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COMMUNICATION

HABITAT SELECTION OF HIMALAYAN MUSK DEER *MOSCHUS LEUCOGASTER* (MAMMALIA: ARTIODACTYLA: MOSCHIDAE) WITH RESPECT TO BIOPHYSICAL ATTRIBUTES IN ANNAPURNA CONSERVATION AREA OF NEPAL

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Habitat selection of Himalayan Musk Deer *Moschus leucogaster* (Mammalia: Artiodactyla: Moschidae) with respect to biophysical attributes in Annapurna Conservation Area of Nepal

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Abstract: Himalayan or White-bellied Musk Deer *Moschus leucogaster*, an IUCN indexed endangered species, is distributed in isolated pockets in the Himalaya. The deer population is decreasing owing to several pressures that include habitat loss and fragmentation, and poaching. It is essential to identify preferred habitat characteristics to support appropriate management strategies for conserving this endangered species. This study was carried out in the Nysheang basin of Annapurna Conservation Area of Nepal to identify habitats preferred by the musk deer. Habitat field parameters were collected using transect surveys. To analyze vegetation use and availability, nested quadrat plots size 20 m² were established. Ivlev's electivity index (IV) (-1 to +1) was employed to determine habitat preference, and one-way ANOVA (F) and chi-square tests (χ^2) were used to examine different habitat parameters. Similarly, the importance value index (IVI) of the vegetation was calculated. Our results showed that the Himalayan Musk Deer strongly preferred habitats at 3601–3800 m altitude (IV= 0.3, F= 4.58, P < 0.05), with 21–30° slope (IV= 0.2, F= 4.14, P < 0.05), 26–50 % crown cover (IV= 4.45, F= 4.45, P < 0.05), 26–50 % ground cover (IV= 0.15, F= 4.13, P < 0.05), and mixed forest (IV= 0.29, χ^2 = 28.82, df= 3, p < 0.001). Among the trees, *Abies spectabilis* (IVI= 74.87, IV= 0.035) and *Rhododendron arboretum* (IVI= 55.41, IV= 0.02) were the most preferred, while *Rhododendron lepidotum*, *Cassiope fastigiata* (IV= 0.35) and *Berberis aristata* (IV= 0.25) were the most preferred shrubs, and *Primula denticulata* (IV= 0.87) and *Primula rotundifolia* (IV= 0.31) were the most preferred herbs. These preferred habitat conditions should be maintained and conserved to sustain a viable population of deer in the study area. Further studies will be required to assess the effects of climate change on habitat suitability.

Keywords: Climate change, conservation, habitat suitability, Nysheang Valley, White-bellied Musk Deer.

Nepali संक्षिप्त: हिमालयन अथवा हवाईट विल्ड कस्तुरी मृग *Moschus leucogaster*, IUCN मा सुचित लापोन्मुख प्रजाति, हिमालय क्षेत्रका विभिन्न ठाउँहरूमा अवस्थित छन्। यी मृग प्रजातिको संख्यामा कमी हुनुको मुख्य कारण वासस्थानको क्षेती र विखण्डनका साथै चोरी शिकारी हुन। यी लोपोन्मुख प्रजातिको संरक्षणका लागि उपयुक्त व्यवस्थापनको रणनीतिहरू तय गर्न उनीहरूको प्राथमिकतामा पर्ने वासस्थानहरूको विशेषताहरू पहिचान आवश्यकता छ। यो अध्ययन नेपालको अन्नपूर्ण संरक्षण क्षेत्रको निस्याङ्ग भ्यालीमा कस्तुरी मृगले मन पराउने वासस्थानको पहिचान गर्न गरिएको थियो। यस अध्ययनका लागि ट्रान्सेट सर्वेक्षण प्रयोग गरि उनीहरूको वासस्थान क्षेत्रका प्यारामिटरहरू संकलन गरिएको थियो। वनस्पति प्रजातिहरूको प्रयोग र उपलब्धताको विश्लेषण गर्न २० वर्ग मिटर आकारको नेष्टेड क्वाड्रेट प्लटहरू स्थापना गरिएको थियो। उनीहरूको वासस्थानको प्राथमिकताको निर्धारण गर्नका लागि Ivlev's electivity index (IV) (-1 to +1) प्रयोग गरिएको थियो भने विभिन्न वासस्थान प्यारामिटरहरूको परिक्षण गर्नका लागि वान वीय ANOVA (F) र chi-square tests (χ^2) टेस्टहरू प्रयोग गरिएको थियो। त्यसै गरि वनस्पतिहरूको लागि Importance Value Index (IVI) निर्धारण गरिएको थियो। हाम्रो अध्ययनले हिमालयन कस्तुरी मृगले ३६०१-३८०० उचाई (IV= 0.3, F= 4.58, P < 0.05), २१-३० डिग्री भिरालोपन (IV= 0.2, F= 4.14, P < 0.05), २६-५० प्रतिशत कानन कभर (IV= 0.25, F= 4.45, P < 0.05), २६-५० प्रतिशत ग्राउण्ड कभर (IV= 0.15, F= 4.13, P < 0.05) र मिश्रित वन (IV= 0.29, χ^2 = 28.82, df= 3, p < 0.001), रहेका वासस्थानहरूलाई निकै मन पराएको देखिन्छ। रुख प्रजातिहरूमा *Abies spectabilis* (IVI= 74.87, IV= 0.035) र *Rhododendron arboretum* (IVI= 55.41, IV= 0.02) धेरै मन पराईएका छन् भने भुईँ प्रजातिहरूमा *Rhododendron lepidotum*, *Cassiope fastigiata* (IV= 0.35) र *Berberis aristata* (IV= 0.25) धेरै मन पराईएका छन् र भुईँ घाँस प्रजातिहरूमा *Primula denticulata* (IV= 0.87) र *Primula rotundifolia* (IV= 0.31) बढि मन पराईएका छन्। यस अध्ययन क्षेत्रका कस्तुरी मृगको स्वयंसमर्थता जनसंख्यालाई दिगो बनाउन उनीहरूको प्राथमिकतामा परेका वासस्थानहरूको अवस्थालाई कायम राख्न र संरक्षण गर्न आवश्यकता देखिन्छ। साथसाथै, उनीहरूको वासस्थान उपयुक्ततामा जलवायु परिवर्तनका प्रभावहरूको आंकलन गर्न थप अध्ययन अनुसन्धान आवश्यक छ।

