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Spatial Habitat Overlap and Habitat Preference of Himalayan Musk Deer (*Moschus chrysogaster*) in Sagarmatha (Mt. Everest) National Park, Nepal

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Abstract: The musk deer (*Moschus chrysogaster*), which is native to Nepal, China, Bhutan, and India, is an endangered species, which suffers a high level of poaching due to the economic demand for its musk pod. The World Heritage Site (WHS), Sagarmatha (Mt. Everest) National Park (SNP), provides prime habitat for this species. Our aim in this study was to perform a quantitative assessment of the habitat preferences of musk deer in SNP, and evaluate how preferred habitat might be impacted by anthropogenic activities. Results showed that the musk deer population is distributed in 131 km^2 of the park area. We recorded 39 musk deer (11 male, 16 female and 12 unidentified) in Debuche, Tengboche, Phortse Thanga, Dole, and associated areas in SNP. The musk deer in these areas preferred gentle to steep slopes with the altitudinal range of 3400-3900m and also displayed a preference for dense forest and sparse ground/crown cover. The musk deer preferred the trees-*Abies spectabilis*, *Betula utilis*, shrubs- *Rhododendron* spp., *Rosa sericea*, and herbs-*Usnea* spp. and *Rui grass*, many of which are harvested for construction and firewood. There was, in addition, a significant overlap (35%) in the habitat of musk deer and the distribution of livestock within the region. Future planning for the conservation of musk deer must take into the habitat impacts because of anthropogenic activities and livestock grazing.

Key words: Habitat use, musk deer, spatial habitat overlap, Sagarmtha (Mt. Everest) National Park (SNP)

INTRODUCTION

Musk deer (*Moschus* spp) are artiodactyls in the genus *Moschus*, the only genus of family *Moschidae*. They differ in many respects from cervids or true deer. Unlike cervids, musk deer lack antlers and facial glands, have only a single pair of teats, possess a gall bladder, a caudal gland, a pair of tusk-like teeth and, of particular economic importance to humans, a musk gland. Musk deer are shy, solitary crepuscular animals. The males are highly territorial (Kattel, 1992), and are believed to use their habitual defecation sites as social markings. A high degree of illegal hunting that is conducted to meet the commercial demand for their scent glands has put considerable pressure on musk deer populations. Habitat destruction and predation are also considered to have contributed to their decline.

Due to their unique morphological skeletal characteristics, the exact taxonomy and the number of sub species of the musk deer is still under debate. Musk deer have previously been classified in the family Cervidae, but are now generally classified within their own separate family, Moschidae (Groves and Grubb, 1987; Whitehead, 1972). While it was previously assumed that one to three species existed (Green, 1986; Groves and Grubb, 1987), there is now broad agreement over the existence of four species (Wemmer, 1998): Siberian Musk Deer (*Moschus moschiferus*) (Russia, Kazakhstan, Kyrgyzstan, China, Korea, and Mongolia); Forest Musk Deer (*M. berezovskii*) (China and Vietnam); Himalayan Musk Deer (*M. chrysogaster*) (Afghanistan, China, India, Nepal, and Pakistan); Black Musk Deer (*M. fuscus*) (Bhutan, China, India, Myanmar, and Nepal).

The Himalayan musk deer (*Moschus chrysogaster*), which is the least studied of the deer-like animals, is considered an endangered species. It appears in Appendix I of CITES (Convention on International Trade of Endangered Flora and Fauna), is listed as endangered by

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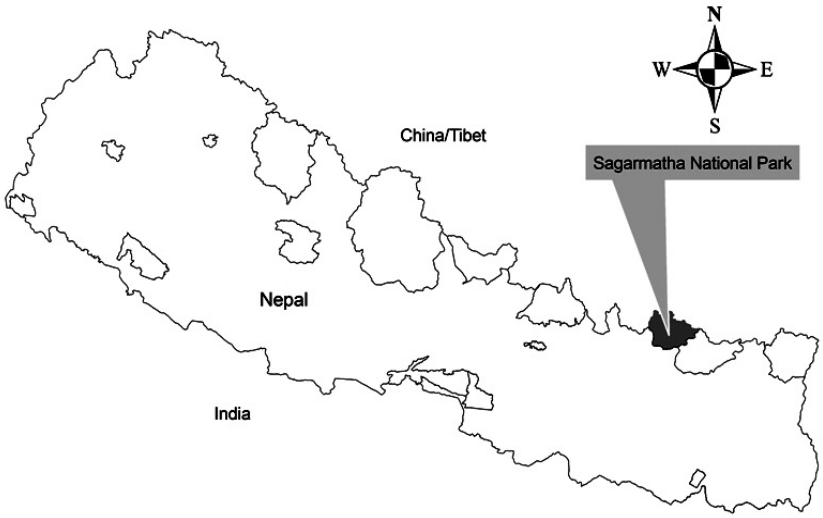

