INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 5, Issue 4, October-December 2014: 535-546 www.ijcs.uaic.ro

SPRING HABITAT PREFERANCE, ASSOCIATION AND THREATS OF HIMALAYAN MUSK DEER (MOSCHUS LEUCOGASTER) IN GAURISHANKAR CONSERVATION AREA, NEPAL

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Abstract

This study conducted in Gaurishankar Conservation Area, Nepal aimed to determine the habitat preferred by musk deer during spring season, assess biophysical factors associated with the musk deer habitat and identify the current conservation threats prevalent in the area. We randomly selected 69 quadrates representing all the habitat types and recorded all biophysical variable related to musk deer habitat. Our study revealed that musk deer mostly preferred to inhabit in the mixed forest but avoid alpine scrub during spring season. Habitat types, fuelwood and timber cutting, rock cover, litter cover and distance to settlements affected on selecting the habitat of musk deer. Unlike species composition of trees and forbs, the certain species of shrubs was mostly associated with habitat of musk deer. Poaching and human induced habitat alterations were the main causes for reducing population of musk deer.

Keywords: *Habitat preference; Plant composition; Poaching; Musk deer; Nepal.*

Introduction

Habitat preference is a significant behavior since; it determines the regime of natural selection that affects adaptation to the environment [1]. It is a function of environmental variables which may lead to the development of resource selection function [2, 3]. A resource selection can be permanently or temporarily depleted by the activity of animal. Besides, habitat preference is the disproportionality between usage and availability [3]. Animals are subject to competing demands and motivations such as needs to acquire food, find mates, rear offspring, defend limited resources and avoid predators. In order to meet these objectives, their choice of habitat selection is affected and adjusted their location in space [4]. Most of wildlife managers have been focused on habitat selection for management of populations and predicting effects of habitat disturbances [5]. Besides, it can be used as a tool to understand how environment, behavior and fitness are linked [6, 7].

Himalayan musk deer (*Moschu leucogaster*) is the endangered and protected mammal of Nepal found in the sub-alpine and alpine vegetation of the Himalayan region at an altitude of 2500 to 4500m [8]. They prefer to inhabit steep, forested or shrub-covered slopes, mainly in the sub-alpine zones of mountain regions. Dense undergrowth of rhododendron, bamboo and other

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shrubs form the typical habitat [8, 9]. It has been commercially exploited by poachers for its valuable musk pod, which is usually excised after killing the deer [10, 11]. Due to the interaction between natural forces and human disturbances, habitats of musk deer are fragmented and isolated [12]. Owing to excessive hunting and habitat degradation, population of musk deer has been declining dramatically, which lead them to be endangered or even extinct in some areas [11]. Though Himalayan musk deer (hereafter musk deer) is classified as Endangered (EN) in IUCN (International Union for Conservation of Nature) Red List of threatened species; appendix I of CITES (Convention on International Trade of Endangered flora and fauna) [13], only few studies on this species has been done in Nepal. This study aimed to analyze the most preferred habitat by the musk deer, the biophysical factors associated within its habitat and current conservation threats prevalent in newly declared Gaurishankar Conservation Area.

Materials and Methods

Study area

Gaurishankar Conservation Area (GCA) declared as "Conservation Area" in January 2010, is located in the High mountain region of Nepal and entrusted its management for a period of 20 years to National Trust for Nature Conservation (NTNC) in July 2010. It has an area of 2179 km^2 covering Ramechhap, Dolakha and Sindhupalchok districts which connect Langtang National Park and Sagarmatha National Park [14]. This conservation area consists of 35.38% forestland, 9.76% shrubland and 8.79% grassland respectively. GCA comprises 16 major vegetation types while in faunal diversity it includes 34 species of mammals, 16 species of fishes, 10 species of amphibians, 8 species of lizards, 14 species of snakes and 235 species of birds [15].