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For **Author details** and **Author contributions** see end of this article.



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INTRODUCTION

Musk Deer under genus *Moschus* are of taxonomic, biological, and commercial interest; the latter primarily arising from the value of the musk produced by adult male deer (Khadka & James 2016). Refined and improved knowledge has enabled the recognition of seven *Moschus* species (Li et al. 2016), with three occurring in Nepal (Satyakumar et al. 2015): the Black Musk Deer *M. fuscus*, Alpine Musk Deer *M. chrysogaster* of the eastern Himalaya, and the Himalayan or White-bellied Musk Deer *M. leucogaster* of the central Himalaya. Based on the mtDNA analysis, Singh et al. (2019) validated that the southern parts of the Himalaya of Nepal, India, and Pakistan hold the ranges of two species, Himalayan Musk Deer and Kashmir Musk Deer *M. cupreus* of western Himalaya and Hindu Kush.

The National Parks and Wildlife Conservation Act, 2029 (1973), Nepal (GoN 1973) includes the Musk Deer *Moschus chrysogaster* (Image 1) in Schedule-1 as a “Protected Wildlife” species. Earlier, *M. chrysogaster* was believed to be the only Musk Deer species of Nepal. *M. fuscus* was believed to be extinct, or not recorded in Nepal (Bhujju et al. 2007, page 30, 106), and *M. leucogaster* was earlier treated as subspecies of *M. chrysogaster* (Satyakumar et al. 2015). In the present study, we have treated the Musk Deer of Annapurna Conservation Area as *Moschus leucogaster* (hereby Musk Deer) in central Nepal. The species is categorized as ‘Endangered’ in the IUCN Red List (Harris 2016).

The Musk Deer is a solitary and crepuscular mammal that is found at higher elevations from 2500 to 4500 m (Green 1986). The species inhabits in the mountain forest of China, northern India, Bhutan, and Nepal (Green 1986; Grubb 2005). It is confined in protected areas of high mountainous regions of Nepal, namely Api Nampa Conservation Area (ANCA), Khaptad National Park (KNP), Rara National Park (RNP), Shey Phoksundo National Park (SPNP), Sagarmatha National Park (SNP), Dhorpatan Hunting Reserve (DHR), Annapurna Conservation Area (ACA), Manaslu Conservation Area (MCA), Langtang National Park (LNP), Makalu Barun National Park (MBNP), and Kanchenjunga Conservation Area (KCA) (Jnawali et al. 2011; Aryal & Subedi 2011). Forests of oak, rhododendron, blue pine, juniper, and grasslands are the preferred habitat types of the Musk Deer (Green 1986; Kattel & Alldredge 1991).

Habitat preference is an intrinsic behavior that determines the selection and fitness of species to particular habitat (Jaenike & Holt 1991). It is an element of natural factors which may prompt to



Image 1. Musk Deer captured during fieldwork in Annapurna Conservation Area.

the improvement of asset choice behavior (Boyce & McDonald 1999; Manly et al. 2007). An asset choice may be forever or briefly exhausted by the action of the creature (Green 1986). Moreover, habitat preference is the disproportionality among utilization and accessibility (Manly et al. 2007). Creatures are liable to contending requests and inspirations for example, must secure nourishment, discover mates, raise offspring, protect restricted assets, and maintain a strategic distance from predators. So as to achieve these goals, their decision of natural surrounding selection is influenced and balanced over their area in space (Hebblewhite & Merrill 2009). The majority of the wildlife conservationists have concentrated on natural surrounding selection for managing the populaces and anticipating impacts of natural surrounding disturbances (Boroski et al. 1996). Other than this, however, it can be utilized as an apparatus to see how environment, behavior and wellness are connected (McLoughlin et al. 2008; Gaillard et al. 2010). The growing anthropogenic weight and their following impacts on natural life has been well seen all around (Millenium Ecosystem Assessment 2005).

