Oza, 1988; Kattel & Alldredge, 1991). Though the species is distributed throughout the Nepal Himalaya, Himalayan musk deer is one of the little studied deer species (Aryal et al., 2010) and there is limited information from Gaurishankar Conservation area. Therefore, this study aims to explore the habitat preference of Himalayan musk deer in the Lapchi Valley of the Gaurishankar Conservation Area.

* Corresponding author: npkoju.2003@gmail.com

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Materials and Methods

Study area

Lapchi Valley is located in Gaurishankar Conservation Area (GCA) at the foot of the LapchiKhang mountain range, which is an important pilgrimage destination for Tibetan Buddhists and is known for the meditation caves of the most famous Tibetan saint and poet, JetsunMilarepa. The caves surround the main monastery of Lapchi, 'ChöraGephel Ling.' Lapchi Valley comprises sub-tropical to nival bio-climatic zones with 16 major vegetation types and faunal diversity of 235 bird species, 34 mammal species, 16 fish species, 14 snake species, 10 amphibian species and eight lizard species (NTNC, 2013). Musk deer, Himalayan bear, Assamese macaque (*Macaca assamensis)*, snow leopard (*Panthera uncia*), and leopard cat (*Prionailurus bengalensis*) are some of the nationally threatened species living in GCA (NTNC, 2013; Koju et al., 2020a). Major precipitation in the area includes rain during the summer monsoon from June to August and snow in winter from January to March (NTNC, 2013). GCA is divided into six blocks, namely Gumba, Lambagar/Lapchi, Rolwaling, Bigu/Kalinchowk, Marbu-Khare and Gumdel/Marbu (Koju et al., 2020b; NTNC, 2013; NTNC, 2020) . Lapchi Valley lies between 86°10'32.53"E to 86°29'9.45"E and 28°20'13.19"N to 28°21'54.55"N with elevation range 2600 masl to 4950 masl (NTNC, 2013; NTNC, 2020). The Valley is surrounded by the China border on the east, west and north (Fig. 1).

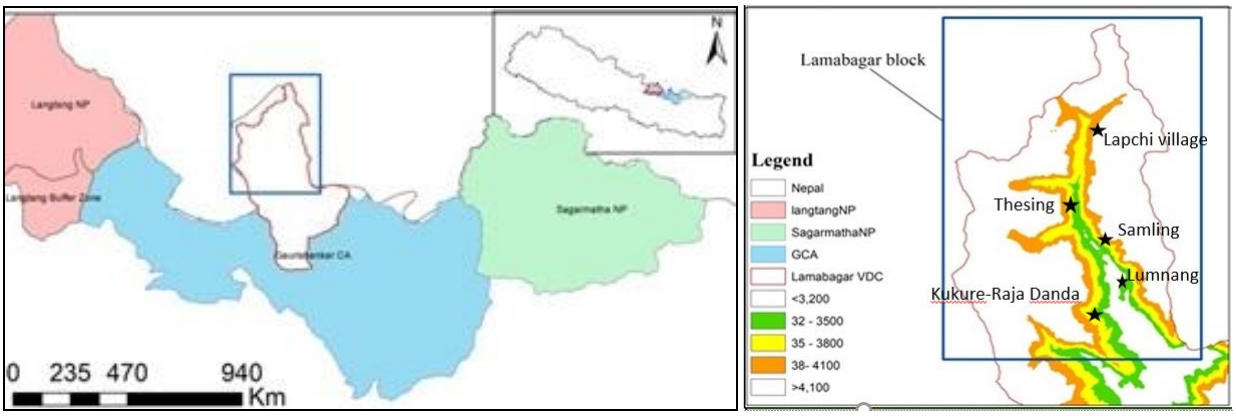

Figure 1 Map showing Lapchi Valley in Gaurishankar Conservation Area

Data collection and analysis

The habitat used by musk deer was assessed through the signs survey in the study area. Sign survey (especially pellet and fur) was carried in April 2019. For elusive ungulate species living in dense forests and/or complex terrain, indirect sign survey has proved to be a more practical means to explore habitat preferences (Aryal et al., 2010; Li et al., 2016; Li et al., 2018). Musk deer fecal pellets can be accurately discriminated from other sympatric ungulate droppings. Musk deer pellets are egg shaped smoothed at both ends (Fig. 2). Musk deer poops at one location, frequently called toilet. Defecation consisting of at least 20 pellets is considered a pellet group record. This makes the pellet count method a reliable method for estimating its abundance. To estimate the population density and habitat preference of musk deer, the method based on the number of musk deer pellet groups count was used (Ilyas, 2015; Maksimova et al., 2015).

