Prey Density and Diet Relationship of Snow Leopard (*Uncia uncia*)

A Research Report Submitted by

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Abstract

The snow leopard (*Uncia uncia*) is possibly a barometer for assessing environmental health and biodiversity conservation in high mountainous areas. This study was conducted in Shey Phoksundo National Park to estimate wild prey densities in relation to diet composition and to determine livestock depredation status and frequency in the diet of snow leopards. Population density of blue sheep (*Pseudois nayaur*) was estimated by vantage point count methods and densities of other wild prey species were estimated through line transect methods and analyzed in program DISTANCE 6.0. Household surveys (n=250) were conducted to determine livestock numbers and frequency of depredation. Scats (n=40) were analyzed through micro histolysis to determine the diet composition of snow leopards.

Himalayan marmots (*Marmota himalayana*) had the highest density (132.57animal/km^2) while blue sheep had a density of 2.27 animals/km^2. Most local inhabitants were subsistence farmers, many dependent upon local livestock breeds, with an average holding of 32.62 animals/household. Household lost an average of 3.6 animals/household annually, with a total depredation rate of 11.08%. Loss to snow leopards averaged 1.6 animals/household and this was the major source of mortality. Blue sheep was the major prey item, with a 30% occurrence in the snow leopard diet. Among the livestock, sheep was the major prey item with 15% frequency of occurrence in the scat. Food habits of snow leopards were independent of the density of its prey species; there was no proportional relationship between the prey density and diet of snow leopard. The number and replication of line transects should be increased and standardized to better estimate prey densities and scats should be collected in all seasons to understand diet composition changes throughout the year.

Key Words: snow leopard, prey density, livestock depredation, scat analysis, Shey Phoksundo National Park

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Abbreviations

CBS	Central Bureau of Statistics
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DNPWC	Department of National Parks and Wildlife Conservation
GPS	Global Positioning System
HMGN	His Majesty's Government of Nepal
Hrs	Hours
IUCN	International Union for Conservation of Nature and Natural Resources
Km	Kilometer
LNP	Langtang National Park
MFSC	Ministry of Forest and Soil Conservation
NMCP	Northern Mountain Conservation Project
SLIMS	Snow Leopard Information Management System
SLT	Snow Leopard Trust
SPNP	Shey Phoksundo National Park
VDC	Village Development Committee
WWF	World Wildlife Fund

Chapter One: Introduction

1.1 Introduction

The snow leopard *(Uncia uncia)* remains an under-studied animal and most information available is either in the form of natural history or anecdotal notes (Chundawat & Rawat, 1994). It is the top predator of the high altitude mountains of central and southern Asia and is the striking symbol of world's highest place (Schaller, 1977). It ranges from elevations of 3000m to 5500m in 12 Asian countries encompassing a total potential habitat area of 1,835,000 km^2 (Mecarthy & Chapron, 2003). It is listed as endangered on IUCN Red List of threatened species since 1988 (IUCN, 2002) and included in Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) since 1975, and hence all international commercial trade in the species, its parts and derivatives is prohibited (McCarthy & Chapron, 2003). In Nepal, it has been fully protected by National Parks and Wildlife Conservation Act 1973.

The presence and survival of the snow leopard is also an indicator of intact, "healthy" eco-regions they inhabit (Jackson & Hunter, 1996). This flagship and keystone species of alpine eco-regions is found along Nepal's northern border with the Tibet autonomous region, China, with the largest population in Dolpa, Humla, Mugu, Manang, Mustang, and Myagdi districts (WWF Nepal, 2000). Unfortunately the snow leopard's population is declining throughout its range due to various survival threats including habitat and prey loss and persecution (Nowel & Jackson, 1996). Shey Phoksundo National Park provides a good habitat for snow leopard but the region continues to suffer from illegal hunting, human-wildlife conflicts, and degradation of habitat.

Blue sheep are considered as an important primary prey for snow leopard in Nepal and elsewhere in the Himalayan region (Oli *et al.*, 1994; Schaller, 1977). Himalayan tahr *(Hemitragus jemlahicus),* musk deer *(Moschus spp.)*, nayan *(Ovis ammon),* goral *(Naemorhedus goral),* Himalayan marmot *(Marmota himalayana),* pika *(Ochotona species),* hares *(Lepus oiostolus),* Tibetan snowcock *(Tetraogallus tibetanus),* Himalayan snowcock (*Tetraogallus himalayensis*) chukar *(Alectoris chukor)* are among the prey species of snow leopards (Sharma *et al.,* 2006; Khatiwada, 2004).

Snow leopards have been reported to kill livestock in most parts of their range but the extent of this predation and its impact on local farmers is poorly understood (Mallon, 1984; Sherpa and Oli, 1988). Loss of livestock to wild predators is an important cause of anxiety amongst Himalayan Pastoralists (Namgil, 2004; Jackson *et al.,* 1996). Livestock depredation has become a significant problem across the snow leopard range in central Asia, being most severe in and around protected areas (Schaller, 1998).

Knowledge of a predator's diet is important not only for understanding its ecology, but also for predicting its influence on the dynamics of the prey population, and for designing and implementing conservation programs (Oli, 1991). The need for precise information on the diet of snow leopard further arises from the suggestion that they kill livestock over most of their range (Mallon, 1984; Sherpa & Oli, 1988) bringing them into a conflict with humans. Analysis of scat is one way to determine which is the preferred wild prey species of the snow leopard and to what extent livestock feature in the diet.

The detailed ecological study of snow leopards in Nepal has shed light on its secretive behavioral habits (Jackson & Ahlborn, 1989), but very little is known about feeding habits. In addition, very little is known about the role of alternate prey in a predator's diet (Shaw, 1977). The role of smaller mammals and domestic livestock as alternate prey of snow leopard has been not yet studied. This may be of great importance because alternate prey availability may be directly impacted by availability of larger, wild prey species such as blue sheep (Chundawat & Rawat, 1994). The relative abundance of natural versus domestic livestock can be assessed by analyzing food remains in scats collected (Gurung & Ale, 2000) giving us insight into the potential role of these species in snow leopard feeding ecology.

This study will further advance our understanding of snow leopard ecology by linking scat analysis to domestic and wild prey distribution and abundance across the landscape. The advanced understanding gained from this study aim to provide information on prey density and diet of the snow leopard to aid in management and conservation of protected areas. The study focuses on the prey density and diet relationship of snow leopard.

1.2 Objectives

The goal of the study was to determine the wild prey density, livestock status (including depredation events) and diet of the snow leopard. The specific objectives of this study are to;

1. Estimate densities of wild prey species of the snow leopard
2. Determine the livestock population and its depredation rate in the study area.
3. Determine the prey preference of snow leopards by analyzing diet from scat.

Chapter Two: Literature Review

The snow leopard was first described to science by Russian naturalist Shreber in 1778. In 1970, Schaller took the first photograph of the snow leopard in the wild in Chitral Gol, Pakistan. In 1974 the snow leopard was listed as endangered on the World Conservation Union/IUCN Red List (Snow Leopard Trust, 2008). Schaller studied snow leopards along with other associated species in 1977 (Sharma *et al.,* 2006).

Studies on marking patterns of captive snow leopards have been conducted by Wemmer & Scow (1977), Reiger (1978, 1980), Blomqvist & Sten (1982) and Freeman (1983) (Sharma *et al.* 2006). Studies on free ranging snow leopards have been conducted by Schaller (1977), Mallon (1984) in India, Ahlborn & Jackson (1988) in Nepal, and McCarthy & Munkhtsong (1997) in Mongolia. Fox (1994) estimated the total snow leopard population to vary from 4,500 to 7,500 individuals in its entire range but Nowell and Jackson (1996) estimated the total effective population size of snow leopard as 2,500 mature breeding individuals with a declining trend. All these estimates were rough guesses and detail surveys are urgently needed. Several ecological surveys have been conducted in India, Nepal, China and Mongolia, which gives information on the status and distribution of snow leopards (Jackson, 1979a &1979b; Mallon, 1984a &1984b; Fox *et al*., 1988; Schaller *et al*., 1988; Chundawat *et al*., 1988; Fox, 1989 & 1994; Oli, 1991; Jackson, 1996; Gurung, 2002: cited in Sharma *et al.,* 2006).

Snow leopards were radio-collared in the wild for the first time in Shey Phoksundo National Park in 1982 and for the second time in early 1990's in the Annapurna Conservation Area, Nepal (WWF Nepal, 2000). In 1999, a survey was conducted on snow leopard and their prey species in Shey Phoksundo National Park, Dolpa. Twenty five permanent transects to count the indirect snow leopard signs were established in this survey. In the same year, the first field methods training workshop of its kind was held for park staff in Shey Phoksundo National Park, Nepal (WWF Nepal, 2000). For a second and third time, the permanent transects were monitored in 2006 and

2007 respectively, resulting in estimates of 5-7 snow leopards per 100km^2 by indirect sign methods in 2382.45km^2 potential area (NMCP, 2007).

Shah (1985) used radio-collaring to study behavior of snow leopards (1986a) and blue sheep (1986b) in Nepal. Jackson (1996) studied the home range, distribution and ecology of snow leopards in Langu valley in Dolphu. This was followed by another study in Manang in 1998. Fox and Jackson (2002) reported a questionable inverse relationship between snow leopard density and blue sheep in Trans Himalaya of Nepal. Jackson and Ahlborn (1990) concluded that 65% of this snow leopard population was located outside Nepal's protected area. Ale (2005) studied snow leopards and the Himalayan tahr in the Sagarmatha National Park, Nepal. Khatiwada and Chalise (2006) determined status of the snow leopard in Kanchenjunga Area. Some aspects of snow leopards and prey were analyzed in the Langtang National Park through indirect and direct methods (Adhikari, 2004; Khatiwada, 2004 and Chalise *et al.,* 2005).

Among the wild prey species of snow leopard, blue sheep is the most studied animal in Nepal. Aspects of the population ecology of blue sheep were studied in Dhorpatan hunting reserve (Wegge, 1979), the average herd size was 11.1 animals and larger groups used more open habitats than smaller groups. The highest density of blue sheep was observed in Shey area of Shey Phoksundo National Park with 8.8 to 10 animals/sq.km (Schaller, 1977). A study conducted in Bardia National Park on predator-prey relationships considering tiger and leopards as predator showed that, the most abundant species (*Axis axis* and *Axis porcinus*) were killed less frequently than expected, where as the lower density wild boar (*Sus scrofa*) was preferred (Wegge *et al.,* 2009).

