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Selection of latrine sites by Himalayan musk deer (*Moschus leucogaster*) in Neshyang Valley, Annapurna Conservation Area, Nepal

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ABSTRACT

Musk deer is threatened by poaching for musk pod and habitat fragmentation. The species is endangered within its distribution range including Nepal, Bhutan, India, Pakistan, Mongolia, China, Korea and Russia. In Nepal, the deer is confined to protected areas throughout the Himalaya. It is a solitary and shy forest dweller with a crepuscular activity pattern. It prefers and repeatedly uses one or more specific defecation sites. Such behaviour is believed to function in chemical communication among individuals. This study was conducted in Neshyang valley in the Annapurna Conservation Area, and aims to evaluate how musk deer selects the latrine site in its habitat taking into account both biotic and abiotic factors. In order to achieve this aim, we laid out a total of 23 transects of 500 m length throughout the study area. Within each transect, 20 m × 20 m nested structured quadrats were located at an interval of 100 m. We found that musk deer preferred to use latrine sites in fir forest while they avoid both blue pine forest and open areas. Furthermore, distance from water sources and mixed forests have a crucial role in selecting latrine sites by musk deer.

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Musk deer; latrines; mixed forest; Himalaya

1. Introduction

Many mammals develop latrines by defecating repeatedly at a single site and the scents of these latrines serve various functions, particularly, chemical communication. Latrines may have other functions such as avoidance of parasite transmission (Gilbert 1997), avoidance of detection by predators (Boonstra et al. 1996), kin recognition (Ramsay and Giller 1996), advertisement of reproductive status (Walls et al. 1989; Heise and Rozenfeld 2002), interaction of prey and predators (Lewis and Murray 1993), maintaining territory or home range (LentiBoero 1995), dispersal and dispersion (Gorman and Stone 1990; LentiBoero 1995) and establishing dominance, hierarchies and an internal group-bond (Gosling and Wright 1994; Gosling et al. 1996). Both solitary and gregarious animals use latrines, particularly nocturnal mammals (Droscher and Kappeler 2014). Oribi (*Ourebia ourebi*) use latrines for strong territorial marking (Brashares and Arcese 1999) while bush buck (*Tragelaphus scriptus*) use them for inter-sexual communication (Wronski et al. 2006). Furthermore, the latrine site of raccoons (*Procyon lotor*) is a place where hosts-raccoons and parasites are found interacting (Page et al. 1999). Regarding the ecological significance of the latrine, it enriches soil nutrients to some extent and plays a crucial role in maintaining plant diversity and composition (McNaughton 1983; Day and Detling 1990; Willott et al. 2000; Moe and Wegge 2008).

Latrines are ecologically important for musk deer because of its unique behaviour and habitat use pattern (Kattel 1992; Green and Kattel 1997). Olfaction is a highly developed way

of communication in musk deer due to minimal visual contact, dense forest cover, solitary behaviour and no vocalization (Green 1987; Lai and Sheng 1993). Musk deer use latrines more often from November to December when copulation mostly occurs whereas they use latrine haphazardly in spring and summer (Green 1987). Latrines are also critical to monitoring and recording musk deer in a particular habitat.

Poaching for musk and habitat fragmentation are the two major causes of declining musk deer population (Green 1986; Wemmer 1998; Homes 2004). Musk remains one of the most expensive natural products, much more valuable even than gold (Green 1986; Shrestha 1998; Homes 1999). East Asia and Southeast Asia traders are the major providers and also the main consumers of musk products, primarily for medicinal purposes (Mills 1998). Consequently, the demand for musk has pushed this deer to the verge of extinction. Musk deer are mainly poached by setting snares on the basis of location of the latrines. Only male musk deer have musk pods. However, use of snares kills musk deer indiscriminately. The Himalaya is a vast and tough mountain terrain. However, it is almost impossible to save musk deer without patrolling its habitat. To prepare a strategic patrolling plan, latrine site selection and their location should be known at first hand. Musk deer latrines may be affected by various biophysical factors such as aspect, altitude, slope, distance from water, tree density, shrub density, ground cover, and location of forest types. In addition, herbaceous plant species composition may vary in

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latrine sites due to the effect of defecation and urination. Considering all the above-mentioned factors, this study is aimed at investigating how musk deer select latrine site and which factors affect latrine site selection within its home range.