Line transects were placed over the potential habitat of musk deer nearly 69 km² in Lapchi valley of GCA. A total of 11 transects were surveyed alone the trail during the fieldwork resulting in 16348 m length. Minimum 100 m distance was kept apart between two transects except in places near the cliff, landslides and high rolling areas. The transect length varied from 365 m to 3581 m in length with an average length of 1486 ± 271.93 m. Transects were laid covering all the possible habitats of musk deer. Scrubland alone comprised two transects (2061 m length), forest area alone comprised six transects (9223 m length) while other three transects (5064 m length) were laid such that covering portions of both forest area and scrub land along the trail where indirect sign like pellet group were recorded 80 plots of 10m x 10m plot was surveyed at every 300 m interval. Among these 80 plots musk deer signs were recorded from 56 plots six parameters: elevation, aspect, ground cover, distance from the water source, crown cover and rock exposure recorded from the location were assessed in these plots (Aryal, 2006; Khadka & James, 2016).

Elevation was measure using GPS (Garmin eTrex® 32x) and categorized into six groups (<3200, 3200-3400, 3400-3600, 3600-3800, 3800-4000 and >4000 masl), aspect by clinometer which is classified to eight group according to direction, ground cover, crown cover and rock exposure was estimated classified to four groups (<25%, 25-50%, 50-75% and >75%), and distance from water sources was measured by using Vortex Optics Impact Laser Rangefinders and grouped to four classes (<150 m, 150-300 m, 300-450 m and above 450 m (Fig. 3).

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Figure 2 Pellets of musk deer observed in the study area