Snow leopards are frequently blamed for loss from other sources of mortality, such as disease, consumption of poisonous plants, and accidents. In Annapurna Conservation Area, local residents considered eliminating snow leopards as only viable solution (Oli *et al.,* 1994). Not, surprisingly, livestock often greatly outnumber wild ungulates within many protected areas (Mishra, 1997). It is important to know the status of livestock and the depredation rate to understand the conflict between wild animals and people. A major source of conflict between park authorities and local communities in the Indian subcontinent resolves around livestock and crop damage within protected areas or their buffer zones (Hussain, 2003; Mishra, 1997). The primary threats to snow leopards in Nepal are conflict with humans due to significant livestock depredation resulting retaliatory killings, poaching, and loss of habitat and prey base due to high degree of livestock grazing pressure. Human- snow leopard conflicts and retaliatory killing is one of the serious threats to the snow leopard. Snow leopard predation of livestock was studied in Annapurna Conservation Area and was found that 2.6% of total livestock was predated by this cat (Oli *et al.,* 1994). In Qomolangma Nature Preserve, Tibet, livestock loss to snow leopard ranged from none to as much as 9.5% livestock in the eight settlements studied (Jackson, 1991). Mishra (1997) studied the livestock depredation by large carinvores in the Indian trans-Himalaya and found that conflict seemed to have intensified related to 37.7% increase in livestock in the last decade. Thapa (2006) studied status and distribution of snow leopard and blue sheep including people interactions and found that the livestock holding per household in Phoksundo and Vijer VDCs of Shey Phoksundo National Park was 21.2 and 2.5% of the total livestock were predated to snow leopard. Thapa (2006) also reported that 4.2% of the total livestock was lost to snow leopard in Kanchanjungha Conservation Area, Nepal. Bhattarai (2009) studied human-tiger (*Panthera tigris tigris*) in Bardia National Park, Nepal where the livestock holding was 6.7animals/household and depredation rate due to tiger was 0.25animals/household.

Past researchers focused on the home range, distribution, and abundance of the snow leopard and its prey. Other studies used scat analysis and revealed information on the feeding habits of wild cats which may not be possible when using other techniques such as locating and identifying the kills (Grobler & Wilson, 1972; Smith, 1978; Meche *et al.,*1990: cited in Maheshwari, 2006). The work on feeding ecology of the common leopard (*Panthera pardus)* through scat analysis and standardization has been done by Mukherjee *et al.* (1994), Sankar *et al.* (2002) in India and Bothma *et al.* (1994) on Kalahari leopards (Maheshwari, 2006). Mukherjee *et al* (1994) determined the minimum number of hairs that need to be examined per scat and the minimum number of scat required for estimating leopard diet in Gir forest, India. They concluded that examination of twenty hair/scat enable the detection of multiple prey species and a minimum of eighty scats is needed to reliably estimate leopard diet. Amarsanaa (1985) worked on winter diet of the snow leopard (*Uncia uncia*) in Mongolia (Lhagvasuren & Munkhtsog, 2002). Teerink (1991) developed an identification key for hair of West-European mammals.

Scat analysis provides useful information on the feeding ecology of mammals (Riney, 1957; Putman, 1984: cited in Maheshwari, 2006). Population distribution and behavior of prey influence the quality of a predator's habitat and the health of predator populations. Therefore, some knowledge about the prey species of any predator is essential before one can understand the ecology of the predator. Prey species distribution and abundance is influenced by resources and predation rates. The snow leopard, like most opportunistic predators, is thought to take prey species in proportion to their abundance. Factors which influence food habits or prey selection then are: absolute abundance, relative abundance, and relative value of potential prey (Estabrook *et al.,* 1976: cited in Maheshwari, 2006). These three factors are interrelated and the theory of optimal diet predicts that higher abundance of prey species results in greater specialization by increased foraging for the most profitable food item (Pyke *et al.,* 1977: cited in Maheshwari, 2006). Chundawat (1994) studied the food habits of snow leopard and its predation on blue sheep in Hemis National Park, India and found that blue sheep was the major species (46%), and other animals such as marmots, pikas and birds formed substantial part of snow leopard diet. In Nepal, Oli (1991) & Oli *et al* (1993) analyzed total 213 snow leopard scats in Annapurna Conservation Area and found that its prey items included seven species of wild animals, five species of domestic mammals and birds. Blue sheep was the most frequently identified prey item with its hair being detected in 51.6% of scats followed by Himalayan marmot (20.7%), Royle's pika (16%) and domestic species (13.6%). In Sagarmatha National Park, Himalayan thar (*Hemitragus jemlahicus*) was the staple prey item of snow leopard with relative occurrence of 48% summer and 37% autumn diet (Lovari *et al*, 2009).

Chapter 3: Study Area

3.1 Location

Shey Phoksundo National Park (29°15'-29°45' N and 83°08'-83°31' E), the largest national park of the country was established in 1984 with an area of 3,555 Km^2 (figure 1). It lies in Dolpa and Mugu district in the Midwestern development region of Nepal (DNPWC, 2007), whose micro-climatic condition, ecology, ecosystem and flora and fauna resemble the Tibetan desert type. It has a buffer zone area of 1349 km^2, with 11 village development committees (9 VDCs of Dolpa and 2 VDCs of Mugu districts) (DNPWC, 2007).

The study was carried out in three VDCs of Shey Phoksundo National Park namely, Phoksundo, Vijer and Saldang. Saldang and Vijer represents the trans-Himalayan bio-climate zone where Phoksundo represent South Himalayan and inner Himalayan zone.

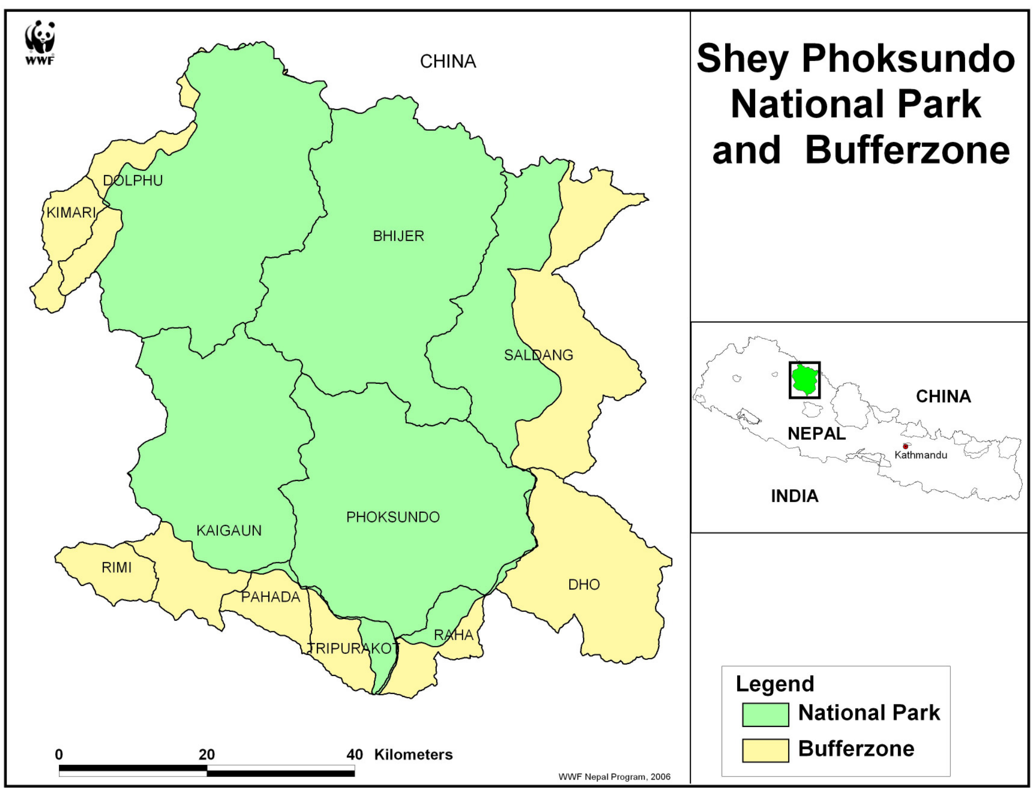

Figure 1: Map of the study area (Source: WWF Nepal 2006)

3.2 Climate

Located within the rain shadow of Mt. Dhaulagiri (8172m), it experiences sharp seasonal differences in temperature and rainfall. The varied topography and varied climatic conditions support a unique biotic system in the park. In SPNP, regional climatic variation is high because of the varied topography of the park covering both north and south sides of the main Himalayan division. Due to these variations annual precipitation ranges from 500 mm in the northern steppes to 1500 mm in Suligad valley, in the south. About 60-65% of the annual precipitation occurs during the monsoon period: July-September (Wilson, 1981: cited in DNPWC, 2007). The ground surface remains frozen in early spring and throughout autumn season but thaws in the summer. Winter is severe with temperature below freezing point and frequent snowfall above 2500 m altitude. Occasional heavy snowfall closes the trails in the park for several days and snow avalanches frequently pose threats to local people, livestock and wildlife.

3.3 Flora

Vegetation is highly diversified at SPNP due to altitudinal variations and intrinsic climatic variations. The level of endemism is high in Dolpa, with 50 species of plants representing 46% of the total endemics of Western Nepal (Ghimire et al., 2000; Shrestha and Joshi, 1996: cited in DNPWC, 2007). In the south, where it receives sufficient rainfall, the steep hill slopes are dominated by temperate and sub-alpine vegetation. In the lower valley, dense forests are composed of blue pine (*Pinus wallichiana*) intermixed with spruce (*Picea smithiana*), deodar (*Cedrus deodara*), hemlock (*Tsuga dumosa*), and silver fir (*Abies spectabilis*). The middle story of this forest is covered with populus and the ground story dominated by bamboo. Silver birch (*Betula utilis*), and Juniper (*Juniperus recurva*) dominates the landscape at the upper tree line. More than 417 species of plants are found in the national park, of which 30 species are endemic to Nepal (Regmi, 2003). 407 MAPs have been identified, distributed in 226 genera and 80 families. Major medicinal plants include Atis (*Delphinium himalayan*) Kutki (*Picrorhiza scrophulariiflora*), Panchaunle (*Dactylorhiza hatagirea*), Yarsagumba (*Cordyceps sinensis*), Padamchal (*Rheum australe*), Jatamansi (*Nardostachys grandiflora*) and Samayo (*Valeriana wallichii*), which are harvested by most of the households.