2. Materials and methods

2.1. Study area

Annapurna Conservation Area (ACA) located in Nepal's western region (28.325°N, 84.397°E to 28.603°N, 84.455°E and 29.235°N, 83.772°E to 28.482°N, 83.648°E) covers 7629 sq.km and is the largest protected area of the country (NTNC 2013; DNPWC 2016). It comprises a wide range of habitats, from sub-tropical forest to Alpine tundra. It harbours 105 species of mammals, 488 birds, 20 fish, 23 amphibians, 40 reptiles and 347 butterflies (DNPWC 2016). It is well known that it provides habitat for Himalayan musk deer (*Moschus leucogaster*) (hereafter musk deer), red panda (*Ailurus fulgens*), snow leopard (*Panthera uncia*), lynx (*Felis lynx*), Himalayan brown bear (*Ursus arctos*), blue sheep (*Pseudois nayaur*), Tibetan argali (*Ovis ammon*), grey wolf (*Canis lupus*), leopard cat (*Prionailurus bengalensis*), Himalayan monal (*Lophophorus impejanus*), satyr tragopan (*Tragopan satyra*) and cheer pheasant (*Catreus wallichii*) among other species (KMTNC 1997; Inskipp and Inskipp 2001; DNPWC 2016).

Musk deer are generally found in valleys of Manang and Mustang of ACA. Among these valleys, the Neshyang valley of Manang (Figure 1), located in the east-north part of ACA is one of the prime habitats for musk deer. It covers an area 689.6 sq.km and has an altitudinal range of 2900–7939 m. Forests in Neshyang valley consist blue pine forest (hereafter pine forest), Himalayan fir forest (hereafter fir forest), Himalayan birch forest (hereafter birch forest) and mixed forest. The altitudinal ranges of each forest are from 2900 to 3600 m, 3000 to 3800 m, 3800 to 4200 m, 3600 to 4000 m asl respectively. The mixed forests comprise mainly a mix of two species either Himalayan birch and Himalayan fir or blue pine and Himalayan fir. In the same sections of habitat, all these three species can be found intermingled.

2.2. Sampling design

Neshyang valley was divided into four sections: Pisang, Humde, Bhraka-Manang and Khangsar, based on the traditional boundary of the forest. The Marsyangdi River flows from west to east and runs through the flood plain. Most of the forests were located within the northern aspect of the Annapurna Himalayan range. Transects of 0.5 km length were laid on mountain slopes extending from lower altitude to higher altitude and the flood plain (i.e. agricultural land) was avoided. Seven transects were laid out in Pisang, 5 transects in Humde, 6 transects in Bhraka – Manang and 5 transects in Khangsar (Figure 2).

Quadrats of 20 m × 20 m were placed at the intervals of 100 m within each transect. Inside the 20 m × 20 m quadrats, small quadrats of 5 m × 5 m and 1 m × 1 m were laid in a nested structure (Figure 3). Trees (dbh > 10 cm) in each 20 m × 20 m quadrat, shrubs and sapling (tree species > 1 m height and < 10 cm diameter) in 5 m × 5 m quadrat and

seedlings (tree < 1 m in height) in 1 m × 1 m quadrats were measured and recorded. In addition, biophysical factors such as musk deer latrine, aspect, altitude, slope, distance from water, shrub density, tree density, ground cover locations of latrine and forest types were recorded within the quadrats.

2.3. Data analysis

The degree of latrine preference was calculated using Ivelve's electivity index (IEI) = $(U - A) / (U + A)$ where U = Proportion of use of a habitat and A = Proportion of availability of that habitat (Ivelve 1961). The value of IEI lies between -1 and +1 where negative and positive values denote avoidance and preference. In our study area, we sampled a total of 92 plots, of these 55 plots had latrine of musk deer whereas 37 plots in different habitat types were considered as latrine absent plot.