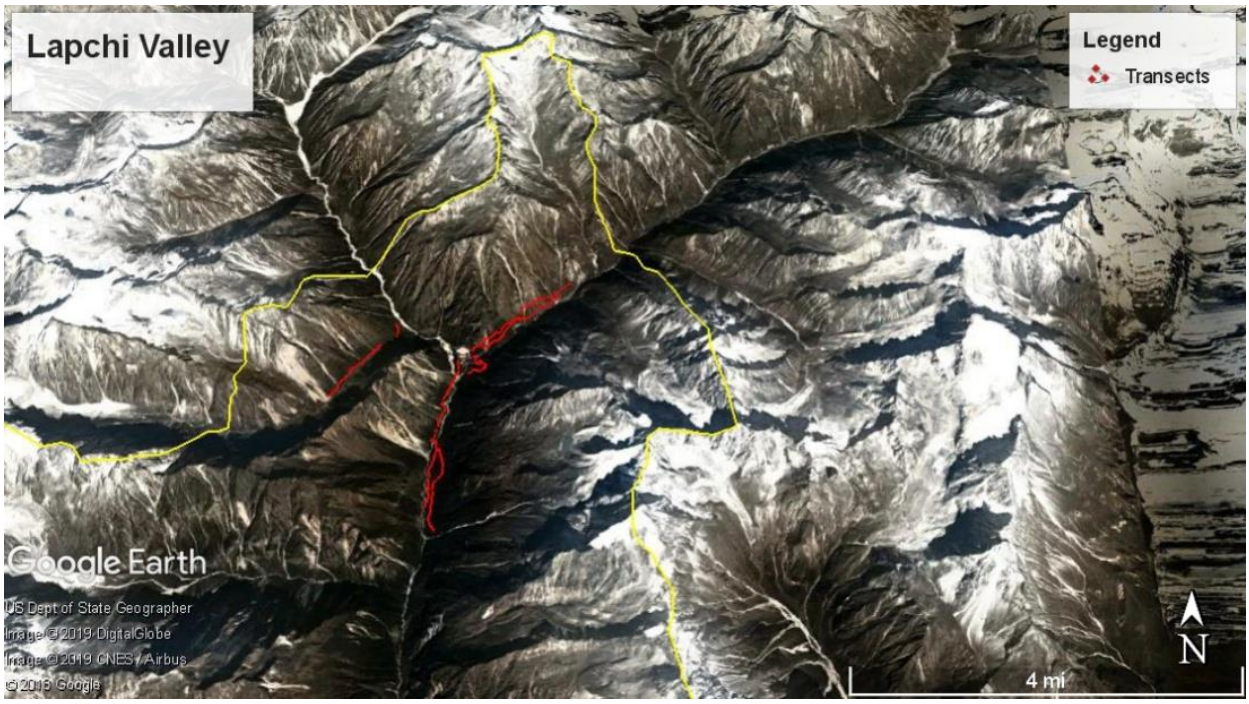

Figure 3 Transects plotted in Lacphi forest area

All data from the sign survey were analyzed using Ms-Excel and GIS tools. χ^2 – test was carried to establish the relation between these selected parameters and available pellet groups, and finally, the probable habitat range map was constructed for musk deer in Lapchi Valley in GIS. The information and data from slope, elevation, rock exposure, distance from the settlement, crown cover and land cover was used to prepare a potential suitable habitat map.

Results and Discussion

Pellet encounter rate

Altogether 157 musk deer pellet groups were encountered. Mean of 14.27 ± 2.91 pellet groups per transect. Musk deer pellet groups were encountered in all transects except one; the highest number of pellet groups (N=26) were recorded in a transect of lower Lapchi in forest area (Table 1; Fig. 4). Musk deer pellet encounter rate was 10.29 ± 2.00 pellet groups per km in GCA.

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Table 1 Pellet groups and pellet encounter rate along different transects

Transect No.	Pellet Groups	Length (m)	Encounter Rate (pellet group/km)
T01	26	3581	7.26
T02	1	1741	0.57
T03	0	365	0
T04	12	1596	7.52
T05	20	1473	13.58
T06	30	1950	15.38
T07	8	445	17.98
T08	23	1107	20.78
T09	11	923	11.92
T10	12	1021	11.75
T11	14	2146	6.52

Pellet encounter rate was higher in the forested area while the lowest in scrubland. Scrubland opposite of Lacphi village had a very low musk pellet encounter rate, while scrubland towards the NE of Gumbha had a relatively higher encounter rate. On the other hand, transects in forest areas had higher musk pellets encounter rates. Among them, the forest opposite to Gumbha scored the highest encounter rate, while the forest of Lumnan village had a relatively low musk pellet encounter rate.

