HABITAT SELECTION AND SEASONAL DIET ANALYSIS OF HIMALAYAN MUSK DEER (*Moschus chrysogaster*, HODGSON 1839) AND LIVESTOCK IN MUSTANG, NEPAL

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Nepal

August, 2016

DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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LIST OF ABBREVIATIONS

Abbreviated Forms	Details of Abbreviations
° C	Degree Celsius
ACA	Annapurna Conservation Area
ACAP	Annapurna Conservation Area Project
CBS	Central Bureau of Statistics
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DHM	Department of hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife conservation
GIS	Geographical Information System
GLM	Generalized Linear Model
GoN	Government of Nepal
GPS	Global Positioning System
ITNC	International Trust for Nature Conservation
IUCN	International Union for Conservation of Nature
KMTNC	King Mahendra Trust for Nature Conservation
MP	Mega Pixel
NBS	Nepal Biodiversity Strategy
NTFPs	Non-timber forest products
NTNC	National Trust for Nature Conservation
SN	Serial Number
Sq km	Square Kilometer
TAR	Tibetan Autonomous Region
UK	United Kingdom
USSR	Union of Soviet Socialist Republics
VDC	Village Development Committee

ABSTRACT

The Himalayan Musk Deer (*Moschus chrysogaster*) is a small member of family Moschidae and classified as "endangered" by IUCN, "Appendix I" by CITES and legally protected under the National Parks and Wildlife Conservation Act 1973. To conserve this species, their habitat features, resource-use pattern and potential negative effects of livestock grazing should be known. Therefore, a study was focused on their feeding and habitat ecology with the livestock and; conducted in winter and summer seasons of 2015 at Mustang district of Annapurna Conservation Area. Three location of Jomsom VDC of Mustang district; Obang, Chhamachoo Lake and Raniban were intensively monitored. The presence and absence data of Musk Deer and livestock were recorded based on indirect signs of fecal pellets, footprints and resting site along with the transect on the basis of elevational gradient and associated topographic features (elevation, slope, aspect, distance to water, ground cover and crown cover) also recorded. Using logistic regression model, it was found that slope (Estimate=0.0877, $P<0.05$, S.E=0.02969) and ground cover (Estimate= -0.0340, $P<0.05$, S.E=0.0163) in the area significantly affect the likelihood of habitat selection by Musk Deer. In particular, they selected the steep slope of the area with less vegetation cover of ground area whereas low altitude with high vegetation of ground area significantly selected by livestock. The habitat overlap between Musk Deer and livestock of the area was calculated through Jaccard's similarity index. The result (J=0.33) indicated that habitat less overlap existed between Musk Deer and livestock. Diet analysis were done using micro-histological techniques. A total of 26 and 25 plant species found in the diet of Musk Deer and livestock respectively: in winter season whereas 24 and 26 plant species in summer season; respectively. Tree and shrub contributed the major percentage of diet to Musk Deer and livestock in both seasons. The study showed that the both Musk Deer and livestock were selective feeder. The most preferred plants species for Musk Deer were *Abies spectabilis, Pinus wallichiana and Berberis asiatica;* and for livestock it were *Pinus wallichiana, Abies spectabilis and Hedysarum kumaonense*, The diet overlap was calculated by Simplified Morisita's index (C_λ). The result showed high diet overlap between Musk Deer and livestock in the both seasons (Winter C_λ=0.57, Summer C_λ=0.71). Similar studies are to be conducted in other parts of nation to explore their status, habitat evaluation, diet composition and; grazing impact of livestock on it.

Keywords: Diet overlap, grazing impact, habitat overlap, micro-histological, selective feeder

1. INTRODUCTION

1.1 Background

Habitat selection is usually a behavioural consequence of animals actively selecting where they live, or passively persisting in certain habitats (Southwood 1977). The distribution and availability of trophic resources are important factors that affect habitat selection basically comprises of food, cover and water (Moen 1976, Schmitz 1991). So, the species are said to be the product of their habitat (Smith 1974). Habitat may be different according to the geographic range of a species (Johnson 1980). Habitat selection by the species studies often compare the habitat parameters that used in their habitat (Thomas and Taylor 1990). Hence, habitat parameters were observed to determine habitat selection that effect on Musk Deer and livestock.

Rates of biodiversity loss are usually related to a reduction in the extent of original habitat (Grelle *et al.* 1999, Tews *et al.* 2004, Sinclair and Byrom 2006) and habitat loss is one of the most critical issues currently facing wildlife populations (Wright 2005). Fragmentation and destruction of suitable habitat can affect the wildlife behavior and their population densities (Bender *et al.* 1998, Visconti *et al.* 2011). In the Himalaya region, ill-planned developmental activities and uncontrolled levels of grazing by domestic livestock are the main reasons for habitat degradation and loss of suitable habitat of wild ungulates both within and outside protected areas (Kala and Rawat 1999). Livestock production is the primary source of livelihood in the Himalayan region (Namgail *et al.* 2007); so in some areas, pastoralists tend to increase their livestock populations beyond the carrying capacity of the rangelands to enhance their economy (Mishra *et al.* 2001). Such increase in the population of domestic livestock effects on the nutritional balance of wild ungulates (Schaller 1977) because domestic livestock share pastures with the native wildlife (Prins 1992, Schaller 1998). As well as similar habitat selections and overlap can completely exclude the wildlife from their better habitat via interference competition (Fleischner 1994, Noss 1994, Mishra *et al.* 2004). Hence, livestock grazing pattern is considered as major reasons for declining pastoral habitat and; on the distribution and abundance of wild ungulates (Mishra 2001, Bagchi *et al.* 2002, Kittur *et al.* 2010). Thus, exploring habitat overlap between Musk Deer and livestock provides extent of grazing impact on Musk Deer.

Diet information is an important component to understand the animal ecology, evolution and interspecies competition (Hobbs *et al.* 1983). Feeding habits of mammals are in the center of interest of population biology and ecology (Green 1987b) and knowledge on the food habits of wild and domestic ungulates is a basic requirement for the management of rangeland resources (Hobbs *et al.* 1983). However, food plays an important role in species reproduction, growth and survival (Pekins *et al.* 1998). The feeding habits of wildlife may vary with season, land use, plant composition and population status (Korschgen 1962) and can be linked to the abundance, phenology and nutrient quality of plants (Short 1971). The high similarity in the diet between ungulates indicates the competitive interaction for food resource (Shrestha *et al.* 2005, Wegge *et al.* 2006, Bhattacharya *et al.* 2012). Among the study of food habits of herbivores, fecal analysis through micro-histological techniques has been used for the identification of the epidermis fragments in the fecal sample (Baumgartner 1939, Dusi 1949). This method is practical in particular for some rare, endangered and evasive wild herbivores like Musk Deer on which collecting ruminal samples are not possible (Gonzalez and Duarate 2007).

1.1.1 Nomenclature

Himalayan Musk Deer (*Moschus crysogaster)* is one of the most primitive deer like ruminants (Kattel 1992). It is commonly known as "Kasturi Mriga" in Nepali (Rajchal 2006). It belongs to the order Artiodactyla, family Moschidae and genus *Moschus* (Green 1985, Aryal *et al.* 2010). Previously, Musk Deer were classified in the family Cervidae (Flower 1875) but many scientists have grouped them within their own separate family, Moschidae (Flerov 1952, Whitehead 1972, Brooke 1878, Groves and Grubb 1987). Earlier three species of Musk Deer were recognized following taxonomic revisions of genus (Green 1986) but current information shows seven species of Musk Deer, Anhui Musk Deer (*Moschus anhuiensis),* Forest Musk Deer (*Moschus berezovskii),* Alpine Musk Deer (*Moschus crysogaster),* Kashmir Musk Deer (*Moschus cupreus),* Alpine Musk Deer (*Moschus fuscus),* Himalayan Musk Deer (*Moschus leucogaster),* Siberian Musk Deer *(Moschus moschiferus)* (IUCN 2013). In Nepal, three species of Musk Deer are found, Alpine Musk Deer (*Moschus chrysogaster),* Himalayan Musk Deer (*Moschus leucogaster*) and Black Musk Deer *(Moschus fuscus*) with species wise distribution throughout the Himalayan region (Jnawali *et al.* 2011). However; photographic evidence shows the presence of *M. leucogaster* at lower Mustang (Singh 2011).

1.1.2 Morphology

The Himalayan Musk Deer is a small forest dwelling creature with dark brown color and body is covered over with coarse and brittle hairs where individual hairs contain air-filled cells for better insulation (Green 1985). The adults have two white spots one on either side of the neck below the jaws (Kattel 1992). They have large ears with a short tail along a long hair at the arial region and it is composed of the facial gland, gall bladder, caprine gland in between hooves which suggest that the deer is more closely to bovids (goat antelopes) than to cervids (Shrestha 1997, Hassanin and Douzery 2003). Musk Deer is about 60 cm tall, 13-18 kg in weight, has a shoulder height of 20 cm and presence of musk gland (pod) only in the male which is the characteristics features of the species (Shrestha 1989)**.** Female Musk Deer are larger than males with length 97.4 cm compared to 92.9 cm, wider in the chest (59.9 cm compared to 57.5 cm) and body mass 10.7 kg compared to 10.3 kg; respectively**.** It does not have antlers but males possess elongated upper canine teeth (6-10 cm) that rises far below the lower lip that is used in fight between rivals (Green 1985). Their hind legs are longer than the forelegs that help them for jumping and galloping mode of life. Their movement appears more like jumping than running and their toes are large and can be spread to find the secure footing in mountains and on snow (Green 1985).

1.1.3 Breeding Biology

Musk Deer breeds seasonally (Green and Kattel 1997). The male Musk Deer produces musk that mixed with its urine, has a pink colour and strong smell that is believed to stimulate the female to begin oestrus (Macdonald 2001, Homes 2004). The copulated season extends from November to January depending on area altitude and region. The baby is born after the gestation periods of 178-198 days during May and June. Litter size ranges from one to three young and twin births predominate in Forest Musk Deer and Siberian Musk Deer, while single offspring is mostly common in the Himalayan Musk Deer (Green and Kattel 1997). The birth weight of Musk Deer depends on the species that varies from 400g to 600g. Like all deer species, Musk Deer also nurse their offspring and keep them secretly in the undergrowth and suckled first two months. At the age of about two months they start to follow their mother and are weaned (Green 1987a) and by the age of six months, they become independent from their mother and sexual maturity at 18 months of age and their life-expectancy period up to 20 years (Nowak 1999, Macdonald 2001, Homes 2004, Rajchal 2006). Female Musk Deer are capable of breeding after their first year (Green 1987a, Green 1989).

1.1.4 Feeding Ecology

Musk Deer is herbivore and selective feeders (Kattel 1992). Primarily, the food of Musk Deer consists of leaves of trees, shrubs and forbs and they prefers for easily digestible nutritious foods which are rich in energy content, high in protein and low in fiber (Kholodova and Prikhod'ko 1984, Green 1987b). During the summer, forbs and parts of trees and woody shrubs form the main part of the diet but in winter, dry leaves of shrubs and trees, forbs and grass species with two species of arboreal lichens (*Usnea* sp.) are consumed (Kattel 1992).

1.1.5 Social Behaviour

The Himalayan Musk Deer is shy and solitary animal with it occupies home range 13 to 22 hectares area (Green 1998). Male is highly territorial, only allowing the female to enter but defending the other males within their home range whereas female territories may overlap (Green 1997b). Territories are marked by carefully placed defecation sites and strong-smelling secretions, which are rubbed onto the surrounding vegetation (Nowak 1999, Macdonald 2001, Homes 2004). The Musk Deer depends on its sense of hearing to locate sources of danger (Zhivotshenko 1988). When frightened, they make great leaps (up to 6 meters or 19 feet in length) and great changes in direction are made during flight, and in every few jumps they stop and listen (Shrestha 1997). Communication between individuals based on their sense of smell, due to the high development of the glands (Green 1985). Primarily silent, Musk Deer will emit a loud double hiss if alarmed and may scream plaintively if wounded (Green 1987c).

1.1.6 Habitat

Musk Deer is generally nocturnal, shy, solitary and crepuscular creature. They are mostly active at dusk and dawn, throughout that period they feed and take rest (Green and Kattel 1997). At night, they can be seen in the open area in their habitat as they graze but during day time they remain in the dense cover area. They are mainly distributed in forested and alpine scrub habitats mostly consists of oak, fir, rhododendron, blue pine, juniper, grass, lichens and scrub in the mountains of southern Asia, notably the Himalayas with moderate to steep slopes (Green 1987b, Kattel and Alldredge 1991).

1.1.7 Distribution

In Nepal, Himalayan Musk Deer are widely distributed across the mountainous parts of the Himalayas from about 2500 m to 4500 m (Kattel 1992). Usually they are found in the 12 protected areas of Nepal i.e. Api Nampa Conservation Area, Khaptad National Park, Shey Phoksundo National Park, Rara National Park, Dhorpatan Hunting Reserve, Annapurna Conservation Area, Manaslu Conservation Area, Langtang National Park, Gaurishankar Conservation Area, Sagarmatha National Park, Makalu Barun National Park and Kanchanjunga Conservation Area (NBS 2002, Aryal and Subedi 2011). Outside the protected areas they are found in the districts of Humla, Darchula, Baitadi, Bajhang, Achham, Dolpa, Jumla and Rolpa (Green 1986). In the context of outside the Nepal, it is found in Afghanistan, Bhutan, China, India, Korea, Mongolia, Pakistan, Russia and Vietnam (Green 1986, Khan *et al.* 2006).

1.1.8 Conservation Status

In an effort to protect Musk Deer from local extinction, the government of Nepal has listed it as a protected species (HMGN 1973). The Act recognized and protects Musk Deer in two ways: through listing *Moschus spp.* as a protected species and by providing additional protection for populations located in protected areas designated under the authority of the Act. Article 10 of the Act mentioned the species as protected and their poaching is prohibited. The protection provided by Article 10 is very strong as are they prescribed penalties that range between NRs 50,000 to 1, 00,000 and up to 15 years of imprisonment (Rajchal 2006). Internationally, it is listed as 'Endangered' by the IUCN Red List (IUCN 2014) and also listed Appendix I by CITIES (CITIES 2003) making an international trade of this species illegal (Wang and Harris 2008).

1.2 Rationale

Himalayan Musk Deer is one of the least studied animals among the deer like species (Aryal *et al.* 2010). The population of Musk Deer has declined because of multitude reasons, however, intensive poaching of Musk Deer for the demand of musk pod is responsible for the dramatic decrease in the population of Musk Deer (CITES 2003, Wang and Harris 2008, Aryal *et al.* 2010). Although, grazing competition with the livestock also responsible for the decline of Musk Deer population (Aryal 2005). In the present context, its distribution is broken into small fragments that have subpopulations in isolated pockets of the Himalayas (Green 1987a,

Sathyakumar 1991, 1992, Sathyakumar *et al.* 1993*a*). Livestock production is the primary source of livelihood and income in the high steep and alpine regions of the Trans-Himalaya (Brown 1971, Goldstein *et al.* 1990, Homewood and Rodgers 1991, Prins 1992). So people tend to increase their livestock populations beyond the carrying capacity of the rangelands to enhance their income as a result that effects on the pastoral habitat and; on the distribution and abundance of wild ungulates including Musk Deer as well as chance of transferring disease from livestock being habitat overlap (Mishra 2001, Bagchi *et al.* 2002, Raghavan 2003, Mishra *et al.* 2004, Namgail *et al.* 2007). Although, the ill-planned development activities, timber and firewood collection has undoubtedly contributed impact on the population of Musk Deer (Aryal 2005).

In Nepal, less information is available on competition of food resource between wild ungulate and livestock at Trans-Himalayan region (Shrestha *et al.* 2005). But for conservation of the species, good understanding of their ecology is required, especially habitat and feeding ecology. Realization on these fact, study was focused on the habitat and feeding ecology of the Musk Deer and; their habitat and diet overlap with the livestock in Mustang district. So, it is hoped that this research findings will baseline information to develop strategies to conserve this species.

1.3 Objectives

The main objective of the study was to find out the habitat of Musk Deer and its seasonal diet. Moreover, the aims of the study was to quantify the potential diet and spatial habitat overlap with the livestock. Furthermore, the specific objectives of study were:

- To find out the habitat characteristics that affect habitat selection of Musk Deer and livestock,
- To analyse the habitat overlap between Musk Deer and livestock,
- To analyse the diet and diet niche breadth of the Musk Deer and livestock over summer and winter season and
- To quantify the diet overlap of Musk Deer with livestock.