3.4 Fauna

The park is home to more than 32 species of mammals, 200 species of birds, 6 species of reptiles and 28 species of butterfly (Chaudhary, 2003; Regmi, 2003). The park supports several endangered species of wild animals, which include; snow leopards (*Uncia uncia*), wolves (*Canis lupus*), and musk deer (*Moschus chrysogaster*). Wild animals such as blue sheep *(Pseudois nayaur)*, Himalayan marmot (*Marmota himalayana)*, Tibetan snowcock *(Tetraogallus tibetanus)*, Himalayan snowcock *(Tetraogallus himalayensis)*, hare (*Lepus oiostolus)*, Royle's pika (Ochotona roylei) and chukar *(Alectoris chukar)* are present in the upper region of the park. The Himalayan tahrs (Hemitragus jemlahicus) are found on the southern slopes of the Kanjiroba range and southeast of Phoksundo Lake between 2500-4000m. A large number of birds, herpetofauna, and invertebrates make the park's wildlife composition unique (Basnet, 1998: cited in DNPWC, 2007). In the lower elevations langur (*Presbytis entellus*), wild boar (*Sus scrofa*), Himalayan black bear (*Selenarctos thibetanus*), goral (*Nemorhaedus goral*), serow (*Capricornis sumatraensis*), yellow-throated marten (*Martes flavigula*) and common leopard (*Panthera pardus*) occupy the forested and open areas.

3.5 Socio-economy

Dolpa has the lowest human population density in Nepal with a population of 25,013 in 1991 and 29,653 in 2001 (CBS, 2001) in an area of 793,230 hectares. There are about 3,000 people in the park alone and a total of 13,252 people in the buffer zone and more than 2,374 households in the park and buffer zone of the Dolpa district (NMCP, 2001). More than 68% of the total households' main occupation is animal husbandry, which is more popular in the northern part of the district (Shrestha *et al.,* 1998). People residing within the buffer zone of SPNP graze their cattle within the park and in the buffer zone. The people of Kaigaun, Rimi, Pahada, Tripurakot, Raha and Dho VDC of buffer zone have traditionally been using the different pastures within and around the park. These areas are equally important for wildlife populations.

Major ethnic groups in Dolpa include Brahmin, Chhetri, Gurung, Lama, Magar, Thakuri, Kami, Damai and Sharki. Chhetri, Lama, and Gurung respectively make up 29%, 23%, and 13% of the total population, and all other groups together make up 35% (Shrestha *et al.,* 1998).

Chapter Four: Density of Wild Prey Species

4.1 Introduction

Population density is the single parameter of greatest intrinsic interest to biologist studying population dynamics (Krebs, 1985; Buckland *et al.*, 1993; Turchin, 1998). Population distribution and behavior of prey influence the quality of a predator's habit and the health of predator population. Therefore, some knowledge about the prey species of any predator is essential before one can understand the ecology of the predator. The distribution of prey species is influenced by resource gradients, their combination and rate of exploitation. Knowledge of prey density and predator-prey ratios can help set limits for validating snow leopard numbers in a particular area. There must be sufficient prey to support the predicted predator population (Jackson & Hunter, 1996). The snow leopard is an opportunistic predator capable of killing prey more than three times its own weight. Therefore, it may potentially prey on most herbivores found in the same range except for fully grown yak or wild ass (Schaller, 1977). In general, food habit studies indicate that the primary prey of the snow leopard consists of the dominant wild ungulates of the region, along with a variety of smaller birds and mammals (Jackson & Hunter, 1996). Ecologists have emphasized the important role that wild prey species play in ecosystems through their influences on the composition, productivity, nutrient cycle and succession (Crawely, 1983) and ultimately on the population of the predator. Many researchers have drawn different inferences from the analysis of snow leopard scats without considering the density of their prey species.

4.2 Methodology

The major wild prey species of the snow leopard were identified from the literatures, discussion with the park staff and local people of the area. The study area was divided into four blocks, namely Phoksundo, Shey, Samling and Vijer. Blue sheep were surveyed only in Shey, Sambling and Vijer block only with a total area of 134.05 km^2. 27 line transects ranging from 0.72 km to 1.37 km (mean 1.058 km) were laid with a total length of 28.56 km and walked one time. The GPS reading of starting and end point of transects were recorded. All the species were directly observed from the transect, the distance of the animal from the transect was measured using Range finder and the angle taken using a pocket compass (Harris, 1996). Within 20m radius of the angle reading, slope, aspect, elevation, habitat type, landform ruggedness, dominant topographic feature as mentioned in the Snow Leopard Information Management System (SLIMS) manual was recorded (WWF Nepal, 2000). When an animal group was first encountered, bearings were taken. Although the animals usually flush from their original location as approached, the bearings were recorded, as nearly as possible, to the original location of the animals, not the location at the time of subsequent bearings (Harris, 1996). From the transect animal groups were scanned using 8x30 binoculars and 15-60x zoom spotting scope to identify the prey species and their number. For already identified prey such as blue sheep, direct observations in the morning (0600-1000 hrs) and evening (1400-1700 hrs) from the transects/trails and fixed point method (vantage point) was conducted (Schaller, 1977; Oli, 1996; Jackson & Hunter, 1996).

4.3 Data Analysis

27 transects were monitored in spring 2009 walking a total distance of 28.56 km. The analysis was carried out separately for each species in each transect. The transect data was analyzed using the program DISTANCE 6.0 (Thomas *et al.* 2009) to estimate species density, mean group size, and encounter rate.

4.4 Results

4.4.1 Wild Prey Species of Snow leopard

Blue sheep *(Pseudois nayaur)*, musk deer (*Moschus Chrysogaster)*, Himalayan marmot (*Marmota himalayana)*, Tibetan snowcock *(Tetraogallus tibetanus)*, Himalayan snowcock *(Tetraogallus himalayensis)*, hare (*Lepus oiostolus)*, Royle's pika (Ochotona roylei) and chukar *(Alectoris chukar)* were the major wild prey species identified in the line transects.

4.4.2 Density of Wild Prey Species

The densities of wild prey species of the snow leopard, except blue sheep were determined by distance sampling. The total combined prey species density estimate (not including blue sheep) was 195.31 animals/Km^2. The Himalayan marmot had the highest density, 132.57 animals/km^2 and hares had the lowest value of density, 2.27

animals/km^2. The effective strip width (ESW) for the transect taken was 15.41m. The overall and individual species density is summarized in table 1.

Table 1: Density and density of cluster of six prey species of snow leopard

Species	Density			Density of Cluster		
	D	SE	95% of CI	DS	SE	95% of CI
Pooled	195.31		121.61 - 313.69	45.438		30.585 - 67.505
Chukur	16.970	10.863	4.5504 - 63.285	4.5438	2.1842	1.7897 - 11.536
Himalayan Snow cock	31.352	16.160	11.701 - 84.003	9.0876	4.4029	3.5555 - 23.228
Hare	2.2719	1.5853	0.62479 - 8.2613	2.2719	1.5853	0.62479 - 8.2613
Himalayan Marmot	132.57	39.370	74.102 - 237.17	21.583	5.2242	13.340 - 34.920
Royle's pika	7.2516	3.9322	2.5567 - 20.567	4.5438	2.2485	1.7456 - 11.828
Tibetan Snow cock	4.8999	2.7973	1.6525 - 14.529	3.4079	1.9431	1.1504 - 10.095

D= density = animals/km^2, SE= standard error, CI= confidence Interval, DS= density of cluster

The effective strip width is the product of the width of the line transect and probability of observing an animal within the area. Most of the animals sighted from the line transect were either individual or in very small group. In table 1 the density of individual species is higher than that of density of cluster, this indicates that most of the animals sighted were single or in very small group.

4.4.3 Group Size, Encounter Rate and Detection Probability of the Species

The Himalayan marmot had the highest cluster size as well the encounter rate. Hare had the lowest encounter rate. The mean and expected cluster size of the six prey species and their encounter rate is summarized in table 2. It shows that larger the cluster size, encounter rate is also higher. Himalayan marmot had both the encounter rate as well as expected/mean cluster size greater as compared to other species.

The expected value of group size at 95% confidence interval was estimated.

Table 2: Encounter rate, expected and mean cluster size of six prey species of snow leopard.

Species	Encounter Rate	Expected Cluster Size			Mean Cluster Size	
		E(S)	SE	95%CI	M(S)	SE
Chukur	0.14004	3.7347	1.5789	4.2837 - 8.8072	4.0000	0.81650
Himalayan Snow cock	0.28007	3.4499	0.60701	2.2504 - 5.2889	2.7500	0.36596
Hare	0.070018	1.0000				
Himalayan Marmot	0.66517	6.1422	1.0569	4.2837- 8.8072	5.5789	0.68533
Royle's pika	0.14004	1.5959	0.35389	1.0000 - 4.0965	1.2500	0.25000
Tibetan Snow cock	0.10503	1.4378	0.040577	1.0046 - 2.0578	2.6667	0.66667

n/L= encounter rate, SE=standard error, E(S)= expected cluster size, M(S)= mean cluster size

Half normal key model was used to determine the detection probability of the species in the transect. The probability of detection of an object in defined area was 0.40649 at 0.49408E-01 standard error, 12.15% coefficient of variation and 0.31827-0.51941 at 95% confidence interval. Figure 2 shows that the detection probability of the species in the transect decreased to half beyond 15m perpendicular distance, and detection of any object was not possible beyond 35m perpendicular distance.

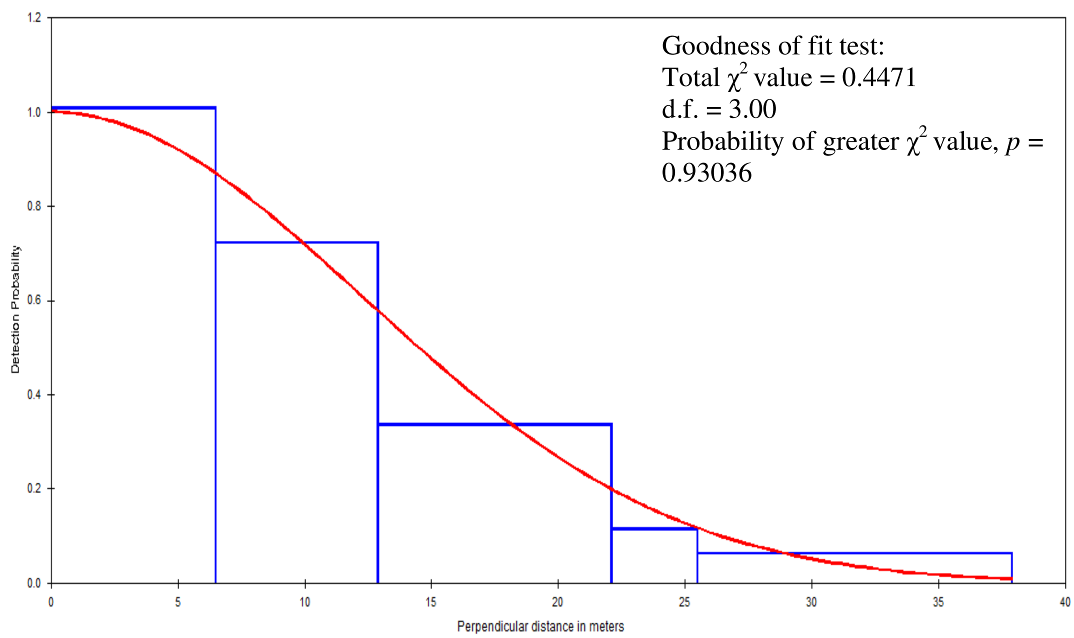

Figure 2: Detection probability of the species

4.4.4 Density and Population Size of Blue Sheep

The density of blue sheep was estimated through vantage point count method. In all the three blocks covering a total area of 134.05 km^2, a total of 304 blue sheep were sighted. The area had a crude density of 2.27 individuals per km^2. The highest density of blue sheep was observed in Vijer block with 2.65 animals/km^2 and lowest in Samling block, 1.90 animals/km^2. 20 herds were observed, the heard size ranged from 2-49 animals/herd with an average of 15.2 animals/herd. The sex ratio constituted of 67 males/100 females. Figure 3 shows that the 50.99% of the animals observed were female and the herd consisted only 2.63% of medium male during the season.