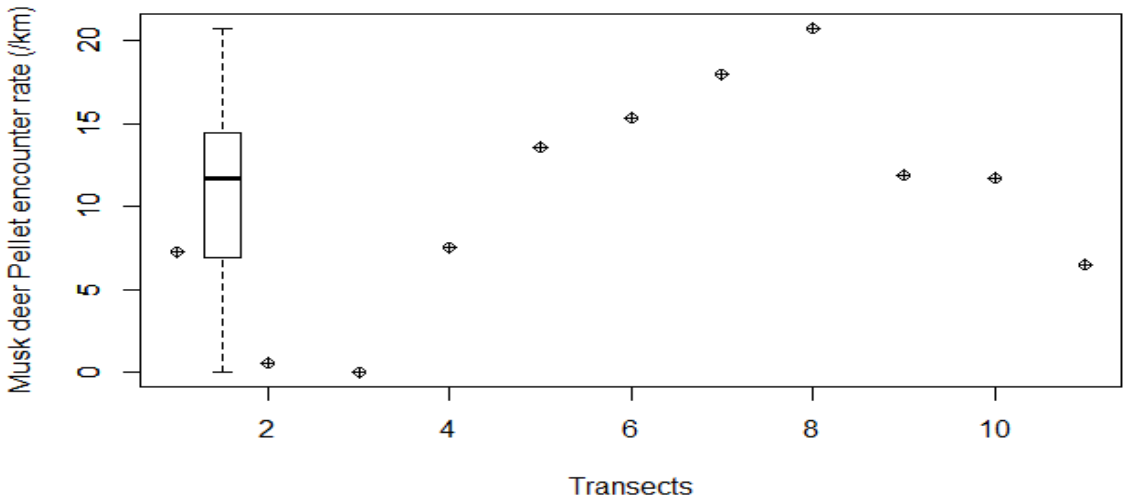

Figure 4 Musk deer pellet group encounter rates along transects

Habitat preference in different parameters

Musk deer were distributed in forested areas above Lumnang village, in Samling areas and in Kukure-Raja-Danda forested areas at a higher elevation. In Lumnang village, musk deer were distributed above 3200 m, while in Kukure-Raja-Danda forest, they were distributed above 3500 m. In forest areas of Samling, musk deer distribution was above 3400 m. On average, musk deer in Lapchi were distributed from 3292-4109 m elevation. Musk deer mostly preferred habitat between 3600-4000 m elevations in Lapchi valley of GCA (Fig. 5A). On applying the χ^2 - test to the above data, it was found that there was a significant difference between musk deer signs distribution among the elevation range ($\chi^2 = 25.31$, at 95% level of significance, d.f. = 4 and $p = 0.00004356$), i.e., the signs were not evenly distributed along with the elevation range. Musk deer are reported to be distributed between 2400-4300 m elevation in birch (*Betula*), fir (*Abies*), juniper, and rhododendron forests in the different protected area of Nepal (Aryal, 2006; Aryal et al., 2010; Green, 1978; Lahkar et al., 2018; Shrestha & Meng, 2014; Subedi et al., 2012) . However, a radio collar musk deer was recorded up to 4410 m elevation (Kattel & Alldredge, 1991). In this study, any sign of musk deer was not recorded below 3200 m throughout forested areas and in scrubland but distribution of musk deer around Lapchi village, Lumnang village, Samling forest, Kukure-raja-danda area, Thesing forest area and lower Lapchi forest areas that lie in between the range of the previous studies in Nepal.

Musk deer were distributed across all the aspects at GCA. However, musk deer preferred the areas with North-West (NW), South (S) and South-East (SE) aspects. East (E) aspect had the least preference (Fig. 5B). Thakuri (2016) reported that North, north-west and east aspects were

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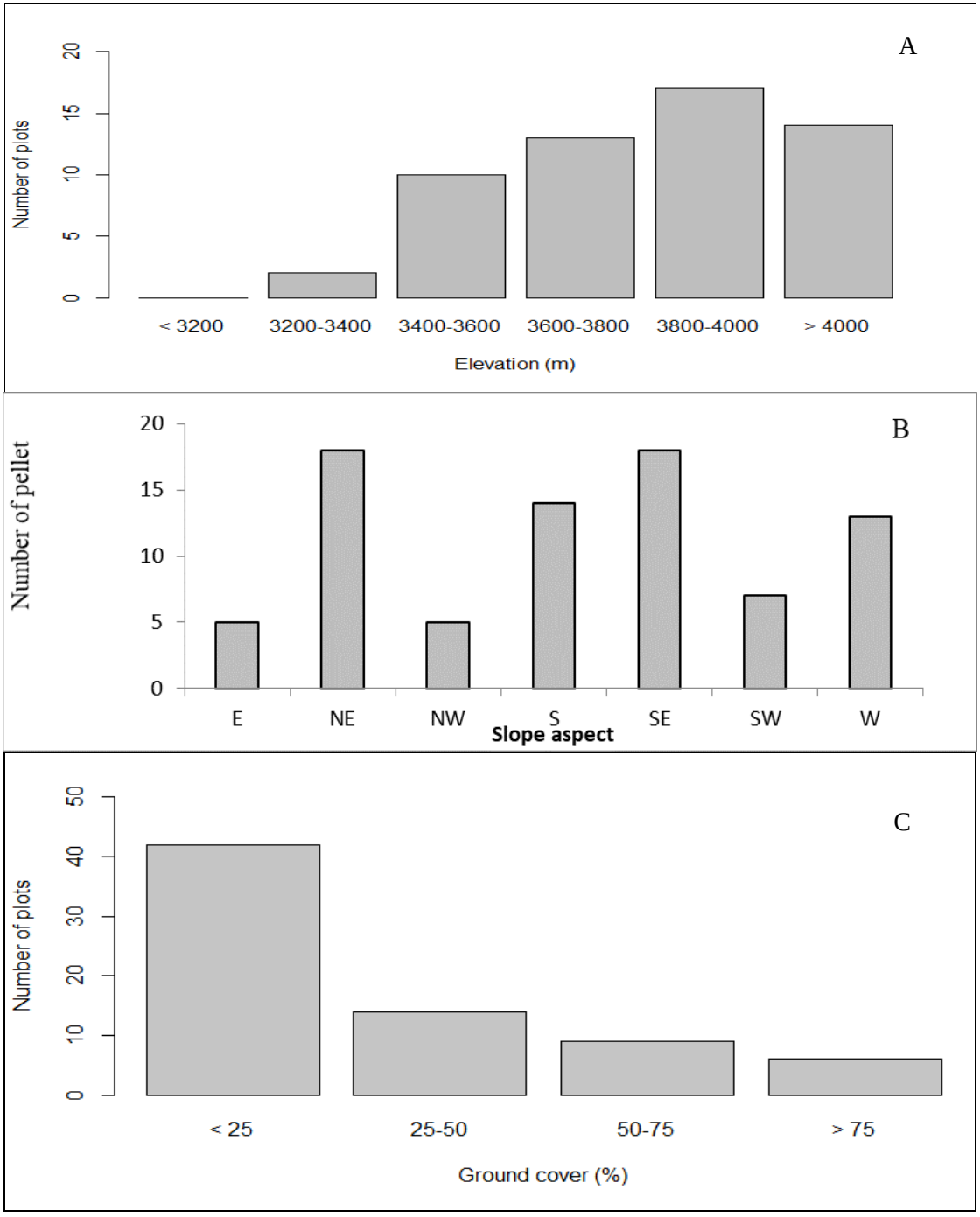
preferred by musk deer at Sagarmatha National Park whereas west and east in Kangchenjunga Conservation Area, north, north-west and south-west from Langtang National Park (Sharma et al., 2008) and recorded more in North-west (NW), south (S) and south-east (SE) slope at Annapurna Conservation Area (Aryal, 2006; Singh et al., 2019). Statistically, on applying the χ^2 – test showed a significant difference in musk deer signs distribution among different aspects at GCA (χ^2 = 15.25, at 95% level of significance, d.f. = 6 and p = 0.00184) supporting finding of previous researches in Nepal. Musk deer were distributed mostly in the forested area and scrubland with bushes of *Rhododendron* species. The musk deer signs were distributed throughout the areas with various ground covers (%). Musk deer signs were present higher in plots with ground cover less than 25%, while the preference decreased with an increase in ground cover (Figure 5C).