1.4 Limitations

The study in the Himalayan terrain is always difficult as its harsh climatic conditions and highly dissected landscape. Following were some limitations found during the study.

- Heavy snowfall during winter field made difficulties in collection of data. High snow cover in some potential study sites of Musk Deer restricted the systematic and complete research.
- Study sites were far from the village (approximately four hours distance). So, study was confined in small area.
- Restricts to direct sampling as the Musk Deer is very shy, solitary and crepuscular habits (Green 1986).

2. LITERATURE REVIEW

Literature review reveals that most of the research conducted on Musk Deer was found focused on the habitat but only few were found on diet. Among the literature reviewed, based on national and international level, overall 21 literatures has been mentioned below.

Study of Musk Deer in Nepal

A study conducted in Sagarmatha National Park revealed that Musk Deer diet composed of shrubs (*Rosa* sp., *Rhododendron* sp. and *Cotoneaster* sp.), forbs (*Bistorta* sp. and *Polygonum* sp.), grass (*Arudinaria* sp.) and Lichen (*Usnea* sp.) in summer while in the Winter it were tree (*Betula utilis*), shrub (*Rhododendron* sp. and *Cotoneaster* sp.), forb (*Polygonum* sp.), grass (*Arundinaria* sp.) and lichen (*Usnea* sp. and lichen sp.) and Musk Deer were found as browser (Gurung 1991).

Kattel (1992) conducted the study with major focus on ecology of Musk Deer in Sagarmatha National Park. The study resulted that Musk Deer found as selective feeder and feeding mostly on easily digestible foliage of shrubs and trees, flowers and inflorescences of forbs and fronds in summer. During the winter, Musk Deer consumed dry leaves of shrubs and trees, forbs, grass species and two arboreal lichens (Usnea spp). The species mostly preferred Birch and Rhododendron forest; and inhabited elevation ranges from 3000 to 4200 m asl.

Aryal (2005) studied on Musk Deer in Manang district of Annapurna Conservation Area. From the study, Musk Deer found to prefer elevation range of 3300m to 3700m, slopes (36°-45°), crown cover (50% to 75%), ground cover (50% to 75%) with North, North-West aspects and dense vegetation (forest) cover. Their presence was found high in forest followed by the scrub, pasture and open land. *Betula utilis, Abies spp., Pinus wallichiana, Cupressus tortulosa, Juniperus sp.* and *Rhododendron campanulatum* were the major vegetation found in the habitat of Musk Deer. Study shows poaching, overgrazing by domestic livestock, forest fire, timber and NTFP etc. were the threats facing by the Musk Deer.

Pandey (2006) conducted the study on the status and habitat utilization of Musk Deer in Langtang National Park. He concluded that *Betula* sp. forest and mixed forest were the suitable habitats for Musk Deer and preferred the animal trail for walking. North facing slope of hillside area along huge cave store was preferred for bedding sites. Poaching, overgrazing, firewood and timber collection, tourism and construction works were found problematic factors faced by Musk Deer.

Rajchal (2006) conducted the study of Musk Deer in Sagarmatha National Park at Phortse during September 2005. He found that Musk Deer were distributed between elevations 3000-4200 m asl. at forested areas (Birch-Rhododendron) and preferred big stone for bedding sites. Haphazardly livestock grazing and poaching were the major threats for Musk Deer.

Aryal (2007) carried out the study of Musk Deer by direct field inventory, population/pellet count and questionnaire survey in Annapurna Conservation area of Mustang district of Marpha Village Development Committee. Through the survey found that Musk Deer preferred the forest area, elevation between 3300 m. asl to 3700 m. asl, moderate crown cover (50-70%), moderate ground cover and slope (10° to 45°). *Abies* sp. followed by *Betula utilis, Juniperus* sp., *Cupressus torulosa, Pinus wallichiana* were found prominent vegetation in the habitat of Musk Deer and high habitat overlap was found (68%) with the livestock.

The study conducted at Dhorpatan Hunting Reserve found that Musk Deer's concentration was found at the elevation ranges between 3400-4000 m. asl and preferred forest land than shrub land and grass land whereas mostly it utilized the 60° slopes along the North-East, North-West and South-East aspects. *Abies spectabilis, Rhododendron* sp. and *Betula utilis* were found dominant vegetation in the habitat of Musk Deer (Karki 2008).

Sharma *et al.* (2008) carried out the survey of Musk Deer in Kanchanjunga Conservation Area, Langtang National Park and the Buffer Zone. They recorded that Musk Deer were mostly distributed between the elevations of 3339 to 4547 m asl and preferred west aspects with mean slope 50.7° in Kanchanjunga Conservation Area and 3500 to 4100 m asl. and northern aspects with mean slope 51.3° in Langtang National Park.

Aryal *et al.* (2010) studied the spatial habitat overlap and preference of Musk Deer in Sagarmatha National Park. They concluded that Musk Deer preferred gentle (26-35º) to steep slope (36- 45º) with and elevational ranges of 3400 to 3900 m asl. Musk Deer showed the preference of dense forest with sparse ground /crown cover and vegetation like trees- *Abies spectabilis, Betula utilis*, shrubs- *Rhododendron* spp., *Rosa sericea,* and herbs-*Usnea* spp. and *Rui grass.* In addition, a significant overlap (35%) between Musk Deer and livestock in the habitat was found.

According to Aryal and Subedi (2011), Musk Deer was found both in protected and non-protected areas of Nepal, of which 19.26% in protected areas and 80.73% in non-protected areas. Poaching, habitat destruction, livestock grazing and forest fire were found important challenges for the conservation of Musk Deer.

Joshi (2011) conducted study of Musk Deer in Mustang. Through the study, Musk Deer was mostly found at elevation ranges between 3500m to 3900m in the forest habitat with the slope 21° to 80°, North-East aspect (45%) of the hillside containing of the high percentage of litter. Climate change and forest fires were the threats for Musk Deer habitat in Lower Mustang.

Subedi *et al.* (2012) studied the habitat ecology of Musk Deer in Manaslu Conservation Area where they found that Musk Deer preferred elevation ranges between 3601 to 3800 m asl with 21° to 30° slope, 26% to 50% of crown cover, 26% to 50% of ground cover. *Abies spectablis, Betula utilis* and *Rhodoendron* sp. were found the preferred plant species in the Musk Deer habitat.

Subedi (2013) had done pellets group count method for the survey of Musk Deer habitat in Annapurna Conservation Area, Lower Mustang. From his survey, it was found that Musk Deer mostly used an area between 3500 to 4000 m. asl elevation range with the slope (30° to 45°), aspects (North–East), crown cover (51%-75%), sparse (0-25%) and moderate (25-50%). Himalayan Brich, Rhododendron sp., West Himalayan fir, Blue pine and the mixed habitat of these species as well shrub land is dominated by *Rosa* sp., *Caragana* sp., and *Rhododendron* sp. dominant vegetation were found in the habitat of Musk Deer.

Study of Musk Deer outside Nepal

Zhou *et al.* (2004) reviewed the distribution, status and conservation of Musk Deer in China. They reported that to conserve the Musk Deer in-situ protection should be improved, halted the unsustainable forest exploitation, restrict in domestic use of musk, introduced of ex-situ protection, Musk Deer farming developed according to biological requirements.

Musk trade possess a major threat to the survival of the Musk Deer. The other causes of the decline of Musk Deer were the destruction of natural habitat due to nomadic and local grazing, along with unsustainable commercial logging and extraction of medicinal plants by the government as well as by the locals (Khan *et al.* 2006).

Jianping *et al.* 2006 was studied the summer habitat selection of Siberian Musk Deer (*Moschus moschiferus*) by transect line methods. They found that musk deer preferred the coniferous broadleaved forests and avoided Shaw forests. They had also found that Musk Deer often select upper slope locations near a water source with steep rocky slopes and far away from human disturbance.

Qamar *et al.* (2008) studied the distribution and population status of Himalayan Musk Deer in the Machiara National Park, Azad Jammu and Kashmir. They found that Musk Deer undergo seasonal migration towards lower elevation during the heavy snowfall and it was found that the species mostly preferred Himalayan moist temperate forest.

Bhattacharya *et al.* (2012) recorded the 25 plant species in the diet of Musk Deer and 35 species in livestock in Nanda Devi Biosphere Reserve, India. Diet overlap between them was found high (0.97) and Musk Deer showed a gradual shift from monocotyledons to comparatively high nutritious dicotyledons in winter.

Wangchuk (2012) conducted study on the status, distribution, habitat use and potential threats of Musk Deer in Thrumshingla National Park, Bhutan. He concluded that Musk Deer was adapted to live in steep slopes (60°-80°) of the sub-alpine and temperate matured coniferous forest areas with an altitudinal range of 2630-3624 m. asl at where dominant shrub was *Rhododendron lepidotum, Rosa sericea* and *Vaccinium retusum*. The species were recorded higher on the southern aspect followed by the west.

In Musk Deer National Park Guraiz, Azad Jammu and Kashmir, Pakistan**,** Musk Deer utilized lichens and branches of conifer trees as food during winter seasons and resting sites were at the vantage point for surveillance of predators. Their presence was found mostly in the forest area than shrub land and open grassland. *Betula utilis, Abies pindrow, Picea smithiana* and *Taxus wallichiana* were dominant in their habitat. Deforestation, livestock grazing, and construction of seasonal houses in the core habitat of the deer were the major responsible causes for the decline in the population of Himalayan Musk Deer (Qureshi *et al.* 2013).

Syed and IIyas (2015) studied the pre- monsoon and post-monsoon feeding and habitat ecology of alpine Musk Deer in Kedarnath Wildlife Sanctuary, Uttarakhand, India. They observed that Musk Deer consumed 36.62% herbs, 2.74% grasses, 36.99% unidentified herbs and 23.64% unidentified grass species in the pre-monsoon season. *Anemone* spp. was found to be the greatest (19.90%), followed by *Polygonum amplexicaula* (15.83%) and *Potentilla* spp. (13.48%) during pre-monsoon season. While in the post-monsoon, the species consumed 22.45% herbs, 19.82% grass, 29.56% unidentified herbs and 28.16% unidentified grass species. The highest proportion of consumed plant species was recorded for *Danthonia cachemeriana* (21.32%) followed by *Cyperus* spp. (12.98%) and *Thamnocalamus spathiflora* (11.92%). Habitat overlap of Musk Deer with Himalayan tahr and livestock was found high during pre-monsoon and post monsoon.

3. MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location

The study area extends between 28°52'-28°78' N latitudes to 83°37'- 83°59' E longitudes in the Jomsom village Development committee (VDC) of Lower Mustang, Nepal (Figure 1). It lies in the central north region of the country in the rain-shadow part of Annapurna and Dhaulagiri Himalaya ranges (Khadka and James 2016). The study area is located in the Annapurna Conservation Area Project (ACAP), the largest protected area of Nepal, covering 7629 sq. km, was established in 1992 (Aryal and Subedi 2011) and undertaken by National Trust for Nature Conservation (NTNC).

Mustang district is one of the northern remote districts of high altitude Himalayan region of Nepal and extends northward onto the Tibetan plateau with Jomsom as its headquarters, covers an area of 3,573 km² and has a population (2011) of 13,452. Mustang district is bordered by the Tibetan Autonomous Region (TAR) of China in the north-east, north and north-west, Manang district to the east, Dolpo to the west and Myagdi to the south. The elevation range from 1640 m asl. (Kopchepani of Kunjo VDC) to 7061 m asl (north of Nilgiri). Tukuche peak (6920m), Nilgiri South (6839m), Yakwakang Peak (6462m), and Damodar Himal (6004m) are the peaks above 6000 m asl in the district. Thorung Pass (5416m), probably the world's highest and busiest pass, is located in this district. Mustang is geographically divided into two broad regions; Upper Mustang and Lower Mustang.

An intensive study was carried out in Jomsom VDC with an area of 184.85 sq. km (K.C. *et al.* 2014), the intensive field survey was carried out in Obang, Chhamachho Lake and Raniban. Thini and Lubra are the village closest from the study area (Figure 1).

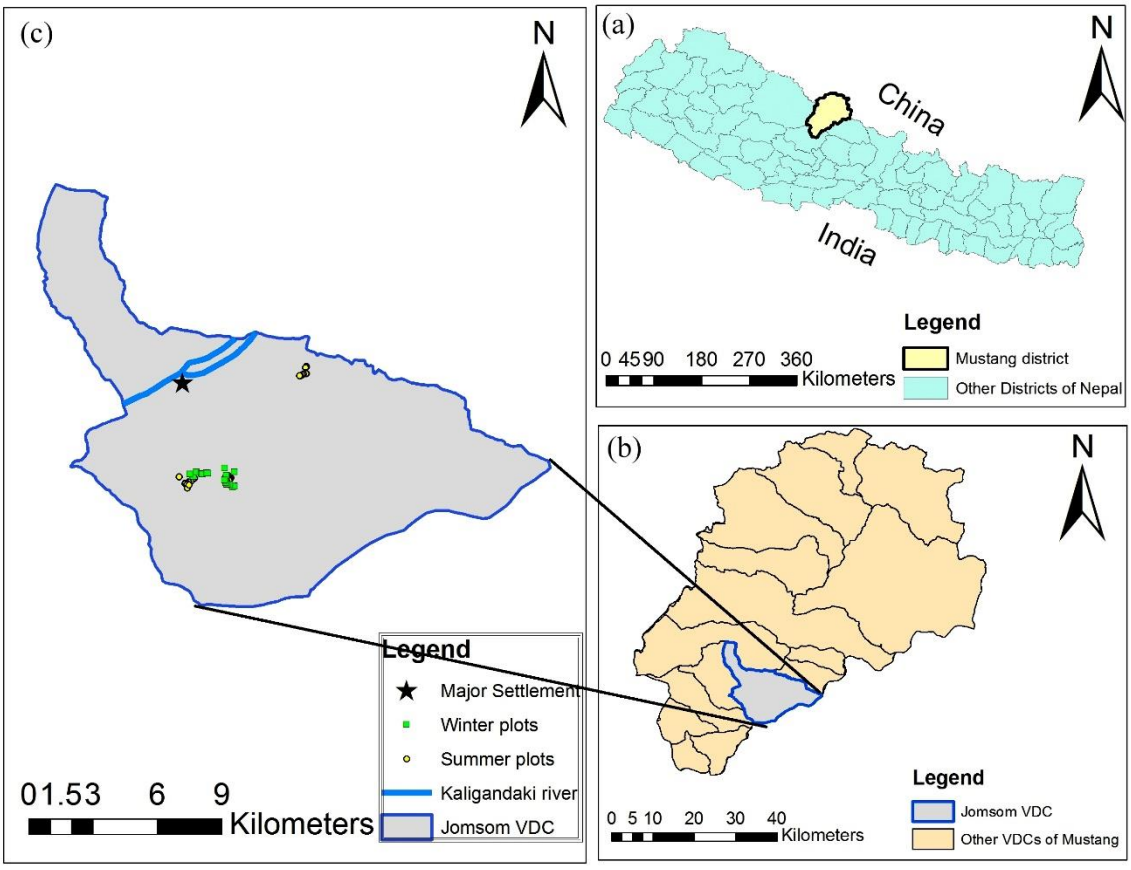

Figure 1: Map showing Study area and Study sites: (a) Map of Nepal, (b) Mustang district and (c) Study area

3.1.2 Drainage and River System

The entire area of the district is drained by Upper Kali Gandaki River and its various tributaries. The river Kali is the westernmost main tributary of Sapta Gandaki river system of central Nepal. The river Kali Gandaki originated from the Tibet Autonomous Region of China and ultimately named as Kali Gandaki only after the confluence of three tributaries as Mustang Khola, Charang Khola and Dhenchayan Khola (K.C. *et al.* 2014). Thini Khola and Panda Khola are the main rivers in the study area and these rivers are also the tributaries of Kali Gandaki River. Dhumba Lake and Chhamachho Lake are the important lakes in the study area.

3.1.3 Biodiversity

Mustang is rich in both temperate and trans-Himalayan biodiversity. Biodiversity of Upper Mustang is comparatively well studied and documented than the Lower Mustang (K.C. *et al.* 2014). *Abies* sps., *Pinus* sps., *Betula utilis*, *Juniperus* sps., *Rosa* sps., *Caragana* sps., *Berberis asiatica*, *Rhododendron lepidotum*, *Hedysarum kumaonense*, *Kobresia* sp. etc. are the common

plant species of the study area. Mustang is the habitat for Snow leopard (*Panthera uncia*), Musk Deer (*Moschus chrysogaster*), Tibetan wild ass (*Equus kiang*), Blue sheep (*Psedois nayur*) and Tibetan gazelle (*Procapra picticaudata)* etc. (NTNC 2008).