Total number with age and sex was classified in the field. Group composition was classified according to the Schaller classification of 1973 into class 1, 2 and 3 males, female, yearling and lambs.

Class 1 (Young male): Horn size between 15 – 35 cm & 2 to 3 years old small size males

Class 2 (Medium male): Males with horn longer than 30-35cm but curving backward slightly, presumably consisting 4 to 7 years old.

Class 3 (Adult male): Fully grown male with an estimated horn length of at least 45 - 50cm, horns curving noticeably backwards, animals mostly older than 7 yrs.

Lamb: Less than one year old

Yearling: 1 to 2 years old

Female: More than 2 years old

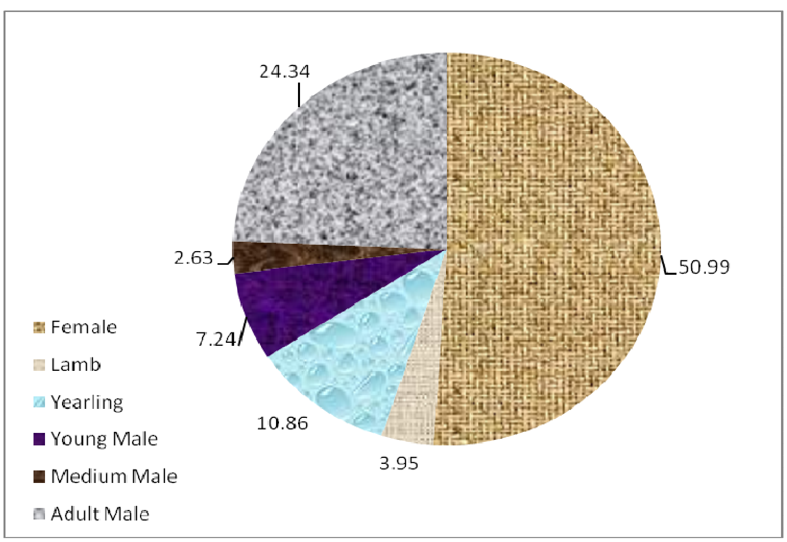

Figure 3: Estimated population structure of blue sheep

4.4.5 Distribution pattern of Blue Sheep according to habitat parameters

Habitat parameters such as landform ruggedness, vegetation types, topographic features and distance from mean sea level were considered to define the distribution pattern of blue sheep. 20 herds of blue sheep were sighted in spring 2009. Blue sheep preferred broken habitat to slightly broken habitat. As in figure 4, 35% of the herds were sighted in broken landform whereas the least one were sighted in flat (10%) and moderately broken (10%) landform.

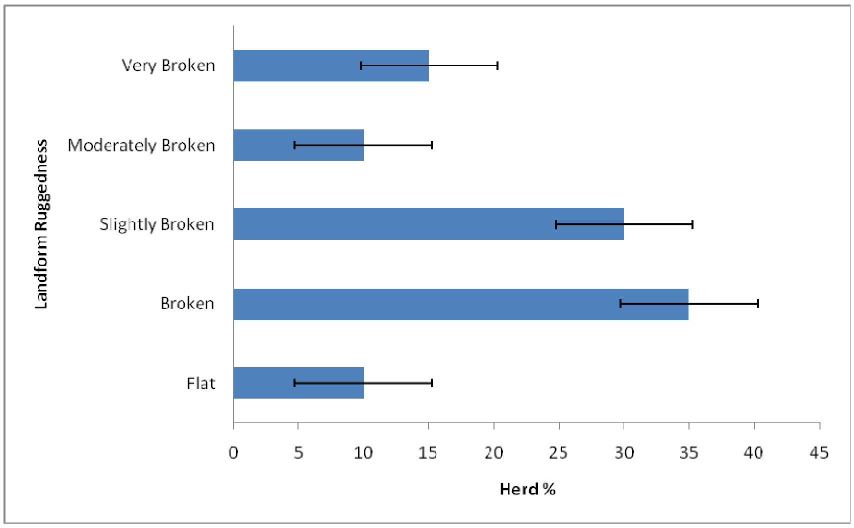

Figure 4: Distribution of blue sheep by landform ruggedness

90% of the blue sheep herds sighted during the study period were in the grasslands (figure 5). Only 10% herds were observed in barren lands.

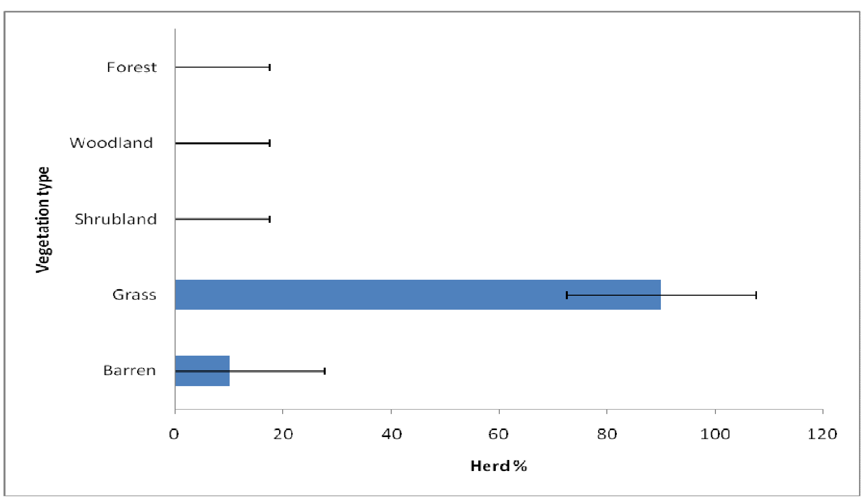

Figure 5: Distribution of blue sheep herd by vegetation type

Topographic features are one of the major parameters that determine the distribution of blues sheep. Groups of blue sheep were sighted on hillsides (45%), followed by ridgelines (30%). Figure 6 shows the distribution of blue sheep herds in different topographic features.

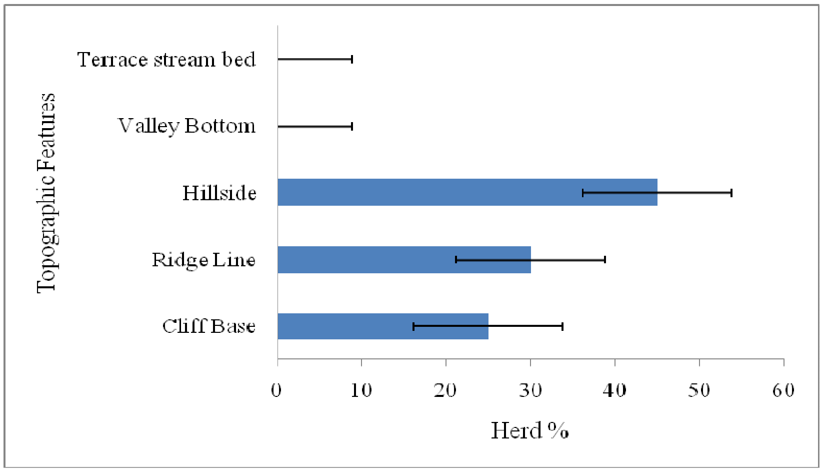

Figure 6: Distribution of blue sheep herds by topographic features

The distribution of blue sheep herds by altitudinal range (3795m to 4792m) with the mean altitude of 4418.25m.Most of the herds were observed above 4200m (Figure 7).

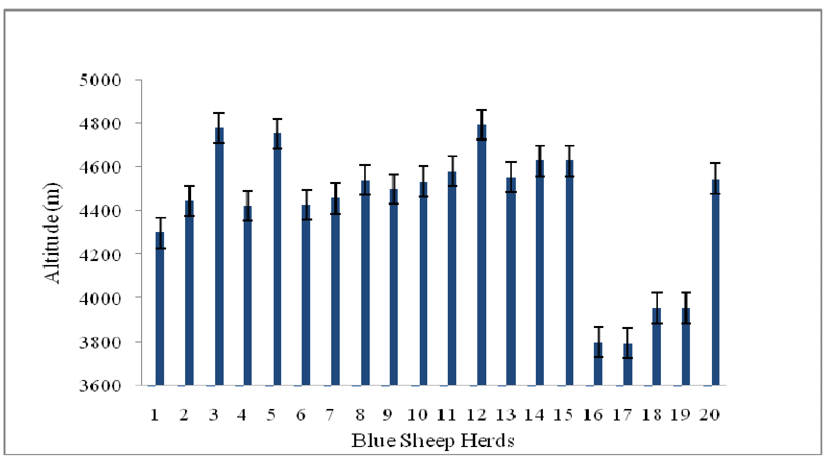

Figure 7: Distribution of blue sheep by altitude

Blue sheep prefer areas near cliff, 70% of the herds were observed less than one hundred meters from the cliff. Figure 8 shows the the preferences of blue sheep to cliff.