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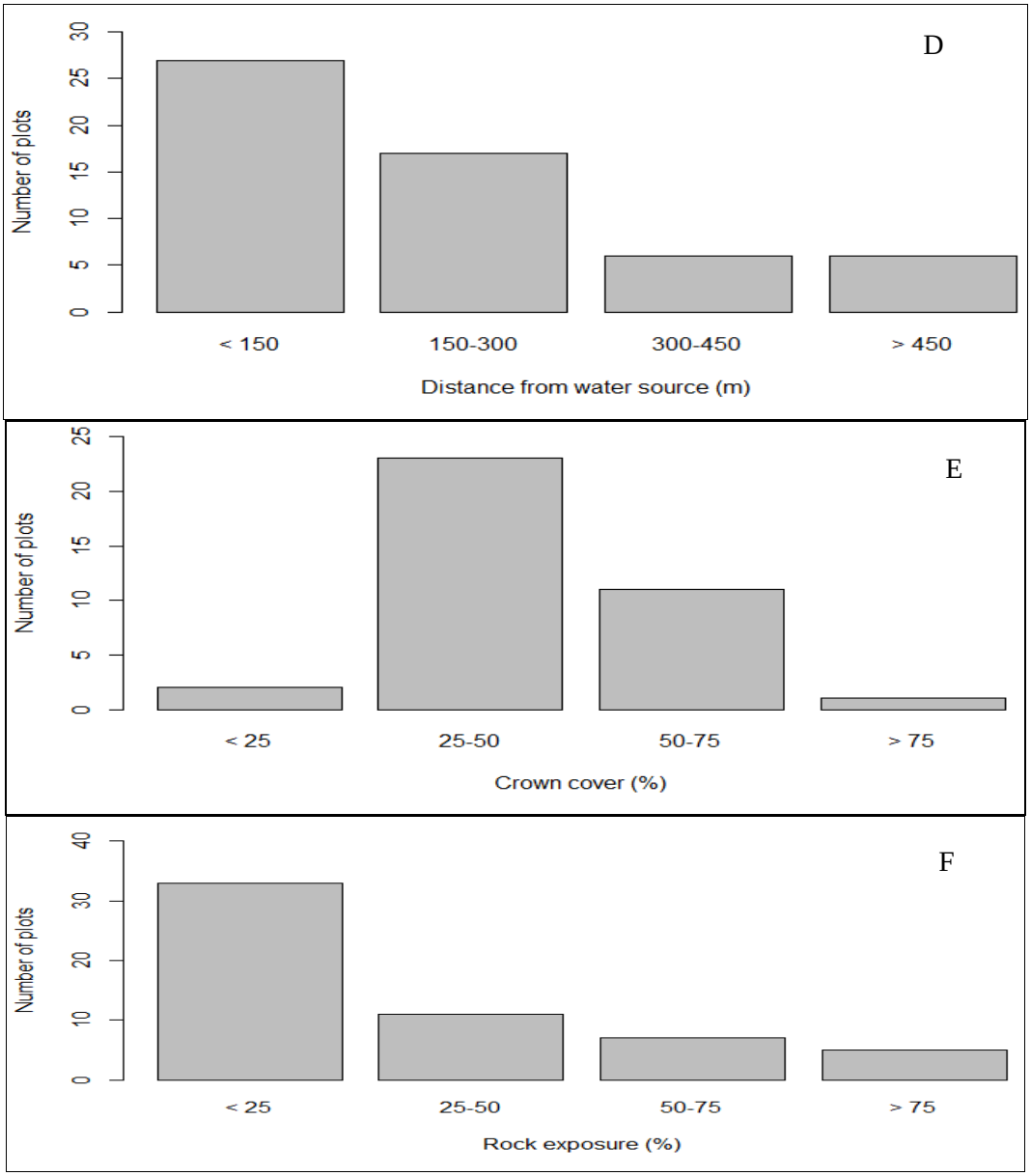