3.1.4 Climate

Climatically, Mustang district falls in the rain shadow area and receive very little rain generally dry with strong winds and intense sunlight and most of the precipitation in the form of snow. Due to great variation in the altitude aspects and slopes with different landscape, there is great variation in the climate and mainly found three type of bio-climatic zones i.e. cold temperate climate (below 3000 m asl), alpine climatic (3000- 4500 m asl) and tundra (above 4500 m asl) (NTNC, 2008). On the basis of the meteorological record, the maximum rainfall recorded of 118.4 mm in the month of June, 2013 (Figure 2). The mean annual temperature of Mustang district ranges from 7.9 °C to 23.8 °C whereas winter is very cold and freezes with the annual minimum temperature ranges between -3.9 °C to 14.9 °C (DHM 2014) (Figure 2). January is the coldest month with an average of -1.85°C during ten year periods (2005-2014) (Figure 2).

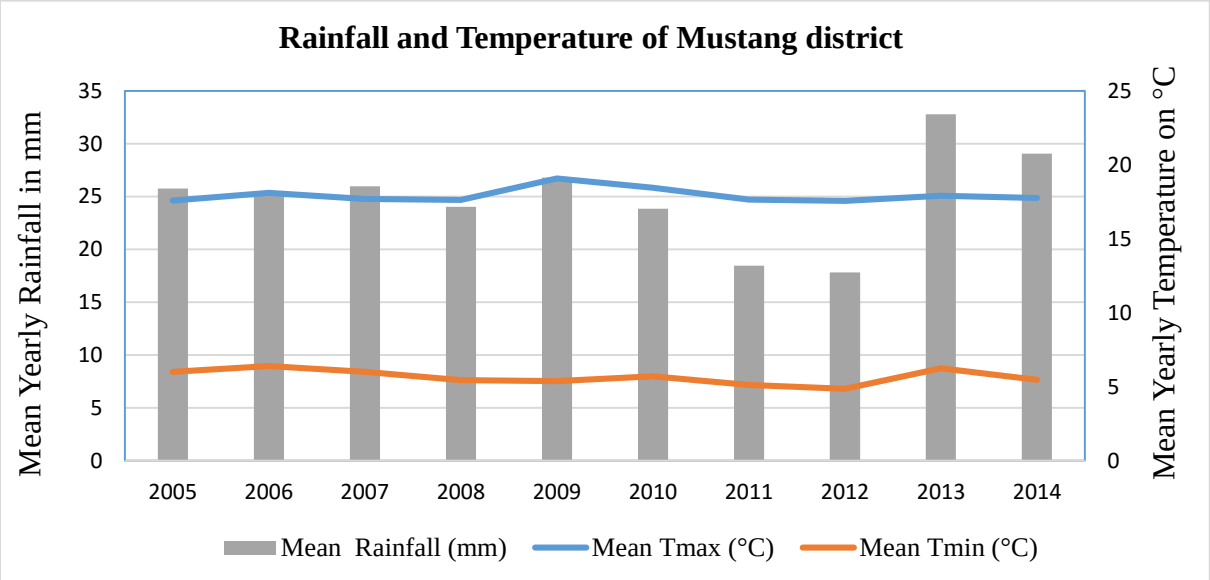

Figure 2: Mean Annual Rainfall (mm) and Mean Annual Temperature (°C) of Jomsom Station (2005-2014) of Mustang District. (Source: DHM)

3.1.5 Socioeconomic attributes

The total household number of Jomsom VDC is 430 with the population of 1,370 (male- 702 and female-668) having the population density of 7.41 people/ km² (CBS 2012). Gurung, Thakali, Kami/Damai, Magar, Thakuri and others are the ethnic group of the Jomsom (CSB 2012). Natives here are followers of Bonpo and Buddhist religion and still practice traditional lifestyle. Thakali culture and old houses found in the Thakali settlements give a glimpse of the area. The natural beauty and cultural heritage and grandeur have already been contributed to making most popular trekking destinations in the world and an area famous for tourist so, the locals depend heavily on tourism, however, agriculture and animal husbandry is practiced for their livelihood. Thini Gumba, Khampa Camp, Dhumba Lake are the famous place of this area.

3.2 Methods

The field work was carried out in two seasons winter (January) and summer (July) of 2015. Habitat parameters data taken from the field were used to evaluate the habitat selection and habitat overlap between Musk Deer and livestock. While reference plants and fecal samples collected from the field were used to evaluate the diet analysis of Musk Deer and livestock through micro-histological method. Plants collected from the field were identified by National Herbarium and Plant Laboratories, Lalitpur and lab work was done in Central Department of Zoology, TU.

3.2.1 Research Design

Total 69 plots (winter = 32 and summer = 37) were laid out in the study area. Each plot was of 10 m × 10 m at intervals of 100 m along line transect in elevational gradient (Mcdonald *et al.* 2005). Musk Deer and livestock presence/absence were recorded based on indirect signs such as fecal pellets, footprints and resting sites. Intensively searched each plot for any signs of the presence or use to maximize the probability of detection. Opportunistic sampling was carried out in difficult terrain where moving along transect was not feasible. The parameters such as GPS coordinates, elevation (m), slope (degree), canopy-cover (%), distance to vantage point (m) (rock, cliff, and wooden log), aspect, distance to water (m), dominant herb spp., shrub spp., and tree spp. were recorded from each plot.

3.2.2 Reference plant collection

Forty-one potential food plant species (leaves, twigs, flowers and bark) were collected from the study area to prepare reference slides. All the collected plants parts and species preserved in herbarium sheet and brought to National Herbarium and Plant Laboratories, Lalitpur for further identification and confirmation.

3.2.3 Pellet Collection

A total of 44 fresh (less than two weeks) Musk Deer pellet samples (20 from winter and 24 from summer) were collected systematically in the line transects and opportunistically, in the study area. The collected pellet samples were put in polythene zip lock bags. Each sample was labelled with GPS co-ordinates, collection date and status of the sample. The collected samples were air-dried in the field to remove moisture and prevent fungal growth. If the multiple samples were found at the same place only one sample was collected.

Pellet groups were identified on the basis of their size and shape. Some were cylindrical in shape with pointed end while other was like chickpeas. Musk Deer used communal pellet deposition sites for defecation (Green 1987b). So, easy way of observing Musk Deer pellets was latrine site. But dropping in small amount was also observed where pellets are intact regardless to that of the goat which is dispersed. Also, musk pellets were usually smaller in size than that of goat. Similarly, livestock fecal samples (20 form winter and 24 form summer) were collected and put in zip lock bag and air dried in the same day.

3.2.4 Micro-histological Analysis of Faeces

Micro-histological technique has been widely used to study the diet of wild and domestic animals from herbivores to carnivores (Holechek *et al.* 1982, Alipayo *et al.* 1992). This technique introduced by Baumgartner and Martin (1939) was used to identify diet composition and diet niche breadth of Musk Deer and livestock. This method was based on the microscopic recognition of indigestible plant fragments mainly the epidermal features, which are characteristic of different plant groups (Metcalfe 1960). This method is efficient for studying diet of secretive and/or endangered species (Anthony and Smith 1974) due to its simplicity and effectiveness (Holechek *et al.* 1982). In the context of Nepal, this method has been widely applied by researchers (Jnawali 1995, Pokharel 1996, Shrestha *et al.* 2005, Chhetri 2006, Pradhan *et al.* 2008, Thapa 2010, Panthi *et al.* 2012) for estimating diet composition of

herbivores. This method required the collection, preservation and preparation of fecal samples and reference slides.

3.2.4.1 Slide preparation

Both samples of reference plants and fecal were air dried in the oven at 60 °C in the laboratory of Central Department of Zoology, Tribhuvan University. The dried samples were separately ground in the electric blender into tiny fragments. The fragments were sieved through sieve mesh size 1mm to 0.3 mm to ensure homogeneity in size of the fragments. The fragments remain on the 0.3 mm sieve was chosen as slide preparation of both samples (reference plant and fecal).

The method adopting by Norbury (1988) was used to prepare the slide because of its effectiveness, less time consuming and; slide prepared were clearer and easier (Kunwar 2014, Singh 2015). In this method, 0.5 gm from each sample was placed in Petri dishes and bleached with 50 ml of 4% Sodium hypochlorite for 6-12 hours at room temperature to remove mesophyll tissue and to render the epidermis identifiable. The bleached fragments were then rinsed with distilled water thoroughly in a sieve and treated with few drops of staining substance-gentian violet solution for 5 sec and again rinsed with distilled water. The stained fragments were mounted on standard microscope slides in a glycerin medium with cover the slip of 22 X 50 mm^2. Both reference slides and sample slides were observed in compound microscope at magnifications of 100X and 400X and each fragment was photographed using the digital camera for the microscope (DCM510; USB2.0; 5M pixel, CMOS chip) in a laptop using software- ScopeTek Scope Photo; Version: x64, 3.1.615 (*http://www.scopetek.com*).

3.2.4.2 Slide interpretation

The key features of the epidermis such as epidermal cell shape, size and arrangement; vascular vessels type; stomata type and arrangement; shape and arrangements of hairs and trichome, crystal etc. of the fragments of the reference plants were first photographed through a 10x and 40x microscope. Then, each fecal sample, non-overlapping and distinguishable 50 fragments, observed while moving the slides from left to right in the microscope and identified by comparing the key features of reference plants.

3.3 Data Analysis

3.3.1 Habitat Selection Assessment

Logistic regression model was developed for the resource selection probability function to assess resource selection classified in used (presence) and unused (absence) plots as described by Boyce and McDonald (1999). We used multiple logistic regression to predict linkage between responses of dependent variable (musk or livestock) with independent variables (slope, elevation, canopy cover, ground cover and distance from the water source). The response variable was kept as binary (presence=1 and absence=0) for Musk Deer and livestock. Habitat parameters such as elevation, slope, canopy cover, ground cover and distance from water source were kept as explanatory variables to compute the association with the response variable. Significant habitat parameters were recorded from the developed regression model. Generalized Linear Model (GLM) was used in R software (version 3.2.1) for statistical analysis.

3.3.2 Habitat Overlap Assessment

The spatial habitat overlap was analyzed using methods developed by Real (1999) and Real and Vargas (1996). All the data collected from same 69 plots (10m×10m) were used as described above, to find the habitat overlap of Musk Deer with livestock. Habitat overlap between Musk Deer and livestock were compared using Jaccard's similarity index (J) expressed as

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

Where, A is the number of plots used by Musk Deer only, B is the number of plots used by livestock only, and C is the number of plots used by both Musk Deer and livestock. The value of J ranges from zero to one where zero means no overlap while one means highly overlap.

3.3.3 Diet Composition

Diet composition was expressed in relative frequency (RF) based on total number of fragments identified (as adopted by Chetri 2006) and calculate as:

$$RF = \frac{n}{N} \times 100\%$$

Where, n= Total number of fragments identified for a given food species.

N= Grand total number of fragments counts made in all sample.

3.3.3.1 Diet Niche Breadth

Levins' measure of Niche Breadth (Levins' 1968) described by Krebs (1999) was used to evaluate the degree of selectivity of plant species included in the diet of Musk Deer and livestock (as adopted by Bhattacharya *et al.* 2012), which measures how uniformly resources are being utilized, was used.

The equation is

$$B = 1/\sum_{i=1}^{n} P_i^2$$

Where, P_i= proportion of diet contributed by resource i (i= 1, 2……, n)

n= total number of plant species in all samples.

Pi = Ni/Y,

Ni= Number of individuals found in or using resources state i.

Y= ∑Ni = total number of individual sampled.

Diversity was standardized to a scale of 0.0 to 1.0 by using Hurlbert's method (Krebs 1999)

$$Bs = B-1/n-1$$

Where, Bs= Levins' standardized niche breadth,

B is Levins' measure of niche breadth, and n is the number of possible resources.

A low value of Bs indicates that the animal is selective of specific forage.

3.3.4 Diet Overlap

The Simplified Morisita's index (C_λ) proposed by Horn (1966) was used to estimate the diet overlap between Musk Deer and livestock (as adopted by Shrestha *et al.* 2005). It is calculated by:

$$C_\lambda = 2\Sigma (P_{ij} * P_{ik}) / (\Sigma P_{ij}^2 + \Sigma P_{ik}^2)$$

Where,

C_λ = Simplified Morisita Index of overlap (Horn 1966) between species j and species k

P_{ij} and P_{ik} are the proportion of resource in the total resources used by the species j (Musk Deer) and k (livestock).

The value of overlap ranges from 0 (no overlap) to 1 (complete overlap), with substantial overlap indicated when the index is >0.60 (Zaret and Rand 1971).

4. RESULTS

4.1 Habitat Selection Assessment

Slope and ground cover were found to be statistically significant to habitat selection by Musk Deer. Slope (Estimate=0.0877, P<0.05, S.E=0.02969) was positively correlated to the likelihood of habitat selection, while the ground cover (Estimate= -0.0340, P<0.05, S.E=0.0163) was negatively correlated. Elevation and distance from the water sources were not found to be statistically significant. Besides, canopy cover was also not statistically significant (Table 1).

Table 1: Significance level of habitat parameters that affect Musk Deer

Coefficients					Mean
	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-22.7684	13.1155	-1.736	0.0826.	
Slope	0.0877	0.02969	2.955	0.0031 **	43.04°
Elevation	0.0059	0.0038	1.586	0.1128	3623.86 m.
Canopy cover	0.0069	0.0143	0.486	0.6267	39.78 %
Ground cover	-0.0340	0.0163	-2.090	0.0366 *	30.87 %
Distance from water sources	-0.0024	0.0022	-1.106	0.2687	435.90 m.
Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

Likewise, ground cover (Estimate=3.277e-02, P<0.05, S.E=1.616e-02) and elevation (Estimate= -7.459e-03, P<0.05, S.E=3.867e-03) were found to be statistically significant on the likelihood of habitat selection by livestock with negative and positive correlation value respectively but slope, canopy cover and distance from water sources were not statistically significant (Table 2).

Table 2: Significance level of habitat parameters that affect Livestock.

Coefficients:					**Mean**
	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**	
(Intercept)	2.695e+01	1.335e+01	2.019	0.0435 *	
Slope	-2.299e-02	2.422e-02	-0.949	0.3426	43.04°
Elevation	-7.459e-03	3.867e-03	-1.929	0.0537**.**	3623.86 m.
Canopy cover	1.717e-02	1.546e-02	1.110	0.2668	39.78 %
Ground cover	3.277e-02	1.616e-02	2.028	0.0426 *	30.87 %
Distance from water sources	5.064e-05	2.177e-03	0.023	0.9814	435.90 m.
Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

4.2 Habitat Overlap Assessment

Of the 69 plots studied, Musk Deer signs were found exclusively in 22 plots. Similarly, livestock signs were found exclusively in 22 plots while signs of both Musk Deer and livestock were found in 22 plots. Jaccard's index for habitat overlap was found to be 0.33 (Table 3). The mean value (±SD) of habitat parameters used by both Musk Deer and livestock were found; slope of 47±11.06°, elevation of 3623±90.41 m, canopy cover of 41±18.49 %, ground cover of 32± 20.85% and distance from water sources of 429± 127.83 m.

Table 3: Number of plots used by Musk Deer, Livestock and both**.**

Ungulates	No. of sign recorded plots	Percentage	J=C/(A+B+C)
Musk Deer only (A)	22	33.33	0.33
Livestock only (B)	22	33.33	
Both (C)	22	33.33	
Total	66	100	

4.3 Diet Composition

Fifty fragments from each prepared slide was recorded for analysis through micro-histological technique. A total of 2200 fragments of 44 slides (20 from winter and 24 from summer) from each Musk Deer and livestock sample were observed and identified. A total of 31 plant species belonging to 22 families and 29 plant species of 19 families were recorded from the Musk Deer and livestock fecal samples respectively (Table 4).

Table 4**:** Relative frequency of various plant categories (F.C. = Functional Category, family and species) identified in pellets of Musk Deer and Livestock in summer and winter seasons in Mustang, Nepal.