Fig. 1: Study area (Sagarmatha (Mt. Everest) National Park)

IUCN (Wang and Harris, 2008), and is protected by Nepal's National Park and Wildlife Conservation Act (1973) in Appendix I. The species is widely but discontinuously distributed across the mountainous parts of the Himalayas from about 2500 to 4500m (Green 1985). Within protected areas numbers of this species are increasing, although the recent resurgence of predatory snow leopards in the Everest region might limit their population growth rate. Sagarmatha National Park has an estimated population of 600-800 animals, with a density of up to 45per km^2. There is an estimated 500 animals in Langtang National Park, 20 in Rara National Park, and greater than 1000 in Shey-Phoksundo National Park (Kattel, 1992; Wemmer, 1998). Himalayan musk deers are also found in Annapurna Conservation Area, Kanchanjunga Conservation Area, Dhorpatan Hunting Reserve, Khaptad National Park, and Makalu-Barun National Park. Outside of protected areas they continue to decline.

An aspect of musk deer ecology that needs further study concerns the extent of habitat overlap with domestic livestock. It is well known that foraging by wild animals can be affected by habitat overlap with livestock (Kittur *et al*., 2009; Schaller, 1977) and several studies on Himalayan ungulates have shown that livestock grazing patterns have an impact on the pastoral habitat and on the distribution and abundance of wild animals (Mishra, 2001; Bagchi *et al*., 2002; Raghavan, 2003; Mishra *et al*., 2004; Namgail *et al*., 2007). In Sagarmatha National Park, domestic yak (*Bos grunniens*) and their hybrids with zebu cattle (*Bos indicus*), and horses utilize the area for grazing. They share the habitat with musk deer but, thus far, no data are available on the pattern of spatial habitat overlap between the musk deer and livestock.

Our aim in this study was to obtain a better understanding of the distribution and habitat preference of the Himalayan musk deer, and determine the extent of spatial overlap with domestic livestock. Such information will help policy makers to prepare a conservation strategy for proper management of these animals in-situ.

MATERIALS AND METHODS

Study area: The study was conducted in Sagarmatha (Mt. Everest) National Park, a World Heritage Site (WHS) of Nepal. Sagarmatha National Park is located in eastern Nepal (27°57 55"N 86°54 47"E), and contains parts of the Himalayas and the southern half of Mount Everest (Fig. 1). The park was created in 1976, and in 1979 it was inscribed as a Natural World Heritage Site (Jefferies, 1991).

The park encompasses an area of 1,148 km² and ranges in elevation from its lowest point of 2,845 m (9,335 ft) at Jorsalle to 8,850 m (29,035 ft) at the summit of Mt. Everest. Most of the park area is rugged and steep, with its terrain cut by deep rivers and glaciers. Unlike other parks, this park can be divided into four climate zones because of the range of altitudes. The climatic zones include a forested lower zone, a zone of alpine scrub, the upper alpine zone, which includes the upper limit of vegetation growth, and the Arctic zone, which is devoid of plants. Different plants and animals are found in the park at different altitudes. The park contains the upper watershed of the Dudh Kosi river basin system (Jefferies, 1991).

The park's visitor centre is located in Namche Bazaar, which is also where a company of the Nepal Army is stationed for the park's protection. The park's southern

entrance is a few hundred meters north of Monzo at 2,835 m (9,300 ft), a one-day hike from Lukla.

In the lower forested zone, birch, juniper, blue pines, firs, bamboo and rhododendron grow. Above this zone, all existing plants are dwarfed or shrubs. As the altitude increases, plant life is restricted to lichens and mosses. Plants cease to grow at about 5,750 m (18,690 ft), as this is the permanent snow line in the Himalayas.