This study included the surrounding areas of Risan Gumbo Himal from Hum danda to Gumbo danda at Lapche of Lamabagar VDC of Dolkha district which encompasses an elevation range of 3500-4200m and lies between 28° 6′ 7″ and 28° 7′ 3″ N latitude and 86° 9′ 59″ and 86 ° 10′ 52″ E longitude (Fig. 1).

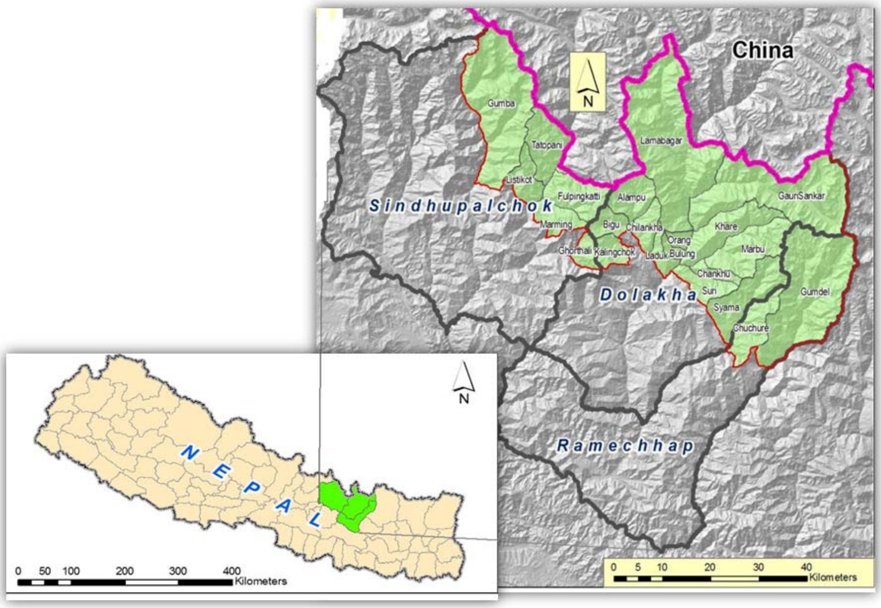

Fig. 1. Map showing the study area

GCA comprises sub-tropical chir pine forest to alpine scrubs and due to high variation in climate and altitude, the conservation area harbors a wide range of flora and fauna [15]. This study site comprised of 4 types of vegetation. Betula forest which is solely dominated by *Betula utilies*, mixed forest consisted of mixed species of *Betula utilies, Abies spectabilies, Sorbus* spp.*, Rhodondendron campanulatum, salix* spp. and *Juniperus indica*, rhododendron forest consists of purely of its low stature *Rhodondedron campanulatum forest* and alpine scrub which is mostly dominated by rhododendron shrubby species like *Rhododendron lepidotum, Rhdododendron ciliatum* and *Rhododendron anthopogan.* Among endangered species found in GCA are snow leopard *(Panthera uncia)*, clouded leopard *(Neofelis lupus)*, leopard cat (*Felis benghalensis*), red panda *(Ailurus fulgens,)*, wolf *(Canis lupus), and* Chinese Pangolin (*Manis pentadactyla*). Besides, the park is well known as one of the prime habitats for musk deer, the focal species in this study [15].

Field sampling

A preliminary field investigation was conducted to assess vegetation types, physiographic condition, bio-physical features and the potential areas occupied by musk deer. The field study was carried out in April-May of 2013. Following the preliminary survey, a total of 69 quadrates of size 10x10m were randomly positioned in the study area. Inside the 10x10m quadrates, one 5x5m plot was laid out randomly and two 1x1m subplots were laid out randomly inside 5x5m plot and two 1x1m subplots outside the 5x5m plots but inside 10x10m quadrate (Fig. 2).