F.C	**Family**	**Food Plants**	**Winter**		**Summer**	
			Musk (R.F)	**Livestock (R.F)**	**Musk (R.F)**	**Livestock (R.F)**
Grass	Cyperaceae	*Carex* sp.	0	0	0.083	0.083
		Kobresia sp.	0		0.083	3.333
	Poaceae	*Calamagrostis scabrescens*	0	6.5	0.833	7.167
		Festuca sp.	0	0.1	0	0.417
Herbs	Boragineceae	*Arnebia euchorma*	0.1	0.1	0	0
	Compositae	*Anaphalis contorta*	0.1	0	0	0.083

	(Asteraceae)	*Taraxacum* sp.	0.3	0.2	0.083	0.167
	Geraniaceae	*Geranium donianum*	0.1	0.1	0.083	0.083
	Iridaceae	*Iris goniocarpa*	0.1	0	0.083	0.167
	Leguminosae (Fabaceae)	*Hedysarum kumaonense*	0.2	7.9	0.333	4.583
		Oxytropis	0.1	0	0	0.417
	Liliaceae	*Polygonatum* sp.	0.1	0.5	0	0
	Polygonaceae	*Bistort* sp.	0.5	0	0.083	0
	Ranunculaceae	*Anemone rivularis*	0.1	0	0.083	0
		Thalictrum sp.	0.5	0.9	0.25	0.333
Shrubs	Berberidaceae	*Berberis asiatica*	18.8	3	7.583	3.5
	Caprifoliaceae	*Lonicera purpurea*	2.2	0.1	0.083	0
		L. spinosa	0.5	0.9	0.083	5.5
		L. webbiana	5.4	0.3	0.916	0.75
	Cupressaceae	*Juniperus* sp.	6.1	0.3	1.583	2.583
	Ephedraceae	*Ephedra gerardiana*	0	1.3	0.167	0.167
	Ericaceae	*Rhododendron lepidotum*	0.7	0.1	0	0.25
	Leguminosae (Fabaceae)	*Caragana* sp.	2.8	0.7	1.5	0.75
	Oleaceae	*Syringa emodi*	0.2	0.3	0.083	0.083
	Ranunculaceae	*Clematis barbellata*	0.2	0	0	0
	Rosaceae	*Cotoneaster ludlowii*	1	2.6	1.5	2.1667
		Rosa sericea	1.4	2	1.167	0.75
		Spiraea arguta	0	0.1	0.083	0.083
	Salicaceae	*Salix* sp.	0.4	0.5	0	0.083
Tree	Betulaceae	*Betula utilis*	0.4	1.6	1	2.833
	Pinaceae	*Abies spectabilis*	23.1	5.3	62.583	24.667
		Pinus wallichiana	18.1	44.3	15.083	30.25
Unknown		Unknown	16.5	13.9	4.583	8.75

4.3.1 Winter diet composition of Musk Deer and Livestock based on functional plant category

Trees and shrubs were found as the higher proportion of diets for Musk Deer (r.f= 41.6 % and 39.7% respectively) whereas herbs was very less consumed (r.f=2.2%) and grass was completely avoided by Musk Deer. Similarly, livestock was also found of being consumed the tree mostly (r.f=51.2 %) rather than grass (r.f = 13 %), shrub (r.f =12.2%) and herbs (r.f=9.7%) (Figure 2, Appendix 2).

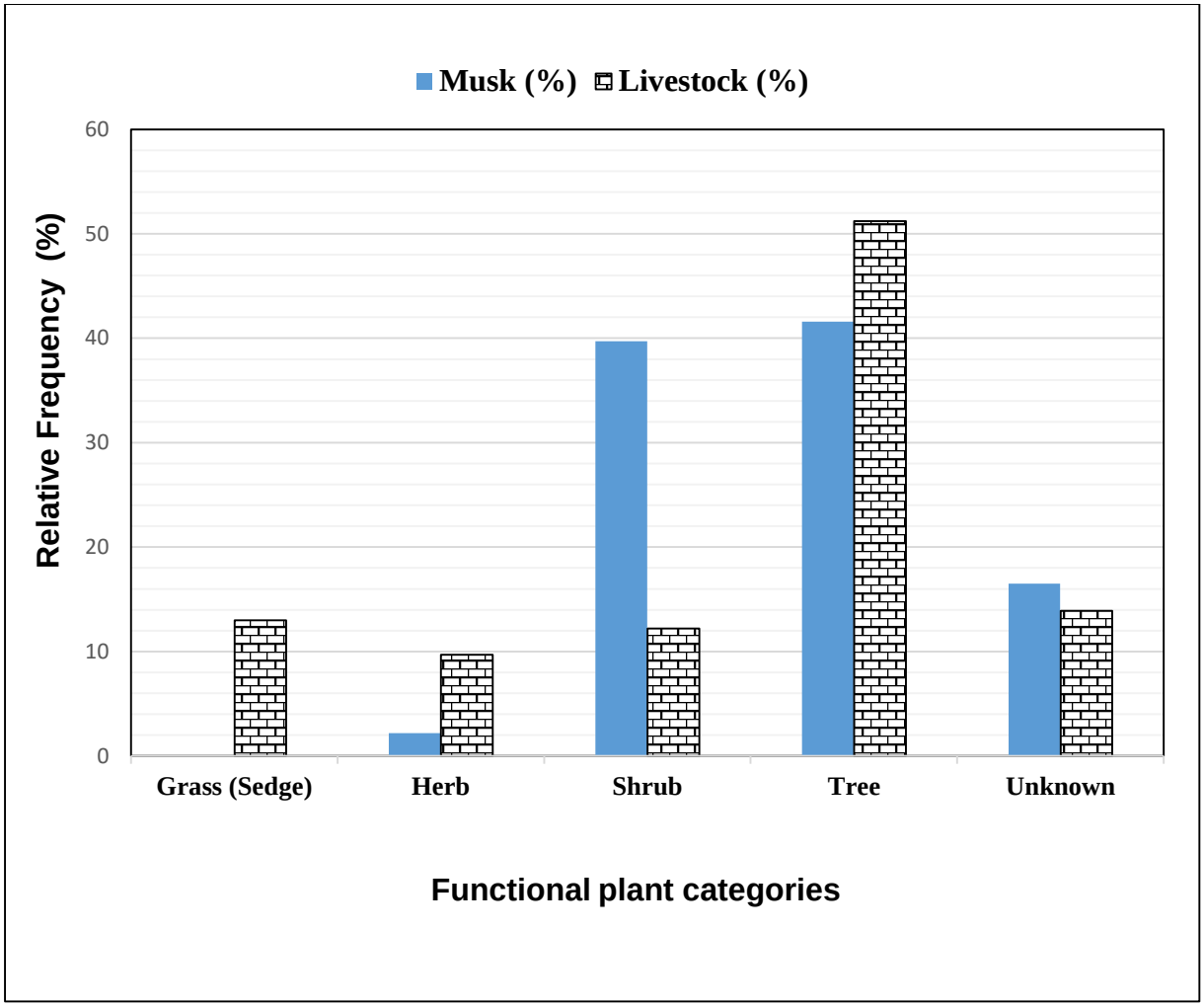

Figure 3: Winter diet composition of Musk Deer and Livestock based on functional plant category.

4.3.2 Winter Diet composition of Musk Deer and livestock

During winter season, 26 plants species were found as the diet of Musk Deer, while 16.5% of the diet was found unknown (Figure 4). Among the known identified diet of the Musk Deer, the major dietary species was *Abies spectabilis* (23.1%) which was followed by *Berberis asiatica* (18.8%), *Pinus wallichiana* (18.1%), *Juniperus* sp. (6.1%), *Lonicera webbiana* (5.4%), *Caragana* sp. (2.8%), *Lonicera purpurea (*2.2%), *Rosa sericea (*1.4%) (Figure 4, Appendix 3). Also, plant species *viz*. *Cotoneaster ludlowii*, *Rhododendron lepidotum*, *Bistorta* sp., *Betula utilis*, *Lonicera spinosa*, *Thalictrum* sp., *Salix* sp., *Taraxacum* sp., *Clematis barbellata*, *Hedysarum kumaonense*, *Syringa emodi*, *Anaphalis contorta*, *Anemone rivalaris*, *Arnebia euchorma*, *Geranium donianum*, *Iris gonicarpa*, *Oxytropis* sp., and *Polygonatum* sp., were consumed in small proportion by the Musk Deer (Figure 4).

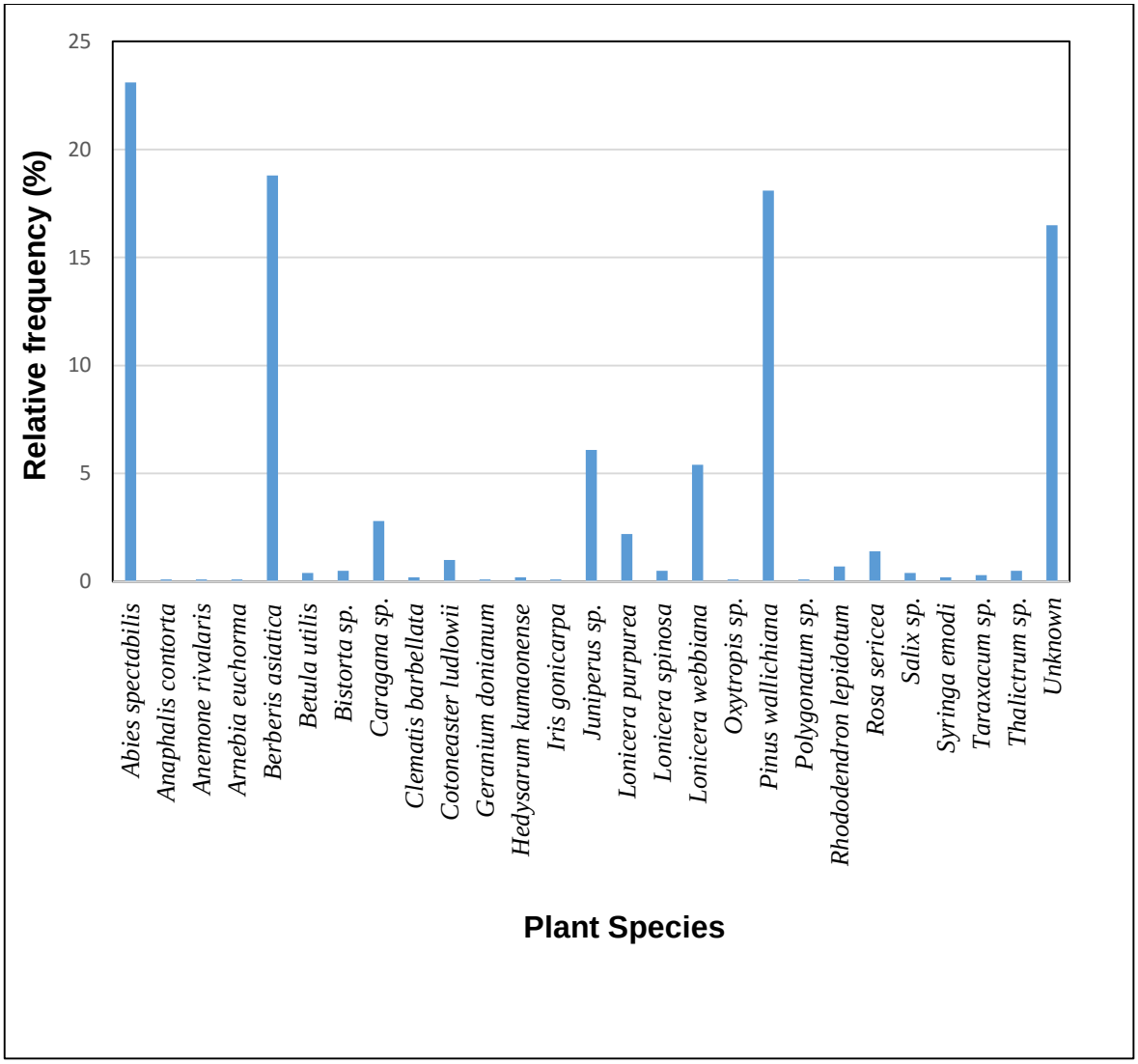

Figure 4: Winter diet composition of Musk Deer.

A total of 25 plant species were identified as the diet of livestock, while 13.9% of their diet were found unknown (Figure 5). *Pinus wallichiana* (44.3%) was found to be the major contributor to the diet of livestock, followed by *Hedysarum kumaonense* (7.9%), *Calamagrostis scabrescens* (6.5%), *Kobresia* sp. (6.4%), *Abies spectabilis* (5.3%), *Berberis asiatica* (3%), *Cotoneaster ludlowii* (2.6%), *Rosa sericea* (2%), *Betula utilis* (1.6%); respectively (Appendix 4). Additionally, other plant species consumed by livestock were *Ephedra gerardiana, Caragana* sp., *Lonicera spinosa, Thalictrum* sp., *Polygonatum* sp., *Salix* sp., *Juniperus* sp., *Lonicera webbiana, Syringa emodi, Taraxacum* sp., *Arnebia euchorma, Festuca* sp., *Geranium donianum, Lonicera purpurea, Rhododendron lepidotum and Spiraea arguta.*

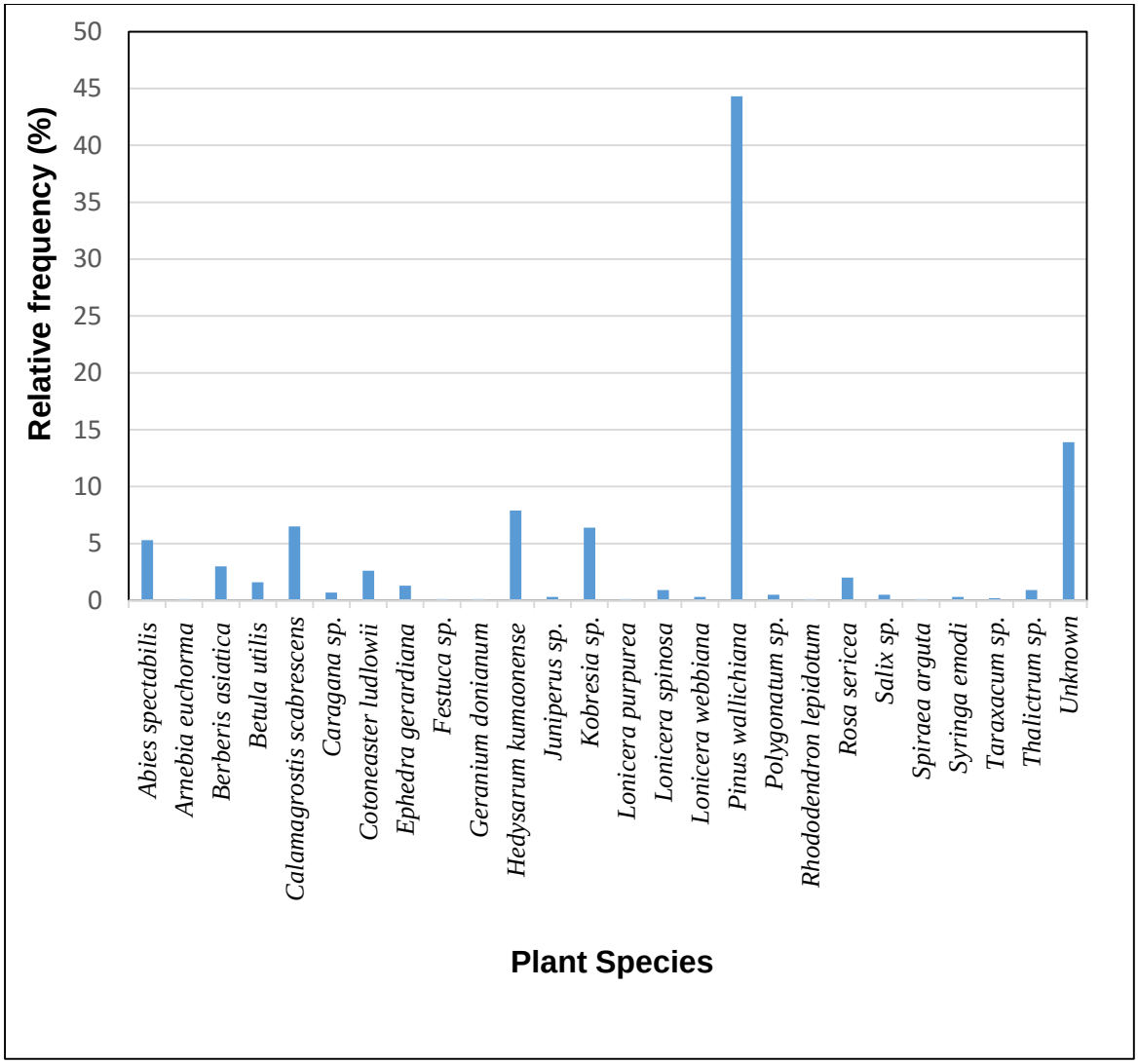

Figure 5: Winter diet composition of Livestock.