Forests of pine and hemlock cover the lower elevations of the national park. At elevations of around 3.500 m and above, forests of silver fir, birch, rhododendron and juniper trees are found. The forests provide habitat for at least 118 species of birds, including Himalayan Monal, Blood pheasant, Red-billed chough, and yellow-billed chough. Sagarmatha National Park is also home to a number of rare species, including snow leopards, musk deer, Himalayan black bears, and red pandas. Himalayan thar, Himalayan serow, langur monkeys, hares, foxes, and martens are also found in the park (Lovari *et al*., 2009).

The field information was collected from June to July, 2008, and from June to December, 2009.

Population and distribution: Preliminary information on the distribution of musk deer was gathered through informal interviews with National Park staff, villagers, and herders. Additionally, formal discussions were carried out with villagers regarding wildlife-human relations and mask deer distribution in and outside the park.

Habitat surveys, which were carried out in each of the potential musk deer locations with the assistance of local people, consisted of searching for musk deer and for signs of the animals. Animal sightings were recorded and other signs (faecal pellets, footprints, hair, etc.) were also recorded to confirm the presence or absence of the deer. We counted musk deer when they were encountered directly or seen during visual scans using binoculars (10-45x).

Spatial habitat overlap between musk deer and livestock: The spatial habitat overlap was analyzed using methods developed by Real (1999) and Real and Vargas (1996). Two hundred and six 10m x 10m plots were randomly selected from the potential musk deer habitats (113 km^2) (further details regarding the methodology for selecting plots are described below in the Habitat Preference section). In each plot, musk deer and livestock signs were recorded and spatial habitat overlap between musk deer and livestock were compared using the Jaccard's similarity index (J) (Real, 1999; Real and Vargas, 1996), expressed as

$$J = C / (A + B - C)$$

where; A is the number of plots used by musk deer, B is the number of plots used by livestock, and C is the number of plots used by both musk deer and livestock. Associated probability for J was calculated to determine if the value for the index differed from what would be expected at random (Real and Vargas, 1996; Real, 1999), using the formula found below. In this case, the probabilities associated with Jaccard's index depend on the total number of attributes present in either of the two habitats compared (N). N was calculated as

$$N = (A + B)/(1 + J)$$

Habitat preference: Hall *et al.* (1997) defined "habitat use" as the way an animal uses (or consumes in a generic sense) a collection of physical and biological components (i.e., resources) in a habitat. Hall *et al.* (1997) defined "habitat availability"as how accessible and procurable physical and biological components of a habitat are to animals. This is in contrast to the abundance of these resources, which refers only to their quantity in the habitat, irrespective of the organisms present (Wiens, 1984).

Random sampling was used to collect different habitat parameters from the field. Habitat use and availability plots were laid out thorough out study area. Habitat use plots (U) were laid out in areas that contained musk deer signs (faecal pellets, hair, footprints, resting sites, etc). Furthermore, other parameters such as slope, altitude, crown cover, ground cover, and land features were recorded from same plots. Simultaneously, *habitat availability* plots (A) were laid out in a random direction at a distance of 100-150 m (Aryal, 2009) and the same parameters noted above were also recorded in these plots. If any signs of musk deer were found in the habitat availability plots, the plot's status was changed to " habitat use", as "habitat availability" plots should not contain any signs of musk deer.

The quadrate size was selected as suggested by Schemnitz (1980) for vegetation analysis in both the use and availability plots: $10\times10m^2$ for the tree layer, (plants above 3 m height and 5 cm DBH), $4\times4m^2$ for the shrub layer (woody plants below 3m height), and $1\times1m^2$ plots for herbs (plants up to 1 m height). The slope at each site was measured using Abney's level. Slope corrections were made using the trigonometric formula;

$$\text{Horizontal distance} = L \cos\theta \quad \text{for each plot}$$

In each plot, different parameter of the trees were recorded (e.g. DBH, height, crown, cover, ground cover, number of trees, frequency of shrubs and herbs, signs of other animals, and other anthropogenic pressures). Different animal signs were recorded in each plot to analyze any habitat overlap between other wildlife and musk deer.