Figure 5 Musk deer distribution across GCA along: A. Elevation, B. Aspect, C. Ground cover (%), D. with distance from the water source, E. Crown cover, and F. Rock exposure

Distance from the water source affects the distribution of the musk deer. Musk deer signs were distributed as near as five m to 800 m from the water source. Musk deer favored habitats that were near water sources. Musk deer were distributed heavily in habitats that were at less than 150 m from water sources (Fig. 5D). The preference decreased with an increase in distance from the water source. Among 80 plots, 30 quadrats were in scrubland; hence they had no crown cover and remaining 50 plots were laid in forest area, crown cover varied from above 25% to above 75%. Musk deer favored areas with crown cover 25%-50% (Fig. 5E). Singh et al, (2018) suggested that distance from water sources and mixed forests have a crucial role in selecting latrine sites by musk deer. Lapchi valley in GCA is suitable for musk deer as the area is near to water sources with a river flowing alongside and waterfalls and springs within the forest area. Musk deer preferred habitat with lower to medium range of rock exposure (Fig. 5F). The forest in this area is a mixed hardwood forest comprising *Abies*, *Juniperus*, *Betula* and *Rhododendron* species. Along with that, the area also harbors rocks rolling areas and cliff nearby, thus proving a viable location for musk deer. In this study, musk deer pellets were most abundant in areas near water sources, indicating that distance to water source has importance in habitat selection by musk deer. These findings are also supported by study of Singh et al (2019), which concluded that topographical attributes including aspect, elevation, distance to water source, and slope were also discriminated by musk deer.

As the terrain at higher mountains has a fragile structure, the presence of rocks and boulders also affected the musk deer

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presence. Musk deer signs were recorded in areas with rock exposure ranging from as low as less than 25% to as high as greater than 75% (Fig. 5F). Higher shares of musk deer signs were recorded in plots with rock exposure less than 25%. Preference decreased gradually with an increase in rock exposure. Impact of crown cover of the forest in distribution of musk deer was reported in Shrestha and Meng (2014). They reported that the large number of pellet groups was recorded from the forest area therefore forest area or crown cover is important factor for distribution of musk deer. Similar report was recorded in KCA and LNP (Sharma et al., 2008), and in MCA (Subedi et al., 2012). These results are different from our study as in GCA, where very low and very high crown cover seem to be low favored by musk deer. Crown cover preference gradually increases with an increase in crown percentage and then gradually decreases. This might be due to the cover from predator and availability of food sources in terms of moss and lichens and bark and leaves of trees and to avoid the potential threat from human.