4.3.3 Summer diet composition of Musk Deer and Livestock based on functional plant category

Trees contributed the higher proportion of diet of Musk Deer (78.67 %) and livestock (57.75%) followed by shrubs; 14.75% and 16.67% respectively. However, graminoids and forbs each, contributed 1% of the diet of Musk Deer and their contribution was 11% and 5.83%; respectively to the diet of livestock (Figure 6, Appendix 5).

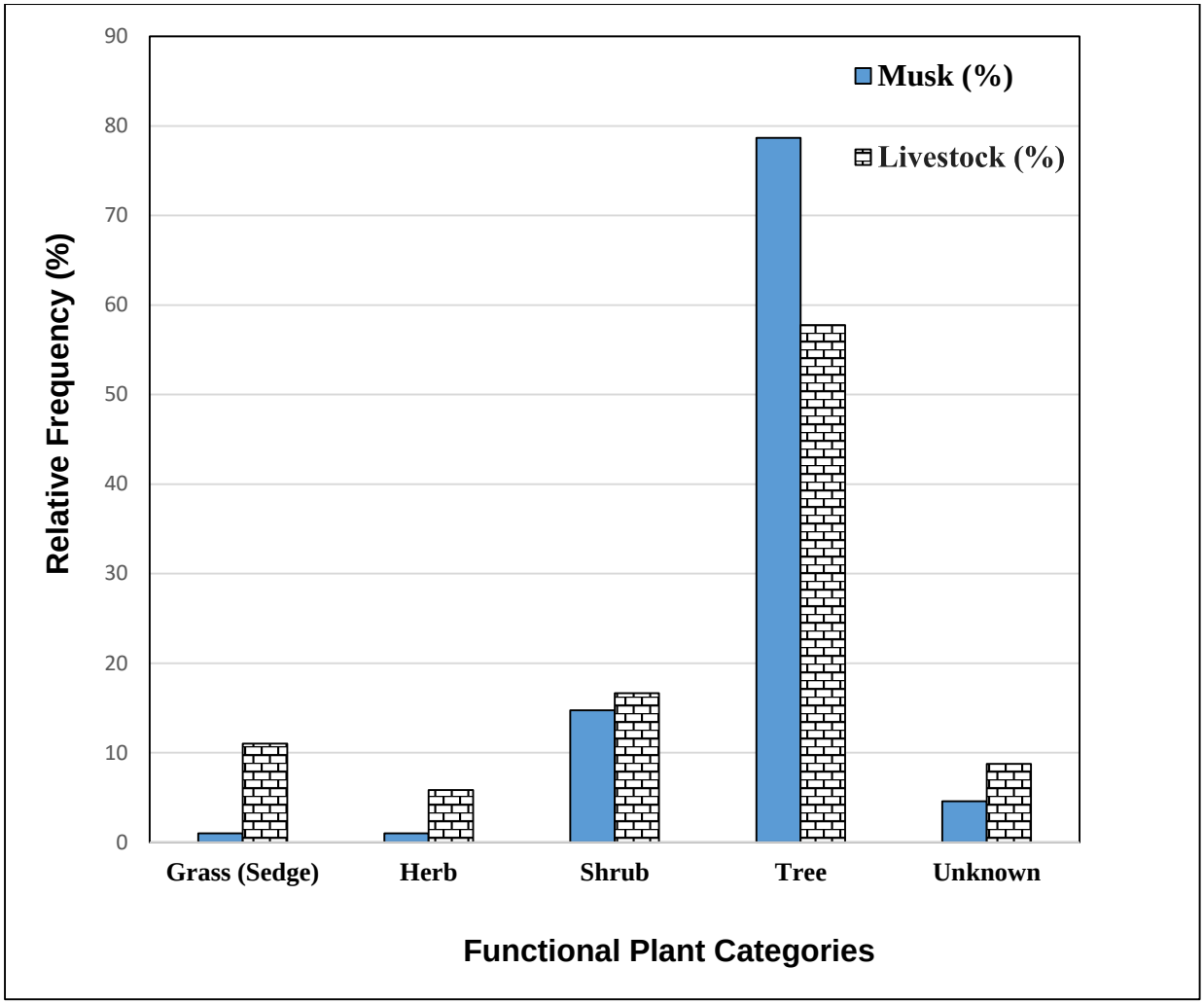

Figure 6: Summer diet composition based on functional plant category of Musk Deer.

4.3.4 Summer Diet composition of Musk Deer and Livestock

During summer season, 24 plant species were identified while 4.58% of the consumption was unidentified in the diet of Musk Deer (Figure 7). *Abies spectabilis* (62.58%) was found as the dominant dietary plant species, other plant species like *Pinus wallichiana* (15.08%), *Berberis asiatica* (7.58%), *Juniperus* sp. (1.58%), *Caragana* sp. (1.5%) and *Rosa sericea* (1.17%) also contributed to the diet of Musk Deer. *Geranium donianum, Lonicera webbiana, Spiraea arguta, Syringa emodi, Taraxacum* sp., *Thalictrum* sp., *Cotoneaster ludlowii, Betula utilis, Ephedra gerardiana, Hedysarum kumaonense, Bistorta sp., Calamagrostis scabrescens, Carex* sp., *Anemone rivalaris, Iris gonicarpa, Kobresia* sp., *Lonicera purpurea* and *Lonicera spinosa* (Figure 7, Appendix 6) were found to be consumed in relatively small proportion in the diet of Musk Deer.

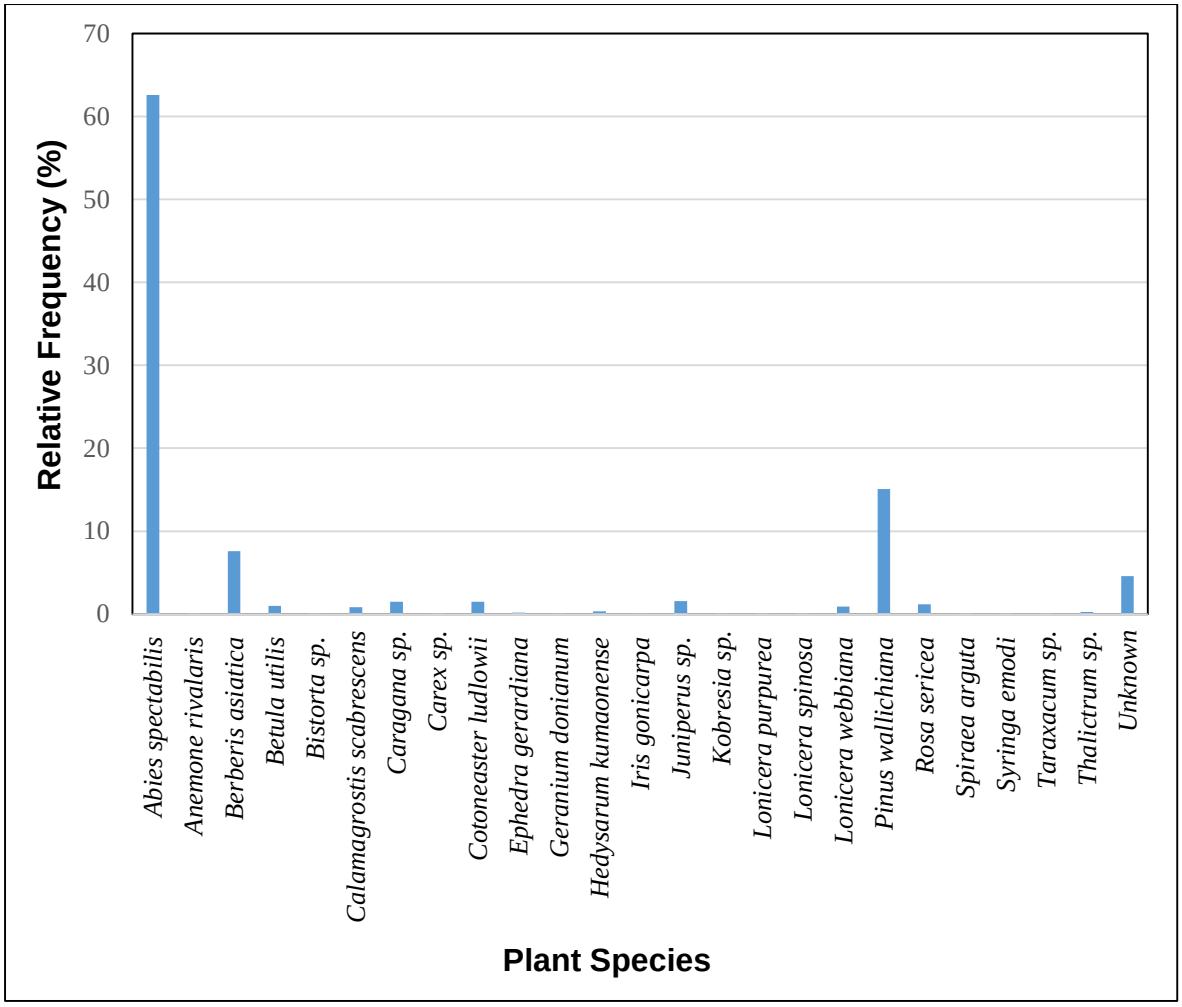

Figure 7: Summer diet composition based on species of Musk Deer.

A total of 26 plant species were found in the diet of livestock and 8.75 % of the diet was unidentified (Figure 8). *Pinus wallichiana* (30.25%) and *Abies spectabilis* (24.67%) were found the major dietary species of livestock whereas, *Calamagrostis scabrescens* (7.17%), *Lonicera spinosa* (5.5%), *Hedysarum kumaonense* (4.58%), *Kobresia* sp. (3.33%), *Betula utilis* (2.83%), *Juniperus* sp. (2.58%) and *Cotoneaster ludlowii* (2.17%) were also contributed moreover, other species *viz*. *Rosa sericea, Lonicera webbiana, Caragana* sp., *Festuca* sp., *Oxytropis* sp., *Thalictrum* sp., *Ephedra gerardiana, Iris gonicarpa, Taraxacum* sp., *Anaphalis contorta, Rhododendron lepidotum, Carex* sp., *Geranium donianum, Salix* sp., *Spiraea arguta and Syringa emodi* were also found in small quantity in their diet (Figure 8, Appendix 7).

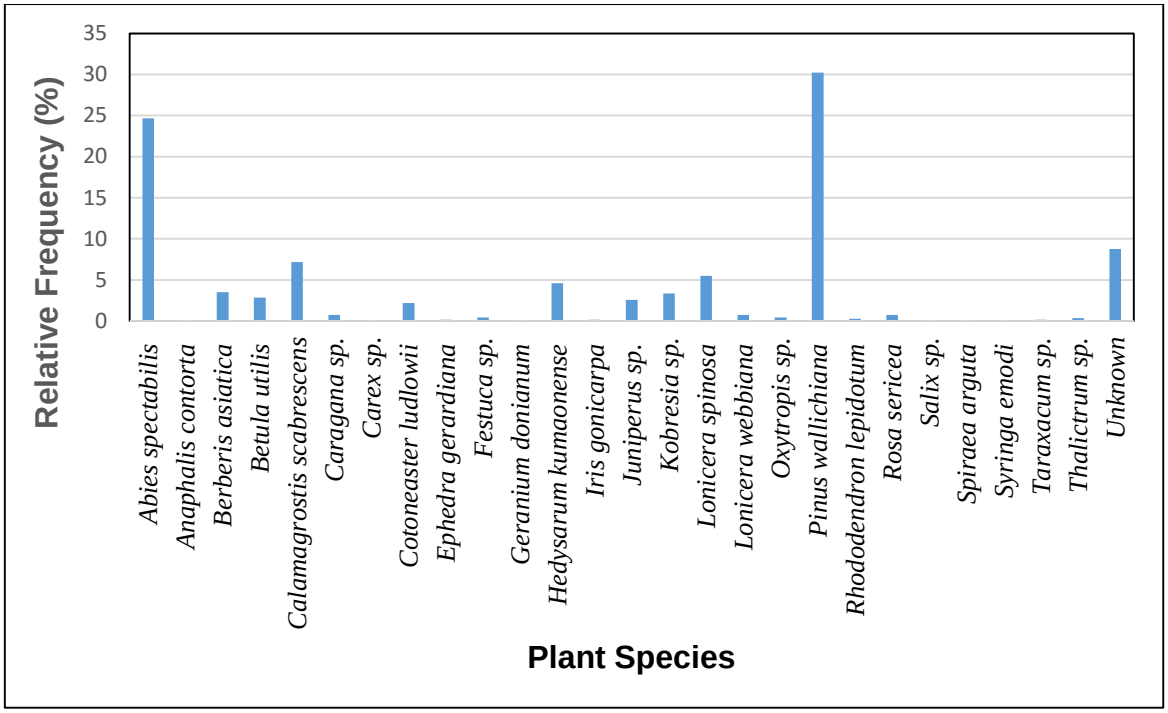

Figure 8: Summer diet composition of Livestock.

4.3.5 Diet Niche Breadth of Musk Deer and Livestock

During winter, diet niche breadth (Bs) value of Musk Deer and livestock were found 0.206 and 0.129 respectively. Similarly, summer diet niche breadth for Musk Deer and livestock were 0.057 and 0.182; respectively (Figure 9, Appendix 8, 9, 10 and 11). Both Musk Deer and livestock niche breadth values were found minimum as it was near to zero in both seasons.

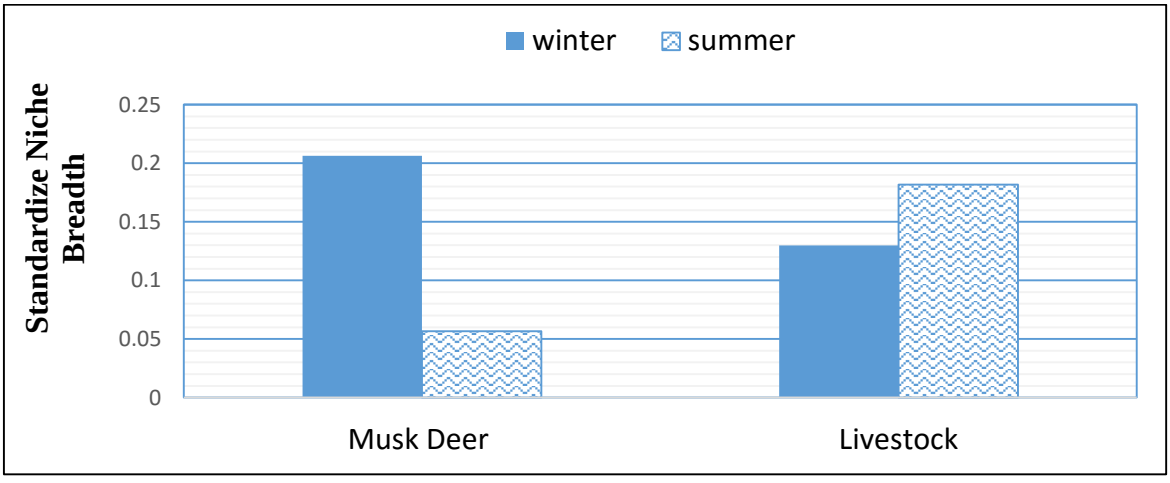

Figure 9: Seasonal Diet Niche Breadth of Musk Deer and Livestock

4.4 Diet Overlap

A total of 31 plant species were identified in the diet of Musk Deer and livestock in winter season. Out of these, 20 species were common in the diet of both. Whereas, 29 species recorded in summer and 21 species were found common in both. Diet overlap (C_λ) between Musk Deer and livestock during winter and summer seasons were 0.57 and 0.71 respectively. Diet overlap was found high in the summer than the winter. This result showed considerable similarity in food selection of Musk Deer and livestock in both seasons (Table 5) (Appendix 12 and 13).