Ivelv's electivity index (IV): The habitat preference of musk deer was analyzed using Ivelv's electivity index where positive values indicate preference, negative values indicate avoidance, and 0 values indicate random use. Values of this index range from -1.0 to +1.0. Following Ivlev's electivity index (IV) (hereafter Ivlev's Value (IV)), the following formula was used to calculate of habitat preference of musk deer:

IV= (U% - A%) /(U% + A%) (Aryal, 2009; Krebs, 1989; Ivelv, 1964).

where "A" represents "availability plots" and "U" represents "use plots". All together, 206 plots (103 Availability, 103 Use) were analyzed in the survey area. Habitat preference based on different habitat parameters such as altitude, slope, trees, shrubs, herbs was analyzed. In this approach, if for a habitat attribute (e.g. a species of plant) IV > 0, this indicates a preference by the animals for that attribute, while IV < 0 indicates avoidance and IV = 0 indifference. One-way ANOVA was used to test for significant levels of preference for the different habitat parameters with the null hypothesis being that all habitats are used in proportion to their availability.

Vegetation analysis: The data collected were used to calculate species richness, density, relative density, frequency, and relative frequency of the trees and shrubs in the study area by using the following relation:

Density of species

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

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

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

Relative Frequency of species

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

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.

Threats identification: Information was collected through informal discussion with local people and project staff in order to determine issues concerning musk deer conservation. Issues were assessed based on direct observation in the field. Disturbances in the habitat, signs of grazing, and felled tree stumps were recorded in the plots. Furthermore, human dependency on the forest was assessed through interviews with local people.

RESULTS

Distribution: Musk deer are distributed throughout approximately 131 km^2 of the park area (Fig. 2). We recorded 39 musk deer (11 Male, 16 Female and 12 Unidentified) in Debuche, Tengboche, Phortse Thanga, Dole, and associated areas during the field survey.

Musk deer are permanently distributed in Khumjung, Namche, and in Chaurikharka VDC's forests (e.g. Syanboche, Tengboche, Tasinga, Phortse, Dole, Kyanjuma, Pare, Khongde, and Top Danda). They are distributed mostly in three VDCs with a greater extent in Khumjung VDC followed by Namche and Chaurikharka VDC. In Khumjung VDC, musk deer have a wide range of distribution. On the route to Mt.Everest Base camp, musk deer are found in Kyanjuma, Tasinga, Phungithanga, Thulo odar, Nagdin, Tengboche up to Pangboche (3930 m). On the way to Gokyo they are found in Phortse thanga , Phortse pakha , Phortse up to Dhole (4200 m). In Namche VDC, they are found in Thop Danda, Phurte, Thamo, Pare, and up to Thame. Musk deer have been reported at Jorsalle, Kongde Danda in Chaurikharka VDC, which is outside the park boundary and called the Buffer Zone (BZ) area.

Altitude: Musk deer randomly used areas at an altitude of < 3000 m and preferred areas that gradually increased in altitude from 3000 to 3700 m then gradually increase from 3700 to 4000m. Musk deer avoided areas at an altitude of >4000m in the study area and mostly preferred areas from 3600 to 3700 m in altitude (IV = 0.11) (Fig. 3). There was a significant difference found between the use of different altitudes proportional to availabilities ($F = 14.28$, $p<0.05$).

Slope: Musk deer preferred the slope range of 26º - 35º (IV = 0.21) followed by the slope range of 35º- 45º (IV =0.12) (Fig. 4). They avoided areas with a slope below 15º while they randomly used areas with a slope above the 45º. Steep slope areas (36- 45º) were used by musk deer as a resting place while gentle slope areas (26-35º) were used for grazing. Plain slope areas (0-25º) are mostly used by livestock and are also highly influenced by human activities. Thus, the plain areas were avoided by the musk deer (IV = -0.33), as musk deer prefer to avoid interactions with livestock and humans. There was a significant difference between the use of different slopes proportional to available slopes ($F = 3.1$, $p<0.05$).