The population of Musk Deer is declining due to several anthropogenic pressures, including illegal hunting and habitat loss or degradation (Jnawali et al. 2011) due to human encroachment, firewood collection, etc. (Thapa et al. 2018). Suitable living space for deer is principally limited to protected areas in fragmented habitats (Singh et al. 2018a). As per Shrestha (2012), Musk Deer is one of the least studied mammals and its population is found in highly isolated areas. Hence taking all these considerations, our study was focused to identify and explore the state of the habitats in respect

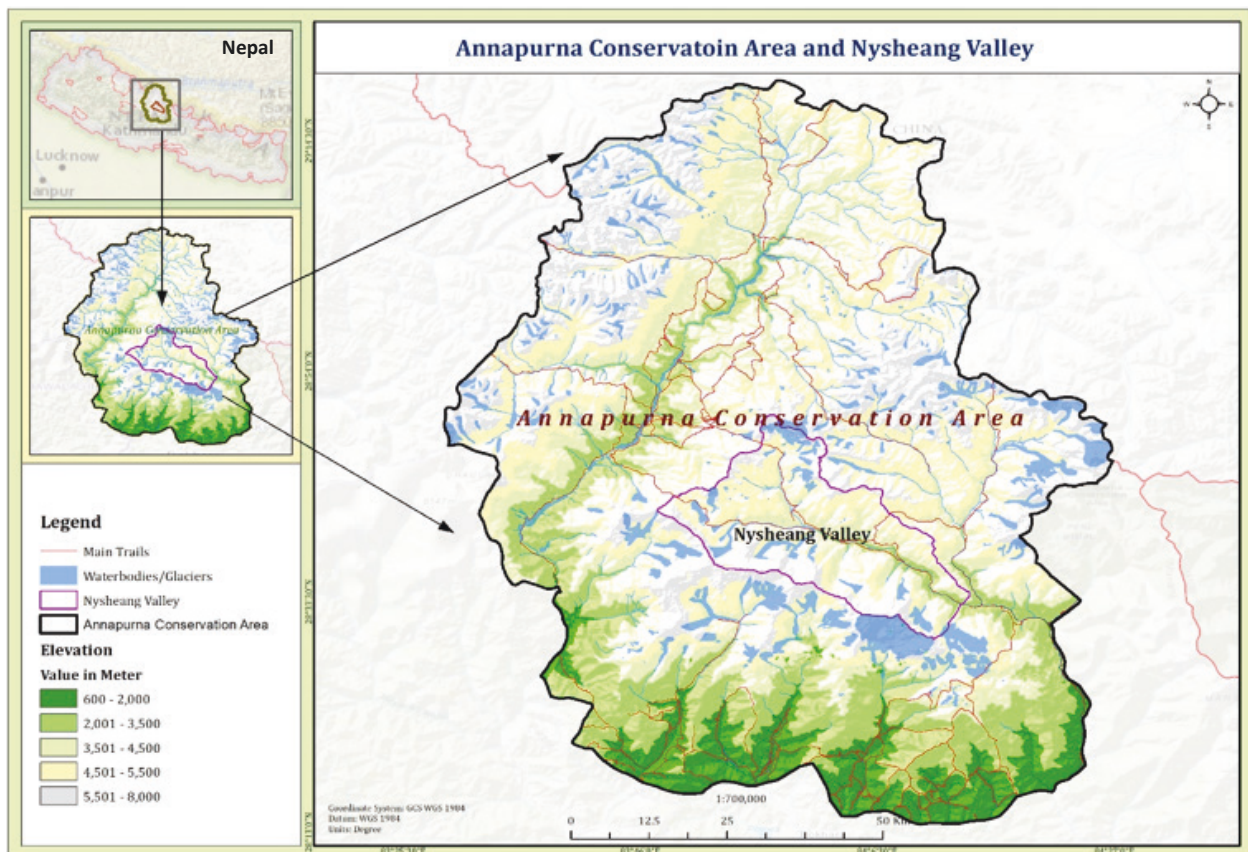


Figure 1. Location map of Annapurna Conservation Area and Nysheang Valley, Nepal.

of topographic and vegetation highlights that portray their habitat preferences.

MATERIALS AND METHODS

Study Area

The Annapurna Conservation Area (ACA) is located in the hills and mountain of west-central Nepal (28.231–29.336°N and 83.486–84.445°E) and covers a total area of 7,629 km² under five districts (DNPWC 2016). It is the first and largest conservation area of the country. To the north, it is bounded by the dry mountainous deserts of Dolpa and Tibet, toward the west by the Dhaulagiri Himal and the Kaligandaki Valley, toward the east by the Marshyangdi basin, and toward the south by the valleys and lower regions incorporating Pokhara. It harbors number of faunal species including 488 birds, 23 amphibians, 20 fish, 105 mammals, 40 reptiles and 347 butterflies (DNPWC 2016). ACA supports living space for several threatened mammal species including Himalayan Brown Bear *Ursus arctos*, Red Panda *Ailurus fulgens*, Common Goral *Nemorhardus goral*, Lynx *Felis*

lynx, Himalayan Marmot *Marmota himalayana*, Red Fox *Vulpes vulpes*, and bird species including Danphe *Lophophorus impejanus*, Lammergier *Gypaetus barbatus*, Golden Eagle *Aquila chrysaetos*, Cheer Pheasant *Catreus wallichi*, Crimson-horned Pheasant *Tragopan satyra* (Inskipp & Inskipp 2001; DNPWC 2016). The Musk Deer mainly occurs in the valleys of Manang and Mustang districts of ACA. The Nysheang Valley of Manang (Figure 1), within the north-east portion of ACA is one of the major pocket areas for Musk Deer (Singh et al. 2018a). It occupies an area 689.6 km² and elevation ranging 2,900–7,939 m.