Generalized linear models (GLM) were used to determine important predictors of presence of latrines in a given plot from a set of potential predictors (aspect, altitude, slope, distance from water, tree density, shrub density, ground cover, location of latrine and forest types) using the statistical software R 3.0.3 (R Development Core Team 2014). Latrines were treated as a binomial variable (presence or absence). The best-fitted model was selected based on the lowest AIC (Akaike Information Criterion) value performed by an automatic 'step-wise' model selection approach from both directions (Appendix I). Logistic regression was performed using the GLM function in R where latrine (presence or absence) was considered as a response variable and altitude as a predictive variable. The result of logistic regression is presented in both line and histogram formats, based on the probability of latrine occurrence with respect to altitude using the popbio package in R 3.0.3 (R Development Core Team 2014).

CANOCO was used to perform a canonical correspondence analysis (CCA) to determine the association of musk deer latrines with woody plant composition. Plant forms such as trees, shrubs, saplings and seedlings were treated as response variables. Other biophysical variables, such as aspect, altitude, slope, distance from water, shrub density, tree density, ground cover and livestock grazing were treated as explanatory variables. In terms of seedlings, saplings, and shrubs, the number of individuals was extrapolated to the plot size of the tree to make uniform plot size for analysis. Species data were transformed to logarithm and the rare species were down weighed and then, manual Monte Carlo permutation tests based on 499 permutations were performed. Only the significant variables ($p < 0.05$) were included in the final analysis showing their importance in explaining the total variability in the species composition (Leps and Smilauer 2003).

3. Results

3.1. Distribution of musk deer latrines with respect to forest types

The results showed that the distribution of latrines was significantly different among the forest types (Fisher's exact test,

