Prey Preference and Dietary overlap of Sympatric Snow leopard and Tibetan Wolf in Central Part of Wangchuck Centennial National Park

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Abstract

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. There has been even no effort in looking at predator-prey relationships and often we make estimates of prey needs based on studies from neighboring regions. Therefore this study is aimed at analysing livestock depredation, diets of snow leopard and Tibetan wolf and its implication to herder's livelihood in Choekhortoe and Dhur region of Wangchuck Cetennial National Park. Data on the livestock population, frequency of depredation, and income lost were collected from a total of 38 respondents following census techniques. In addition scats were analysed to determine diet composition and prey preferences. The results showed 38 herders rearing 2815 heads of stock with average herd size of 74.07 stocks with decreasing trend over the years due to depredation. As a result Choekhortoe lost 8.6% while Dhur lost 5.07% of total annual income. Dietary analysis showed overlap between two species indicated by Pianka index value of 0.83 for Dhur and 0.96 for Choekhortoe. The prey preference for snow leopard and Tibetan wolf are domestic sheep and blue sheep respectively, where domestic sheep is an income for herders and blue sheep is important for conservation of snow leopard. This study therefore indicates potential effects of both herder's livelihoods and prefer diet (blue sheep) of carnivore species. It concludes that the livestock depredation in WCNP is a serious issue which needs to be addressed through appropriate compensation and/or other conservation strategies to reconcile biodiversity conservation and socio-economic development. This is the first results of its kind, so data from seasonal variation covering spatial and temporal extend is highly recommended to determine the possible variation.

Key words: conflicts, dietary, habitat, snow leopard, Tibetan wolf, Wangchuck Centennial National Park

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List of Abbreviations

ANOSIM	Analysis of Similarity
BWS	Bumdelling Wildlife Sanctuary
CITES	Convention for International Trade in Endangered Species
D	Jacobs Index
DEM	Digital Elevation Model
DO	Dietary Overlap
DoFPS	Department of Forest and Park Services
FNCR	Forest and Nature Conservation Rule
FO	Frequency of Occurrence
IUCN	International Union for Conservation of Nature
JDNP	Jigme Dorji National Park
m	Mean
m	Meter
masl	Meters above sea level
PAs	Protected area system
RO	Percent of Relative Occurrence
ROC	Receiver Operating Characteristics
SD	Standard Deviation
SLC	Snow Leopard Conservation
Sqkm	Square Kilometer
WCNP	Wangchuck Cetennial National Park

List of Acronyms

Chewog:	Administrative sub-block
Dzongkhag:	District
Gewog :	Administrative Block
Tsamdro:	Registered grazing land/pastureland in GRF
Tshokpa:	Village headman

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Chapter One

Introduction

1.1 Background

The snow leopard (*Panthera uncia*) is an icon for conservation in the mountain regions of Asia (Shaller, 1977) and Tibetan wolf (*Canis lupus chanco*) is a predatory, carnivorous mammal of the family canidae and has the largest range of any land mammals (Srivastav and Nigam, 2009). As a top-order predators, their presence and survival is also an indicator of intact, ''healthy'' eco-region (Jackson et al., 1996). However, they are one of the poorly known among predators and their population is believed to be declining due to killing by herders as a livestock predator, poaching for fur, and loss of habitats. With the decline in population over 20% in last two decades, the conservation of these predators has now become a global concern (Jackson and Hunter, 1996).

In the mountain ecosystem of Central Asia and the Tibetan Plateau, they are threatened by retaliatory killings, poaching, a decline of prey species and habitat degradation (McCarthy and Chapron, 2003). Reduction in prey base resources is also considered as major reasons for decline in population (Jackson et al., 2008). The habitat degradation and fragmentation due to human population expansion and livestock grazing, poaching for pelts and bones are some of the other major reasons for decline in population (Shehzad et al., 2012).

It also revealed an important interaction between snow leopard and wolf (Canis lupus) and their prey species in Pamirs of Northwestern China (Wang et al., 2014). Based on analysis of genetically confirmed scats, significant dietary overlap (*Pianka's index* = 0.91) between snow leopard and grey wolf was also found at Sarychat-Ertash Reserve in the Tien-Shah mountain of Kyrgzstan. This will intensify competition for food and affect both predators negatively (Jumabay-Uulu et al.,2013).

In Wangchuck Centennial National Park (WCNP) in Bhutan, the density of snow leopard was recorded 2.39 individuals per 100 Sqkm. The density was found low compared to the neighboring ranges in Nepal and India, presumably because of low prey numbers and the prevalence of multiple predators including Tibetan wolf (Shrestha, 2013). Like any of the range countries, the human snow leopard and wolf conflict was also found common in Bhutan (Sangay and Vernes, 2008). Therefore this study intends to find out livestock depredation and diets of snow and Tibetan wolf and its implication to herder's livelihood in central part of Wangchuck Cetennial National Park. The understanding gained from this study will aid in managing human-wildlife conflict and conserving prey base resources for conservation of endangered predators for all times to come.

1.2 Problem statement

Snow leopards and Tibetan wolves have been reported to kill livestock in most parts of their range (Shehzad et al., 2012) but the extent of this predation and its impact on local herders is poorly understood. Further, there has been limited effort to look at predator-prey relationships and often we make estimates of prey needs based on studies of other carnivores. Our understanding of snow leopard and Tibetan wolf prey preference and use in Bhutan comes primarily from a few studies in India, Mongolia, and Nepal. The capability of protected areas to support viable snow leopard and Tibetan wolf populations, when based on non- predator-prey data, is potentially faulty and misleading.

1.3 Research question

How does the diet composition of snow leopard and Tibetan wolf correspond with the livestock depredation and their habitat?

1.4 Objectives

1. Determine the extent of livestock depredation and its effect on local livelihood
2. Analyze prey preferences and dietary overlap of snow leopard and Tibetan wolf

Chapter Two

Literature Review

2.1 Introduction

This chapter covers the general aspects of the snow leopard and Tibetan wolf, including taxonomy and morphological characteristics. At first, aspects of the taxonomy, morphological characteristics, and social behavior are discussed to help investigator know and design the study appropriately (Figure 2.1). The later on discusses about the habitat, prey, human interaction and legislation and institution for understanding methods and results that has been carried out in other range countries.