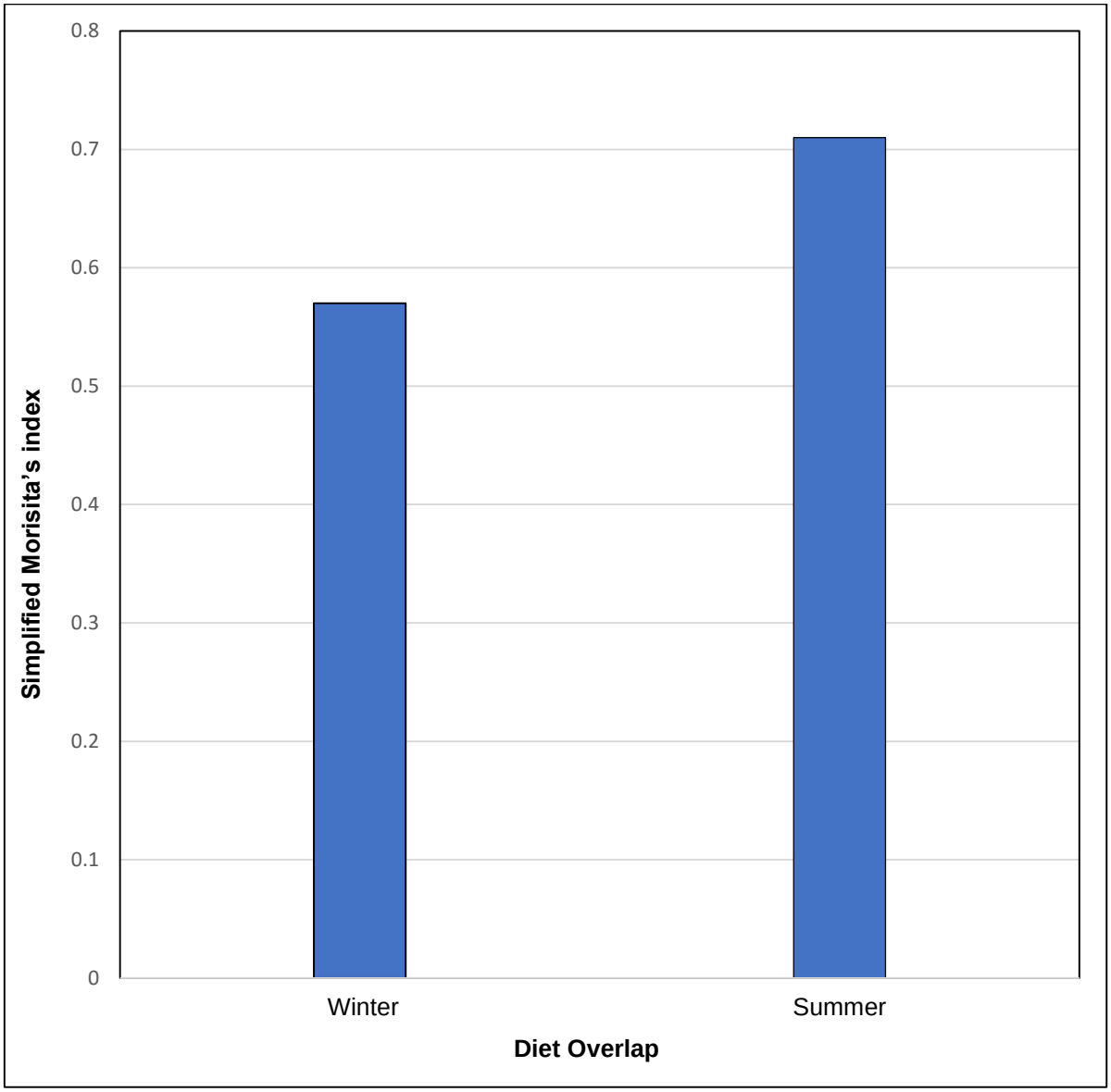

Figure 10: Simplified Morisita's index (Cλ) of diet overlap (Horn 1966) between the winter and summer diets of Musk Deer and Livestock. Cλ: from 0.0 for completely dissimilar diets to 1.0 for complete overlap.

5. DISCUSSION

5.1 Habitat Selection Assessment

The present study describes the important picture of habitat selection by Musk Deer and livestock in the study area. Slope was found to have the significant impact on the Musk Deer presence as Musk Deer presumably selected the area with the steep slope. This might be because Musk Deer selected the steep slope to avoid the threats of livestock and human encroachment, as well as special feature of their feet help to climb in rough terrain (Green 1985). Wangchuk (2012) had also obtained the similar result that Musk Deer was adapted to live in the steep slopes (60°-80°) in Thrumshingla National Park, Bhutan whereas Aryal *et al.* (2010) found slope preference for Musk Deer was above 45° in Sagarmatha National Park, Nepal and highly preferred between 41°-60° (Joshi 2011) in Mustang, Nepal which is in accordance to this result. Elevation, crown cover and distance from water sources were relatively not significant on the likelihood of habitat selection by Musk Deer in the area. However, ground cover was significant thereby suggested that the Musk Deer selected the area with less ground vegetation. This is presumably because the Musk Deer selected the dense forest where ground vegetation was low. This result is similar to the finding of Aryal *et al.* (2010) and Green (1986) that with less vegetation in ground, Musk Deer could view to the far distance and easily see the predators or dangers. On the other hand, livestock likely used the low altitude and high vegetation of ground area. This might be because in the highly dense ground cover area they could easily get their diet. The other reason might be it is energetically costly to livestock to ascend to high elevation for foraging. Hence, they selected the areas with high forage availability in the lower elevation. Vegetation analysis of the study area showed that dominant tree species around its habitat were *Abies spectabilis*, *Betula utilis* and *Pinus wallichiana*. Similar results were also obtained by (Kattel 1992, Aryal 2005, Rajchal 2006, Pandey 2006, Aryal 2007, Karki, 2008, Aryal *et al.* 2010, Joshi 2011, Subedi *et al.* 2012, Subedi 2013). Also Dominant shrub species such as *Berberis* sp. and *Rosa* sp. was similar to finding of Aryal (2005) and Subedi (2013).

5.2 Habitat Overlap Assessment

Habitat overlap between Musk Deer and livestock was not significant; suggesting spatial segregation of these two groups of herbivores. The use of habitat parameters (slope, elevation

and ground cover) were significantly different for Musk Deer and livestock. So, the less habitat overlap between them was found. This result is in contrast with the findings of Aryal (2007), Aryal *et al.* (2010), Syed and IIyas (2015), where high habitat overlap between Musk Deer and livestock was observed. However, concordance with of Joshi (2011) and Singh (2015), where they found no such significant habitat overlap at Lower Mustang. Namgail *et al.* (2007) found Tibetan Argali shifted to areas with less vegetation cover after livestock entered their habitat and moved to steeper areas near the cliffs in response to the livestock's presence in Gya-Miru Wildlife Sanctuary (proposed), Ladakh, India. Also, studies on the spatial displacement of wild ungulates by livestock/cattle had been reported in the mule deer (Loft *et al.* 1991), mountain elk (Stewart *et al.* 2002), and Iberian ibex (Acevedo *et al.* 2007). Researches (Schaller 1977, Jackson and Ahlborn 1987, Paudyal and Bauer 1988, Bauer 1990, Prins 1992, Mishra 2001, Bagchi *et al.* 2002, Raghavan 2003) suggested that livestock grazing patterns and using herding dogs (Namgail *et al.* 2004b) had affected distribution and abundance of wild ungulates considerably in the past. Similarly, according to current study result also Musk Deer choose to live in the steep slope with less vegetation of ground area. It might be because of livestock enter in their habitat in the past and displace them from their habitat. Hence, this may be the reason behind the less habitat overlap between Musk Deer and livestock in the study area.

5.3 Diet Composition and Diet Niche Breadth

Overall, 32 plant species were recorded in the diet of Musk Deer and 19 species were found common in both seasons. On the whole, trees contributed the major part of the diet followed by shrubs, herbs but grasses was completely avoided in the winter whereas found partly consumed in summer. The result coincided the result obtained by Bhattacharya *et al.* (2012), Singh (2015). This might be because of the density of trees and shrubs were high among the vegetation in the study area. The availability of vegetation affect directly on the foraging habits of the species (Shrestha *et al.* 2005). But this is contradict with Syed and Ilyas (2015) where they obtained forbs as the main diet of the Musk Deer in the in Kedarnath Wildlife Sanctuary, Uttarakhand, India.

A total of 29 plant species were identified as the diet of livestock and 22 species were common in diet of both seasons. Overall, trees were found the major diet composition of livestock in both the seasons which was followed by shrubs, grasses and herbs. Many investigators had reported that grasses to be the most important component of livestock diet (Van Dyne *et al.* 1980) but this study showed the trees as the main diet of the livestock. This could be because

of low availability of grasses in the study area. Harris and Miller (1995) also reported that livestock diets varied significantly depending on vegetation communities in local areas and were likely influenced by herding practices that potentially limit the variability of their diet. This might be the reason that tree found as the major diet of livestock, as the trees saplings (*Abies spectabilis, Pinus wallichiana)* was dominant vegetation at the study area.

Standardized Niche Breadth value of Musk Deer was low in both seasons (Bs=0.198 in winter and Bs=0.057 in summer). The low value shows that Musk Deer is the selective feeder in both seasons. This might be because of specific forages in their diet. Gurung (1991) and Kattel (1992) had also found that Musk Deer as selective nature of feeding habit which was similar to our finding. For livestock, the Standardized Niche Breadth value was also low in both seasons (B_S=0.129 in winter and Bs= 0.169 in summer). The low value indicates that livestock has selective feeding habit in nature. Both the species (Musk Deer and livestock) were found as selective feeders (specialist).

5.4 Diet Overlap

In this study, both Musk Deer and livestock were found as a selective nature of feeding habits, so diet overlap seems to be inevitable (Schaller 1977). Hence, they were expected to compete for the same forage when feeding in the same habitat. It was found that high diet overlap between Musk Deer and livestock in both winter and summer seasons. But, diet overlap was found more in summer than winter. This might be because of suitable climatic condition in summer in which livestock forage easily at high altitude of Musk Deer's habitat but in winter, harsh climatic conditions obstacle the livestock for foraging at the high altitude. The present study resembled with the result obtained by the Bhattachary *et al.* (2012) where high diet overlap was found between Musk Deer and livestock. Overall diet composition of Musk Deer and livestock for both seasons was found similar with a few exceptions (11 plant species in winter and 8 plant species in summer, appendix 15). Many plant species (appendix 12 and 13) were found to be shared by both the groups so competitive interactions for food is presumably high.

6. CONCLUSION AND RECOMMENDATIONS

From the present study, the following conclusions were deprived:

- Slope and ground cover were found to be the prevailing habitat parameters affecting Musk Deer whereas elevation and ground cover for livestock. Musk Deer preferred the steep slope with less vegetation ground cover area while livestock preferred low elevation with high vegetation ground cover area.
- Habitat overlap between Musk Deer and livestock was not significant as their habitat parameters (slope, elevation and ground cover) preference was difference.
- The diet of Musk Deer was dominated by the tree in both winter and summer seasons. It consumed altogether 31 plant species, among which *Abies spectabilis, Pinus wallichiana* and *Berberis asiatica* were major food items. Likewise, livestock consumed 29 plant species in which tree species was dominant. Among the plant species consumed by livestock *Pinus wallichiana, Abies spectabilis Hedysarum kumaonense, Calamagrostis scabrescens* and *Kobresia* sp. were found the dominant food items. As both, Musk Deer and livestock were found as selective feeders.
- Diet overlap between Musk Deer and livestock was found high as both were selective feeder and feeding habits also found similar. This represented that high competition for food resources in the study area.

From the study, following recommendations are suggested:

- Freely grazing of livestock in the habitat of Musk Deer should be controlled. A core habitat should be delineated in the prime habitat of Musk Deer and restricted to graze domestic livestock and collect forest products or to carry out any activities which may disturb Musk Deer. Grazing should be managed by securing the support of local villagers. Also regular patrolling should be done in the Musk Deer habitats.
- Awareness and conservation programs should be conducted focused for the herder, students and local people in order to develop the attitude of people towards the conservation of Musk Deer and other species as well.
- Scientific studies of the species in other part of the nation should be undertaken to explore their status, habitat evaluation, diet composition and; their habitat and diet overlap with livestock.

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APPENDICES

1. List of plants collected from forest area of Jomsom for reference library.

S.N.	Plant name	Family	Functional category
1	*Abies spectabilis*	Pinaceae	Tree
2	*Anaphalis contorta*	Compositae (Asteraceae)	Herb
3	*Androsace strigillosa*	Primulaceae	Herb
4	*Anemone rivularis*	Ranunculaceae	Herb
5	*Arnebia euchorma*	Boraginaceae	Herb
6	*Artemisia* sp.	Compositae (Asteraceae)	Herb
7	*Berberis asiatica*	Berberidaceae	Shrub
8	*Betula utilis*	Betulaceae	Tree
9	*Bistorta* sp.	Polygonaceae	Herb
10	*Calamagrostis scabrescens*	Poaceae	Grass
11	*Caragana* sp.	Leguminosae	Shrub
12	*Carex* sp.	Cyperaceae	Grass
13	*Clematis barbellata*	Ranunculaceae	Climbing Shrub
14	*Cotoneaster ludlowii*	Rosaceae	Shrub
15	*Cremanthodium* sp.	Compositae	Herb
16	*Festuca* sp.	Poaceae	Grass
17	*Geranium donianum*	Geraniaceae	Herb
18	*Hedysarum kumaonense*	Fabaceae	Herb
19	*Iris goniocarpa*	Iridaceae	Herb
20	*Juniperus* sp.	Cupressaceae	Shrub
21	*Kobresia* sp.	Cyperaceae	sedge-grasslike
22	*Lonicera purpurea*	Caprifoliaceae	Shrub
23	*Lonicera spinosa*	Caprifoliaceae	Shrub
24	*Lonicera webbiana*	Caprifoliaceae	Shrub
25	*Oxytropis* sp.	Leguminosae (Fabaceae)	Herb
26	*Pedicularis* sp.	Scrophulariaceae	Herb
27	*Pinus wallichiana*	Pinaceae	Tree
28	*Polygonatum* sp.	Liliaceae	Herb
29	*Potentilla fruticosa*	Rosaceae	Shrub

30	*Rhododendron lepidotum*	Ericaceae	Shrub
31	*Rosa sericea*	Rosaceae	Shrub
32	*Salix* sp.	Salicaceae	Shrub
33	*Spiraea arguta*	Rosaceae	Shrub
34	*Syringa emodi*	Oleaceae	Shrub
35	*Taraxacum* sp.	Compositae (Asteraceae)	Herb
36	*Thalictrum* sp.	Ranunculaceae	Herb
37	*Thermopsis barbata*	Leguminosae (Fabaceae)	Herb
38	Unknown grass		Grass
39	Unknown herb 1		Herb
40	Unknown herb 2		Herb
41	Unknown shrub		Shrub

2. Winter Diet composition of Musk Deer and Livestock based on functional plant category.

S.N	Functional Plant Category	Musk Deer (n)	R.F (%)	Livestock (n)	R.F (%)
1	Grass (Sedge)	0	0	130	13
2	Herb	22	2.2	97	9.7
3	Shrub	397	39.7	122	12.2
4	Tree	416	41.6	512	51.2
5	Unknown	165	16.5	139	13.9

3. Winter Diet composition of Musk Deer.

S.N.	Plant species	Musk Deer (n)	R.F (%)
1	*Abies spectabilis*	231	23.1
2	*Anaphalis contorta*	1	0.1
3	*Anemone rivalaris*	1	0.1
4	*Arnebia euchorma*	1	0.1
5	*Berberis asiatica* (Chutro - Nepali)	188	18.8
6	*Betula utilis*	4	0.4
7	*Bistorta* sp.	5	0.5

8	*Caragana* sp.	28	2.8
9	*Clematis barbellata*	2	0.2
10	*Cotoneaster ludlowii*	10	1
11	*Geranium donianum*	1	0.1
12	*Hedysarum kumaonense*	2	0.2
13	*Iris gonicarpa*	1	0.1
14	*Juniperus* sp.	61	6.1
15	*Lonicera purpurea*	22	2.2
16	*Lonicera spinosa*	5	0.5
17	*Lonicera webbiana*	54	5.4
18	*Oxytropis* sp.	1	0.1
19	*Pinus wallichiana*	181	18.1
20	*Polygonatum* sp.	1	0.1
21	*Rhododendron lepidotum*	7	0.7
22	*Rosa sericea*	14	1.4
23	*Salix* sp.	4	0.4
24	*Syringa emodi*	2	0.2
25	*Taraxacum* sp.	3	0.3
26	*Thalictrum* sp.	5	0.5
27	Unknown	165	16.5