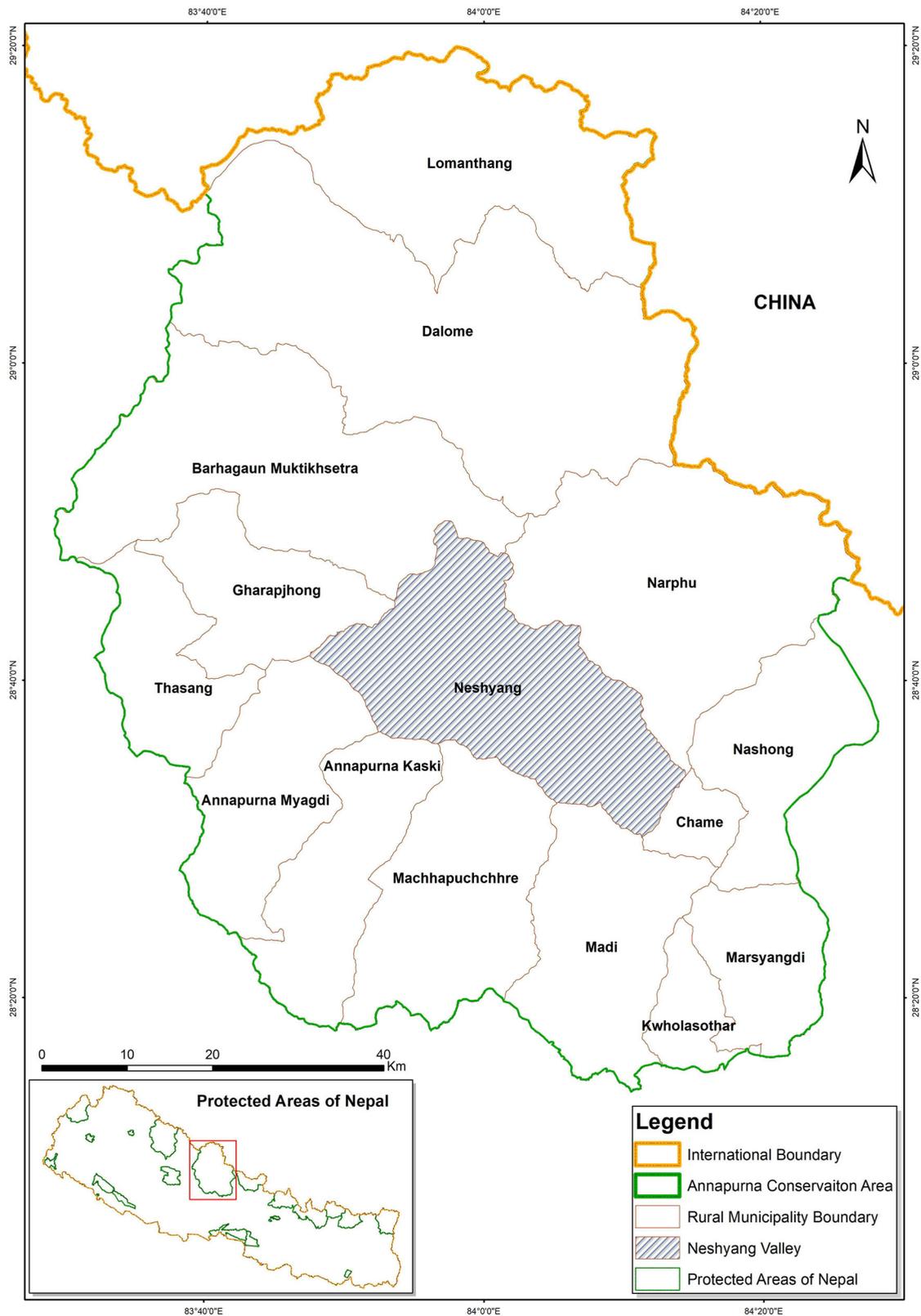


Figure 1. Study Area; Neshyang Valley located in Annapurna Conservation Area, Nepal.

$p < 0.01$). Regarding the degree of preference (Figure 4), musk deer preferred to locate the latrine in fir forest (IEI = 0.46) followed by mixed forest (IEI = 0.27) but they mostly avoided both blue pine forest (IEI = -0.55) and open areas (IEI = -0.55).

3.2. Factors affecting the distribution of musk deer latrine sites

Slope, distance from water, forest types, shrub density and tree density were the major factors affecting the distribution of