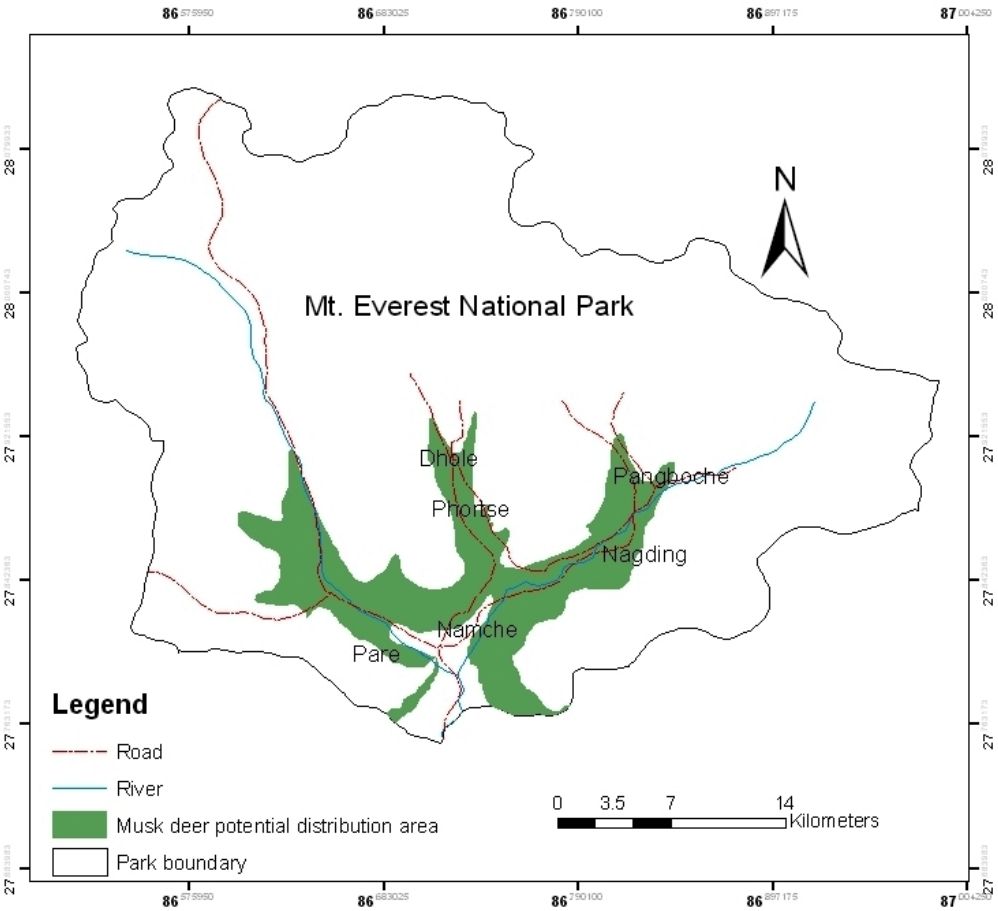

Fig. 2: Map of potential habitat of musk deer in Sagrarmatha (Mt. Everest) national park

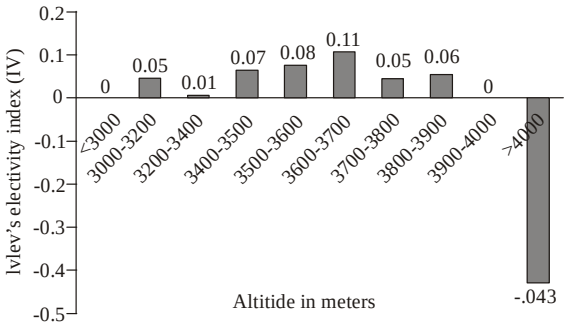

Fig. 3: Altitude preference by musk deer

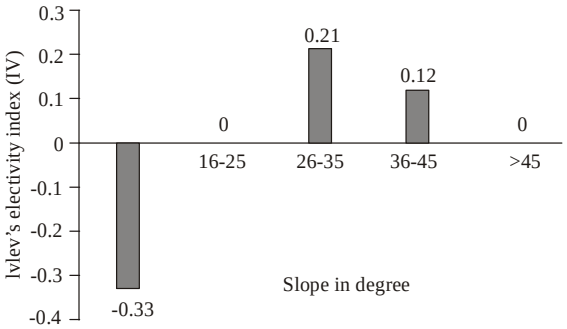

Fig. 4: Slope preference by musk deer

Cover: Musk deer preferred forested areas (IV = 0.39), with a gradual decrease in preference for caves (IV = 0.14) and cliffs (IV = 0.11). Rocky areas were used randomly (IV = 0) with these types of areas mostly being used for resting on sunny days. Musk deer completely avoided gullies (IV = - 0.28) and streambeds (IV = -0.36) (Fig. 5).