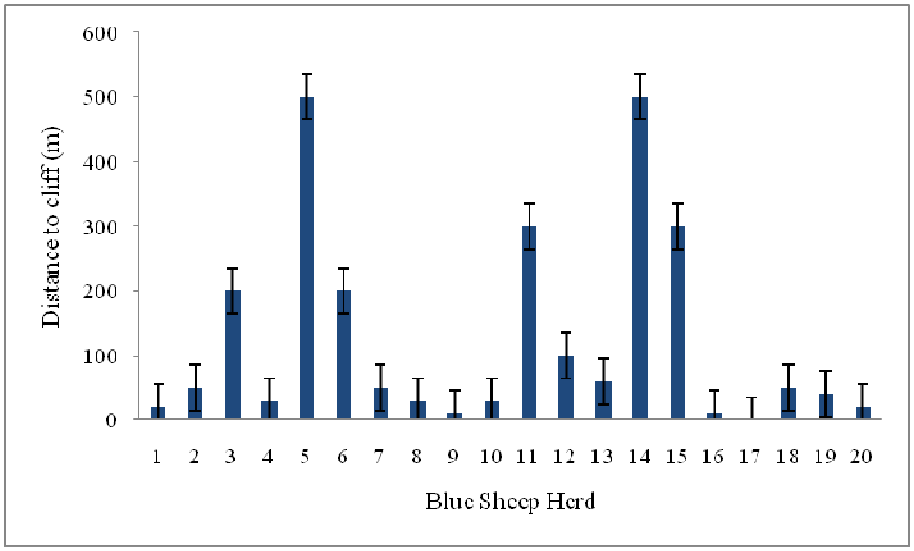

Figure 8: Distance to cliff

4.5 Discussions

4.5.1 Wild Prey Species of the Snow Leopard

The species identified as prey of the snow leopard in this study are similar to those from other studies. Oli *et al* (1993) identified seven wild species as prey which also included blue sheep, Himalayan marmot, Royle pika in Annapurna Conservation Area, Nepal. Snow leopards preyed on *Pseudois nayaur, Capra ibex*, *Capricornis falconeri*, *Hemitragus jemlahicus*, *Muschus chrysogaster*, *Ovis ammon*, *Equus hemionus kiang*, *E. h. kulan*, *Naemorhedus goral, Marmota himalayana, Ochotona species, Lepus oiostolus, Tetraogallus tibetanus, Alectoris chukor* and livestock (Fox, 1989; Schaller, 1977; Schaller *et al*., 1987; Jackson, 1979).

4.5.2 Density of Wild Prey Species

Prey species play a vital role in limiting the population of predator. Thus it is important to have the knowledge of the density of prey species and their fluctuations through time. Population size is a demographic parameter that can be used in wildlife management to assess the success of a management program.

This study shows that the Himalayan marmot has the highest density among the prey species identified. The marmot is considered a buffer prey species for snow leopards. Himalayan marmots hibernate during the winter and are only seen after the winter.

During the spring they come up onto the land from below ground, and this may be the why the density of this species is so high as compared to other species. Another reason is that they are sighted more easily and frequently. They had higher delectability from the encounter rates as well.

The density of pikas is low, 7.25/km^2. Both the Himalayan snowcock and Tibetan snowcock had good density in the study area. Chukar were sighted only in Vijer and Samling in areas having low altitude as compared to Shey blocks. The density of hares is low overall.

4.5.3 Group Size, Encounter Rate and Detection probability of the Species

Himalayan marmot had the highest group size as well as encounter rate, which again justifies that this area is suitable habitat for this species. Himalayan marmots are more easily seen in the field as compared to other species (figure 9). This species makes many borrows in the ground which makes detection easier. Burrows are used for hibernation as well as for escaping from the predators. Marmots are generally seen in pairs with upto nine in group. Pikas and hares were solitary, while both Tibetan and Himalayan snow cocks were observed in pairs, Chukar were also seen in pairs and upto groups of four.

Figure 9: Himalayan marmot

The detection probability of the mentioned species decreases beyond 15m perpendicular distances. Distance sampling generally requires a minimum of 60 observations to generate an acceptable, more robust, density estimate (Buckland *et al.*, 2001). Because most of the species had fewer than 60 observations, density estimate may be inaccurate due to small sample sizes. More observations are needed for estimating population trends (i.e. density) more accurately and precisely for the species considered. In estimating the density of ungulatfor the es in and precisely low land of Bardia National Park, both the block count and distance sampling gave similar estimates (Wegge & Storaas, 2009). In the highlands like Shey Phoksundo National Park, both block and distance sampling should verify the result obtained.

4.5.4 Density and Population Size of Blue Sheep

The crude density of 2.27/km^2 compared to an independent study by Schaller (1977) as 8.8-10/km^2 is quite less. However, Schaller studied around Shey block which still shows slightly higher density (2.65/km^2) as compared to two other blocks in the present study. Oli (1991) estimated the density of 6.6 to 10.2 animals/km^2 in Manang area of Annapurna Conservation area, this is quite high as compared to the present study. In 2008, Aryal conducted similar study in Dhorpatan Hunting Reserve and found that the area had a crude density of 1.8 animals/km^2, this study compares favorably with the present study.

Compared to the study by Schaller (1977), the density of blue sheep has decreased drastically over a period of more than one decade. Human disturbance and habitat destruction may be the major causes of decline of blue sheep in the area. Previous studies of the density of blue sheep give similar results to the present study in other part of Nepal (Table 3).

Table 3: Density of blue sheep

S.N	Study Area	Density (number/km^2)	Source
1	Kangchu, Nepal	1.4	Schaller (1977)
2	Shey, Nepal	8.8 – 10	Schaller (1977)
3	Kanjiroba area, Nepal	0.9 – 1.3	Schaller (1977)
4	Dhorpatan, Nepal	1.9 – 2.7	Wegge (1976)
5	Dhorpatan, Nepal	2.6 – 2.7	Wilson (1981)
6	Dhorpatan, Nepal	1.8	Aryal (2008)
7	Manang, Nepal	10	Wegge and Oli (1988)
8	Manang, Nepal	6.6 – 10.2	Oli (1993)
9	Manang, Nepal	9.4	Shrestha (2007)
10	Shey & Vijer, Nepal	2.27	This study

The average herd size of 15.2 animals/herd is similar to the herd size of 15.6 animals/herd reported by Oli (1991) in the Manang District of Annapurna Conservation Area. Schaller (1977) reported 18.4 animals/herd around the Shey area. Wegge (1979) reported 11.1animals/herd in the Dhorpatan region. Sherpa and Oli (1988) reported a herd size of 17.4 sheep from Nar and Phu valley, Manang, Nepal. In Hemis National Park, India, herd size varied from 9 in winter to 19 in summer (Chundawant *et al.,* 1990).

Previous studies show that the herd size of blue sheep varies year round. There is marked reduction in herd size in winter (Oli, 1991). Limited distribution and abundance of forage in winter and presence of snow play a vital role in determining the herd size.

4.5.5 Distribution pattern of Blue Sheep according to habitat parameters

35% of the blue sheep herds were observed in broken land form and 30% in slightly broken landform. Less than 15% of the herds were observed in flat and very broken landform. Wegge (1979) reported that larger group sizes were commonly associated with open habitats. In this study also only small groups were observed in very broken surface, while the larger groups were in open habitats.

90% of the herds were observed in grasslands. Oli (1991) observed only 50% of blue sheep herd in grasslands in the Manang area of Annapurna Conservation Area. In the spring more herds were observed in barren habitat. 45% of the blue sheep herds were found along the hillside and 30% along the ridge line. Oli (1991) found 39% of the herds on undulating slopes, which is less than this study. This indicates that blue sheep prefer grassland and safe areas from predators. The ridge line itself provides a vantage point for sheep to watch for predators and if attacked, provide some safe places for escaping from predators.

The sheep were distributed at a mean altitude of 4418.25m. This is almost identical to the study conducted by Oli (1991) in the Manang of Annapurna Conservation Area recording 4415m as mean altitude of blue sheep distribution.

70% of the blue sheep herds were closer than 300m from cliff. Cliff are considered safe places for escaping predator attack.

Chapter Five: Livestock Status and Depredation

5.1 Introduction

High altitude grasslands, both within and outside protected areas have long been used for rearing livestock by the local inhabitants. These grasslands are also used by wild animals as their habitat. Occasional killing of livestock by wild carnivores becomes inevitable when wild predators share their habitats with livestock, thereby bringing wildlife into direct conflict with human populations (Oli, 1991). Loss of livestock to wild predators is an important cause of anxiety amongst Himalayan pastoralists (Namgil, 2004; Jackson *et al.,* 1996). Livestock depredation has become a significant problem across the snow leopard range in central Asia, being most severe in and around protected areas (Schaller, 1998). Livestock predation by predators has been one of the major causes of conflict between wildlife and humans throughout Nepal (Uperati, 1986). Mass attacks in which as many as 100 sheep and goats are killed in a single incident inevitably result in retaliation by local people (Jackson & Wangchuk, 2004).

Dependency of wild predators on livestock is perceived to have increased in recent years (Namgil, 2004) which might be due to decline in natural prey. Theoretically snow leopards should attack livestock as their secondary prey only when their natural prey is either depleted or hard to find. The snow leopard is endangered (IUCN, 2002). Therefore, its dependency on domestic livestock increases conflict with the local communities and has resulted in increased retaliatory killing. This has been an important issue in snow leopard conservation throughout its range. Conservation strategies such as the snow leopard survival strategy (McCarthy & Chapron, 2003) and the snow leopard conservation action plan for the Kingdom of Nepal (MFSC, 2005) have emphasized the need to assess the extent of conflict between local communities and snow leopards in order to reduce the impact of the interaction. Snow leopards have been reported to kill livestock in most parts of their range but the extent of this predation and its impact on local herders is poorly understood (Mallon, 1984; Jackson, 1991).

5.2 Methodology

A well designed questionnaire with close ended questions was prepared prior to going to the field. Questionnaires were prepared in English and interpreted in Nepali language for ease of enumerators. Enumerators who were proficient both in Nepali and Tibetan language were selected. The enumerators were trained to fill the questionnaire. Three enumerators, one in each village was assigned to visit each household of the study area and collect the information. Field work was conducted during April to June, 2009. Total households (n=250) in different settlements of the village were considered for the household survey following the method used by Sharma *et al.*, (2006). Information on herd size, composition, mortality and major pasture used were obtained from the villagers. Depredation of one year period was only considered for the study. Only adults who were aware of livestock herding were interviewed.

Key informants such as buffer zone committee members, snow leopard conservation committee members, lamas (Buddhist monks) and local teachers were also interviewed to rank the major pastures.

5.3 Data Analysis

All quantitative data were analyzed using Microsoft excel 2007. Results were presented in bar diagrams.

5.4 Results

5.4.1 Livestock Status

All the households residing in Phoksundo, Vijer and Saldang village development committee own livestock. 250 households of these three villages owned 8157 livestock. Saldang had the highest livestock holding per household with 49.07 animals, while Vijer had 32.07 animals/household and Phoksundo had 17.42 animals/household. The highest livestock holding was 156 in Saldang and the least numbered one animal in Vijer. 20.8% of the total households did not have Yak/Chauri and only one household had 50 plus Yak/Chauri. Goat/Sheep was the majority forming 61.76% of the total livestock. 46% of the total household held small herds of

20 or fewer animals per household. Figure 10 shows the status of livestock in the study area, where goat/sheep number the highest and cow the least.