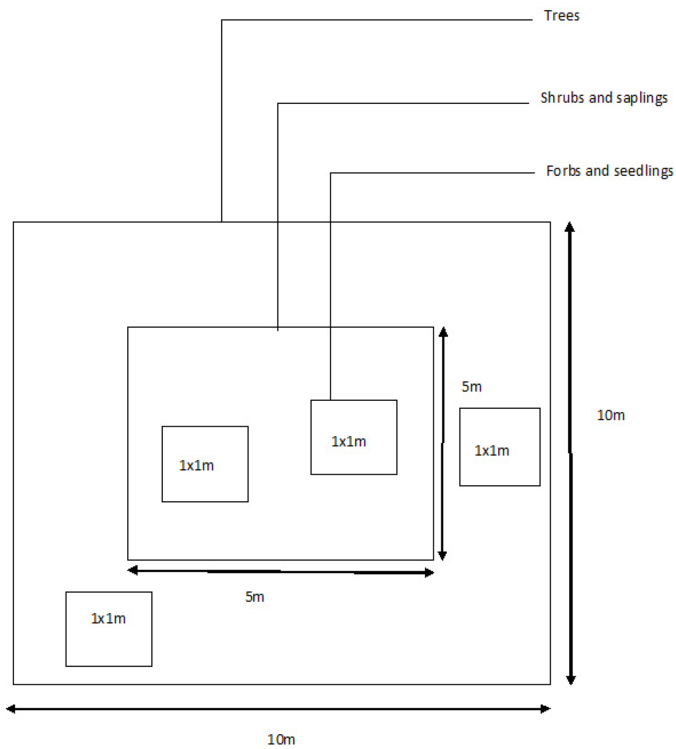

Fig. 2. Sampling design showing a quadrate (10x10m), plot (5x5m) and subplots (1x1m).

Trees (dbh > 10cm) were identified and measured in 10x10m quadrates. Shrubs (woody plant other than tree species) and saplings (trees > 1m in height and/or < 10cm dbh) were recorded in 5x5m plots. Forbs and seedlings (trees < 1m in height) were identified and recorded in the 1x1m subplots. Latrine sites, slope, aspect, latitude, longitude, altitude, cattle grazing intensity, firewood and timber cutting, rock cover, litter cover, distance to settlements, edge distance, distance to water, road and rock cover were also recorded. All coverage data were taken in percentage. Distance from water, road, edge and settlements were calculated using topographical map and field measurements. Cattle grazing intensity and firewood and timber cutting were separately assessed in the ordinal scale from 0 to 4. Cattle grazing intensity was assessed using cattle dung as a proxy, 0 = no cattle dung, 1 = cattle dung in one of four 5x5m within a quadrate, 2 = cattle dung in two of four 5x5m within a quadrate, 3 = cattle dung in three of four 5x5m within a quadrate, 4 = cattle dung in all 5x5m within a quadrate. Similarly for firewood and timber cutting, 0 = no firewood and timber cutting, 1 = firewood and timber cutting scars in one of four 5x5m within a quadrate, 2 = firewood and timber cutting scars in two of four 5x5m within a quadrate, 3 = firewood and timber cutting scars in three of four 5x5m within a quadrate, 4 = firewood and timber cutting scars in all 5x5m within a quadrate.

Questionnaire survey

Key person, locals and project staffs were interviewed and discussed about the musk deer. The questionnaires based on distribution, threats and conservation of musk deer were asked in order to determine conservation threats and its issues regarding musk deer. Disturbances in the habitat of musk deer such as signs of cattle grazing and their dung deposition, human trampling and their activities such as firewood and timber cutting, cattle herding, left tree stumps, traps were also analyzed in the field visits.

Data analysis

Habitat preference of musk deer was calculated by using Ivlev's electivity indices [16] i.e IEI = U–A/U+A, where U is the proportion of use of a habitat type and A is the availability of that type. Thus, an IEI of positive value indicates preference of a habitat type, 0 denotes use exactly according to availability and negative value denotes avoidance. Out of 69 quadrates in our study, 13 quadrates were considered as used habitat of various types due to presence of musk deer latrines and remaining 56 were considered as available habitat of those types.