4. Winter Diet composition of Livestock.

S.N.	Plant species	Livestock (n)	R.F (%)
1	*Abies spectabilis*	53	5.3
2	*Arnebia euchorma*	1	0.1
3	*Berberis asiatica*	30	3
4	*Betula utilis*	16	1.6
5	*Calamagrostis scabrescens*	65	6.5
6	*Caragana* sp.	7	0.7

7	*Cotoneaster ludlowii*	26	2.6
8	*Ephedra gerardiana*	13	1.3
9	*Festuca* sp.	1	0.1
10	*Geranium donianum*	1	0.1
11	*Hedysarum kumaonense*	79	7.9
12	*Juniperus* sp.	3	0.3
13	*Kobresia* sp.	64	6.4
14	*Lonicera purpurea*	1	0.1
15	*Lonicera spinosa*	9	0.9
16	*Lonicera webbiana*	3	0.3
17	*Pinus wallichiana*	443	44.3
18	*Polygonatum* sp.	5	0.5
19	*Rhododendron lepidotum*	1	0.1
20	*Rosa sericea*	20	2
21	*Salix* sp.	5	0.5
22	*Spiraea arguta*	1	0.1
23	*Syringa emodi*	3	0.3
24	*Taraxacum* sp.	2	0.2
25	*Thalictrum* sp.	9	0.9
26	Unknown	139	13.9

5. Summer Diet composition of Musk Deer and Livestock based on functional plant category.

S.N	Functional Plant Category	Musk Deer (n)	R.F (%)	Livestock	R.F (%)
A	Grass (Sedge)	12	1	132	11
B	Herb	12	1	70	5.83
D	Shrub	177	14.75	200	16.66
E	Tree	944	78.67	693	57.75
F	Unknown	55	4.58	105	8.75

6. Summer Diet composition of Musk Deer.

S.N.	Plant Species	Musk Deer (n)	R.F (%)
1	*Abies spectabilis*	751	62.583
2	*Anemone rivalaris*	1	0.083
3	*Berberis asiatica*	91	7.583
4	*Betula utilis*	12	1
5	*Bistorta* sp.	1	0.083
6	*Calamagrostis scabrescens*	10	0.833
7	*Caragana* sp.	18	1.5
8	*Carex* sp.	1	0.083
9	*Cotoneaster ludlowii*	18	1.5
10	*Ephedra gerardiana*	2	0.167
11	*Geranium donianum*	1	0.083
12	*Hedysarum kumaonense*	4	0.333
13	*Iris gonicarpa*	1	0.083
14	*Juniperus* sp.	19	1.583
15	*Kobresia* sp.	1	0.083
16	*Lonicera purpurea*	1	0.083
17	*Lonicera spinosa*	1	0.083
18	*Lonicera webbiana*	11	0.9167
19	*Pinus wallichiana*	181	15.083
20	*Rosa sericea*	14	1.167
21	*Spiraea arguta*	1	0.083
22	*Syringa emodi*	1	0.083
23	*Taraxacum* sp.	1	0.083
24	*Thalictrum* sp.	3	0.25
25	Unknown	55	4.583

7. Summer Diet composition of Livestock.

S.N.	Plant Species	Livestock (n)	R.F (%)
1	*Abies spectabilis*	296	24.667
2	*Anaphalis contorta*	1	0.083
3	*Berberis asiatica*	42	3.5
4	*Betula utilis*	34	2.833
5	*Calamagrostis scabrescens*	86	7.167
6	*Caragana* sp.	9	0.75
7	*Carex* sp.	1	0.083
8	*Cotoneaster ludlowii*	26	2.167
9	*Ephedra gerardiana*	2	0.167
10	*Festuca* sp.	5	0.4167
11	*Geranium donianum*	1	0.083
12	*Hedysarum kumaonense*	55	4.583
13	*Iris gonicarpa*	2	0.1667
14	*Juniperus* sp.	31	2.583
15	*Kobresia* sp.	40	3.333
16	*Lonicera spinosa*	66	5.5
17	*Lonicera webbiana*	9	0.75
18	*Oxytropis* sp.	5	0.4167
19	*Pinus wallichiana*	363	30.25
20	*Rhododendron lepidotum*	3	0.25
21	*Rosa sericea*	9	0.75
22	*Salix* sp.	1	0.083
23	*Spiraea arguta*	1	0.083
24	*Syringa emodi*	1	0.083
25	*Taraxacum* sp.	2	0.1667
26	*Thalictrum* sp.	4	0.333
27	Unknown	105	8.75

8. Winter Diet Niche Breadth of Musk Deer.

S.N.	Plant species	Musk Deer (n)	P_i	P_i^2	$B= 1/ \sum^n_{i=1} P_i^2$	Bs= B-1/n-1
1	*Abies spectabilis* (Pinaceae family) (tree)	231	0.231	0.053361		
2	*Anaphalis contorta* (Compositae)(herb)	1	0.001	0.000001		
3	*Anemone rivularis* (Ranunculaceae) (Herb)	1	0.001	0.000001		
4	*Arnebia euchorma*(Boraginaceae)(Herb)	1	0.001	0.000001		
5	*Berberis asiatica* (Berberidaceae) (shrub)	188	0.188	0.035344		
6	*Betula utilis* (Betulaceae family) (tree)	4	0.004	0.000016		
7	*Bistorta sp.* (Polygonaceae)(Herb)	5	0.005	0.000025		
8	Caragana sp. (Leguminosae)(Shrub)	28	0.028	0.000784		
9	*Clematis barbellata* (ranunculaceae) (climbing shrub)	2	0.002	0.000004		
10	*Cotoneaster ludlowii* (Rosaceae) (shurb)	10	0.01	0.0001	6.3664	0.2064
11	*Geranium donianum* (geraniaceae) (herb)	1	0.001	0.000001		
12	*Hedysarum kumaonense* (Leguminosae) (herb)	2	0.002	0.000004		
13	Iris gonicarpa (Iridaceae) (Herb)	1	0.001	0.000001		
14	*Juniperus* sp. (cupressaceae) (shrub)	61	0.061	0.003721		
15	*Lonicera purpurea* (caprifoliaceae) (shrub)	22	0.022	0.000484		
16	Lonicera spinosa (Caprifoliaceae) (shrub)	5	0.005	0.000025		
17	*Lonicera webbiana* (caprifoliaceae) (shrub)	54	0.054	0.002916		

18	Oxytropis sp. (Leguminosae) (herb)	1	0.001	0.000001		
19	*Pinus wallichiana* (pinaceae) (tree)	181	0.181	0.032761		
20	*Polygonatum* sp. (Liliaceae) (herb)	1	0.001	0.000001		
21	*Rhododendron lepidotum* (ericaceae) (shrub)	7	0.007	0.000049		
22	*Rosa sericea* (rosaceae) (shrub)	14	0.014	0.000196		
23	*salix* sp. (salicaceae) (shrub)	4	0.004	0.000016		
24	*Syringa* emodi (Oleaceae) (shrub)	2	0.002	0.000004		
25	*Taraxacum* sp. (Compositae) (herb)	3	0.003	0.000009		
26	*Thalictrum* sp. (Ranunculaceae) (Herb)	5	0.005	0.000025		
27	Unknown	165	0.165	0.027225		
	Total	1000		0.157076		

9. Winter Diet Niche Breadth of Livestock.

S.N.	Plant Species	Livestock (n)	P_i	P_i^2	$B= 1/ \sum^{n}_{i=1} P_i^2$	Bs= B-1/n-1
1	*Abies spectabilis* (Pinaceae family) (tree)	53	0.053	0.002809		
2	*Arnebia euchorma*(Boraginaceae)(Herb)	1	0.001	0.000001		
3	*Berberis asiatica* (Berberidaceae) (shrub)	30	0.03	0.0009		
4	*Betula utilis* (Betulaceae family) (tree)	16	0.016	0.000256		
5	*Calamagrostis scabrescens* (Poaceae) (grass)	65	0.065	0.004225		
6	Caragana sp. (Leguminosae)(Shrub)	7	0.007	0.000049		
7	*Cotoneaster ludlowii* (Rosaceae) (shurb)	26	0.026	0.000676		
8	*Ephedra gerardiana* (Ephedraceae) (Shrub)	13	0.013	0.000169		
9	*Festuca* sps (poaceae) (grass)	1	0.001	0.000001		
10	*Geranium donianum* (geraniaceae) (herb)	1	0.001	0.000001	4.24376167	0.12975047
11	*Hedysarum kumaonense* (Leguminosae) (herb)	79	0.079	0.006241		
12	*Juniperus* sp. (cupressaceae) (shrub)	3	0.003	0.000009		
13	*Kobresia* sp. (Cyperaceae) (sedge-grasslike)	64	0.064	0.004096		
14	*Lonicera purpurea* (caprifoliaceae) (shrub)	1	0.001	0.000001		
15	Lonicera spinosa (Caprifoliaceae) (shrub)	9	0.009	0.000081		
16	*Lonicera webbiana* (caprifoliaceae) (shrub)	3	0.003	0.000009		

17	*Pinus wallichiana* (pinaceae) (tree)	443	0.443	0.196249		
18	*Polygonatum* sp. (Liliaceae) (herb)	5	0.005	0.000025		
19	*Rhododendron lepidotum* (ericaceae) (shrub)	1	0.001	0.000001		
20	*Rosa sericea* (rosaceae) (shrub)	20	0.02	0.0004		
21	*salix* sp. (salicaceae) (shrub)	5	0.005	0.000025		
22	*Spiraea* arguta (Rosaceae) (shrub)	1	0.001	0.000001		
23	*Syringa* emodi (Oleaceae) (shrub)	3	0.003	0.000009		
24	*Taraxacum* sp. (Compositae) (herb)	2	0.002	0.000004		
25	*Thalictrum* sp. (Ranunculaceae) (Herb)	9	0.009	0.000081		
26	Unknown	139	0.139	0.019321		
28	Total	1000		0.23564		

10. Summer Diet Niche Breadth of Musk Deer.

S.N.	Plant Species (Summer)	Musk Deer (n)	P_i	P_i^2	$B= 1/ \sum^{n}_{i=1} P_i^2$	Bs= B-1/n-1
1	*Abies spectabilis*	751	0.625833333	0.391667361		
2	*Anemone rivalaris*	1	0.000833333	6.9444E-07		
3	*Berberis asiatica*	91	0.075833333	0.005750694		
4	*Betula utilis*	12	0.01	0.0001		
5	*Bistorta* sp.	1	0.000833333	6.9444E-07		
6	*Calamagrostis scabrescens*	10	0.008333333	6.94444E-05		
7	*Caragana* sp.	18	0.015	0.000225		
8	*Carex* sp.	1	0.000833333	6.9444E-07		
9	*Cotoneaster ludlowii*	18	0.015	0.000225		
10	*Ephedra gerardiana*	2	0.001666667	2.77778E-06	2.361902512	0.0567
11	*Geranium donianum*	1	0.000833333	6.9444E-07		
12	*Hedysarum kumaonense*	4	0.003333333	1.11111E-05		
13	*Iris gonicarpa*	1	0.000833333	6.9444E-07		

14	*Juniperus* sp.	19	0.015833333	0.000250694		
15	*Kobresia* sp.	1	0.000833333	6.9444E-07		
16	*Lonicera purpurea*	1	0.000833333	6.9444E-07		
17	*Lonicera spinosa*	1	0.000833333	6.9444E-07		
18	*Lonicera webbiana*	11	0.009166667	8.40278E-05		
19	*Pinus wallichiana*	181	0.150833333	0.022750694		
20	*Rosa sericea*	14	0.011666667	0.000136111		
21	*Spiraea arguta*	1	0.000833333	6.9444E-07		
22	*Syringa emodi*	1	0.000833333	6.9444E-07		
23	*Taraxacum* sp.	1	0.000833333	6.9444E-07		
24	*Thalictrum* sp.	3	0.0025	0.00000625		
25	Unknown	55	0.045833333	0.002100694		
26	Total	1200		0.4233875		

11. Summer Diet Niche Breadth of Livestock.

S.N.	Plant Species	Livestock (n)	P_i	P_i^2	$B= 1/ \sum^n_{i=1} P_i^2$	Bs= B-1/n-1
1	*Abies spectabilis*	296	0.246667	0.0608444		
2	*Anaphalis contorta*	1	0.000833	6.9444E-07		
3	*Berberis asiatica*	42	0.035	0.001225		
4	*Betula utilis*	34	0.0283333	0.00080278		
5	*Calamagrostis scabrescens*	86	0.071667	0.00513611		
6	*Caragana* sp.	9	0.0075	0.00005625		
7	*Carex* sp.	1	0.000833	6.9444E-07		
8	*Cotoneaster ludlowii*	26	0.021667	0.00046944		
9	*Ephedra gerardiana*	2	0.001667	2.77778E-06		
10	*Festuca* sp.	5	0.004167	1.73611E-05	5.7216	0.1816
11	*Geranium donianum*	1	0.00083	6.9444E-07		
12	*Hedysarum kumaonense*	55	0.045833	0.00210069		
13	*Iris gonicarpa*	2	0.001667	2.77778E-06		
14	*Juniperus* sp.	31	0.025833	0.00066736		
15	*Kobresia* sp.	40	0.033333	0.00111111		
16	*Lonicera spinosa*	66	0.055	0.003025		

17	*Lonicera webbiana*	9	0.0075	0.00005625		
18	*Oxytropis* sp.	5	0.004167	1.73611E-05		
19	*Pinus wallichiana*	363	0.3025	0.09150625		
20	*Rhododendron lepidotum*	3	0.0025	0.00000625		
21	*Rosa sericea*	9	0.0075	0.00005625		
22	*Salix* sp.	1	0.000833	6.9444E-07		
23	*Spiraea arguta*	1	0.0008333	6.9444E-07		
24	*Syringa emodi*	1	0.000833	6.9444E-07		
25	*Taraxacum* sp.	2	0.001667	2.77778E-06		
26	*Thalictrum* sp.	4	0.003333	1.11111E-05		
27	Unknown	105	0.0875	0.00765625		
	Total	1200		0.17477778		

12. Winter Diet Overlap.

S.N.	Plant species	Musk Deer (n)	P_{ij}	P_{ij}^2	Livestock (n)	P_{ik}	P_{ik}^2	$P_{ij} * P_{ik}$	$2\Sigma(P_{ij} * P_{ik})$	$\Sigma P_{ij}^2+\Sigma P_{ik}^2$	$C_H = 2\Sigma(P_{ij} * P_{ik}) / \Sigma P_{ij}^2+\Sigma P_{ik}^2$
1	*Abies spectabilis* (Pinaceae family) (tree)	231	0.280339806	0.078590407	53	0.07391911	0.005464034	0.020722468			
2	*Arnebia euchorma*(Boraginaceae)(Herb)	1	0.001213592	1.47281E-06	1	0.0013947	1.94519E-06	1.6926E-06			
3	*Berberis asiatica* (Berberidaceae) (shrub)	188	0.22815534	0.052054859	30	0.041841	0.00175067	0.009546249			
4	*Betula utilis* (Betulaceae family) (tree)	4	0.004854369	2.35649E-05	16	0.0223152	0.000497968	0.000108326			
5	Caragana sp. (Leguminosae)(Shrub)	28	0.033980583	0.00115468	7	0.0097629	9.53142E-05	0.000331749			
6	*Cotoneaster ludlowii* (Rosaceae) (shurb)	10	0.012135922	0.000147281	26	0.0362622	0.001314947	0.000440075			
7	*Geranium donianum* (geraniaceae) (herb)	1	0.001213592	1.47281E-06	1	0.0013947	1.94519E-06	1.6926E-06			
8	*Hedysarum kumaonense* (Leguminosae) (herb)	2	0.002427184	5.89122E-06	79	0.11018131	0.012139921	0.00026743			
9	*Juniperus* sp.(cupressaceae) (shrub)	61	0.074029126	0.005480312	3	0.0041841	1.75067E-05	0.000309745	0.33691824	0.59545942	0.56581226
10	*Lonicera purpurea* (caprifoliaceae) (shrub)	22	0.026699029	0.000712838	1	0.0013947	1.94519E-06	3.72371E-05			
11	Lonicera spinosa (Caprifoliaceae) (shrub)	5	0.006067961	3.68202E-05	9	0.0125523	0.00015756	7.61669E-05			
12	*Lonicera webbiana* (caprifoliaceae) (shrub)	54	0.065533981	0.004294703	3	0.0041841	1.75067E-05	0.000274201			
13	*Pinus wallichiana* (pinaceae) (tree)	181	0.219660194	0.048250601	443	0.61785216	0.381741294	0.135717526			
14	*Polygonatum* sp. (Liliaceae) (herb)	1	0.001213592	1.47281E-06	5	0.0069735	4.86297E-05	8.46299E-06			
15	*Rhododendron lepidotum* (ericaceae) (shrub)	7	0.008495146	7.21675E-05	1	0.0013947	1.94519E-06	1.18482E-05			