Data Collection

The study was conducted during March of 2018. At that time, the snowfall had decreased and the melting of snow had accelerated, which aided our investigation. To identify habitat parameters, a random sampling technique was utilized. Throughout the study area 'habitat use plots' (U) and availability plots (A) were adopted. On each location where indirect signs of Musk Deer such as latrine, hair, pugmark, and bed site were observed; 'habitat use plot' was established within 50 m

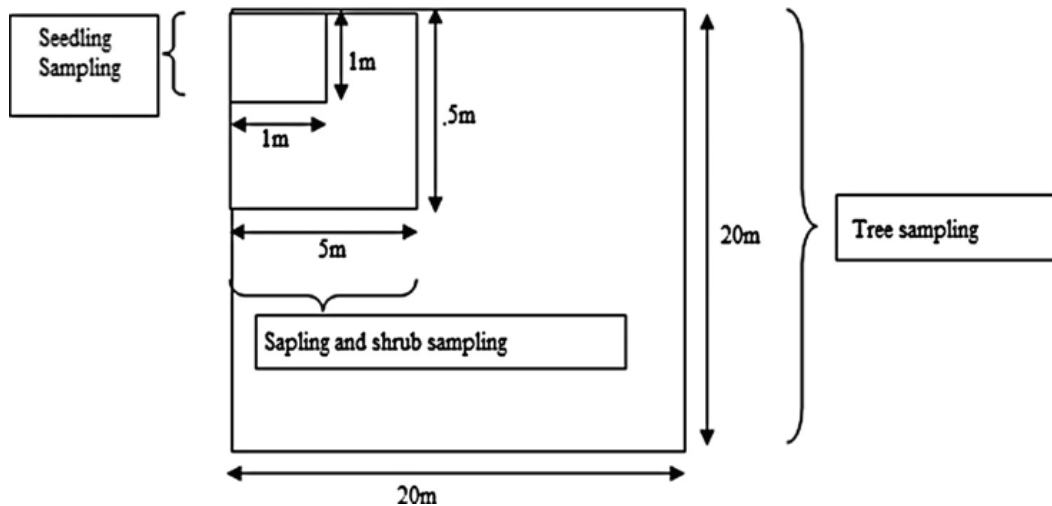


Figure 2. Layout of quadrats within the transect in the study area.

distance. Habitat parameters, in particular the gradient, altitude, crown cover, ground cover and land features were noted from each plot. ‘Habitat availability plots’ were chosen at 100 m distance from the use plots in a random direction (Panthi et al. 2012) and the similar habitat parameters were noted as recorded in the use plots. ‘Availability plots’ were renamed as ‘use plots’ if signs of the deer were present in availability plots. Vegetation analysis was performed within both the use and availability plots. Quadrats of size 20 × 20 m were placed on each transect at the intervals of 100 m (Singh et al. 2018a). Within the quadrats, nested structured small quadrats of size 5 × 5 m and 1 × 1 m were laid (Figure 2). Trees (dbh >10cm) were measured in each 20 × 20 m quadrat, shrubs and sapling (tree species >1 m height and <10 cm diameter) were measured in 5 × 5 m quadrats and seedlings (tree <1 m in height) were measured in 1 × 1 m quadrats and those measurements were recorded. Besides, information such as the tree diameter at breast height (DBH), height, crown cover, number of trees, ground cover, frequency of tree, shrub and herb as well as signs of animals were collected within the quadrats.

Data Analysis

Using Ivlev’s electivity index (IV), habitat preference of deer was analyzed. The IV value ranges from -1.0 to + 1.0. Habitat preference is indicated by the positive value, whereas negative value indicates avoidance and finally, 0 values indicate random use (Ivlev 1964). For this purpose, following relation was used.

$I \text{ or } IV = (U\% - A\%) / (U\% + A\%)$ (Ivlev 1964; Krebs 1989; Panthi et al. 2012), where U and A refer to use and

availability plots, respectively.

Regarding vegetation analysis, the field data was utilized to calculate the species richness, frequency and relative frequency, density, and relative density of tree using following formulae (Smith 1980).

Density of species

$$A = \frac{\text{Total number of individuals of species } A}{\text{Total number of areas surveyed} * \text{Area of plot}}$$

Relative density of species

$$A = \frac{\text{Total number of individual of species } A}{\text{Total number of individuals of all species}}$$

Frequency of species

$$A = \frac{\text{Number of plots in which species } A \text{ occurs} * 100}{\text{Total number of sample plots}}$$

Relative Frequency of species

$$A = \frac{\text{Frequency value of species } A * 100}{\text{Total frequency values of all species}}$$

Relative dominance of species

$$A = \frac{\text{Total basal area of species } A * 100}{\text{Total basal area of all species}}$$

Importance value index (IVI) was calculated as

IVI = Relative density + relative frequency + relative dominance.

Besides, one-way ANOVA and Chi-square test were used to identify the significances of different habitat variables; crown cover, ground cover, forest types with respect to Musk Deer presence at 5% level of significance.



RESULTS

Habitat Preferences

Altitude Preference: The Musk Deer mainly preferred altitudinal ranges of 3,601–3,800 m with (IV= 0.3) (Figure 3). Altitudinal preference increased from 3201 m to 3800 m in a gradual manner. The altitudinal range of 3,801–4,000 m (IV= 0.2) was least preferred. Similarly, the region beneath the elevation 3,200 m (IV= -0.25) and above 4,000 m (IV= -0.8) was avoided. The utilization of different altitude intervals in extent to their availabilities was statistically significant ($F= 4.58$, $P < 0.05$).