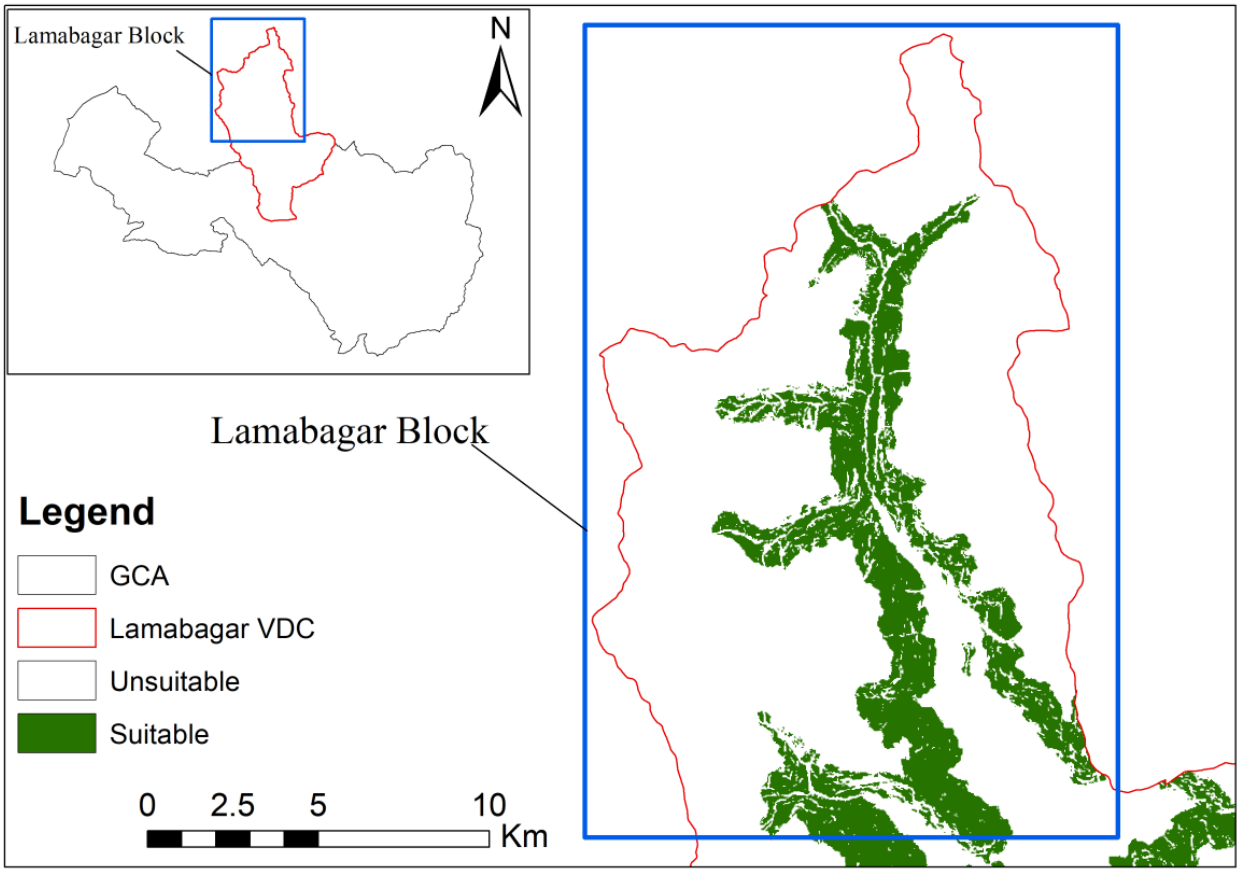

Figure 6 Habitat suitability map for Musk deer

Potential suitable habitat

The map suggested that 38.4% (26.5 km²) of the total area lies between elevation gradient of 3400 masl to 4000 masl has favorable aspect and suitable canopy cover that can be the probable habitat of musk deer in Lapchi valley (Fig. 6).

Conclusion

Musk deer are distributed throughout the Lamabagar block of Gaurishankar Conservation Area (GCA) at higher elevations in mixed forest and scrubland. Pellet group of musk deer encounter rate 10.29 ± 2.00 pellet groups per km in GCA. The elevation range 2800 masl to 3400 masl, with canopy cover between 25-50%, near water resources and rocky surface are preferred by musk deer to inhabit. The area of 26.5 km² (38.4%) of the total study area is potentially suitable habitat for musk deer.

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supervision; BB: conceptualization, field investigation, data curtion and analysis, funding acquisition, drafting original manuscript, reviewing and editing; SNS: conceptualization, field investigation, data curation, funding acquisition, drafting original manuscript.

Conflict of Interest: The authors declare no conflict of interest.

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