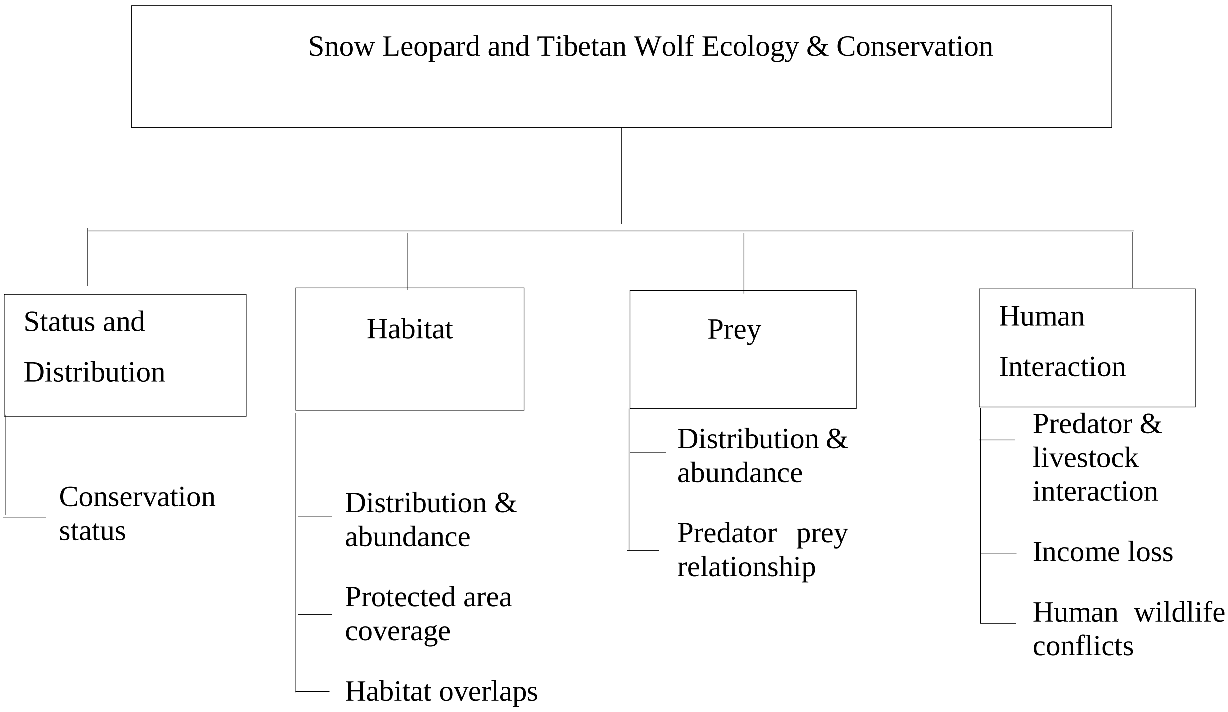

Figure 2.1: Literature framework

2.2 Status of snow leopard (*Panthera uncia* Schreber, 1775)

The snow leopard is a member of the family Felidae, subfamily Pantherinae (Nowak and Paradiso, 1983). Once placed under genus Unicia (Pocock, 1917; Peters, 1980; Sunquist and Sunquist, 2002) owing to the lack of thick pad of fibro elastic tissue in vocal folds to roar like other big cats. However, recent phylogenetic analysis place the snow leopard within the genus Pathera, being most closely related to tiger (*Panthera tigris)* with divergence time estimated to be 2 million years (Johnson et al., 2006). Adult male snow leopards weigh 37–55 kg and females 35–42 kg; they have a shoulder height of 0.60 m, head-body length of 1-1.3 m, and tail 0.8-1 m (Hemmer, 1972; Johansson et al., 2013). It is among the least known 'big cats' due to its elusive nature, secretive habits and the remote and challenging terrain it inhabits (SLC, 2014). Taking the role of top predator, its presence and survival is also an indicator of intact, "healthy" eco- region (Jackson and Hunter, 1996). The population of this iconic species is believed to be declining due to killing by herders as a livestock predator (Oli, 1994), poaching for fur (Theile, 2003), and loss of habitats (Hunter and Jackson, 1996). Hence, it is listed as endangered on IUCN Red List of threatened species since 1998 (Hilton-Taylor, 2000) and included in Appendix I of the Convention on International Trade in Endangered Species of Flora and Fauna. In Bhutan, it is listed under Schedule I of Forest and Nature Conservation Rule, 2006.

2.3 Status of Tibetan wolf (*Canis lupus chanco* Gray, 1863**)**

The Tibetan wolf, also known as the Chinese wolf, Mongolian wolf, Korean wolf, Steppes wolf or Woolly wolf is a subspecies of gray wolf found in parts of Central China, southwest Russia, Manchuria, Tibet and the Himalayan regions of India, Nepal and Bhutan. Tibetan wolf is relatively widespread with a stable population trend and has therefore been assessed as Least Concern by IUCN since 2004 (Mech and Boitani, 2010). Least concerned in Pakistan, India and Nepal as per IUCN, 2011, the status however has reached endangered in certain European counties, mainly because the wolf has declined greatly in numbers during the last few decades (DoFPS, 2012). As per DoFPS (2012) WCNP is the major habitat for Tibetan wolf in Bhutan.

2.4 Distribution

The historic distribution of snow leopard is restricted to the mountains of central Asia. It lives within the elevation range of 3,000 to 5,500m in 12 Asian countries (Devkota, 2010), encompassing a total potential area of 1,835,000 Sqkm (Mecarthy and Chapron, 2003). Its population is estimated to be between 4,500-7,500 throughout its range (Fox, 1994). In Bhutan the potential snow leopard range totals as much as 15,000 Sqkm according to Fox (1994) and 57% of potential snow leopard range falls within existing PA system (Hunter and Jackson 1997). Snow leopard presence has been confirmed in Toorsa Strict Nature Reserve, Jigme Dorji National Park, and Wangchuck Centennial Park. Protected areas with potential habitat are Sakten Wildlife Sanctuary, Jigme Singye Wangchuck National Park and Bumdeling Wildlife Sanctuary (SLC, 2014).

Tibetan wolf was the world's most distributed terrestrial mammal, living throughout the northern hemisphere until it become extinct in much of Western Europe (Boitani, 2000), in Mexico and much of the United States of America (Mench, 1970). Today, its distribution is more restricted to the trans-Himalayan region and the Tibetan Plateau and occurs primarily in wilderness and remote area, especially in Canada, Alaska and northern USA, Europe and Asia from about 75^0 N to 12^0 N (Ray, 2001).

2.5 Habitat

Snow leopards are closely associated with the alpine and subalpine zones above the tree line (Hunter, 1996) . In the Sayan Mountains of Russia and parts of the Tien Shan they are frequently sighted in open coniferous forest (Heptner and Sludskii, 1992). They generally occur between elevations of 3,000–4,500 m, but are found at lower elevations (900–1,500 masl) in northern parts of the range and in the Gobi desert, and may range up to 5,800 masl in the Himalaya and Qinghai-Tibetan Plateau region (SLC, 2014). However, in nearly all parts of their range, snow leopards favor steep, rugged terrain, well broken by cliffs, ridges, gullies, and rocky outcrops (Hunter, 1996). They show a strong preference for irregular slopes in excess of 40° and well–defined landform edges, such as ridgelines, bluffs and ravines, along which to travel about their home range. They may migrate to lower elevations during the winter to avoid deep snow and follow movements of their primary prey species (Dominic, 2016).

Wolves live in the most diverse types of habitat and their broad distribution ranges show the species adaptability to the most extreme habitat conditions (Mech, 1970). The wolf's habitat has been described as everywhere where humans do not kill the species and where food resources are sufficient. Where wolves live depend on wild ungulate prey, their habitat is that of their prey (Mech and Boitani, 2003). However, in Bhutan it is found to be occupying alpine zone above 4000 m above sea level (DoFPS, 2012).

2.6 Prey distribution and abundance

Conservation of key prey species is crucial for the survival of any large predator as changes in preferred prey abundance could alter its population status (Hayward et al., 2007). One of major reasons for the estimated 20% snow leopard population decline in the last two decades is a reduction in prey resource base (Jackson et al., 2008). The effects of such losses contribute to direct decline of snow leopards, as carrying capacity diminishes, and increased use of domestic livestock by snow leopards, elevating conflict and retaliatory killing by pastoralists (Bagchi and Mishra, 2006). Large ungulates (notably blue sheep, markhor, urial, ibex, goats and sheep) often represent the major constituents of the snow leopard's diet (Shehzad et al., 2012). Additional prey items that have been observed include unidentified birds and a wide variety of medium and small mammals, such as marmots and other rodents (Anwar et al., 2011). In Mongolia, Siberian ibex and argali are the natural prey of the snow leopard (Reading et al., 1999).

Wolves are opportunistic feeders predating medium to large sized ungulates. They will however, eat any meat that is available, including non-ungulate species, carrion and garbage. Instances of cannibalism have been reported in wolves, and are believed to occur in times of food scarcity (Srivastav and Nigam, 2009). The wolves are capable of hunting prey much larger than themselves and primarily achieved by hunting in packs. They used different strategies during hunting like stalking and rushing or chasing (Jhala, 2003).

2.7 Human interaction

Livestock depredation by large carnivores and their retaliatory or preventive killing is a worldwide conservation concern and an important socio-economic concern for local communities living within carnivore ranges (Suryawanshi, 2013). Across snow leopards distribution range, conflict over livestock depredation behavior threatens the survival of this iconic species (Jackson and Wangchuk, 2004; Oli, 1994; McCarthy and Chapron, 2003). The impact of livestock depredation by snow leopards and other sympatric carnivores such as the wolf on the local herding communities is considerable (Suryawanshi, 2013). The loss of livestock to snow leopard and wolves account to 3-18% annually (Oli, 1994; Namgail et al., 2007). Amongst all livestock species, snow leopards are reported to predate on horses disproportionately more than their abundance (Mishra, 1997). Due to the greater economic value of the horse, killing of a horse draws greater anger from the local communities (Oli, 1994; Jackson and Wangchuk, 2004). Livestock depredation has hence become a greater challenge in range of snow leopard (Jackson and Wangchuk, 2004). Snow leopards are thought to be one of the major killers of livestock which result in hostility towards the animal from local communities (Mishra, 1997) and retribution killing of snow leopards (Bagchi and Mishra, 2006).

The 60% of the total livestock losses in Gya-Miru Wildlife Sanctuary in Ladakh is attributed to Tibetan wolf. Domestic goats were the most frequent victims (32%), followed by sheep (30%), yaks (15%), and horses (13%) (Namgail et al., 2007). The 90% of stocks killed were small bodied stocks like goats and sheep in Hemis National Park of Ladakh. By comparison, fully-grown yaks are rarely killed, except by large packs of dhole and large predators like leopards and tigers (Bhatnagaer et al., 2000). However in WCNP most herders had given up rearing of small stock (goats and sheep) in the recent past (5 years ago) apparently due to the predation by wild predators as well as decline in demand for wool (Shrestha, 2013). Therefore nomads consider the wolf to be a major problem, with their livestock suffering from frequent night-time attacks, and the only protection afforded is the presence of dogs to scare off predators. In India, Brown bears and snow leopards are lesser threats to livestock (Fox et al., 2002).