16	*Rosa sericea* (rosaceae) (shrub)	14	0.016990291	0.00028867	20	0.027894	0.000778075	0.000473927			
17	*salix* sp. (salicaceae) (shrub)	4	0.004854369	2.35649E-05	5	0.0069735	4.86297E-05	3.38519E-05			
18	*Syringa* emodi (Oleaceae) (shrub)	2	0.002427184	5.89122E-06	3	0.0041841	1.75067E-05	1.01556E-05			
19	*Taraxacum* sp. (Compositae) (herb)	3	0.003640777	1.32553E-05	2	0.0027894	7.78075E-06	1.01556E-05			
20	*Thalictrum* sp. (Ranunculaceae) (Herb)	5	0.006067961	3.68202E-05	9	0.0125523	0.00015756	7.61669E-05			
	Total	824		0.19119674	717		0.40426268	0.16845912			

13. Summer Diet Overlap.

S.N.	Plant Species	Musk (n)	P_{ij}	P_{ij}^2	Livestock (n)	P_{ik}	P_{ik}^2	$P_{ij} * P_{ik}$	$2\Sigma(P_{ij} * P_{ik})$	$\Sigma P_{ij}^2+\Sigma P_{ik}^2$	$C_H = 2\Sigma(P_{ij} * P_{ik}) / \Sigma P_{ij}^2+\Sigma P_{ik}^2$
1	*Abies spectabilis*	751	0.657618214	0.432461715	296	0.274074074	0.075116598	0.180236103			
2	*Berberis asiatica*	91	0.079684764	0.006349662	42	0.038888889	0.001512346	0.003098852			
3	*Betula utilis*	12	0.010507881	0.000110416	34	0.031481481	0.000991084	0.000330804			
4	*Calamagrostis scabrescens*	10	0.008756567	7.66775E-05	86	0.07962963	0.006340878	0.000697282			
5	*Caragana* sp.	18	0.015761821	0.000248435	9	0.008333333	6.94444E-05	0.000131349			
6	*Carex* sp.	1	0.000875657	7.66775E-07	1	0.000925926	8.57339E-07	8.10793E-07			
7	*Cotoneaster ludlowii*	18	0.015761821	0.000248435	26	0.024074074	0.000579561	0.000379451			

8	*Ephedra gerardiana*	2	0.001751313	3.0671E-06	2	0.001851852	3.42936E-06	3.24317E-06			
9	*Geranium donianum*	1	0.000875657	7.66775E-07	1	0.000925926	8.57339E-07	8.10793E-07	0.4781783	0.67143446	0.712174201
10	*Hedysarum kumaonense*	4	0.003502627	1.22684E-05	55	0.050925926	0.00259345	0.000178375			
11	*Iris gonicarpa*	1	0.000875657	7.66775E-07	2	0.001851852	3.42936E-06	1.62159E-06			
12	*Juniperus* sp.	19	0.016637478	0.000276806	31	0.028703704	0.000823903	0.000477557			
13	*Kobresia* sp.	1	0.000875657	7.66775E-07	40	0.037037037	0.001371742	3.24317E-05			
14	*Lonicera spinosa*	1	0.000875657	7.66775E-07	66	0.061111111	0.003734568	5.35124E-05			
15	*Lonicera webbiana*	11	0.009632224	9.27797E-05	9	0.008333333	6.94444E-05	8.02685E-05			
16	*Pinus wallichiana*	181	0.15849387	0.025120307	363	0.336111111	0.112970679	0.053271551			
17	*Rosa sericea*	14	0.012259194	0.000150288	9	0.008333333	6.94444E-05	0.00010216			
18	*Spiraea arguta*	1	0.000875657	7.66775E-07	1	0.000925926	8.57339E-07	8.10793E-07			
19	*Syringa emodi*	1	0.000875657	7.66775E-07	1	0.000925926	8.57339E-07	8.10793E-07			
20	*Taraxacum* sp.	1	0.000875657	7.66775E-07	2	0.001851852	3.42936E-06	1.62159E-06			
21	*Thalictrum* sp.	3	0.00262697	6.90097E-06	4	0.003703704	1.37174E-05	9.72952E-06			
	Total	1142		0.46516389	1080		0.20627057	0.23908915			

14. Data Sheet

S.N	**Name of site**	Plot no	Presence/ absence of Musk Deer	Presence/ absence of livestock	Slope	Altitude	Aspect	Crown cover (%)	Dominant vegetation (tree, shrub and herb)	GPS	If possible, distance to nearest water source	Number of faecal sample		Name of plant species in the plot	Ground cover (%)
												Musk Deer	Livestock		

15. Non-Overlapping diets between Musk Deer and Livestock during winter and summer.

Winter	
Musk Deer	**Livestock**
Anaphalis contorta	*Kobresia* sp.
Iris goniocarpa	*Calamagrostis scabrescens*
Oxytropis sp.	*Festuca* sp.
Bistorta sp.	*Ephedra gerardiana*
Anemone rivularis	*Spiraea arguta*
Clematis barbellata	
Summer	
Musk Deer	**Livestock**
Anemone rivalaris	*Anaphalis contorta*
Bistorta sp.	*Festuca* sp.
Lonicera purpurea	*Oxytropis* sp.
	Rhododendron lepidotum
	Salix sp.

PHOTO PLATES

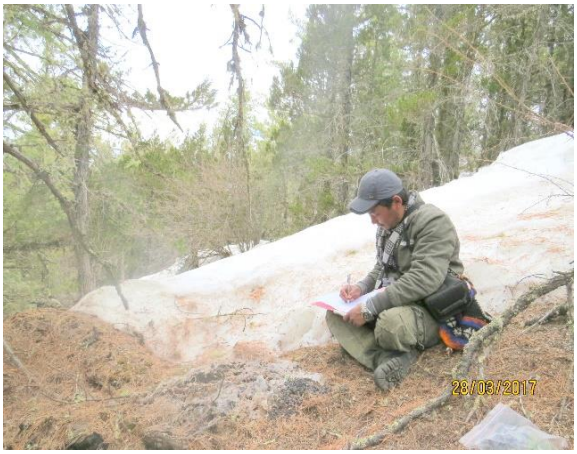
Rescued Musk Deer's baby, Lubra
(Source: NTNC, Jomsom)

Observation of slides at Lab, CDZ, TU

Fresh pellets of Musk Deer

Foot print of Musk Deer

Obang forest, Winter



Noting habitat parameters data

Research Team in the study area

Interact with hearder

Resting site of Musk Deer

Bedding site of Musk Deer under big stone

Obang cattle hut (Goath)

Musk Deer Habitat, Chhamachho lake forest

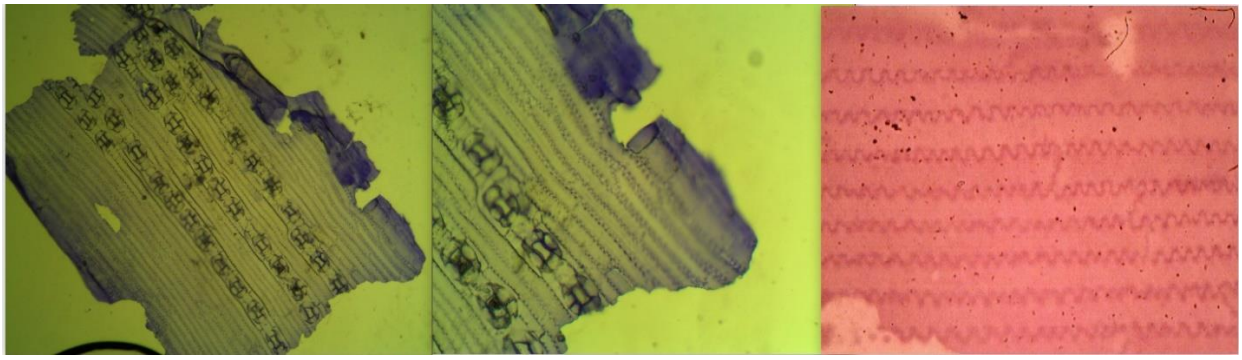
Collecting fecal sample

Livestock at Raniban forest, Lubra

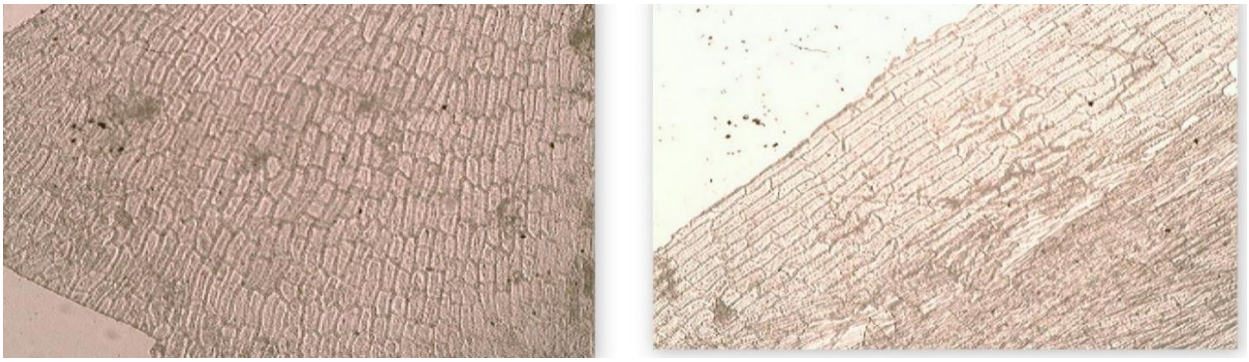
Thini village

Herder taken livestock for grazing at forest

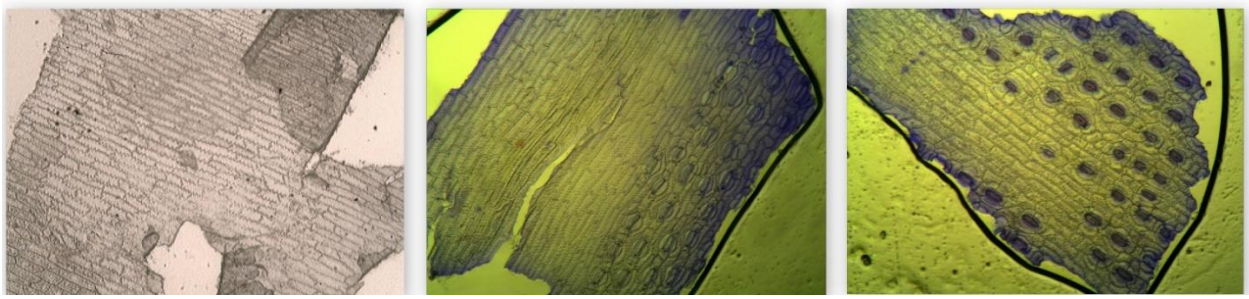
Reference Slides



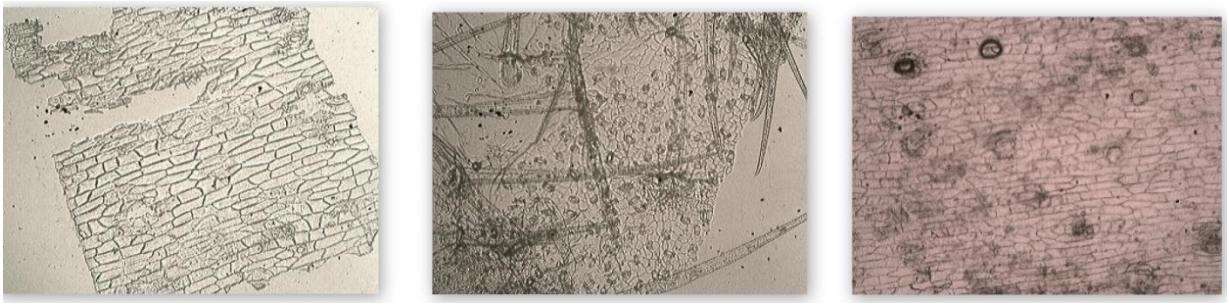
Pinus wallichiana



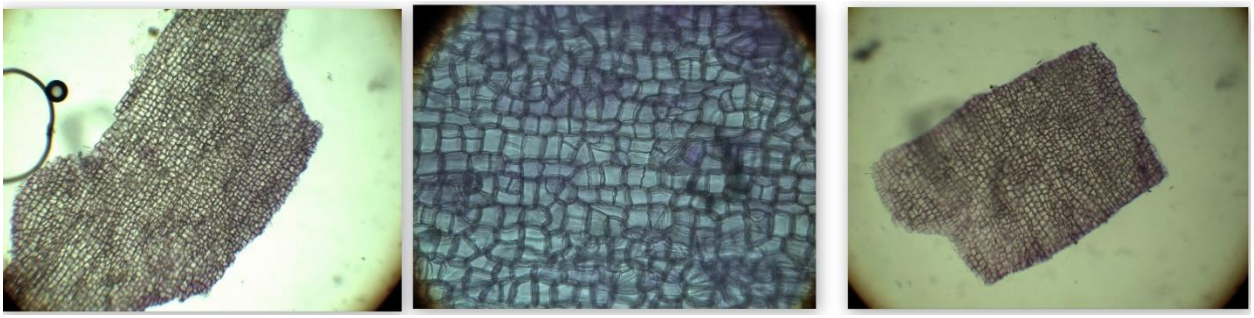
Juniperus sp.



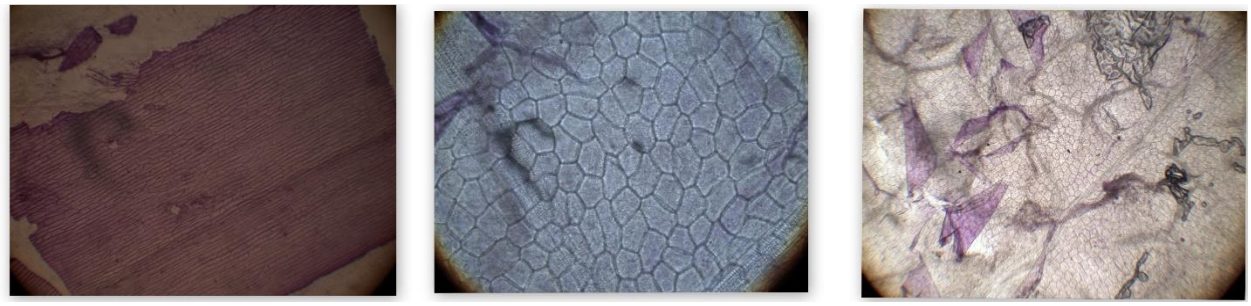
Abies spectabilis



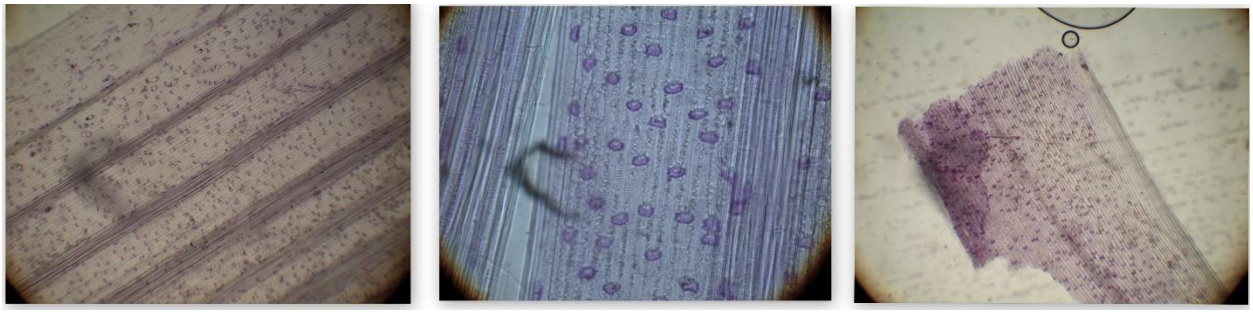
Lonicera webbiana



Hedysarum kumaonense



Berberis asiatica



Calamagrostis scabrescens

Caragana sp.