A generalized linear model (GLM) was used to analyze the relationship between the latrine site as habitat proxy and the explanatory variables (slope, distance to water, distance to human settlements, distance to road, distance to edge, rock cover, litter cover, relative radiation index (RRI), altitude, aspect, cattle grazing intensity, firewood and timber cutting, and tree density) using the statistical software R 3.0.3 [17]. The relative radiation index was calculated by using formula $\{\cos(180° - \Omega)*\sin\beta*\sin Ø\} + \{\cos\beta*\cos Ø\}$ where Ω is aspect, β is the slope and Ø is the latitude of each site [18-21]. All the variables were checked for collinearity prior to analysis. Latrine sites were treated as a binomial variable (presence or absence) with a logit link [22]. The best fitted model was selected based on Akaike Information Criterion (AIC) by automatic "step-wise" model selection approach (both directions).

A canonical correspondence analysis (CCA) was performed using CANOCO 4.5 software package to evaluate species composition of trees, shrubs and forbs respectively in relation to explanatory variables (latrine sites, slope, aspect, distance to water, distance to human settlement, distance to road, rock cover, litter cover, relative radiation index, altitude, cattle grazing intensity, firewood and timber cutting). In the case of seedling and sapling, the number of individual of tree species were extrapolated to $100m^2$ in order to make the uniform size of the tree, sapling and seedling. All the species data were transformed to logarithm and manual Monte Carlo permutation tests based on 499 permutations were performed and only the significant variables ($p < 0.05$) were included in the final analysis [23].

Results

Habitat preference

There was significant difference on the proportion of habitat used by musk deer during spring season ($\chi 2$ = 28.82, df = 3 and p = <0.001. Looking at the strength of the habitat preference (Fig. 3), musk deer preferred mostly the mixed forest (IEI = 0.24), closely followed by Rhododendron forest (IEI = 0.17)) whereas Alpine scrub (IEI = -0.07) followed by Betula forest (IEI = -0.47) were mostly avoided by the musk deer.

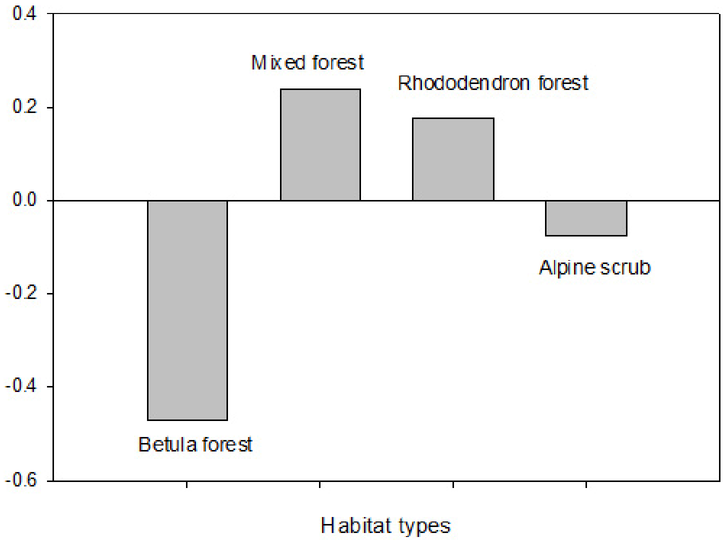

Fig. 3. Strength of habitat preference by Himalayan musk deer measured by Ivlev's electivity index

Association of biophysical variables with the habitat of musk deer

Habitat types, fuelwood and timber cutting, rock cover, litter cover and distance to settlements affected on the selection of the habitat of musk deer where mixed forest, distance to settlements and litter cover were the most significant influencing variables (Table 1).

Table 1. The results of reduced model of GLM selected based on AIC criterion, showing the effect of habitat types, fuelwood and timber cutting, rock cover, litter cover and distance to settlements on the habitat of musk deer.