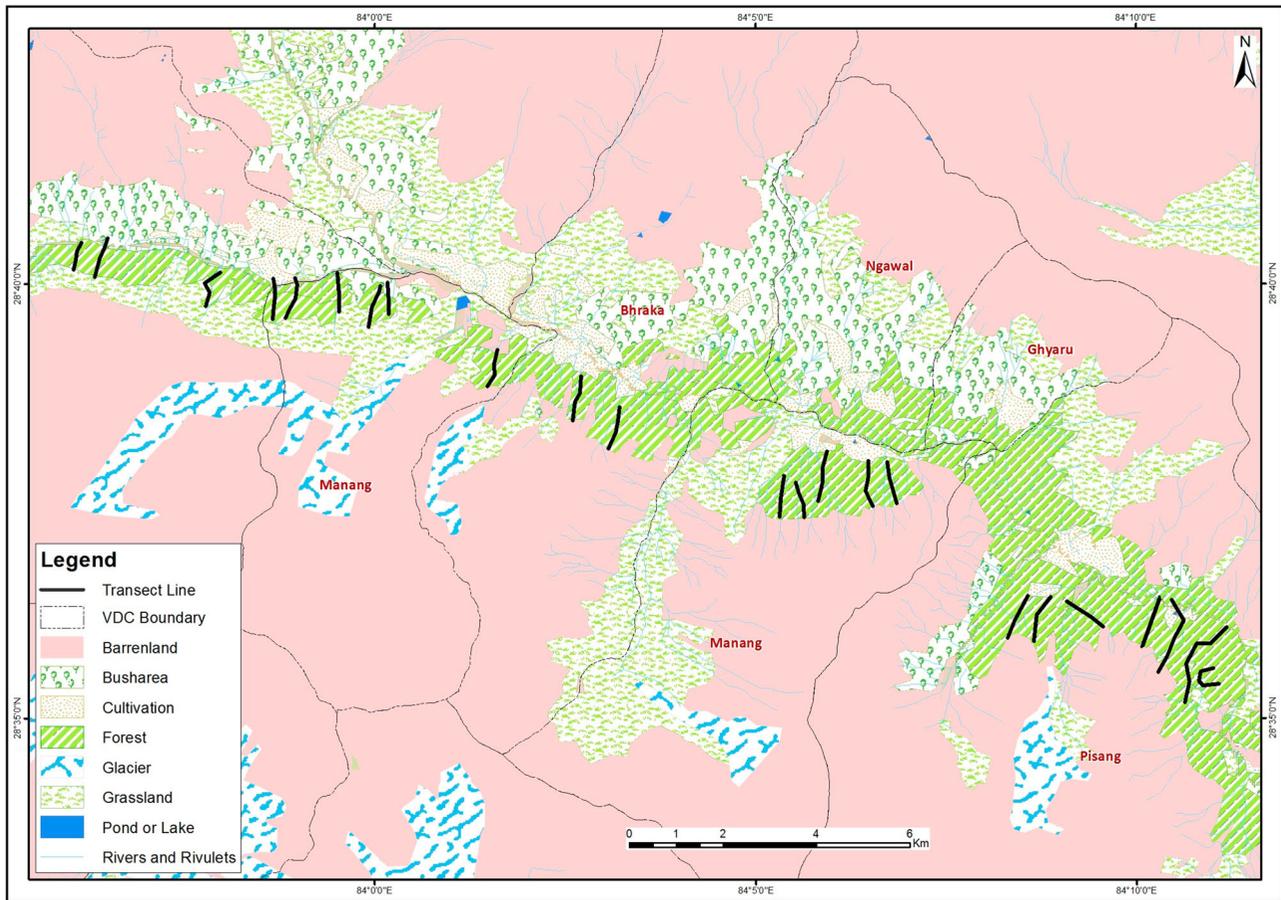


Figure 2. Layout of transects in the Neshyang Valley, Annapurna Conservation Area, Nepal.

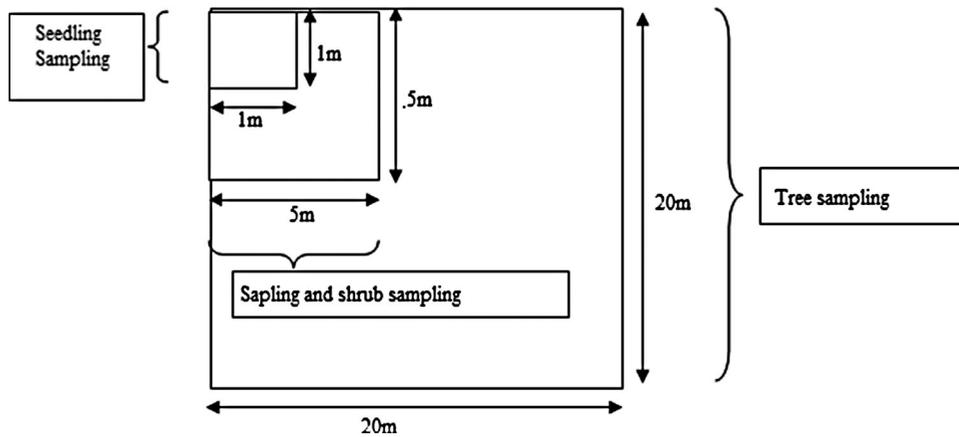


Figure 3. Layout of quadrats within the transects.

musk deer latrines. Among them, distance from water and mixed forest were the most influential variables (Table 1).

3.3. Distribution of latrines along altitudinal gradient

Latrines of musk deer were recorded from the altitudinal range 3200 to 4200 m. The probability of latrine occurrence decreases gradually as the altitude increases and vice versa (Figure 5). Latrine sites distributed sparsely at lower altitudes (> 3200 m ≤ 3600 m asl) and altitudes (> 4000 m ≤ 4200 m

asl), but densely distributed between 3800 m and 4000 m asl.