Overall human–wildlife conflict attracts greatest attention when the wildlife species involved is endangered or where the conflict poses a serious threat to human welfare (Saberwal et al., 1994). However, little attention has been paid to the socio-economic dimension, in which the conflict happens and the amount for economic losses relative to the average family's income is not known (Cozza et al., 1996).

2.8 Income loss

In India's Kibber Wildlife Sanctuary, Mishra (1997) reported 18% of local livestock holdings were killed by snow leopard (*Uncia uncia*) and wolf (*Canis lupus*). It was estimated that the losses valued at US $128 per household per annum, a very significant economic impact given per annual cash incomes of $200-400. The villagers claimed predation rates increased following the establishment of the sanctuary, but surveys indicated a dramatic increase in livestock numbers accompanying changes in animal husbandry systems (Mishra, 2000).

Chapter Three
Materials and Methods

3.1 Study area

3.1.1 Location and conservation significance

Wangchuck Centennial National Park (WCNP) is the largest protected area of the country with an area of 4,914 Sqkm. Declared in 2008, the park is the latest addition to Bhutan's protected area system. Located in the north-central Bhutan (27° 48′ N, 90° 39′ E), WCNP provides for much needed ecological connectivity in the Bhutan Himalaya as it links Jigme Dorji National Park (JDNP) and Bumdeling Wildlife Sanctuary (BWS) to the west and east, respectively (Figure 3.1). Permanent snow covered mountains such as Gangkar Puensum, Rinchen Zoegila and Jazayla and their glaciers nestled within WCNP serve as water towers to Bhutan's major river systems including Punatsangchu, Mangdechu, Chamkharchu and Kurichu.

3.1.2 Climate

Maximum and minimum temperatures recorded during this study were 10°C and -20°C, respectively. As with other regions in the Himalaya, there is a pronounced seasonality in climatic pattern. Winter normally starts from November and lasts until February and is generally cold and dry. Snow and ice start to thaw in March and April. With the onset of the warm monsoon rain and fog in early June, the vegetation virtually explodes thereby attracting herders and medicinal plant collectors to the alpine pastures (Shrestha, 2013).

3.1.3 Land use and vegetation

Ecologically, WCNP can be divided into temperate (2,500- 3,000 m), sub alpine (3,000-4,000 m), and alpine (>4,000 m) zones. Nearly 85% of the land cover belongs to the latter two ecological zones which remain under snow cover for about four months during winter (WCP, 2008). The major land cover consists of 27% snow cover, 22% rock outcrops, 18% Shrubs, 12% Meadows, 12% blue pine forest, 5% mixed conifer forest and rest are comprised by moraines, lakes and agriculture land. As elsewhere in the mountainous landscape, the composition and structure of vegetation here is primarily governed by altitude, aspect and steepness of slope. Southern aspects are drier and comprise mainly of scrublands and xeric vegetation while the northern aspects are moister and dominated by mesic grasslands. Alpine meadows, the important feeding grounds of snow leopard's prey, blue sheep or naur (Shrestha and Wegge, 2008), are patchily distributed in valley floors, around glacier lakes and river basins. Higher up (5,000 masl) the landscape is dominated by sparsely vegetated talus, cliff and scree slopes. Vegetation types are characterized by fir-juniper forests in the sub-alpine habitats (3,000-4,000 masl), and alpine scrub of *Rhododendron* spp., *Berberis asiatica*, and

Rosa spp. are commonly found between altitudinal range of 4,000 – 4,500 m. Alpine meadow vegetation primarily consisted of Kobresia and Carex communities (Shrestha, 2013).

3.1.4 Settlement

Upper Chhoekhor gewog has 322 households in three chewogs of Dhur (three villages), Nasphel (12 villages) and Kharsa (four villages). There are 38 nomads who depend entirely on yak husbandry. They fall under three landless categories of Tendrok, Khandrok and Durdrok settled in upper Choekor gewog (Kinga, 2013). The study site has total area of 1,275 Sqkm. It encompasses 25.93% of WCNP (27° 51′ N, 90° 39′ E) and 83.4% of Chhoekhor gewog (Figure 3.1). The studies specifically targeted 38 herders who depend entirely on yak husbandry.

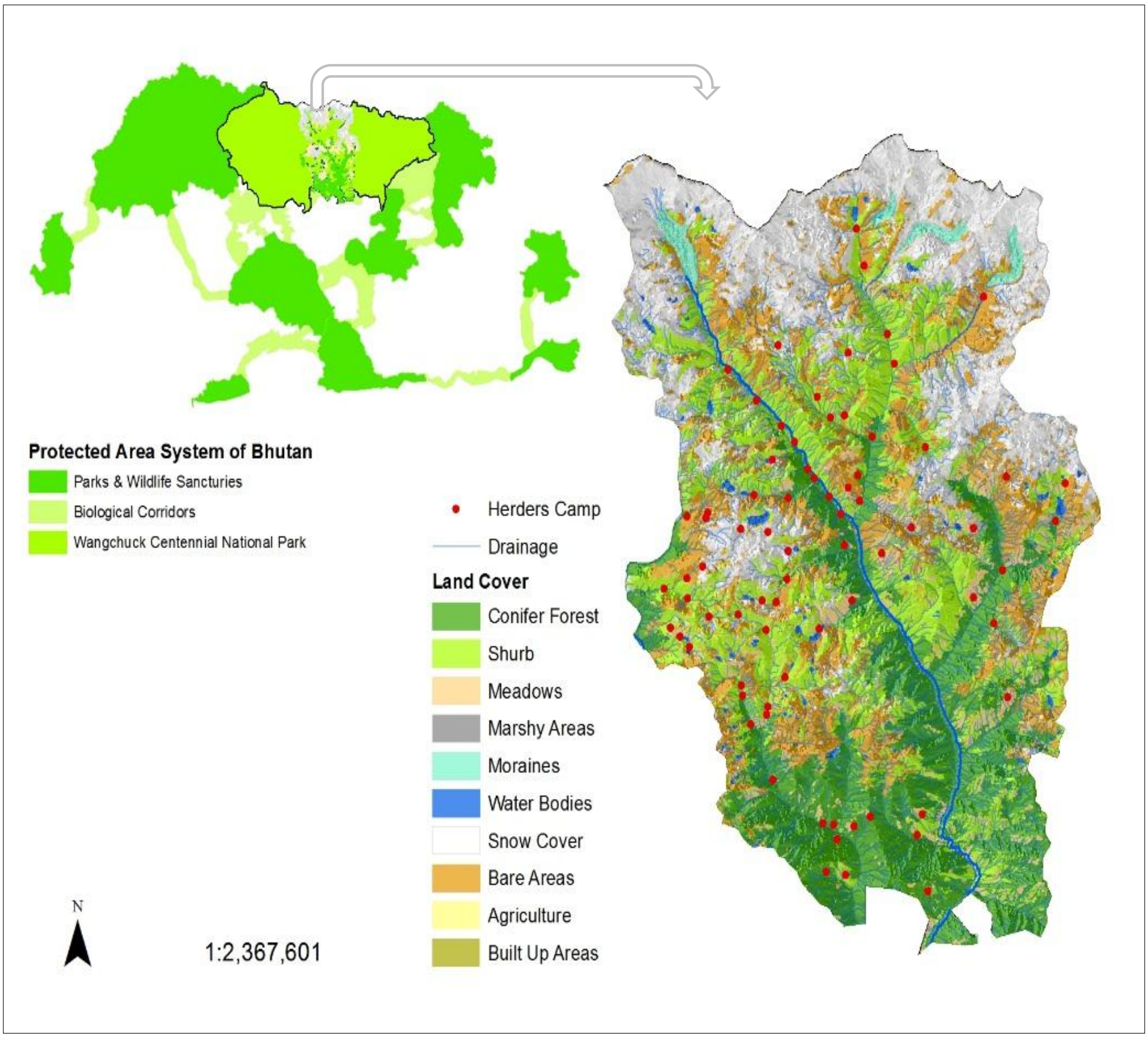

Figure 3.1*: Map of study area

*red dots represents location of herds where questionnaire survey has been carried out

For the dietary composition of snow leopard and Tibetan wolf, only 726 Sqkm upper Chamkharchu watershed (27° 51′ N, 90° 39′ E,) was selected as it represents good potential snow leopard habitat in WCNP, with potential connectivity to adjoining JDNP where snow leopard presence has been documented in the earlier surveys (Figure 3.2). The northern boundary of the study area is marked by Gangkhar Puensum mountain (7,570 masl) and its glaciers, which forms the headwaters of Chamkar River. The southern lower part (<4,000 masl) is mostly dominated by deep river gorges and extensive Fir, juniper and Larix forests. Glacial lakes at higher altitudes (>4,500 masl) dot the landscape and the tree-line goes as high as 4,200 masl.