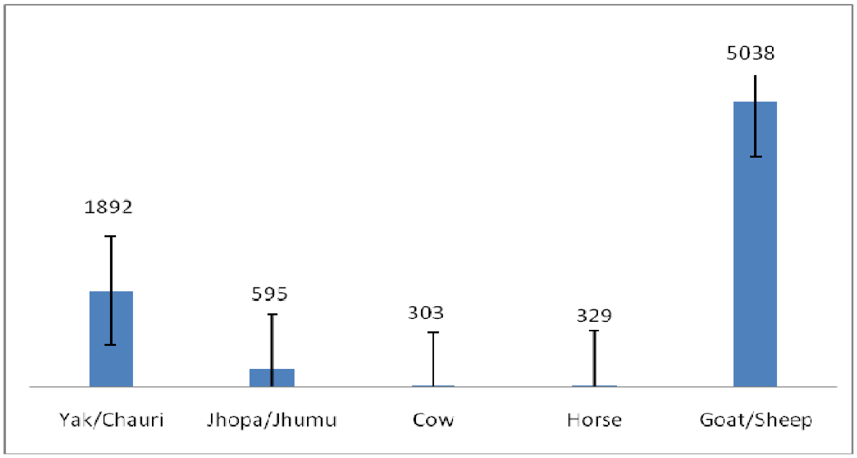

Figure 10: Livestock status

5.4.2 Livestock Depredation

250 households of the study area owned 8157 animals in total and each household lost 3.6 livestock annually. The total loss was 904 (11.08%) of the total livestock population in a year. Goat/sheep were the most depredated animals of the park consisting 67.69% of the total depredation, whereas horse consisted only 2.1% of the total depredation. The highest depredation rate of the livestock was observed in Vijer VDC with 19.18% and the lowest in Saldang with 7.17%. Figure 11 shows the depredation percentage of different livestock type.

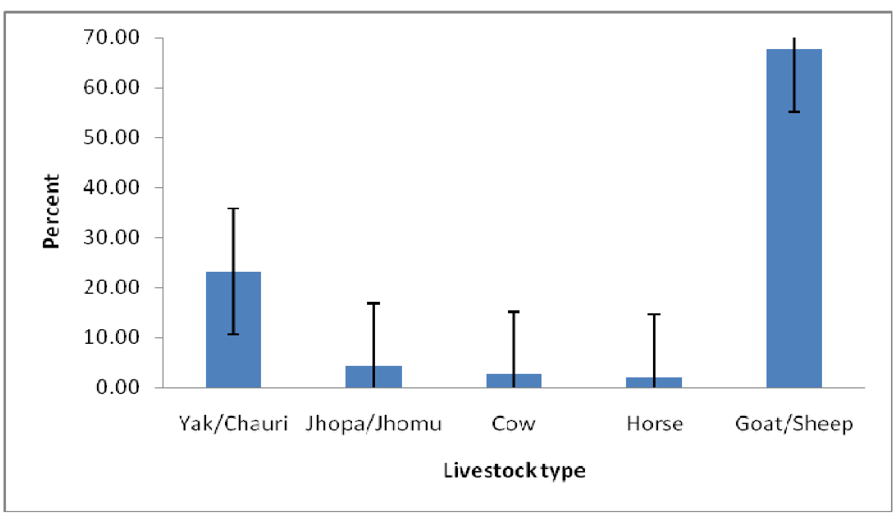

Figure 11: Livestock depredation

5.4.3 Cause of Livestock Depredation

Snow leopards were the main cause of livestock loss in Shey Phoksundo National Park, with 45.58% of the total loss is due to this predator. This is even higher in Vijer where snow leopards caused 59.75% of the total livestock depredation. The Tibetan wolf is the cause of 5.53% of the total depredation of the livestock. Though predators like brown bears and red fox have also have been reported in Shey Phoksundo National Park, their predation on livestock is not reported in this study. This may be due to unawareness of the people of this area regarding their behaviors. Figure 12 presents the cause of livestock depredation with percentage share.

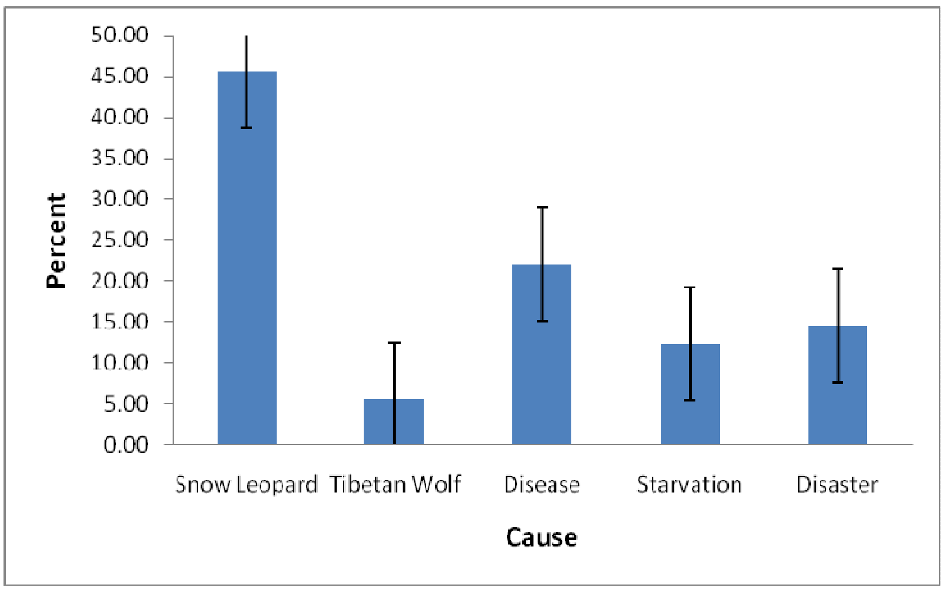

Figure 12: Cause of livestock depredation

5.4.4 Depredation Patterns over Time and Different Seasons

42.25% of the total depredation incidents occurred during the day time, and only 11.69% during the morning. This indicates that the depredation is high during the day time when the livestock are in the pastures for grazing. Proper care during the herding time can reduce the depredation by wild animals. Depredation in different time is presented in figure 13.

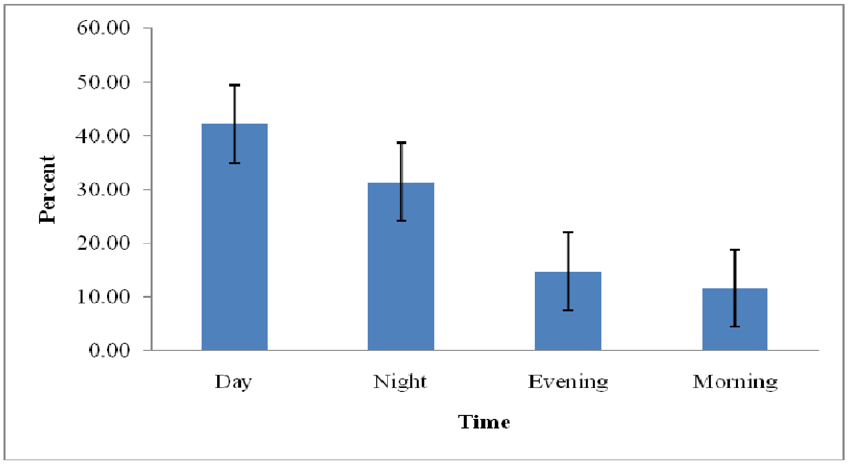

Figure 13: Depredation by time

The highest depredation was observed during the winter season (39.82%). There were marked differences in depredation during different seasons of the year with 30.19% during spring, 15.15% during summer and 14.84% during autumn (figure 14).

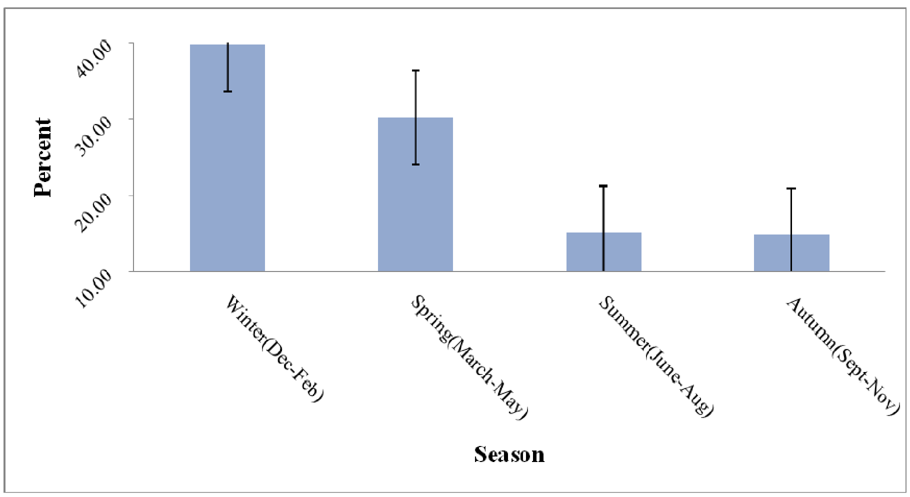

Figure 14: Depredation by season

5.4.5 Major depredation hotspots

Major pastures were identified and ranked according to the depredation incidents of livestock. 17 pasture areas were identified for the livestock of Saldang VDC. However, the highest depredation was observed in the home yard and its periphery (37.10%). In Phoksundo VDC, 19 major pastures were identified, 17.11% of the total depredation occurred at the home yard and its periphery. 17 major pastures were identified in Vijer VDC, with 22.55% of the total depredation occurring at the home yard and it periphery.

The pastures identified in all the villages included all the areas that the villagers take their livestock even during their migration during the winter in lowlands of the district. All the identified pastures were ranked into three categories on the basis of livestock depredation rate by participatory rural appraisal method.

A rotational grazing pattern was practiced in all the villages surveyed. The pattern of herd movement basically depended upon the decision of the herder, availability of grass, and season of the year.

5.5 Discussions

5.5.1 Livestock Status

The livestock holding per household in Hemis National Park, India was 50.3 animals (Bhatnagar *et. al.,* 1999) and in Manang of Annapurna Conservation Area 26.6 animals (Oli *e. al.,* 1994). The livestock holding per household in Shey Phoksundo National Park lies in between these two areas with an average of 32.62 animals per household. Livestock holding per household in Phoksundo VDC has decreased whereas the per household holding has increased in Vijer and Saldang VDCs as compared to 2006. In 2006, per household holding was 20.14, 31.01 and 37.93 in Phoksundo, Vijer and Saldang VDCs respectively (Thapa, 2006). In Phoksundo, people are more attracted towards tourism activities such as hotel, small shops, etc. Beside this, yak holding is higher and more common in Phoksundo, which has fewer number whereas goat/sheep form the majority of holding in Vijer and Saldang.