3.4. Association of musk deer latrine with the plant composition

Altitude, slope, distance from water, tree density and shrub density are the factors that are associated with the species composition of woody plant species (i.e. trees, shrubs, saplings and seedlings). However, latrines were not found to

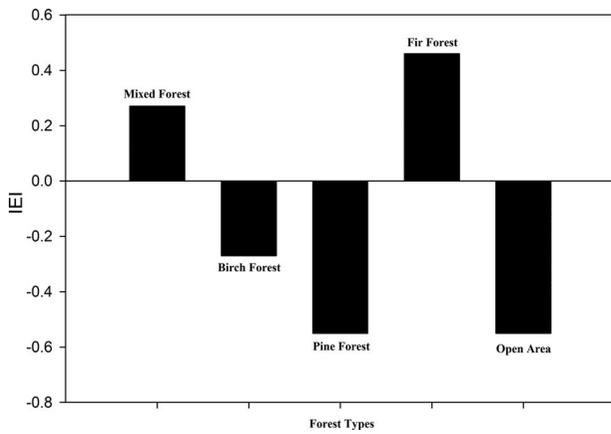


Figure 4. Degree of preference of latrine site selection by musk deer with respect to forest types based on the IJv electivity index.

Table 1. The results of reduced GLM model selected based on AIC criterion, showing the effect of slope, distance to water, forest types, shrub density and tree density on the distribution of latrines.

| Variables | Estimate | Std. Error | Z value | p value |
|---------------------|----------|------------|---------|---------|
| Intercept | 0.99 | 3.63 | 0.27 | 0.78 |
| Slope | 0.43 | 0.38 | 1.12 | 0.25 |
| Distance from water | -0.08 | -0.14 | -2.14 | <0.05 |
| Blue pine Forest | -3.31 | -3.33 | -0.99 | 0.31 |
| Mixed Forest | 1.81 | 2.70 | 2.46 | <0.01 |
| Open area | -1.22 | 3.63 | -1.24 | 0.21 |
| Fir Forest | 1.49 | 1.28 | 1.16 | 0.24 |
| Shrub density | -0.62 | 0.86 | -0.71 | 0.47 |
| Tree density | -3.60 | 3.40 | -1.06 | 0.28 |

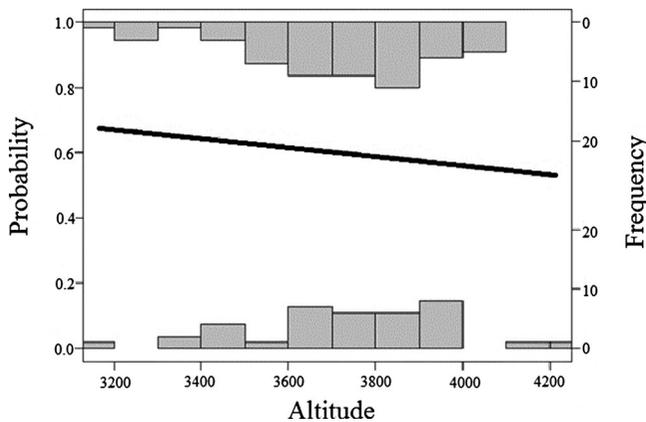


Figure 5. Predictive probability of latrine occurrence along the altitude gradient.

be associated with the composition of different kinds of plant species (Table 2).

Shrub density, tree density and altitude are mostly associated with the first gradient of CCA biplot (Figure 6). On the other hand, slope and distance from water are associated with the second gradient of CCA biplot. Altitude is commonly associated with *Betula utilis*, *Salix* spp., and seedlings of *Betula utilis* and *Abies spectabilis*. Slope is associated with seedlings of *Salix* spp. and *Pinus wallichiana*, tree density is associated with *Juniperus squamata* and *Pinus wallichiana*. Distance from water is associated with shrub species i.e. *Cotoneaster microphyllus* and *Viburnum grandiflorum* and shrub density is associated with *Rhododendron anthopogan* and *Rosa* spp.