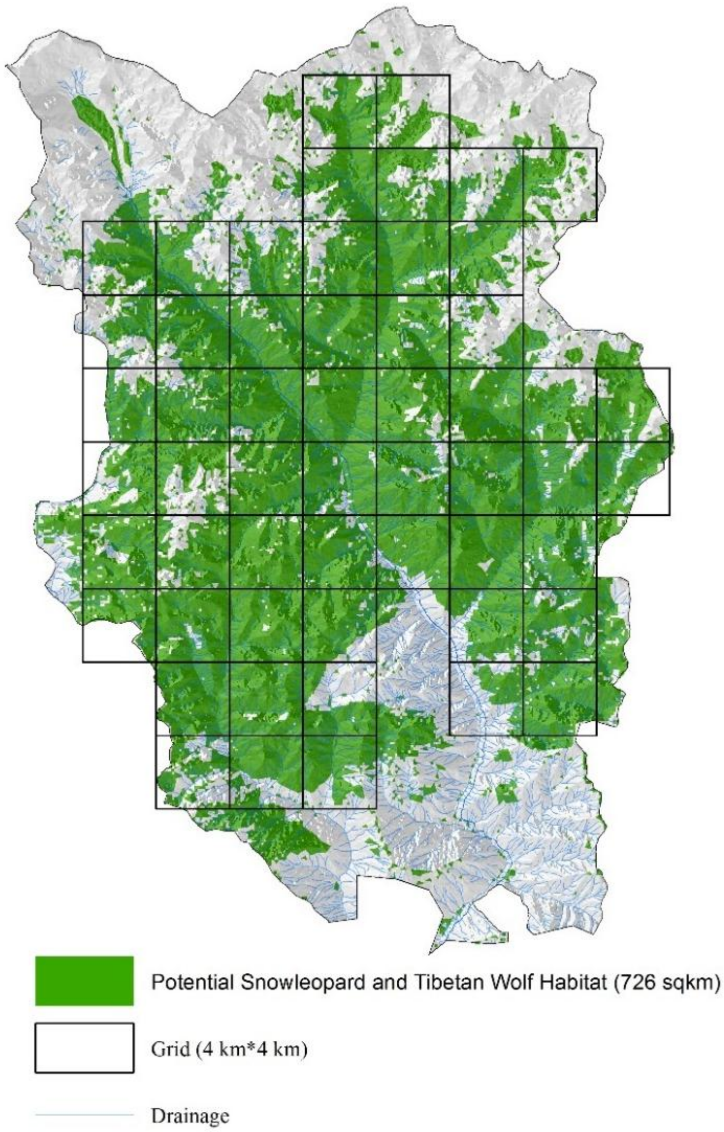

Figure 3.2: Grids (4*4) laid for scat collection survey

3.2 Research design

3.2.1 Questionnaires survey

As per information collected from Chhoekhor gewog administrations and Renewable Natural Resources office, Chhoekhor gewog has 45 yak owning household as of 2013. However, as on December 2016 number of actual yak-herding households reduced to 38 with livestock population of 2,815. Owing to small target population, all yak owners were interviewed (total enumeration) using semi structured questionnaires (Annexure 1).

3.2.2 Stratification

The Geog was stratified into two areas or strata, i.e. (i) Dhur area comprising of two villages, (ii) Choekhortoe area which comprises of seven villages. Dhur and Choekhortoe area two different regions under Choekhor gewog which has distinct characteristic's including age old tradition, dresses and social status. Geographically, they are located along two different tributaries of Chamkharchu; Choekhortoe along main tributaries of Chamkharchu and Dhur along Dhurchu, a sub-tributaries of Chamkharchu.

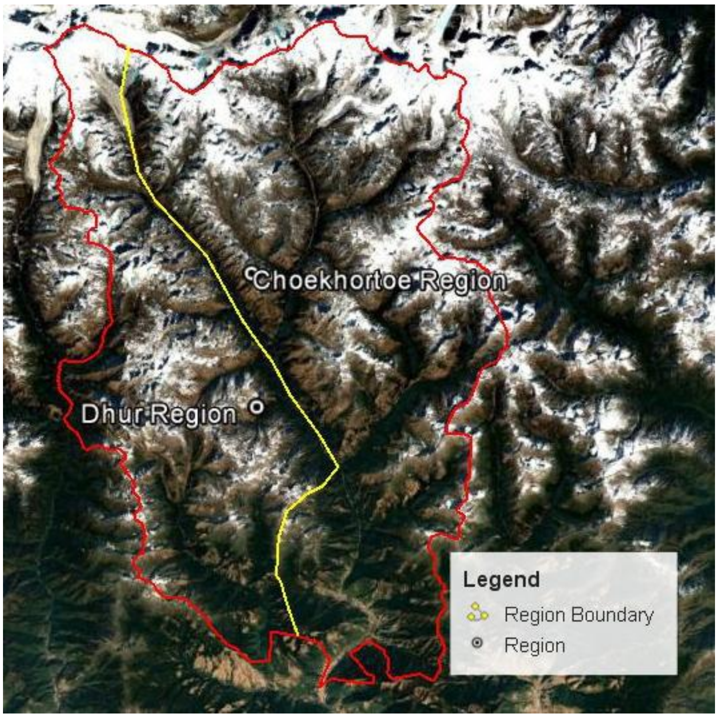

Figure 3.3: Stratification of study area

3.2.3 Conceptual framework

Understanding predator-prey interactions is one of the central concerns of ecology (Suryawanshi, 2013). The predator-prey interactions will aid in mitigating human-carnivore conflicts and conservation of carnivore in general (Lovari et al., 2009). Predator prey relationship is affected by many factors and among which conservation policy is one fundamental factor that we should look into. Policy here refers to laws, regulations and control or protection that helps in reducing the negative impact of human resource use on biodiversity habitat. Without a proper policy, the human resource use in snow leopard habitat can become unmanageable and can cause severe threat to snow leopard and its habitat. Despite the benefits to the few collectors, there are several potential adverse effects of codycep's collection such as physical harassment to local fauna, trampling of grassland, garbage accumulation and firewood consumption (Shrestha, 2013). The collection involves digging of soil which exposes soil to erosion and making it infertile for grasses or other plant species that serve as food for prey species. The grazing competition between snow leopard prey species and livestock is another example that affects the habitat. Most of the snow leopard range overlaps with areas that have been overstocked with domestic ungulates and these has led to decline in wild prey availability due to competition for resources (Lyngdoh et al., 2014). The effects of such losses contribute to direct decline of snow leopards, as carrying capacity diminishes, and increased use of domestic livestock by snow leopards, elevating conflict and retaliatory killing by pastoralists (Bagchi and Mishra, 2006).