Variables	Estimate	Std. error	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
Fuelwood and timber cutting	-0.84	0.45	-1.87	<0.05
Distance to settlements	0.002	0.001	1.53	0.12
Rock cover	0.02	0.01	1.71	0.08
Litter cover	-0.14	0.06	-2.20	<0.05

Latrine site was not significantly correlated with species composition of trees, and forbs but it had a significant relation with species composition of shrub (Table 3). Aspect, cattle grazing intensity, slope and RRI had significant effect on the species composition of trees as shown in CCA biplot diagram (Fig.4a). Sapling and tree of *Juniperus indica* mostly correlated with cattle grazing intensity, *Betula utilis* correlated with RRI, Rhododendron seedling and

Sorbus lanata correlated with the aspect and tree and sapling of *Rhododendron campanulatum* had close correlation with the slope. Rock cover and fuelwood and timber cutting were significantly related with the first gradient whereas RRI, aspect, altitude and latrine sites of musk deer correlated with the second gradient of species composition of shrub community as show in CCA biplot diagram (Fig 4b). Along with musk deer latrines, rock cover, RRI, aspect, altitude and fuelwood and timber cutting had significant correlation with the species composition of shrub community. *Rhododendron ciliatum, Berberis aristata, Rhododendron anthopogan and Cassiope fastiagata* were mostly associated with the latrine sites whereas *Rhododendron lepidotum*, *Juniperus recurva*, *Prunus cornuta* and *Caragana gerardiana* were negatively correlated with the latrine sites.