Slope Preference: Primarily, the Musk Deer preferred the slope 21° to 30° (IV= 0.2) (Figure 4). Preference slope expanded in continuous way from 11° to 30° and somewhat diminished up to 40°. It avoided the slope <10° (IV= -0.25) and >40° (IV= -0.71). The use of different slopes in extent to their availability was statistically significant ($F= 4.14$, $P < 0.05$).

Crown Cover Preference: Mainly, the Musk Deer favored the crown cover of 26 to 50 % (IV= 0.25) followed by crown cover of 51 to 75 % (IV= 0.05), while 76 to 100 % (IV= -0.65) crown cover was evaded (Figure 5). The utilization of different crown cover in extent to their availability was statistically significant ($F= 4.45$, $P < 0.05$).

Ground Cover Preference: Initially ground cover was partitioned in 4 classes for the analysis. Ground cover having 26–50 % (IV= 0.15) and 0–25% (IV= 0.09) was mostly preferred by Musk Deer while it completely

Table 1. Affiliation of different biophysical variables with the living space of Musk Deer in the study area.

Variables	Estimate	SE	Z-value	P-value
(Intercept)	-5.36	2.36	-2.27	<0.05
Betula forest	1.44	1.67	0.85	0.39
Mixed forest	5.06	2.09	2.41	<0.05
Rhododendron forest	1.73	1.63	1.05	0.28
Distance to settlements	0.002	0.001	1.53	0.012
Rock cover	0.02	0.01	1.71	0.08
Litter cover	-0.14	0.06	-2.20	<0.05

SE—Standard error.

avoided 76–100 % cover (IV = -0.75) (Figure 6). This suggests that it preferred scarce and modest ground cover. The use of different ground cover in extent to their availability was statistically significant ($F= 4.13$, $P < 0.05$).

Since most of pellet was documented in forest, it was figured out that the Musk Deer preferred forest (IV= 0.15) (Figure 7). The cliff (IV= 0) and rock (IV= 0) were utilized randomly and the stream-bed (IV= -0.43) was totally dodged. The use of different ground features in extent to their availability was statistically significant ($F= 3.29$, $P < 0.05$).

Forest Types Preference: The proportion of forest types utilized by the Musk Deer was statistically significant ($\chi^2= 28.82$, $df= 3$, $p < 0.001$). From Figure 8, it can be concluded that mixed forest (IV= 0.29) was

Table 2. Musk Deer presence and the occurrence of different tree species in the study area.

	Species	Relative Density	Relative Dominance	Relative Frequency	IVI	Ivlev's Value	Status
1.	<i>Abies spectabilis</i>	21.46	32.25	21.16	74.87	0.035	Prefer
2.	<i>Rhododendron arboretum</i>	16.34	23.73	15.34	55.41	0.02	Prefer
3.	<i>Betula utilis</i>	13.66	5.3	11.82	30.78	0.01	Prefer
4.	<i>Rhododendron campanulate</i>	13.9	19.55	13.4	46.85	0.034	Prefer
5.	<i>Spruce spp</i>	7.56	2.5	7.58	17.64	0.16	Prefer
6.	<i>Taxus bacata</i>	5.61	4.04	6	15.65	0.15	Prefer
7.	<i>Cupressus spp</i>	5.85	2.1	5.82	13.77	-0.36	Avoid
8.	<i>Abies pindrow</i>	4.15	1.56	4.76	10.47	0.14	Prefer
9.	<i>Berberis spp</i>	3.9	3.6	3.88	11.38	0.135	Prefer
10.	<i>Honey suckle</i>	1.71	0.98	2.65	5.34	0.12	Prefer
11.	<i>Pinus wallichiana</i>	2.2	0.62	3	5.82	-0.4	Avoid
12.	<i>Sorbus lanata</i>	0.73	1.22	1.59	3.54	-0.5	Avoid
13.	<i>Rhododendron anthopogan</i>	1.46	1.19	1.41	4.06	0.12	Prefer
14.	<i>Acer spp</i>	0.98	0.88	0.88	2.74	0.15	Prefer
15.	<i>Sorbus sapling</i>	0.49	0.48	0.71	1.68	0.12	Prefer
	Total	100	100	100	300		

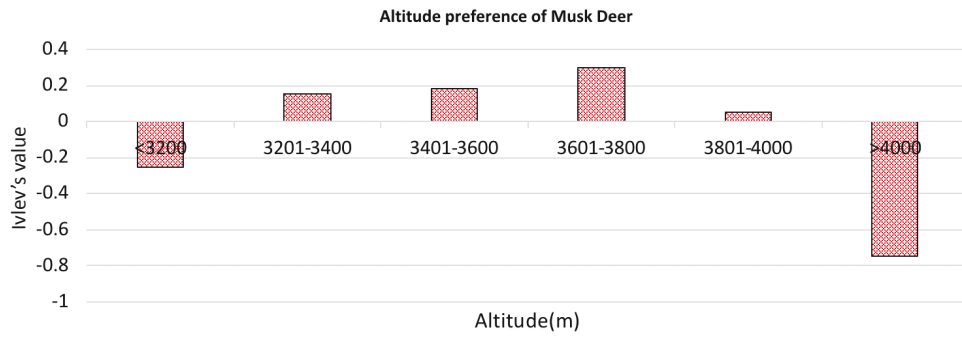


Figure 3. Preferred altitude by Musk Deer in the study area.