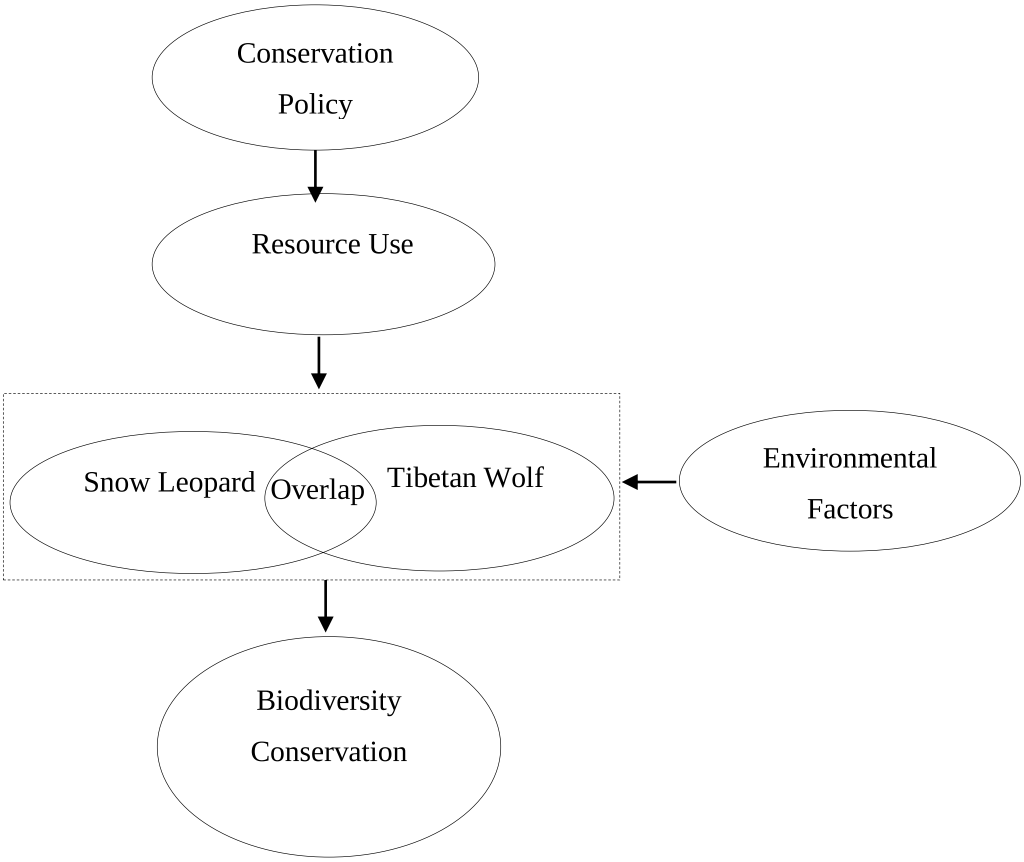

Figure 3.4: Conceptual framework

These conflicts has become a worldwide conservation concern and also an important socio-economic concern for local communities living within carnivores ranges (Suryawanshi, 2013). However, a well-defined and directional nature conservation policy can prevent such incidences from happening and can help in securing good habitat for snow leopard and other important carnivores such as Tibetan wolf in the area. As a top-order predator, its presence and survival is also an indicator of intact, ‘‘healthy’’ eco-region (Jackson et al., 1996). The populations of any predator species is known to directly depend on quality and quantity of available prey and its interactions with other sympatric predators. Nevertheless, in a prey rich areas, predators may co-exist by exploiting different prey species (Karanth and Sunquist, 2000). The habitat can also be affected by local environmental conditions such as slope, aspect, temperature, precipitation and land cover types. Understanding such conditions can help in gathering wider picture for protected area coverage for snow leopard habitat. All these information’s will aid in devising science based conservation strategies to safeguard endangered snow leopard and achieve biodiversity conservation goal as a whole (Figure 3.3).

3.3 Data collection methods

3.3.1 Pre-testing of questionnaire

Before the actual field survey, three herders in Choekhortoe were randomly selected for pre-testing the questionnaires. The pre-testing exercise was instrumental in improving the questionnaire for obtaining reliable data and to get rough estimate on time required to complete the questionnaire which helped in planning the survey.

3.3.2 Primary data collection

For obtaining the information’s on livestock population and depredation, household interviews were conducted as outlined by Wang et al. (2006) and Oppenheim (1992). Since there were only 38 herders residing in the study area, the total enumeration survey (census) was carried out. A well designed questionnaire with both close ended and open ended questions were prepared prior to going to the field. Questionnaires were prepared in English and interpreted in Dzongkha and Bumthap language for ease of enumerators. Depredation of past five year period were considered for the study.

3.3.3 Secondary Data

To corroborate the livestock population and depredation records, the secondary data were collected from WCNP, Wildlife Conservation Division RNR office of Choekhor Gewog.

3.3.4 Field methods for scat collection

Within 726 Sqkm, 55 grids with grid size of 16 Sqkm were laid out (Figure 3.2). The 50% of the grids has been selected using stratified random sampling. Fixed transect (Jackson and Hunter, 1996; Lovari et al., 2009) were laid in each grid. Scats were collected along a fixed trail in all the transects with transect lengths varying from 0.7 -1.4 km as outlined by Devkota et al. (2013). To ensure that samples authentically from snow leopards and Tibetan wolf, scats were collected adjacent to their own signs such as scrapes, scent sprays and clawa rakes (Oli, 1994; Bagchi and Mishra, 2006). The size of scats and associated signs such as scrapes and pugmarks were used to assess the identity of species (Devkota et al., 2013). The presence of felid hair in scat were used to assess and reconfirm the identity of predator species as outlined by Lovari et al. (2009).

3.3.5 Laboratory methods for dietary analysis

Standard micro-histological methods were used to identify prey through the scats hair as outlined by Devkota et al. (2013). In the laboratory, 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. As large bones and teeth generally fragment and becomes difficult to identify, only hairs were used for examination through comparison with reference slides as outlined by Oli (1993).

For reference slides, hair samples were collected from domestic livestock, live wildlife and stuffed specimens in museum collections. Those hair samples has been used to prepare original slides for identification following the methods outlined by Teering (1991) and Oli et al. (1993). The hairs samples from scats were randomly selected from each sample to prepare the slide and determine multiple prey species (Mukherjee et al., 1994). Gelatin solution were used to prepare slides to see cuticular structure of the hair and the cuticular scales can be observed by the impression as followed by Devkota et al. (2013). Prey species were identified by comparing hair found from scat with a reference collection of slides and photographs of the structure of hair of potential prey species (Teering, 1991) (Figure 3.3).

Figure 3.5: Standard micro-histological methods for prey identification using scat hairs

3.4 Data Analysis

3.4.1 Extend of livestock depredation and its effect on livelihood

1. For normality, Kolmogorov tests were done. Other means of normality tests, such as mean and median, skewness and kurtosis were also checked prior to performing tests.
2. Descriptive statistics were used to describe average (mean) livestock holding and depredation rate. The occurrences of depredation were also addressed using this tool. A Levine's test was used to verify equality of variance in the samples (homogeneity of variance) of livestock holding between two different regions.
3. ANOVA compared the mean between different variables, degree and severity of conflicts in different locations.
4. One-Sample T Test, were used to check the difference in numbers of livestock's from 2012 to 2016
5. For correlation, Spearman‘s rs were applied to determine the relationship between the different variables, such as conflict seasons and herd migration periods, severity of conflict and choice of age by predators.
6. Kruskal-Wallis test were used to see the difference between two different villages.
7. Chi-Square tests will be performed for associations between categorical data such as such as age of respondent between two different regions.
8. Mann-Whitney U Tests will be used to compare differences between two independent groups.

3.4.2 Dietary composition of snow leopard and Tibetan wolf (metrics for analysis)

1. Frequency of occurrence (FO)

It is the measure of the proportion of scats that contains a specific prey item. It is calculated by dividing number of scats containing prey item by number of total samples as outlined by Vanak and Gompper (2009):

$FO= (s_x/N)*100$

Where s_x is the total number of scats containing prey item and N is the total number of scats. FO is possible the most frequently reported statistics relating to carnivore's diet (Mills, 2013).

2. Percent relative occurrence (RO)

Percent RO of prey item is more indicative of the relevance of each prey item in the diet. It is calculated based on methods outlined by Vanak and Gompper (2009);

$RO= (px/T)*100$

where p_x is the number of occurrence of prey item x and T is the total number of occurrences of all the prey items in all samples.

3. Niche overlap

Niche overlap or Dietary Overlap (DO) describes the degree to which two or more predator species share a resource. This metric can also be used to describe the joint use of other resources such as time or space (Colwell and Futuyma, 1972) although i considered only food for this study. The niche overlap between snow leopard and Tibetan wolf were calculated using Pianka's index (Pianka and Pianka, 1976);

$$DO = \frac{\sum PijPik}{\sqrt{\sum} P^2ijP^2ik}$$

where Pij is the proportion of prey category i in the diet of predator j; Pik is the proportion of prey category in the diet of predator k. The value ranges from 0 to 1, indicating no dietary overlap to complete overlap respectively.

As outlined by Lyngdoh et al. (2014), Jacobs' index was used to determine the prey selectivity of snow leopards and Tibetan wolf using the formula:

$$D = \frac{ri-pi}{ri+pi-2ripi}$$

where, ri is the proportion of species i among the total kills at a site and pi is the proportion of species i in the available prey community. The resulting values range from +1 (maximum preference) to 21 (maximum avoidance).

Chapter Four

Results and Discussion

The result and discussion section entails three sub sections; Extend of livestock depredation and its effect on livelihood, composition of prey species in the diets of snow leopard and Tibetan wolf and spatial and temporal occupancy of snow leopard and Tibetan wolf in the study area.

4.1 General Livestock Information

4.1.1 Demographic characteristics

Of all herders (n = 38), 71.1% (n = 27) are male and 28.9% (n = 11) were female with an average age of 46 years. The respondent age ranged from 21 to 81 years. The average members of household was recorded as 7.5 (SD ± 2.5). Only 3.7 (SD ± 1.49) members lives in herd. The remaining ones live either in village or in schools. The 44.7% (n = 17) of respondents are from Dhur region and 55.2% (n = 21) from Choekhortoe region (Table 4.1). Dhur has 17 herders from which 15 are from Dhur village itself and two from Lusibi. Choekhortoe has 21 herders; six from Nasiphel, three from Zhabjethang, one from Kharasa, seven from Sangsangma, and four from Dodrong.