Any physical structure such as dense forest, cliffs, caves, rocks, gullies, etc. that provide cover for musk deer and that occurred within a 50 m radius from a pellet group was recorded. Different types of cover were used by musk deer according to their needs, such as predator avoidance and thermoregulatory needs. Dense forests, cliffs, and rocky areas provide good structure for hiding

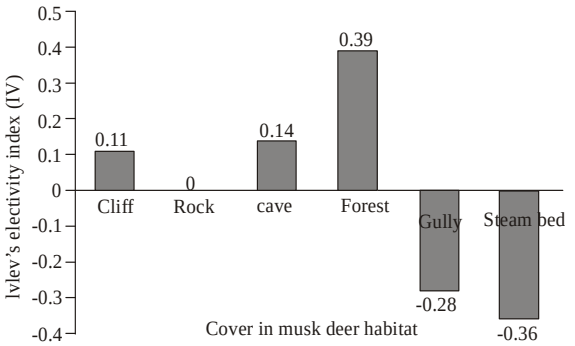

Fig. 5: Cover preference by musk deer

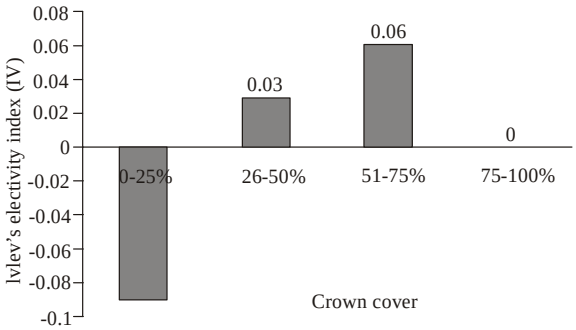

Fig. 6: Crown cover preference by musk deer

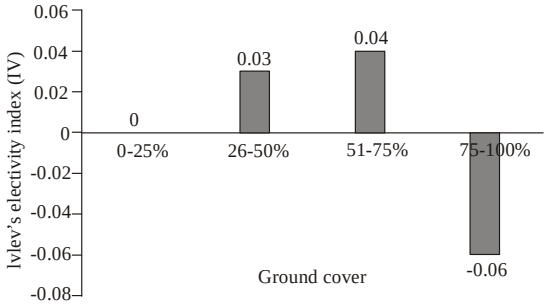

Fig. 7: Ground cover preference by musk deer

and for shade. There was no significant difference in the use of different types of cover proportional to what was available. (F = 0.83, p>0.05)

Crown cover: Musk deer appeared to use the crown cover for hiding and thermal regulation. The majority of pellets found occurred under the moderate (51-75%) and sparse crown cover (26-50%) suggesting that these types of crown cover are preferred by the musk deer (Fig. 6). The zero IV for dense cover (76-100%) suggests that their use of densely covered areas occurs randomly, while the use of sparsely covered areas (0-25%) is avoided (IV = -0.09). There was a significant difference in the use of different crown cover proportional to what type of cover was available with areas of sparse crown cover (26-75%) being preferred by musk deer (F = 3.58, p<0.05).

Table 1: Tree species preferences by musk deer

Species	IVI	Ivlev's Value	Status
Abies spectabilis	58.39	0.08	Prefer
Betula utilis	69.46	0.12	Prefer
Rhododendron campanulatum	5.78	0.03	Prefer
Rhododendron arboretum	3.40	0.02	Prefer
Rhododendron barbatum	9.31	0.02	Prefer
Sorbus spp	8.16	-0.14	Avoid
Messua ferra	6.67	0.03	Prefer
Salix spp	8.05	0.03	Prefer
Juniper spp	16.26	0	Random use
Lyonia ovalifolia	10.27	-0.26	Avoid
Acer oblonqum	5.214	-0.12	Avoid

Table 2: Shrub species preference by musk deer

Shrub	Ivlev's Value	Status
Rhododendron spp	0	Random use
Rosa sericea	0.01	Prefer
Sorbus spp	0.01	Prefer
Messua ferra	0.08	Prefer
Salix spp	0	Random use
Arundinaria spp.	0.11	Prefer
Lyonia ovalifolia	-0.27	Avoid
Abies spectabilis	-0.08	Avoid
Juniper spp	0.13	Prefer
Betula utilis	0.05	Prefer
Berberis spp	-0.17	Avoid

Ground cover: Musk deer preferred sparse (IV = 0.03) to moderate (IV = 0.04) ground cover, with these areas mostly being used for grazing as well as for thermal regulation and for hiding. Areas that contain highly sparse ground cover (0-25%) were used randomly (IV = 0) while areas of dense ground cover (76-100%) were avoided (IV = - 0.06) (Fig. 7). There was a significant difference in the use of different ground cover proportional to what was available (F = 3.16, p<0.05).