5.5.2 Livestock Depredation

In an independent study in the Manang area of Annapurna Conservation Area, the overall depredation rate was 2.6% (Oli, 1991). In Hemis National Park, India, villagers lost 12% of their livestock to predators in a fourteen months period (Jackson & Wangchuk, 2004). However, the percentage of livestock loss is still less than 7.1% of the total livestock lost to snow leopard and wolf in Ladakh (Namgil,2004) and 18% lost to wolf and snow leopard in Kibber Wildlife Sanctuary in India (Mishra, 1997). The overall livestock depredation of the Shey Phoksundo National Park is higher than other studies perhaps because this park has the higher densities of major predators like snow leopards and Tibetan wolves. Another reason may be due to the remoteness of Shey Phoksundo National Park and the livestock rearing system. In 2006, livestock loss per household in Saldang was 2.6 animals/household (Thapa, 2006), which has increased to 3.5 animals/household. This is also due to increase in livestock holding per household.

5.5.3 Cause of Livestock Depredation

Loss to snow leopards averaged 1.6 animals per household and 5.05% of the total livestock holding. Snow leopards are responsible for 45.58% of the total livestock depredation. Oli *et al.,* (1994) reported 2.6% of the livestock predated to snow leopards in Annapurna Conservation Area. This study shows higher livestock number depredated to snow leopards, this may be due to the high density of snow leopard in this park as compared to Annapurna Conservation Area. Mishra (1997) reported predation of 18% of the livestock holding to wild carnivores over a period of 18 months in Kibber Wildlife Sanctuary in India. Cattle are relatively immune to predation by snow leopard compared to high vulnerability of sheep and horses (Jackson *et al.,* 1996). In Hemis National Park, India; the snow leopard (55%) and wolf (31%) were identified as main perpetrators (Jackson & Wangchuk, 2004). 22.01% of the livestock loss was due to diseases, which is the second highest cause of the loss in Shey Phoksundo National Park.

Actual rate of depredation of livestock in Shey Phoksundo National Park is not available. Though this is important but not easy to establish, people generally exaggerate their livestock having been predated to Snow leopard, either deliberately, or due to inability to ascertain the causes of death. Livestock insurance schemes have been piloted in both Saldang and Vijer VDC, where the compensation for the snow leopard predated livestock only is provided. This may be one of the reasons, why people claim their livestock is being predated by snow leopards so that they can obtain compensation even if the cause of death is different. Studies of predation problems in the United States have shown that livestock farmers tend to attribute death of their animals to predators regardless of the actual cause of death, and exaggerate the number of animals lost to predation (Wagner, 1988). In this study, use of local village leaders who were directly involved in verifying the cause of livestock death should have minimized the errors in information obtained.

5.5.4 Depredation Patterns over Time and Different Seasons

The highest depredation was observed during the winter season (39.82%) followed by spring (30.20%), summer (15.15%) and autumn (14.83%). This seasonal variation in livestock depredation is similar to a study conducted in Manang of Annapurna Conservation Area (Oli *et al.,* 1994) where it was found that 42% of losses occured during winter, 28% in spring and15% each in summer and autumn. Oli *et al* (1994) reported 39% of the snow leopard scats collected during winter contained the remains of livestock, the analysis of faeces provided some support for the claim of high predation losses. During winter, sheep and goats grazed unattended and yak were left free roaming in the pastures, which increases chances greater chances of predation by wildlife. However during the summer, shephards guard their livestock in the pastures. In the Khunjerab National Park of Northern Pakistan, Wegge (1989) reported that about 10% of the domestic stock (mostly sheep and goats) were killed annually by snow leopards and wolves, with most of the loss occurring during winter and early spring.

The highest depredation occurred during the day time, followed by night, evening and morning. During the day time livestock are grazed in the open pastures where they share the habitat of wildanimals, likely leading to depredation. Finally, the topographic and steep terrain are the cause of accidental death of livestock.

5.5.5 Major depredation hotspots

Principally livestock depredation should be higher in pastures in case of wildlife attack, but this is not the case in all the three VDCs. Instead the highest depredation was higher around the home yard and its periphery. This is due to the practice of open corrals, where a wild animal can easily enter and kill livestock. During winter, snow leopards entered one of the corrals of Vijer VDC and killed16 goats in a night. While depredation does occur, people also claim that the wild animals come to their homestead and attack livestock, which may not represent the actual situation. Their claim may be biased towards getting better compensation when attacked in the home yard. It was also reported that the major depredation occurred during the day time, which does not coincide with the result.

Chapter Six: Scat Analysis of Snow Leopard

6.1 Introduction

Diets of small and large carnivores have been evaluated by analyzing stomach contents (Bothma, 1965; 1966; Smuts, 1979: cited in Maheshwari, 2006), by examining kills (Kruuk and Turner, 1967: cited in Maheshwari, 2006) and by identifying prey species from hair in scats (Windberg and Mitchell, 1990: cited in Maheshwari, 2006). Estimating the consumption of any particular prey type by carnivores depends upon the reliable analysis of diet. The analysis of scats (Reynolds *et al.* 1991, Mukherjee et al. 1994, Biswas *et al.* 2002, Jethva *et al.* 2003: cited in Maheshwari, 2006) has become a fundamental tool in carnivore research. Scat analysis has the great advantage that material is easy to collect and does not involve destruction of animals from the study population. An understanding of the snow leopard's diet is important in order to elucidate other aspects of its ecology and to design and implement conservation programs (Oli *et al*, 1993). Snow leopards are reported to kill domestic livestock over most of their range (Schaller, 1977; Mallon, 1984; Schaller *et al*., 1987; Fox *et al.,* 1988; Sherpa & Oli, 1988) which brings them into conflict with humans, but the extent of this predation has not been thoroughly assessed. Analysis of snow leopard scat can show whether and to what extent, livestock are represented in the diet (Oli *et al*., 1993).

The inaccessibility of its terrain and its secretive habits make the snow leopard one of the most difficult animals to study in the wild. Snow leopards have been reported to prey upon blue sheep (*Pseudois nayaur*), Asiatic ibex (*Capra ibex*), markhor (*Capricornis falconeri*), Himalayan tahr (*Hemitragus jemlahicus*), musk deer (*Muschus chrysogaster*), Tibetan argali (*Ovis ammon*), Tibetan wild ass (*Equus hemionus kiang*), kulan (*E. h. kulan*), goral *(Naemorhedus goral),* marmot *(Marmota himalayana),* pika *(Ochotona species),* hares *(Lepus oiostolus),* Tibetan snowcock *(Tetraogallus tibetanus),* chukor partridge *(Alectoris chukor)* and livestock (Bannikov, 195; Dang, 1967; Fox, 1989; Hammer, 1972; Mallon, 1984a; Schaller, 1997; Schaller et al., 1987, 1988a, 1988b, Jackson, 1979; Zhirjakov, 1990; cited in Oli, 1991). Most information available on the diet of snow leopard is based on the analysis of scat only, without prior knowledge of prey density of the area under study. In this study, I will present the analysis of diet and relate it to the density of wild prey species and livestock populations, giving insight into snow leopard prey preference.

6.2 Methodology

6.2.1 Collection of Scats

Scats were collected along a fixed trail (Jackson & Hunter, 1996; Lovari *et al*., 2009) in 27 transects which covered the length of 28.56 km, where the signs of snow leopard were found. This basically covered the area of Phoksundo, Saldang and Vijer VDCs. Scats were collected from transect (transect length 0.72 - 1.37 km). All together 40 scats were collected during the spring and early winter. Transects were mostly ≥ 1 km apart. To ensure that samples are authentically from snow leopards, they were collected adjacent to snow leopard signs such as scrapes and scent sprays or claw rakes. Furthermore, the presence of felid hair in scats is commonly used to assess the identity of cat species (Lovari *et al.,* 2009). The scats were identified on the basis of size and associated signs such as scrapes and pugmarks. Scats were collected with information on the date, time and transect number (Gurung & Ale, 2000). Collected scats were air-dried directly after collection in the field and preserved in polyethylene bags to identify food habits.

6.2.2 Analysis of Scats

Standard micro-histological methods were used to identify prey through the scats hair. At the laboratory the remains of prey species were separated and dried. To identify hair remains, hair samples were collected from domestic livestock, live wildlife and stuffed specimens in museum collections. These were used to prepare original slides for identification following the methods outlined by Teerink (1991) and Oli *et al* (1993).

Scats were washed with tap water in a fine mesh sieve and indigestible remains of hair, teeth, hooves, bones, feathers were air dried for 48 hours. The hair was cleaned thoroughly in diethyl ether for 10 minutes and dried between blotting paper and preserved in polyethylene bags (Oli, 1991). 20 hairs samples were randomly selected from each sample to prepare the slide and determine multiple prey species (Mukherjee *et al*., 1994).

Slides were prepared for each sample extracted from snow leopard scat in the laboratory using 100x magnification microscope and photomicrographs taken. Hairs were mounted with DPX for permanent slides to see medulla structure of the hair. Gelatin solution was used to prepare slides for seeing cuticular structure of the hair and cuticular scales were observed by the impression techniques. The slides were observed under a light microscope (400X) and digital photos were taken to see the cuticular and medulla pattern. Prey species were identified by comparison with a reference collection of slides and photographs of the structure of the cuticula and medulla of hair of potential prey species (Teerink, 1991).

6.3 Data Analysis

A total of 40 samples were analyzed for studying the diet contents of snow leopard. Each prey item was recorded when it was examined under microscope, in case of plant materials and feathers of birds, they were examined visually at the time of hair extraction and again during microscopic study.

6.4 Results

6.4.1 Diet Composition of Snow Leopard

A total of 40 scats were analyzed, from which three species of wild and four species of domestic mammals and birds were identified.

Blue sheep dominated the diet of snow leopard which consisted 30% of the identified prey items. Rodents were also the frequently eaten (17.5%) next to blue sheep and the Himalayan marmot was the third most frequently found species in the diet of snow leopards. Although the species of birds present in the scat could not be identified, it was believed that they were Himalayan snowcock, Tibetan snowcock or Chukar as these were the only large birds found in the area. Among the livestock, sheep were the main species found in the diet of snow leopard (15%). The frequency of occurrence of prey items detected in scats is presented in table 4.

Table 4: Frequency of occurrence of prey items in snow leopard diet

S.N	Prey Species	Frequency of Occurrence	Percent frequency of occurrence
1	Blue sheep	12	30
2	Himalayan Marmot	6	15
3	Bird	5	12.5
4	Rodent	7	17.5
5	Goat	1	2.5
6	Sheep	6	15
7	Yak	2	5
8	Horse	3	7.5
9	Plant only	1	2.5

Most of the scats (87.5%) contained only one prey species while two prey types were contained in 12.5 % of the scats. Plant materials such as grass, leaves and twigs were also found in the scat. One scat consisted only plant materials, suggesting that snow leopards may eat plant deliberately.