While comparing the respondent age between two different regions, it was found that there are no significant difference in the age of respondents in the two regions (i.e. Choekhortoe and Dhur), F (1)= .042, $p > .05$, which indicate that the respondents were of similar age groups in both the regions (Annexure 2.1). This helped in making fair comparisons between the regions. There is however significant difference in the total members per household, Z = -5.051, $p < .05$ and actual members living per herd, Z = -5.391, $p < .05$ in two different regions (Annexure 2.2) which indicate that the family members engage in daily household activities were different. The families with more members could guard and supervise their livestock's than the family with lesser members.

Table 4. 1: Socio demographic characteristics

Region	No of herders		Age median	Mean household members	Mean herd members
	Male	Female			
Choekhortoe	17 (80.9%)	4 (19.4%)	47	6.6 (± 2.3)	3.3 (± 1.1)
Dhur	10 (58.8%)	7 (41.4%)	44	8.5 (± 2.6)	4.4 (± 1.7)

4.1.2 Herding characteristics

All herders practice a traditional migratory herding pattern that was long established. This practice demands a high degree of cooperation for most of them needs to share the pasturelands.

Unlike in Jigme Singye Wangchuck National Park (Wang and Macdonald, 2006), the herding patterns here do not vary according to type of livestock and agriculture practices. Here they follow the seasons to migrate their herds year round. Right after completion of winter months, they migrate to alpine pastures before the onset of summer through different herds. They graze in alpine areas until autumn and then descend down to their wintering herds through the same path they travelled. By the time they travel back, the grasses in pasturelands will already be restored (Figure 4.1). This herding pattern can be best described as transhumance as herders rotate their stock from summer to winter pastures along the altitudinal gradient. Such practices has also been referred as transhumance by Shrestha in 2013.

Each herder possesses an exclusive use-right for the designated grazing grounds (tsamdros) and they move their herds three to eight times during the grazing period. Herders occasionally burn pastures to maintain or improve quality of forage and suppress the growth of unpalatable plants. This herding practice is very similar to herding practices in China where they also move their herds in high mountainous areas in summer and migrate to lower elevation in winter months (Alexender et al., 2015).

Besides incredible grazing practice, the herders still face the grazing problems. The problem aroused with the restriction of burning of pastureland by government whereby their grazing lands gets covered with undergrowth particularly with the dwarf alpine trees. Almost all the herders (95%) felt that the problem ascended after the ban of burning of pasturelands by the Department of Forest and Park Services. The grazing ban in Qilianshan in China has also led to arise in such problems (Alexander et al., 2015). Besides grazing problem, livestock diseases and predator kills are other common problems faced by livestock herders here. In Sanjiangyuan region of Tibetan plateau, disease caused about four times the number of the alleged livestock losses as snow leopards (Li et al., 2013).

The 68.4% (n = 26) herders perceived predator kill as most severe problem followed by grazing problem (21.05%) and livestock diseases (10.5%). However 47.3% (n = 18) of herders considers livestock diseases as negligible problem. Only 7.8% (n = 3) of herders consider predator kill as negligible one (Table 4.2). In Qilianshan in China, natural disasters and diseases were responsible for 65% and 63% of livestock loss respectively (Alexander et al., 2015). It is just the opposite with central part of WCNP possibly due to regular animal health checkup by Dzonkhag vertinary office.

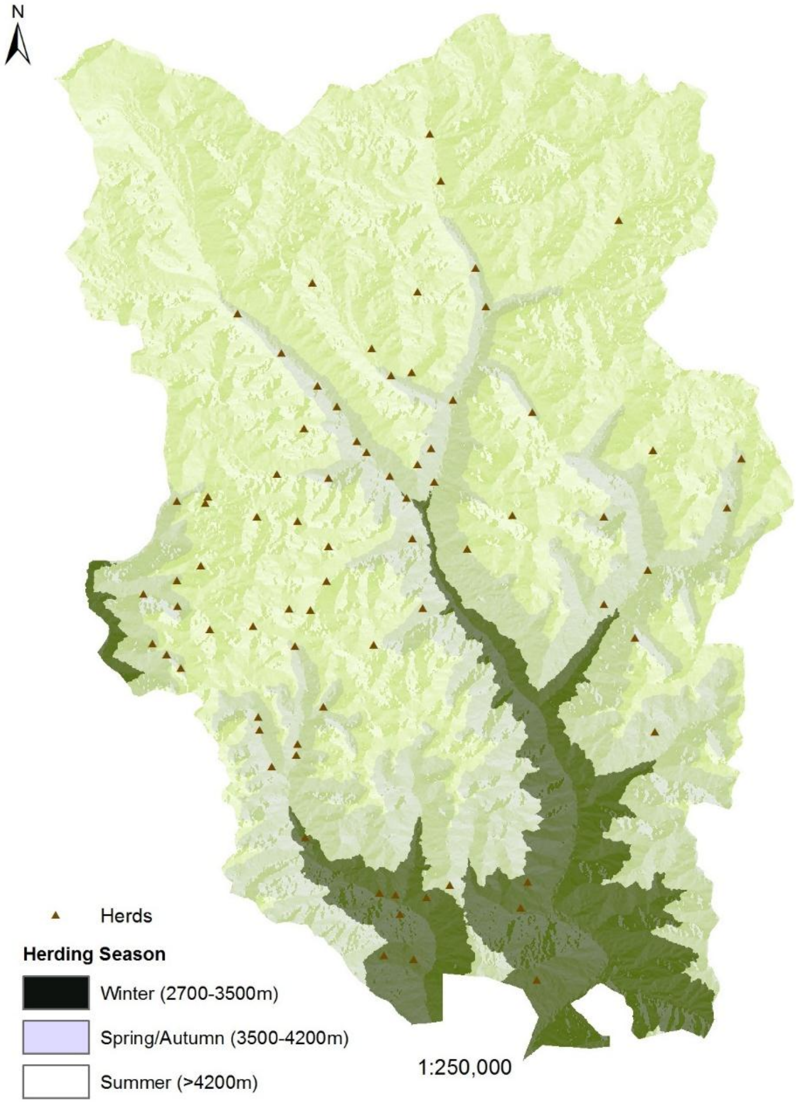

Figure 4.1: Seasonal migratory pattern for herders

Table 4.2: General Livestock problem

Type of Problem	Severe (%)	Moderate (%)	Negligible (%)	Total
Predator Kill	68.4	23.6	7.8	100
Grazing Problem	21.0	34.2	44.7	100
Livestock Diseases	10.5	42.1	47.3	100
Total	100	100	100	

4.2 Livestock population and livelihood strategies

4.2.1 Herd dynamics

In 2016, the 38 herders of Wangchuck Centennial National Park reared a total of 2815 heads of livestock with an average herd size of 74 head of stock. Ownership of livestock by households was highly skewed (range 26-143 stock per household). All the herders (n = 38) reared yak and horse with an average herd size of 38 (*SD* ± 24.37) and 5.184 (*SD* ± 1.92) head of stock respectively. The Sheep and Dogs are reared by 7.8% (*n* = 3) and 76.3% (*n* = 29) of herders respectively. None of the farmers reared cattle.

Of the two regions, Choekhortoe has maximum herders (*n* = 23) with total livestock population of 1593 stocks (*m* = 75.8, *SD* ± 27.12) and Dhur consist of 17 herders with total livestock population of 1222 heads of stock. The average number of livestock holding per household were recorded as Yak (67.6), Sheep (1.8), Horse (5.1) and Dog (1.4) for Choekhortoe and Yak (60.5), Sheep (4.4), Horse (5.3) and Dog (1.6) for Dhur. In both the regions the yak (Choekhortoe, *n* = 1420, 67.6%) (Dhur, *n* = 1029, 60.5%) is the most dominant livestock and Dog is the least dominant with mean size of 1.381 (*SD* ± 1.283) for Cheokhortoe and 1.64 (*SD* ± 1.05) for Dhur (Table 4.3). The average livestock holding per herd in Choekhortoe and Dhur in 2016 is recorded as 75.8 (*SD* ± 27.12) and 71.8 (*SD* ± 30.23) heads respectively. Using a homogeneity of variance, it has found that there are no significant difference (p >.05) between the livestock holding between two regions (Annexure 2.3). The average livestock holding of this study area is more than twice as large as Phu valley and three times as large as Manag of Nepal (Wegge et al., 2012).