Tree, shrub and herb preference:

Trees: A total of 11 species of tree, 11 species of shrub, and 12 species of herb were recorded in the 206 plots. Musk deer showed a preference for 7 of the 11 tree species, including *Betula utilis* (IVI = 69.4, IV = 0.12), *Abies spectabilis* (IVI = 58.39, IV = 0.08), and *Rhododendron* spps. They avoided *Lyonia ovalifolia* (IV = - 0.27) and *Acer oblongum*(IV = -0.11) and only randomly used *Juniper* spp (IV= 0)(Table 1).

Shrubs: We categorised woody plants below 3 m height to be shrubs. Of the 11 species found, 7 species were preferred by musk deer. Species such as *Arundinaria* spp. (IV = 0.11), *Betula utilis* (IV = 0.05), and Juniper spp (IV = 0.13) were preferred by musk deer while Rhododendron spp were used randomly. *Lyonia ovalifolia* (IV = - 0.27) and Berberis spp (IV = -0.179) were avoided by musk deer (Table 2). Musk deer made use of all shrub species in proportion to their availability (F = 1.68, p>0.05).

Herbs: A total 12 herb species were found in musk deer habitat, seven of which were preferred by the musk deer. *Usnea* spp (IV = 0.08), Rui grass (IV= 0.065), Moss (IV = 0.065), *Rheum australe* (IV = 0.065) and *Leontopodium jacotianum* (IV = 0.055) were the most favoured herbs while *Rhododendron lepidoton* (IV = 0),

Table 3: Herb species preference by Musk deer

Herb	Ivlev's Value	Status
Usnea spp	0.08	Prefer
Rui grass *	0.064	Prefer
Moss *	0.064	Prefer
Aconitum	-0.18	Avoid
Rhododendron setosum	0	Random use
Rhododendron lepidoton	0	Random use
Picrorhiza kurroa	-0.078	Avoid
Rheum austral	0.064	Prefer
Unidentified	-0.161	Avoid
Fern*	-0.147	Avoid
Leontopodium jacotianum	0.05	Prefer

*: English name unidentified species

Rhododendron setosum (IV = 0) were used randomly (Table 3). Musk deer made the most use of *Usnea* spp, Rui grass, and *Rheum austral* compared to their availability ($F = 13.61$, $p < 0.21$).

Habitat overlap: A total of 206 plots were laid out in the study area. Of these, musk deer pellets were found in 66, livestock dung was found in 37, and both pellets and livestock dung were found103 of the plots. We assumed that these signs suggested that the site had been used by the respective animal. Thus, if the area only contained musk deer pellets, we defined it as musk deer habitat, if the area only contained livestock dung we defined it as livestock habitat, and if the area contained both livestock and musk deer pellets, we defined the area as a shared habitat. According to the Jaccard's similarity index, we calculated the value of musk deer habitat (A) to be 169, livestock habitat (B) to be 140, and the shared habitat to be 103. The Jaccard's similarity index value is J= 0.5, and according to Jaccard's Table 1, for N = 206, this similarity is higher than is expected to occur at random (with an associated probability of $p<0.05$). Therefore, there is significant overlap between musk deer and livestock, with about 35% of musk deer habitat being overlapped by livestock in Sagarmatha National Park ($J = 0.5$, $p<0.05$).

DISCUSSION

Population and distribution: The population survey of musk deer is largely incomplete due to a paucity of reliable survey data. However, it has been estimated that SNP contains 600-800 musk deer (Wemmer, 1998; Kattel, 1992), Kattel (1992) captured 23 musk deer with the ratio of 4:1 (adult to juvenile) and 1:3 (male to female), which contrasts with the 39 musk deer that we counted in the field. We did not count the population using standard methods, so our population data are likely to yield an underestimate. In order to know the exact population of musk deer, detailed population surveys should be carried out in the park.

Snow leopards (*Uncia uncia*) disappeared from the Everest region in the 1960s but have since made a comeback in SNP (Ale, 2007). This has led to an increase in the risk of a decline in the population of musk deer. Lovari *et al*. (2009) stated that 31% of the snow leopards' diet consists of musk deer in SNP. Local people believe that the snow leopard populations are increasing, which certainly would influence the population dynamics of prey species such as the musk deer. Thus, effective and separate management plans should be implemented to keep both populations in a balance.