Table 2. Summary statistics of Monte Carlo permutation tests for CCA including all the biophysical variables in relation to species composition of woody plant i.e. trees, shrubs, sapling and seedling. Results are based on 499 permutations.

| Variables | F ratio | p value |
|-------------------|---------|---------|
| Altitude | 3.84 | <0.005 |
| Tree density | 2.45 | <0.005 |
| Shrub density | 2.25 | <0.01 |
| Distance to water | 1.86 | <0.01 |
| Slope | 1.66 | <0.05 |
| Aspect | 1.10 | 0.38 |
| Latrine | 1.01 | 0.45 |
| Ground cover | 0.79 | 0.70 |

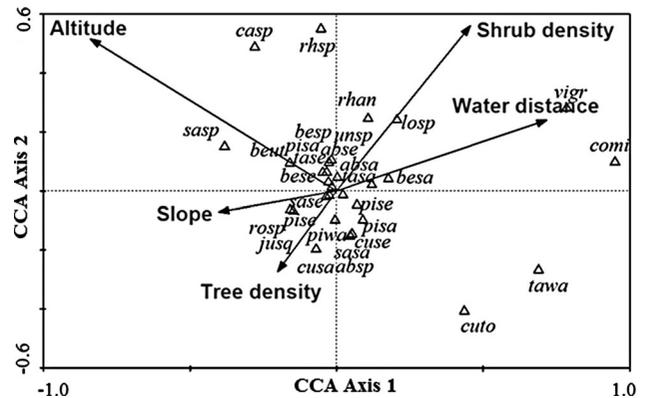


Figure 6. Species-biophysical variables biplot of CCA, showing the association of biophysical variables with the woody plant composition. The arrows indicate the biophysical variables; triangles indicate species and species abbreviated as in Appendix II.

4. Discussion

Musk deer is a solitary mammal, which uses latrines for defecation that can be found scattered throughout its habitat (Green 1987; Meng et al. 2012; Shrestha and Meng 2014; Shrestha and Moe 2015). Our study showed that fir forest is the most preferred habitat for defecation whereas both blue pine forest and open areas are the most avoided habitats. Latrine avoidance by musk deer for defecation is based on the negative value of IJv; however, the negative value of IJv does not indicate that the habitat totally avoided by the species (Steinheim et al. 2005). They use latrine sites occasionally in blue pine forest and open areas. Aryal et al. (2010) described fir forest and birch forest as the most preferable habitats in Sagarmatha National Park whereas Shrestha and Meng (2014) showed mixed forest and rhododendron forest is the most suitable habitat in the Gaurishankar Conservation Area, Nepal. We found musk deer use the different habitats as its most preferred habitats depending on site condition. Forest type is not only factor that determines habitat utilization by musk deer. Habitat utilization also depends on variables; the animal’s activity, time of day and season in response to the availability of cover, food, shelter (Green and Kattel 1997).

Musk deer are generally found in the altitudinal range from 2500 m to 4800 m (Timmins and Duckworth 2015). However, Subedi et al. (2012) showed that the altitude of 3600–3800 m asl is the most preferred altitudinal range. Ilyas (2014) showed that most of the latrines occurred from 4200 m down to

2500 m asl. However, our study did not show any significant effect of altitude on the distribution of latrines. This is because latrines are scattered throughout the deer's habitat. The probability of latrine occurrence is higher as the altitude increases between 3800 and 4000 m asl, thereafter it declines. If we compare this range of latrine occurrence with the types of forest present in the study area, latrine presence lies within the range of mixed forest and fir forest. Moreover, the availability of water was also found to be an influencing factor in constructing latrines by musk deer. We found that the latrine did not have any significant relation to the composition of woody plant species. However, altitude, distance from water, slope, tree density and shrub density were found to be associated with woody plant composition. Similarly, Shrestha and Moe (2015) also showed that there is no association of musk deer latrine with the species composition of tree, shrubs and herbs.