Table 4.3: Average of composition of livestock per herds

Region	N	Yak	Horse	Sheep	Dog	Average[a]
Choekhortoe	21	67.6	5.1	1.8	1.4	75.8
Dhur Lusibi	17	60.5	5.3	4.4	1.6	71.8
Livestock/herd		64.1	5.2	3.1	1.5	72.395
% of the herd		86.7	7.03	4.19	2.02	

N-number of herders in the study region
a -Average number of livestock's held by herd
average calculated from all herd including those that kept none

4.2.2 Livestock population trend (2012-2015)

There was a constant decrease in the total livestock holding in the study area. From 2995 heads (*m* = 78.8, *SD* ± 78.8) in 2012, it decreased to 2815 (*m* = 74.07, *SD* ± 28.2) in 2016 (Figure 4.2). Statistically, it has found that there is a significance decrease (p <.05) in numbers of livestock's from 2012 to 2016 (Annexure 2.4). The decrease could be corroborated by increase in depredation rate in the study area. It was also observed that there was a decline in yak herders within two decades in the study area. The decline in 10 yak herders in 10 years in Choekhor gewog was reported by WCP in 2008 and 17 yak herders in five years by Kinga in 2014. The drop in numbers of yak herders could be aggravated by increase in depredation of yaks by wild predators and also due to livelihood being substantiated by cordyceps (*Ophiocordyceps sinensis*) collection and sale. The households with fewer heads sold their yaks to the neighbors, as migrating round the year between the pastures became uneconomical.

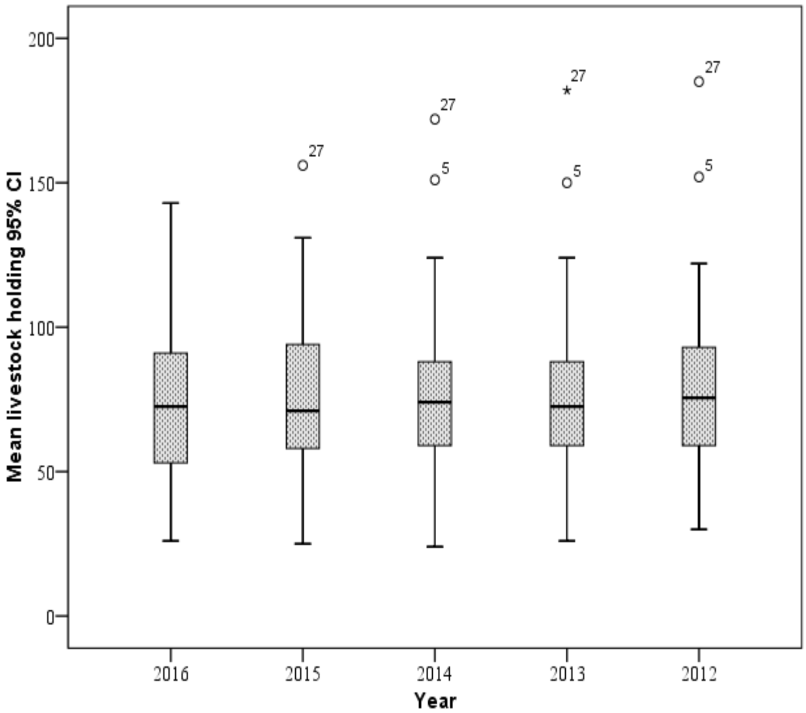

Figure 4.2: Mean livestock holdings for five years

In Chokhortoe, the livestock population decreased from 1,663 heads (*m* = 79.19, *SD* ± 28.66) in 2012 to 1,593 heads (*m* = 75.86, *SD* ± 27.12) in 2016. Similarly, the livestock population in Dhur decreased from 1,332 (*m* = 78.35, *SD* ± 36.48) in 2012 to 1,222 (*m* = 71.88, *SD* ± 30.23) in 2016 (Figure 4.3). The difference in livestock holding between the two different regions were not significant ($p > .05$) (Annexure 2.5). It means that there has been a constant decline in number of livestock in both the regions.

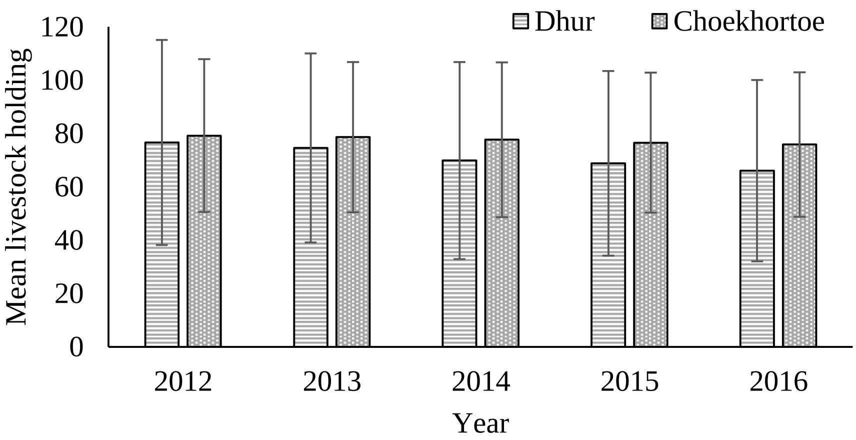

Figure 4.3: Change in mean livestock holdings in Dhur and Choekhortoe in five years

4.2.3 Livelihood strategies

The herders has multiple source of income though mainly dependent on yak husbandry and Cordyceps collection and sale. In general, 94.7% (n = 36) of the herders consider livestock as primary source of income and cordyceps collection and sale as a secondary source of income for their families. Two herds (5.2%) however considers cordyceps collection and sale as main source of income. The sale of cordyceps has contributed major share to collectors annual income in the year 2012 (Wangchuk et al.,2013). Only 67.7% (n = 25) of the herders practice back yard farming for deriving the basic agriculture products. None of the respondents do a commercial farming. The case is different with the herders of neighboring Jigme Singye Wangchuck National Park (JSWNP) where cultivation formed a main source of rural livelihoods followed by livestock and other non-farm activities (Wang and Macdonald, 2006). Around 63% (n = 24) of herders also collect alpine medicinal plants in small quantities for self consumption. Occasionally, herders also take a chance to transport tourist products while they come for hiking in their areas.

Choekhortoe earned a sum of Nu.24, 04,600.00 (Nu.63, 278.00/herder) and Dhur with Nu. 14, 60,000.00 (Nu.38, 421.00/herder) from the sale of livestock products (Table 4.4). However, it showed no significant difference in the average cash income from livestock between two regions, H (2) = 2.950, $p > .05$ (Annexure 2.6). This showed that herders in both the regions have similar income from livestock as there are very less difference in mean livestock holdings between two regions. Spearman's correlation showed significant association between income from livestock and total livestock holding owned, r_s = .4.34, $p < .05$ (Annexure 2.7). More number of livestock's attributed more towards annual income.

From cordyceps collection and sale, Choekhortoe earned Nu.84,15,000.00 (Nu.40, 0714.00/herder) and Dhur earned sum of Nu. 78, 75,000.00 (Nu.46,3235.00/herder). The average annual income from sale of cordyceps is 18 times higher than the reported cordyceps annual income by Wangchuck et al. (2013). This may be true because the average income calculated here is purely for herders unlike Wangchuck's who reported for all cordyceps collectors. With more access and collection experiences, herders are presumed collecting in more quantities than other collectors. The increase in mean amount could also be aggregated by increase in market price in the recent years. The increased in price has also been reported from Qinghai in China. It rose by eight times between 1998 and 2008 and product now sells for $8000.00 per kilogram (highest quality can retail for up to $100,000.00/kg). Similar to Bhutan, this also has become the most important source of cash income for many rural households in parts of the Qinghai-Tibet Plateau (Winkler, 2008).

There is a significant correlation between total income and income from cordyceps business, r_s = .84, p < .001 (Annexure 2.8) indicating that cordyceps business contributed significantly to the total income. The income from cordyceps business in two different regions were not significantly different, H (2) = .197, p > .05 (Annexure 2.9) which indicates that farmers in both the regions are heavy cordyceps collectors. Even in the mountainous communities of northern Nepal, cordyceps business provided 53.3% of total cash income and 21.1% of total household income in average (Shrestha and Bawa, 2014).