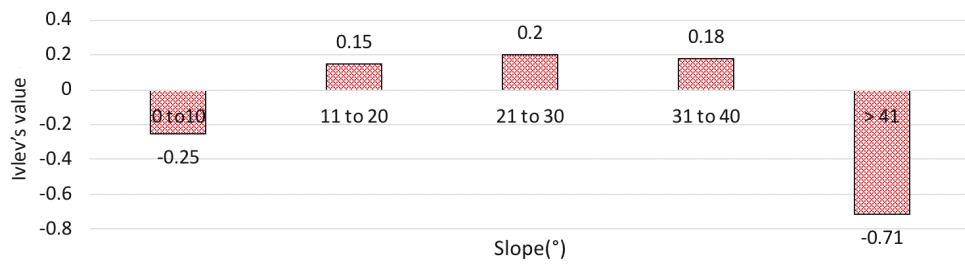


Figure 4. Preferred slope by Musk Deer in the study area.

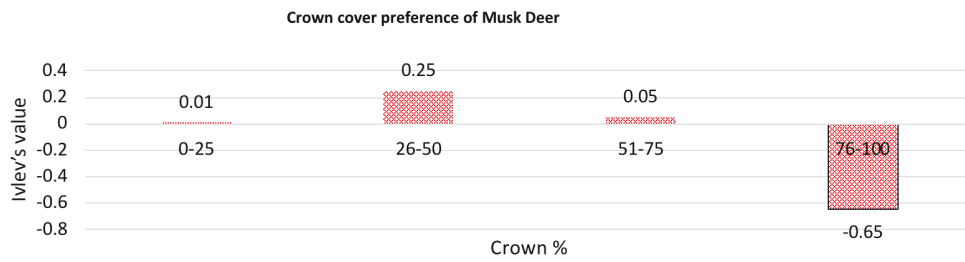


Figure 5. Preferred crown cover by Musk Deer in the study area.

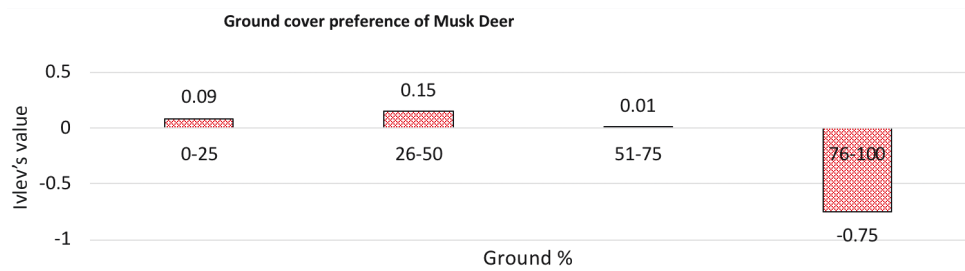


Figure 6. Preferred ground cover by Musk Deer in the study area.

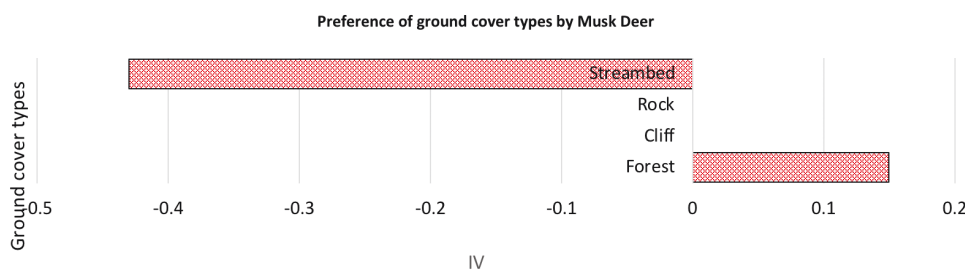


Figure 7. Ground cover types preferred by Musk Deer in the study area.

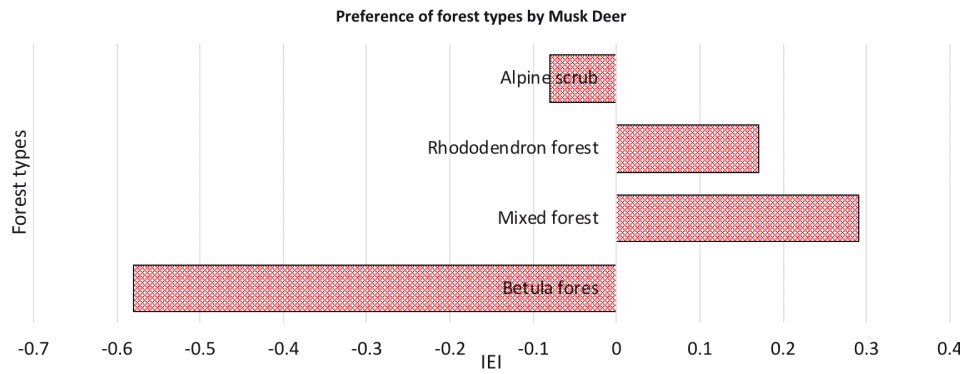


Figure 8. Forest types preferred by Musk Deer in the study area.

mostly preferred, and the second preference was for *Rhododendron* forest (IV= 0.17), whereas, *Betula* forest (IV= -0.58) along with alpine scrub (IV= -0.08) were completely avoided by the Musk Deer.