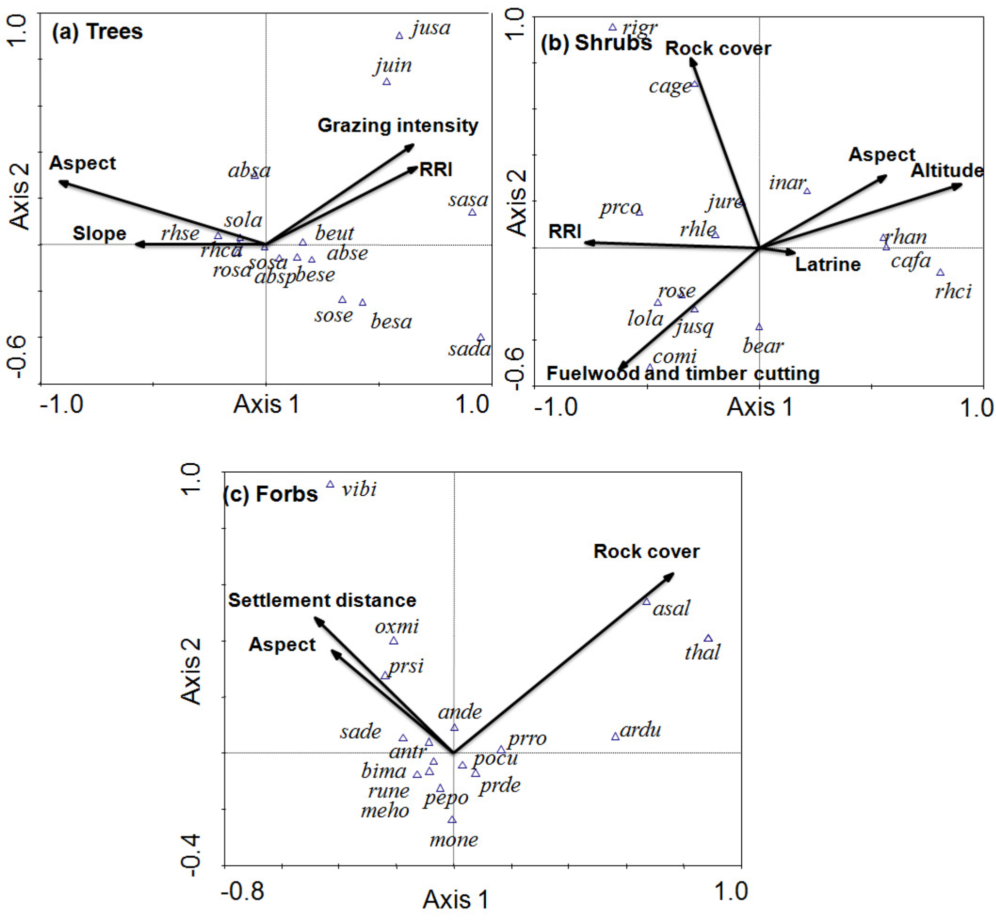

Fig. 4. The species-environmental variables biplot of CCA showing the relationship of environmental variables and the species composition with environmental variables selected by the Monte Carlo permutation tests in (a) Trees, (b) Shrubs and (c) Forbs. The arrows indicated the environmental variables, triangle indicated species and species abbreviation as in Table 2.

Distance to settlements, rock cover and aspect were only the variables affecting the species composition of forbs (Fig. 4c). Distance to settlements and aspect correlated with

Oxytropis microphylla, Primula sikkimensis, *Saussurea deltoidea* and *Anaphalis triplinervis* whereas the rock cover mostly related with *Aster albescens and Thalictrum alpinum.*

Table 2. Table showing the species and their abbreviation, family and plant groups

Name of species	Family	Abbreviation	Plant groups
Betual utilis	Betulaceae	beut	Tree
Rhododendron campanulatum	Ericaceae	rhca	Tree
Abies spectabilis	Pinaceae	absp	Tree
Sorbus lanata	Rosaceae	sola	Tree
Juniperus indica	Cupressaceae	juin	Tree
Salix daltoniana	Salicaceae	sada	Tree
Rhododendron sapling	Ericaceae	rosa	Tree
Betula sapling	Betulaceae	besa	Tree
Abies sapling	Pinaceae	absa	Tree
Sorbus sapling	Rosaceae	sosa	Tree
Salix sapling	Rosaceae	sasa	Tree
Juniperus sapling	Cupressaceae	jusa	Tree
Rhododendron seedling	Ericaceae	rhse	Tree
Abies seedling	Pinaceae	abse	Tree
Sorbus seedling	Rosaceae	sose	Tree
Betula seedling	Betulaceae	bese	Tree
Rhododendron lepidotum	Ericaceae	rhle	Shrub
Cassiope fastigiata	Ericaceae	cafa	Shrub
Berberis aristata	Berberidaceae	bear	Shrub
Rhododendron anthopogon	Ericaceae	rhan	Shrub
Incarvillea arguta	Bignoniaceae	inar	Shrub
Rhododendron ciliatum	Ericaceae	rhci	Shrub
Juniperus squamata	Cupressaceae	jusq	Shrub
Rosa sericea	Rosaceae	rose	Shrub
Caragana gerardiana	Fabaceae	cage	Shrub
Prunus cornuta	Rosaceae	prco	Shrub
Juniperus recurva	Cupressaceae	jure	Shrub
Cotoneaster microphyllus	Rosaceae	comi	Shrub
Lonicera lanceolata	Caprifoliaceae	lola	Shrub
Ribes griffithii	Grossulariaceae	rigr	Shrub
Primula denticulata	Primulaceae	prde	Forb
Primula rotundifolia	Primulaceae	prro	Forb
Primula sikkimensis	Primulaceae	prsi	Forb
Bistorta macrophylla	Polygonaceae	bima	Forb
Anaphalis triplinervis	Asteraceae	antr	Forb
Viola biflora	Violaceae	vibi	Forb
Primula gembeliana	Primulaceae	prge	Forb
Potentilla cuneata	Rosaceae	pocu	Forb
Artemisia dubia	Asteraceae	ardu	Forb
Anemone demissa	Rananculaceae	ande	Forb
Thalictrum alpinum	Ranunculaceae	thal	Forb
Aster albescens	Asteraceae	asal	Forb
Pedicularis poluninii	Scrophulariaceae	pepo	Forb
Morina nepalensis	Dipsacaceae	mone	Forb
Meconopsis horridula	Papaveraceae	meho	Forb
Oxytropis microphylla	Fabaceae	oxmi	Forb
Saussurea deltoidea	Asteraceae	sade	Forb
Rumex nepalensis	Polygonaceae	rune	Forb