Musk deer are distributed both in and outside the park boundary. Poaching is the main threat to the survival of musk deer both inside and outside the park. Musk deer have been hunted for thousands of years despite the fact that the meat is not considered desirable and their pelts are not valuable owing to their tendency to shed hairs (Homes, 1999). The main reason for the intense hunting of musk deer has always been the demand for musk. The price of musk deer in the international market is skyrocketing, leading to an increase in poaching and smuggling from the Himalayan habitat. Local people and park staff expressed the opinion that poaching is a consistent threat within the park region, a view which was supported by the recent discovery by patrolling teams from SNP of 400 nylon snares with one male musk deer trapped in Kalo Odar area. The Pare, Tengboche, Nagding, and Dhole areas of SNP are the most vulnerable sites for poaching of musk deer, although most of the local people denied any involvement in this. On this basis and from interviews with the park staffs and local people ($n = 216$), we suspect that that poachers are primarily from outside the park district, including areas such as the Dhading, Rasuwa, and Nuwakot districts. While the distribution of musk deer outside the protected area is one of the challenging issues for conservation, the Buffer Zone committee is also committed to the conservation of this species in their area. However, evidence of poaching is frequently observed in those areas. Before the insurgency, people observed many musk deer in and around the park head quarter in Namche. In the period of insurgency, however, the forests were cleared for security reasons, and this is a likely cause of the disappearance of musk deer from Namche bazzar.

Altitude and slope: A musk deer with a radio collar has been reported in Dingboche (4410 m) (Kattel and Alldredge, 1991). In our study, however, the maximum altitude where musk deer were found to 4200 m in the Dhole area. Musk deer clearly do not use altitude equally ($F = 14.28$, $p < 0.05$) across different areas, a fact that needs to be considered during the development of a musk deer strategy plan.

The plain slope areas, which are mostly used by livestock for grazing, were not utilized by the musk deer in our study area. This suggests that musk deer avoid areas where livestock are grazing. By contrast, the gentle

slopes were used randomly for grazing and resting by musk deer.

Plants: Musk deer showed a significant preference in their use of tree species such as *Abies spectabilis* and *Betula utilis* as compared to all tree species in proportion to their availability ($F = 34$, $p<0.001$) (Table 1). However, these species, together with other trees utilized by musk deer (e.g. *Juniper*), are at present being harvested in the area for their value as timber for infrastructure development, especially the construction of school buildings, private houses, and hotels. Timber is also harvested to firewood, which owing to the low temperatures and high price of alternate energy sources is in high demand by the locals. Added to this demand is the increased use of firewood associated with the tourist seasons (Autumn and Winter). This use is legal, as the National Park has made provisions under "Mountain National Park Regulation (1979/1980)" which allow for firewood collection twice a year. Managing the trees of SNP is an urgent priority for the conservation of musk deer habitat.

Habitat overlap: Under mutual understanding between local people and the national park, the domestication of any goat species within the Sagarmatha National Park is prohibited. With respect to livestock, 2000 domestic yak (*Bos grunniens*) and their hybrids with zebu cattle (*Bos indicus*) range within the park (Brower, 1991; Lovari *et al*., 2009). These livestock frequently use musk deer habitat: in the study area about 35% of musk deer habitat overlapped with livestock. This is a serious issue, not only because of the direct impact on musk deer grazing, but there is also a risk of disease transfer from wild to domestic stock and *vice versa*.

Because of a high level of influence from humans and livestock, musk deer have changed their behavior. We found evidence of this especially in the Phortse area, where the deer were apparently habituated to humans and allowed us to observe them from close range (<20m). Such behaviour raises the threat from poachers.

Due to high seasonality and low primary productivity, the Himalayan region supports relatively low levels of ungulate / herbivore biomass (Aryal, 2006). It is therefore likely that with the increase in the biomass of domestic livestock in many areas, wild ungulates such as musk deer have suffered competitive exclusion. Sathyakumar (1993) reported that increased livestock grazing and associated impacts have led to low musk deer densities in many areas in the Kedarnath Wildlife Sanctuary, India. Musk deer populations might be decreasing due to such competition with livestock as well as human disturbance.

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