Influencing Biophysical Variables: Habitat sorts, fuel wood and wood cutting, rock cover, litter cover and distance to settlements influenced on the choice of the living space of the Musk Deer where mixed forest, distance to settlements and litter cover were the foremost and critical influencing factors (Table 1).

Tree Species Preference: Altogether 15 species of trees were recorded from 72 plots. Out of 15 tree species, the Musk Deer showed preference for 12 species and avoidance for 3 species (Table 2). Tree species that appeared to have been avoided include *Pinus wallichiana* (IVI= 5.82, IV= -0.4), *Cupressus* spp. (IVI= 13.77, IV= -0.36) and *Sorbus slanata* (IVI= 3.54, IV= -0.5).

Shrub Species Preference: A sum of 10 shrub species was documented within the 72 plots. The Musk Deer preferred *Rhododendron lepidotum* (IV= 0.35), *Cassiope fastigiata* (IV= 0.35), *Berberis aristata* (IV= 0.25), and *Rhododendron anthopogon* (IV= 0.02). Whereas, *Juniperus squamata* (IV= -0.15), *Incarvillea arguta* and *Rhododendron ciliatum* (IV= -0.14) and *Caragana gerardiana* (IV= -0.34) were avoided (Table 3).

Herb Species Preference: Out of total 18 herb species documented, the Musk Deer favored nine species and avoided the remaining nine species. *Primula denticulata* (IV= 0.87), and *Primula rotundifolia*, *Primula sikkimensis*, *Bistorta macrophylla*, *Anaphalis triplinervis*, *Viola biflora*, *Primula gembeliana*, *Potentilla cuneata* and *Artemisia dubia* were in the preferred herbaceous habitat. Whereas, *Rumex nepalensis* and *Saussurea deltoidea* (IV= -0.35) were the most avoided herb species, and *Anemone demissa*, *Thalictrum alpinum*, *Aster albescens*, *Pedicularis poluninii*, *Morina nepalensis*, and *Meconopsis horridula* were in the area avoided by the Musk Deer

Table 3. Musk Deer presence and the occurrence of different shrub species in the study area.

	Species	Ivlev's value	Status
1	<i>Rhododendron lepidotum</i>	0.35	Prefer
2	<i>Cassiope fastigiata</i>	0.35	Prefer
3	<i>Berberis aristata</i>	0.25	Prefer
4	<i>Rhododendron anthopogon</i>	0.02	Prefer
6	<i>Incarvillea argute</i>	-0.14	Avoid
7	<i>Rhododendron ciliatum</i>	-0.14	Avoid
8	<i>Juniperus squamata</i>	-0.15	Avoid
9	<i>Rosa sericea</i>	-0.29	Avoid
10	<i>Caragana gerardiana</i>	-0.34	Avoid

(Table 4).

DISCUSSION

Habitat usage relies upon factors like the creature's behavior, length of the day and the time of year in relation to accessibility of food, shelter, and cover (Green & Kattel 1997). Anthropogenic and natural factors may also influence accessibility to habitats and modify habitat preference (Pulliam & Dailson 1991). It is also possible that preferences vary among species of the same genus. In this context, without attempting to specify species level differences, we observed that our base-line findings (Table 1) on habitat preference by Musk Deer from ACA are comparable to certain extents with other studies in Nepal and neighborhood.

Khadka & James (2016) found that Musk Deer preferred small patch of pine and fir forest in the central Himalayas. While in ACA the preferences were the maximum in mixed forest to the minimum in Betula forest, and the preference for Rhododendron forest was low, close to that of Betula forest. The preference for

Table 4. Musk Deer presence and the occurrence of different herb species in the study area.

	Species	Ivlev's Value	Status
1	<i>Primula denticulate</i>	0.87	Prefer
2	<i>Primula rotundifolia</i>	0.31	Prefer
3	<i>Primula sikkimensis</i>	0.2	Prefer
4	<i>Bistorta macrophylla</i>	0.16	Prefer
5	<i>Anaphalis triplinervis</i>	0.15	Prefer
6	<i>Viola biflora</i>	0.14	Prefer
7	<i>Primula gembeliana</i>	0.12	Prefer
8	<i>Potentilla cuneate</i>	0.04	Prefer
9	<i>Artemisia dubia</i>	0.02	Prefer
10	<i>Anemone demissa</i>	-0.11	Avoid
11	<i>Thalictrum alpinum</i>	-0.13	Avoid
12	<i>Aster albescens</i>	-0.15	Avoid
13	<i>Pedicularis poluninii</i>	-0.16	Avoid
14	<i>Morina nepalensis</i>	-0.16	Avoid
15	<i>Meconopsis horridula</i>	-0.2	Avoid
16	<i>Oxytropis microphylla</i>	-0.34	Avoid
17	<i>Saussurea deltoidea</i>	-0.35	Avoid
18	<i>Rumex nepalensis</i>	-0.35	Avoid

forests of mixed stands and Rhododendron in our study appears similar to the findings by Shrestha & Meng (2014) in Gaurishankar Conservation Area, Nepal.