Threats to musk deer

The major threats for the musk deer were poaching and anthropogenic disturbances especially NTFPs collection, traditional practice of cattle herding, firewood cutting and timber harvesting. Local communities are heavily dependent on forest resources for their subsistence. They lack sustainable forest management practices and their main occupation is animal husbandry which has reduced the forest resources relentlessly. Besides, habitat of musk deer lies between cross border of china and Nepal which stimulated in the poaching of musk deer. Owing to lack of any government conservation actions and local community participation for biodiversity conservation at cross border lead to further threatening of musk deer in the conservation area.

Table 3. Summary statistics of Monte Carlo permutation tests including all the environmental variables in relation to species composition in trees, shrubs and forbs. Results are based on 499 permutations.

Variables	Plant community					
	Trees		Shrubs		Forbs	
	F ratio	P value	F ratio	P value	F ratio	P value
Rock cover	1.66	0.08	3.54	<0.01	2.77	<0.05
Litter cover	0.80	0.63	1.29	0.22	0.96	0.50
Altitude	0.96	0.47	5.4	<0.01	1.42	0.17
Slope	2.10	<0.05	1.32	0.21	0.92	0.52
Aspect	7.31	<0.01	2.48	<0.01	1.85	<0.05
Firewood and timber cutting	0.70	0.73	2.21	<0.05	1.07	0.39
Distance to settlements	1.16	0.27	1.33	0.20	1.76	<0.05
Distance to roads	1.47	0.14	1.38	0.18	0.81	0.63
Distance to water	1.04	0.44	0.84	0.56	1.11	0.33
Distance to edge	1.36	0.21	0.80	0.64	1.11	0.33
RRI	2.51	<0.01	2.34	<0.01	1.44	0.14
Latrine	1.32	0.21	1.87	<0.05	0.93	0.51
Grazing intensity	2.91	<0.01	0.80	0.64	1.01	0.41

Discussion

A study conducted in Sagarmatha National Park by Aryal et al. [24] depicted that musk deer preferred Abies and Betula forest as their prime habitat. However our study contrasted with them and showed that the musk deer mostly preferred to live in mixed forest followed by the Rhododendron forest. Besides, this study showed that the Betula forest was the least preferred among the habitat types. Negative IEI does not mean habitat is totally unsuitable [25]. This may be probably due to large portion of mixed forest is abundant in these areas and spend their considerable time in these habitat for foraging, defecating and other activities which caused it avoidance in terms of use in proportion to availability. Similarly, as natural and anthropogenic factors change the availability of habitats, particular habitat preference by given animals may be altered [26].

Our study revealed that habitat selected by musk deer was affected by the habitat types, fuelwood and timber cutting, distance to settlement, rock and litter cover where mixed forest, distance to settlement and little cover were the most influential variables. Simultaneously, among various plant forms, certain shrub species was significantly correlated with the habitat of musk deer. This is also supported by the study conducted by Meng et al. [27] in western China. According to them, the shrub characteristic, food availability and concealment factor were the most influential variables affecting on the selection of habitat of Alpine musk deer (*Moschus* *sifanicus*). Yang et al. [28] also reported cattle and human disturbances are major habitat degradation factors of musk deer in China. A study conducted by Shrestha [29] in Langtang National Park, showed that musk deer generally located their latrine away from the human disturbance such as timber and fuelwood utilization activities, cattle grazing, human settlements and with higher rocky areas. Musk deer used undisturbed place for latrine defecation in order to avoid detection from their predator [30]. Habitat selection by animal may be affected while fulfilling the ecological needs of food and water resources, avoiding from predator, mating and breeding [4]. It may be fact that musk deer selected their habitat in mixed forest for fulfilling their ecological needs such as defecation, avoiding predator, and finding mates due to the undisturbed and larger unfragmented area.