5. Conclusion

Musk deer use fir forest and mixed forests most frequently to develop latrines. Additionally, the presence of water nearby plays a significant role in the selection of latrine sites. Latrine distribution was found to be sparse at lower altitudes where blue pine was dominant and at higher altitudes near the tree line, and densely distributed between 3800 and 4000 m. Hence, fir forest and mixed forest with a nearby water source between the altitudinal ranges of 3800–4000 m are the best areas to implement conservation measures to save the deer and its habitat effectively. The first step of conservation actions is to prepare local level conservation strategic plan which must contain anti-poaching activities integrated with advance tools, such as SMART (Spatial Monitoring and Report Tool) patrolling and camera trapping, public awareness and protection of forest preferred by musk deer.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix I. Relationships between latrines and biophysical variables aspect, altitude, slope, distance from water, location of latrine, forest type, shrub density, ground cover and tree density tested with GLM. Resulting models selected by a 'step-down' approach are ranked according to AIC. The final model is in printed bold.

| Variables | AIC |
|---|---------------|
| Aspect, altitude, slope, distance from water, latrine location, foresttype, shrubdensity, ground cover, treedensity | 138.28 |
| Aspect, altitude, slope, distance from water, forest type, shrubdensity, ground cover, treedensity | 136.27 |
| Aspect, altitude, slope, distance from water, forest type, shrubdensity, treedensity | 134.28 |
| Altitude, slope, distance from water, forest type, shrubdensity, treedensity | 133.56 |
| Slope, distance from water, forest type, shrubdensity, treedensity | 132.38 |

Appendix II. Species and their abbreviation, plant groups and family found in the quadrats

| Name of Species | Family | Plant types | Abbreviation |
|---------------------------------|----------------|-------------|--------------|
| <i>Pinus wallichiana</i> | Pinaceae | Tree | piwa |
| <i>Betula utilis</i> | Betulaceae | Tree | beut |
| <i>Abies spectabilis</i> | Pinaceae | Tree | absp |
| <i>Picea smithiana</i> | Pinaceae | Tree | pism |
| <i>Cupressus torulosa</i> | Cupressaceae | Tree | cuto |
| <i>Taxus wallichiana</i> | Taxaceae | Tree | tawa |
| <i>Salix</i> sp. | Salicaceae | Tree | sasp |
| <i>Berberis</i> sp. | Berberidaceae | Shrub | besp |
| <i>Juniperus squamata</i> | Cupressaceae | Shrub | jusq |
| <i>Rhododendron anthopogon</i> | Ericaceae | Shrub | rhan |
| <i>Caragana</i> sp. | Fabaceae | Shrub | casp |
| <i>Lonicera</i> sp. | Caprifoliaceae | Shrub | losp |
| <i>Rosa</i> sp. | Rosaceae | Shrub | rosp |
| <i>Cotoneaster microphyllus</i> | Rosaceae | Shrub | comi |
| <i>Viburnum grandiflorum</i> | Sambucaceae | Shrub | vigr |
| <i>Hydrangea species</i> | Hydrangeaceae | Shrub | hysp |
| <i>Robus biflorus</i> | Rosaceae | Shrub | robi |
| <i>Rhododendron_spp</i> | Ericaceae | Shrub | rhsp |
| Unidentified_spp | - | Shrub | unsp |
| <i>Pinus</i> sapling | Pinaceae | Sapling | pisa |
| <i>Betula</i> sapling | Betulaceae | Sapling | besa |
| <i>Abies</i> sapling | Pinaceae | Sapling | absa |
| <i>Picea</i> sapling | Pinaceae | Sapling | pisa |
| <i>Cupressus</i> sapling | Cupressaceae | Sapling | cusa |
| <i>Taxus</i> sapling | Taxaceae | Sapling | tasa |
| <i>Salix</i> sapling | Salicaceae | Sapling | sasa |
| <i>Pinus</i> seedling | Pinaceae | Seedling | pise |
| <i>Betula</i> seedling | Betulaceae | Seedling | bese |
| <i>Abies</i> seedling | Pinaceae | Seedling | abse |
| <i>Picea</i> seedling | Pinaceae | Seedling | pise |
| <i>Cupressus</i> seedling | Cupressaceae | Seedling | cuse |
| <i>Taxus</i> seedling | Taxaceae | Seedling | tase |
| <i>Salix</i> seedling | Salicaceae | Seedling | sase |