Concerning preferences for altitude range, Timmins & Duckworth (2015) suggested that 2,500–4,800 m is the most preferred for *M. leucogaster*, while Thapa et al. (2019) mentioned that 3,700–3,800 m was the foremost favored altitudinal extent for *Moschus* in Khaptad National Park, Nepal. Ilyas (2015) observed that a majority of the latrines of *M. chrysogaster* in Uttarakhand Himalaya, India occurred from 4,200 m down to 2,500 m. A study carried out by Srivastava & Kumar (2018) revealed that Musk Deer preferred the habitat within the altitude range 3,600–3,900 m in Sikkim Himalaya. Likewise, the Musk Deer highly preferred that altitude range 3,600–3,900 m in Api-Nampa Conservation Area, Nepal (ANCA 2018). In our study, the species favored the altitudes of 3,600–3,800 m, which is similar to the altitudinal preference in Api-Nampa Conservation Area, Nepal and Himalaya of Sikkim. However, elevation alone does not directly affect the Musk Deer's distribution. Instead, elevation is correlated with other climatic predictors like precipitation, temperature and solar radiations (Elith & Leathwick 2009) that lead to the change in habitat features and its quality to support the occurrence of the species.

In Api-Nampa Conservation Area, the slopes of 21–30° are highly preferred followed by slopes >40° by Musk Deer and avoid the slope of 0–10° (ANCA 2018). The study carried by Singh et al. (2018b) recorded the majority of latrines of Musk Deer in the slope of 20–40° in ACA. Our study in ACA coincides with these two studies as the principally preferred slope lie at 20–30° and completely avoid the slopes of 0–10° and >41°. Plain slope in our study was avoided due to presence of cattle grazing. Shrestha (2012) also suggested that Musk Deer avoid areas with high human disturbances like fuel wood collection and cattle grazing. And the slope >41° might have been avoided because of difficult terrain that resist them escaping from their predator.

Study carried out by Singh et al. (2018b) reported that Musk Deer prefer greater crown cover with high shrub diversity. In contrast to this, Musk Deer preferred moderate crown cover, i.e., 26–50 % in Api-Nampa Conservation Area (ANCA 2018), which is similar to our study. This is because the dense cover suppresses the growth of the ground level vegetation due to low light penetration, which might create the food shortage for the Musk Deer. This insight is supported by the study of Awasti et al. (2003) who recognized Musk Deer as the mixed feeder, i.e., grazers and browsers.

The thickness of ground cover governs the habitat preference of Musk Deer. The study carried out by Ilyas (2015) stated that Musk Deer prefer sparse ground cover. This study is supported by the study carried out in Api-Nampa Conservation Area where Musk Deer principally prefer the ground cover of 26–50 % (ANCA 2018), which is similar to our study in ACA. The dense ground cover is avoided; the reason could be that it is less friendly since it resists the rapid movement of Musk Deer that hinders to escape from predator. Singh et al. (2018b) reported that 69 % of the Musk Deer latrines were observed under tree, 26.4 % under canopy, and 4.6 % under rock. Similar to this study, forest and cave were found to be preferred and stream bed was found to be avoided in our study, which may be because the forest and caves are used for thermal requirements and escape whereas the streams are difficult to move across.

According to Khadka & James (2016), the Himalayan Musk Deer seems to utilize the region featured by presence of *Pinus* species and *Abies* species forest with moderately thick canopy cover (26–50 %) on higher elevation zone (≥ 3600 m) of the northern aspect. These choices are apparently social and structural adjustments (Futuyma & Moreno 1988). Musk Deer are shy and elusive creatures (Kattel 1993) with longer rear appendages compared to forelimbs, an adaptation for



living in rough terrain at high elevations. The domination of *Abies* species, which have dense crown cover, protects the area from snow, while the rivers flowing through the area serve as major water sources for Musk Deer throughout the year.

Data on habitat parameters and their levels of preference recorded from different protected areas provide valuable baseline data, and offer the scope for determining micro-habitat for different species of *Moschus* in Nepal. Correlations in future when camera traps or molecular studies enable to have clear knowledge on the profile of species in each protected area.

CONCLUSION

The Musk Deer appear to have habitually utilized mixed and Rhododendron stands for defecation and foraging. Deer occurrence is sparse at lower elevations and higher elevations close to the tree line, and they are mostly distributed between 3,600 and 4,000 m. Thus altitudinal ranges of 3,800–4,000 m with mixed and Rhododendron woods adjacent to water sources are appropriate regions to execute conservation programs to protect Musk Deer and their environment. The likelihood of pellet presence diminished with the rise in ground elevation. A total of 15, 10 and 18 species of tree, shrub and herb were recorded, respectively, in the study area. The occurrence of Musk Deer was more around the forested area with crown cover of 26–50 %, and the tree species *Abies spectabilis*, *Betula utilis*, *Acer spp.*, *Rhododendron spp.*, *Spruce spp.*, *Taxus bacata*, *Honey suckle*, *Berberis spp.* etc. The terrain with *Pinus wallichiana*, *Cupressus spp.* and *Sorbus spp.* appear to have been avoided. Likewise, the deer appear to have preferred areas where we have listed four species of shrub and nine species of herb, and further studies are required to assess the habitat suitability of the Musk Deer in response to climate change.

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– Perumal Murugan, Vellingiri Ravichandran & Chidambaram Murugan, Pp. 18953–18955

Response

Comments on the "A checklist of mammals with historical records from Darjeeling-Sikkim Himalaya landscape, India"

– P.O. Nameer, Pp. 18956–18958

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