70% of the diet of snow leopards consisted of wild prey items, among which blue sheep was the major item consisting 40% of the wild prey consumed. Figure 15 shows the percentage composition wild prey items in snow leopards diet

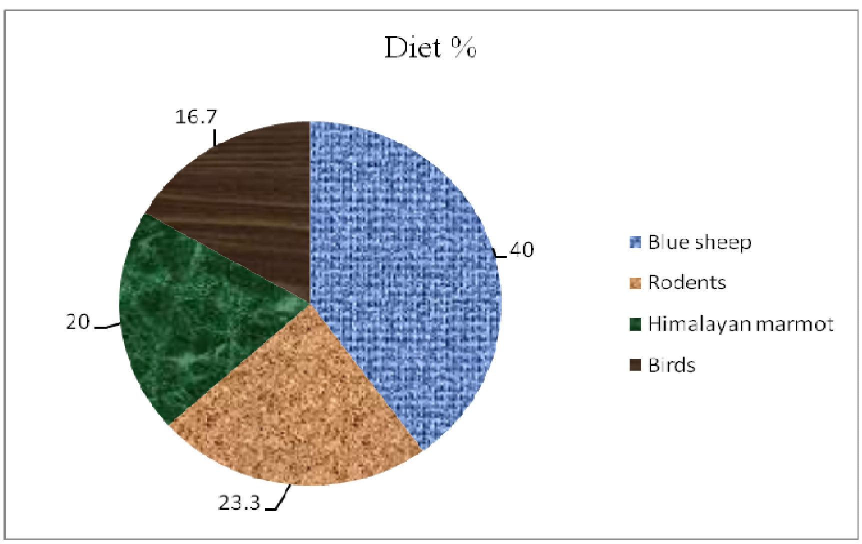

Figure 15: Wild prey items in the diet of snow leopard

30% of the diet of snow leopards consisted of livestock items and sheep were the major component of the snow leopard diet consisting 53.8% of the livestock items (detail in figure 16).

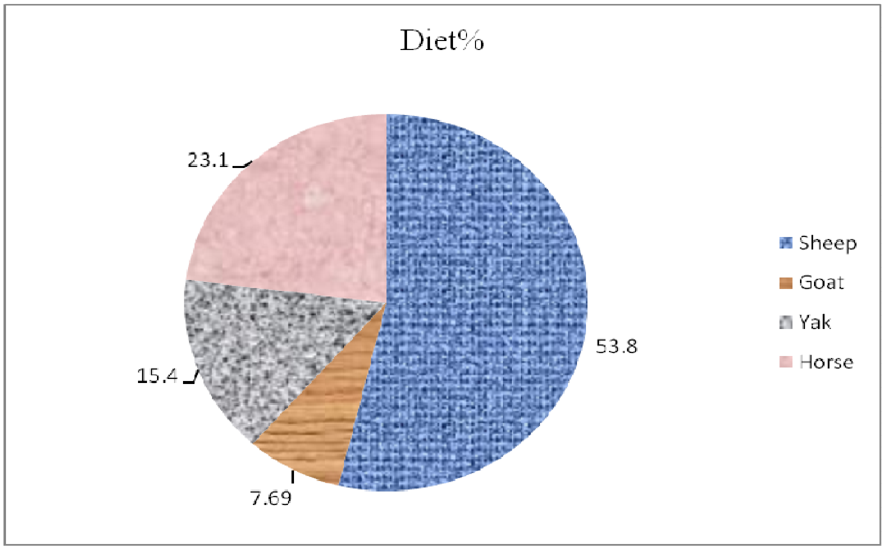

Figure 16: Livestock as a food of snow leopard

The overall prey item composition in the diet of snow leopards is presented in figure 17.

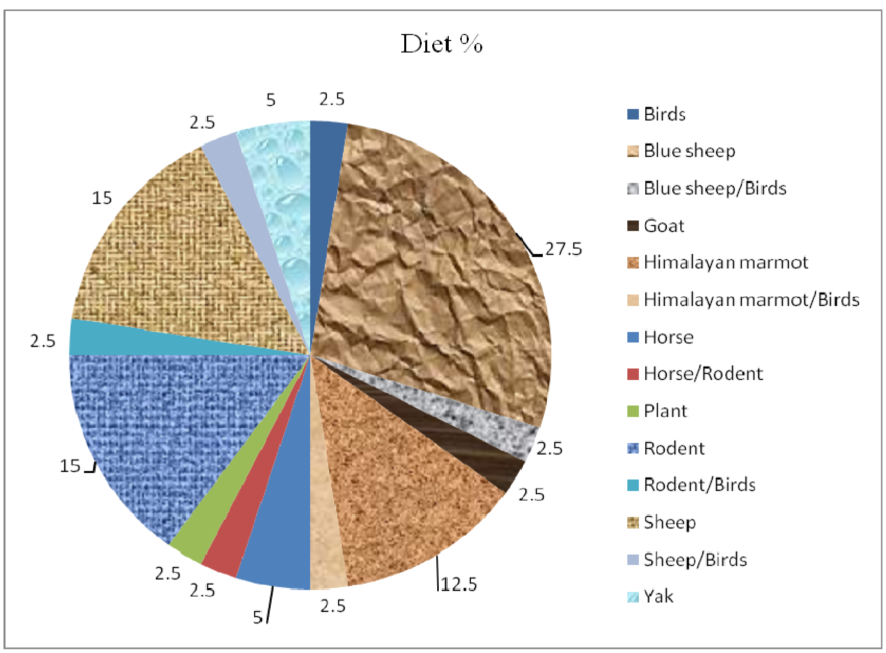

Figure 17: Overall diet composition of snow leopard

6.5 Discussions

6.5.1 Diet Composition of Snow Leopard

The diet of a carnivore reflects both the availability of its potential prey items, as well as a suite of morphological, behavioral and physiological adaptations that allow the individual to locate, capture, ingest and digest a variety of prey taxa (Kok *et al.* 2004: cited in Maheshwari, 2006). This study focused on the diet of snow leopard in spring 2009 and shows that its diet is higher in wild prey species compared to livestock. Blue sheep dominated the diet of the snow leopard but small mammals like marmot and rodents and birds were also a major part of the food items. Marmots go into a prolonged hibernation and are not available during winter (Arnold and Psenner, 1990).

The diet of the snow leopad varies greatly in different part of its range. Blue sheep (*Pseudois nayaur*) was most frequently eaten prey in Shey and Lapche, Nepal, Taxkorgan reserve and Shule Nansham, China, whereas ibex(*Capra ibex*) dominated the diet of Tamur Feng, China. Marmots are known to form a part of snow leopard diet in most of its range (Schaller, 1977; Schaller *et al.,* 1987). Blue sheep were found in 50% and 70% of scats in Shey and Lapche, Nepal, respectively, whereas they were totally absent from the diet of snow leopard in Chitral, Pakistan, where markhor (*Capra falconeri*) was eaten more frequently (Schaller, 1977).

When compared to that found by Schaller (1977) in Shey, the blue sheep in the diet of snow leopards have decreased by 20% in a period of more than three decades. As the density of blue sheep has also decreased, this is most likely, the major reason for the decrease of blue sheep in snow leopard diet. In Dhorpatan Hunting Reserve, the percentage of blue sheep in diet of snow leopards was 20.12% , where blue sheep had density of 1.8 animals/km^2 (Aryal, 2008). In Ladakh, India, blue sheep remains were encountered in 23% of the scat analyzed, it also showed that snow leopards ate considerable amounts of plant matter (Chundawat & Rawat, 1994). Chundawat & Rawat (1994) found that 25 scats contained only plant species (*Myricaria germanica*), in this study also one scat contained only plant species, and other contained small amount in scats. This indicates that snow leopards may feed on plant delibaretly.

Chundawat & Rawat (1994) reported that domestic animals formed a significant part of snow leopard diets in Lakakh, where goat was the major occurring in 10.2% of the scat. Oli (1994) found yak in 13.62% of the scat in Annapurna Conservation Area, Manang, Nepal. In this study, sheep formed the major component of the snow leopard diet among the livestock, forming 15% of overall diet and 53.8% of the total livestock.

6.5.2 Prey Density and Diet Relationship

Himalayan marmots had the highest density among the wild prey species in Shey Phoksundo National Park. Among the domestic animals goats/sheeps had the highest holding and also the highest depredation rates. On analyzing the diet, it was however found that highest frequency in the diet was blue sheep and sheep. This clearly indicates that the diet composition of snow leopards is independent of the density of wild prey species and that blue sheep is the most preferred species of snow leopard. The diet composition of snow leopard is not proportional to prey density.

Chapter Seven: Conclusion and Recommendations

7.1 Conclusion

Blue sheep, musk deer, Himalayan marmot, Tibetan snowcock, Himalayan snowcock, hares, Royle's pika and chukar partridge are the major prey species of snow leopard in Shey Phoksundo National Park. Himalayan marmots had the highest density, cluster size and encounter rate among the prey species identified. The density of blue sheep was 2.27animals/km^2 which has decreased drastically since 1977 when it was 8.8 to 10 animals/km^2.

Livestock herding is the major occupation of the people living in Shey Phoksundo National Park and its buffer zone area. Out of 250 households surveyed, 100% of the people were involved in this occupation. The average livestock holding per household was 32.62 animals. The number of animals owned by household varied from single to a group of 156 animals. Goats/sheep were the major bulk forming 61.76% of the total livestock. The livestock depredation rate was 11.08% annually, which is considered to be the highest in Nepal. Goats/sheep were the most depredated animals of the park consisting 67.69% of the total depredation whereas horse consisted only 2.1% of the total depredation. 45.57% of the total loss of the livestock is due to predation to snow leopard. 42.25% of the total depredation incident occurred during the day time and 39.82% during winter. 25.58% of the total depredation occurred at the home yard and its periphery.

Blue sheep was the preferred prey species for snow leopard, where it constituted 30% in the scat analyzed. Birds like Tibetan snowcock, Himalayan snowcock and Chukar also form the major part of snow leopard diet. Though Himalayan marmot had the highest density, its frequency of occurrence in the diet was after blue sheep and rodent among the wild prey species. The frequency of occurrence in the diet of snow leopard was high for sheep among the livestock. The diet composition of snow leopard is not proportional to the density of the prey species available.

7.2 Recommendations

Based on the study, the following recommendations are put forward.

7.2.1 Replication of line transects should be increased and standardized for more accurate and precise estimation of the prey density in protected areas of high altitude like Shey Phoksundo National Park. Accuracy of line transects can be increased by regularly monitoring the common as well as less frequently sighted animals. A minimum of 60 observations per species is needed to more accurately estimate prey densities.

7.2.2 Compensation for snow leopard predated livestock through livestock insurance scheme should be implemented in Phoksundo VDC. Compensation can change the attitude of people towards snow leopard conservation and at the same time provide income for households.

7.2.3 Scat from all seasons from multiple years should be collected and analyzed to gain better understanding of the diet composition of the snow leopard.

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