There was no significant correlation of latrine with the species composition of trees and forbs but some shrub species was correlated with the latrine sites of musk deer. Mostly effects of variables such as aspect, RRI and anthropogenic effect such as cattle grazing, settlement distance and firewood and timber cutting were detected on the species composition of various plant groups. Variables influencing the species composition vary with the plant community. This study depicted that the species composition of all the community were highly influenced by human activities such as firewood and timber cutting, distance to settlements, and cattle grazing. Hayes and Holl [32] also revealed that cattle grazing had a significant effect on the species composition of native annual forbs in California coastal prairie. Grazing changes the species composition by the selective removal of species [32]. The plant composition changes with response to many abiotic and biotic factors [33]. Altitude and aspect, slope affect on the soil temperature ultimately influence in the length of growing season [34]. A study conducted in Pakistan by Qureshi et al. [35] revealed that certain species of tree, shrub and forbs were associated with musk deer habitat and Aryal et al. [24] had also similar results in Sagarmatha National Park however our study did not reveal any such association with any species of trees and forbs but in the case of shrubs, musk deer latrine had close association with species composition of *Rhododendron ciliatum, Berberis aristata, Rhododendron anthopogan and Cassiope fastiagata.* This probably may be due to the fact that while selecting habitat for defecation they used bushy area in order to dodge from the predator and human beings. Since musk deer is shy in nature [10] and some mammals used their latrine in distant place to avoid parasites transmission [36] and avoid detection from predators [31].

This study area lies between the transition border between China and Nepal which makes easy for poacher to kill musk deer. The principal reason is for demand of the musk which is secreted by males. It has been used in the perfume industries and traditional medicines for a long period of time [37, 11]. In Russia and China, hunting and poaching are considered the prime causes for the reduction of musk deer [11, 37, 38]. Simultaneously, population of musk deer is declining due to poaching in Nepal, it has been estimated that for every male deer that yields one musk pod, four deer are killed [39]. Traditional cattle herding practices is the mainstay economy of local community for their subsistence in these area. They kept hybrid species such Nak, Chauri, Jhopke, Dimu for animal husbandry and transferred their cattleshed according to the season. Besides, traditional open cattle grazing and unsustainable timber and fuelwood utilisation system were common practices in GCA. Unsustainable forest harvesting practices in Himalaya region lead to the subalpine and alpine vegetation in degradable condition [40]. These activities have provoked the degradation and dwindling of wildlife habitat which ultimately contribute in the reduction of musk deer population. The habitats of musk deer in the subalpine and alpine region of the Himalayas are increasingly used for harvesting firewood and as pasture land [41]. Besides, this causes the loss of the understorey vegetation which is used by musk deer for food and shelter against predators [37]. Habitat degradation is also mentioned as a key factor for drastic dwindling of musk deer in Russia, China and Pakistan [11, 37, 42]. Similarly one of studies carried out in Langtang National Park, Nepal revealed that owing to increasing use of birch and rhododendron forest for fuelwood by cheese factory, local inhabitant and tourist degraded the habitat of musk deer [43]. Similarly, Sathyakumar et al. [44] depicted that increased livestock grazing and associated impacts have caused low musk deer densities in Kedarnath Wildlife Sanctuary, India.

Conclusions

Musk deer mostly uses those habitats which are least affected by anthropogenic effects such as domestic cattle grazing, NTPFs collection, fuel and timber utilization, grass cutting. Besides, they select bushy areas and rocky outcrop more often probably for their concealment from predator and human being. Poaching and habitat induced degradation are the most prominent threats for the musk deer. So, conservation biologists, who are working with the musk deer conservation, should focus the conservation strategies prioritizing on these issues.

Acknowledgements

We are indebted to the Department of National Parks and Wildlife Conservation and National Trust for Nature Conservation for granting study permission in the Gaurishankar Conservation Area, Nepal. This project was supported by Idea Wild and Mohamed bin Zayed Species Conservation Fund (project no. 12251244).

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Received: June, 10, 2014
Accepted: October, 30, 2014