The average annual income estimated for the herders of Dhur is Nu.5, 15,219.00 and for Choekhortoe is Nu.5, 49,117.00 (Table 4.4). Statistically, it showed no significant difference in annual income of Choekhortoe and Dhur, H (2) = .062, p > .05 (Annexure 2.10). This is because herders in both the regions do cordyceps business together with yak husbandry. Overall, the mean annual income of herders of central part of Wangchuck Centennial National Park is found as Nu.5, 30,384.00 (*SD* ± 2, 04,800.00). The average income of herders in the study area was comparatively higher than that of farmers and herders in JSWNP which was Nu.11, 000.00 per annum according to Wang and Macdonald (2006) and farmers and herders in Toebesa gewog of Punakha Dzongkhag which was Nu. 58,500.00 (US$900) according to Katel et al. (2014).

Table 4.4: Economic valuation of livestock products

Product	Choekhortoe		Dhur	
	Sum (Nu.)	Mean	Sum (Nu.)	Mean
Butter[a]	556133.3	26482.5 ± 25297	450166.7	26480.4 ± 62989
Dry Cheese[b]	1688667.0	80412.7 ± 58425	868833.3	51107.8 ± 35430
Hair Products[c]	41166.6	1960.3 ± 2231	31700.0	1864.7 ± 5093.5
Meat[d]	108500.0	5166.6 ± 6119	105733.3	6219.6 ± 14043
Tail[e]	10133.3	482.5 ± 639	3566.7	209.8 ± 367.4
Cordyceps[f]	8415000.0	400714.3 ± 145054	7875000.0	463235.3 ± 250935
Total	10819600.0	515219.0	9335000.0	549117.6

Average annual income per herd: Nu. 53, 0,384.00 (*SD ± 2, 04,800*)

Product prices were calculated based on estimated local average local price in 2016:

a- Nu350/kg b-Nu.280/24pcs c-Includes sale of rope, bag, raincoat (cost estimated in lump-sum)
d- 600/kg (Dry) e-Nu.1000/tail (small) Nu 1500/tail (large) f-Nu.900, 000/kg

4.3 Extend of livestock depredation and its effect on livelihood

4.3.1 General livestock predation

In the past five years (2012-2016), 666 livestock were lost to predators that includes 625 yaks, 34 sheep and 7 horses. The kill attributes 133 yaks (m = 2.7, SD ± 1.7) and 24 Sheep (m = 6, SD ± 4.1) in 2012 and 94 yaks (m = 2.4, SD ±1.3), 2 sheep (m = 2) and 2 horses (m = 0.05) in 2013. The depredation shoot up in 2014 with 138 (m = 2.3, SD ± 1.5) yaks, 5 sheep (m = 0.13) and 5 horses (m = 0.13). In 2015, only yaks were killed (n = 139, m = 2.4, SD ± 1.8). In 2016, 121 yaks (m = 2.6, SD ± 1.7) and 3 sheep (m = 0.07) were killed (Table 4.5). The average annual loss for yak, sheep and horses were recorded as 3.3, 0.2 and 0.36 heads per herds respectively. The majority (55.3%) of livestock's killed were adult. Remaining constitutes 37.6% young and 6.8% heifer. The 70.5% kills were during summer season and 19.2% during winter. The autumn and spring had less depredation rates with 7.6% and 2.7% respectively. This is because the nomadic livestock herders seasonally move their livestock's along the altitude gradients from as low as 2,500 masl to 4,500 masl making the livestock's susceptible to predation to numerous predators. The livestock's are susceptible to predation at high altitudes (3,000-5,000 masl) by snow leopard and lower elevations (<4,000 masl) by Tiger (Wangchuk et al., 2004). No kills were attributed to snow leopard in the winter months (October-January) as reported by Sangay and Vernes in 2008.

Table 4.5: Livestock depredation by predators in five years

Year	Yak		Sheep		Horse	
	Mean	N	Mean	Sum	Mean	Sum
2012	2.7	133.0	6.0	24.0		
2013	2.4	94.0	2.0	2.0	0.05	2.0
2014	2.3	138.0	5.0	5.0	0.13	5.0
2015	2.4	139.0				
2016	2.6	121.0	3.0	3.0		

Snow leopards and Tibetan wolves were responsible for the maximum predation, being blamed for 32.6% and 24.2% respectively. Tiger, wild dog and black bear (2.3%, 17.8% and 23.1% respectively) were responsible for remaining 43.2% of livestock loss (Figure 4.4). There was a strong association (r_s=.279, p<.05) between the predator and the choice of season for attacks. Yaks were more predisposed to predation by snow leopard in the summer when herded high altitude meadows where they range freely with natural prey (Sangay and Vernes, 2008). For instance in JSWNP, the leopards were responsible for maximum predation followed by tiger and dhole and bear (Wang and Macdonald, 2006). The greatest proportion of livestock kills by black bear were reported from lower part of WCNP where 27 heads comprising 62% cattle, 22% yak and 16% horse (Jamtsho and Wangchuk, 2016). In the current study, only 23% of livestock's were killed by black bear. This clearly states that livestocks were killed by different predators in habitat areas.

Predation hotspots are also associated with carnivores selecting areas with high prey abundance to maximize encounter rates (Wolf et al., 2015), which in some areas also has abundant livestock that are attacked through increased encounter (Yom-Tov et al., 1995). There are however no significant difference in livestock's types killed by different predators in the study area (p >.05) (Annexure 2.11). The reported loss between each pair of predators were also found not significant (p >.05) (Annexure 2.12).

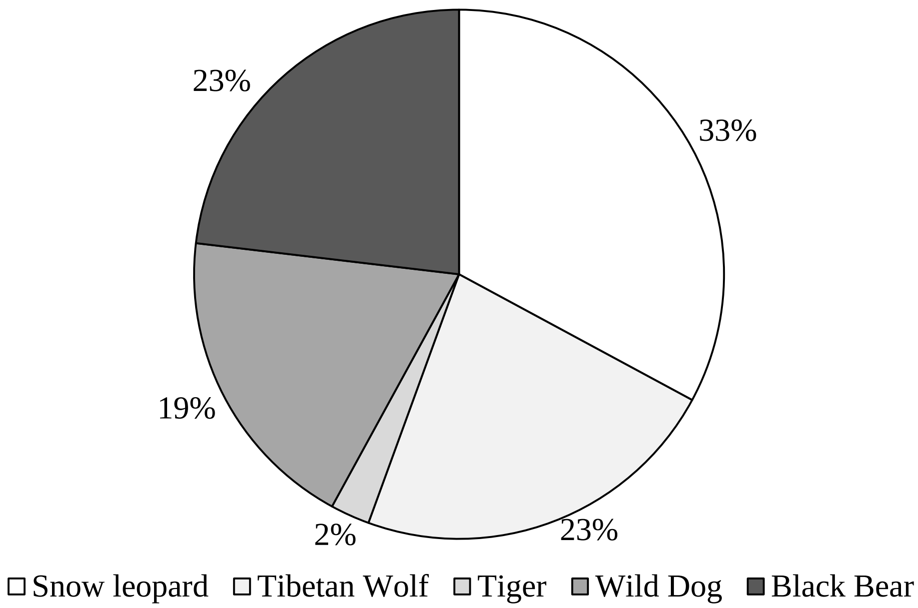

Figure 4.4: Percentage of livestock depredation by predators

There is no significant difference in reported predation by snow leopard (Annexure 2.13) and Tibetan wolf (Annexure 2.14) in five years (F (4) =.526, p >.05, F (4) = .207, p >.05). This means that depredation rate by snow leopard and Tibetan wolf were constant over the years. Even though the overall reported depredation by black bear was not found significant (F (4) = 2.250, p >.05), the depredation rate between year 2012 and 2014 and 2015 were found significant (p <.05) (Annexure 2.15). The overall difference in reported depredation by wild dog were also not significant (p >.05) over the years (Annexure 2.16).

The choice of age group by predator was found highly significant (p <.05) (Annexure 2.17). The 64% (n = 55) of snow leopard kills were young ones, 27.9% (n = 24) adult and only 8.1% (n = 7) were heifer. All livestock kills by snow leopard in Qilianshan in China were also juvenile ones (Alexander et al., 2015). The choice of prey by Tibetan wolf is just the opposite, 73.4% (*n* = 47) of its kills were adult ones, and only 21.9% (*n* = 14) were younger ones. The remaining 4.7% (*n* = 3) were heifer. Tigers attributed to 2% of kills of which both were adults. Tiger kills were reported from 16 of the 20 dzongkhags, and nearly a quarter of these (22%, *n* = 67) were reported from Trongsa (Sangay and Vernes, 2008) which is in close proximity to the study area. The 59.6% (*n* = 28) of wild dog kills were adult ones, followed by 31.6% younger ones and 8.5% heifer. The 67.2% of black bear attacks were on adult ones, 26.2% (*n* = 16) on younger ones and 6.6% (*n* = 4) on heifer (Figure 4.5). There is a significant association between predator and choice of age (r_s = .257, p <.05).

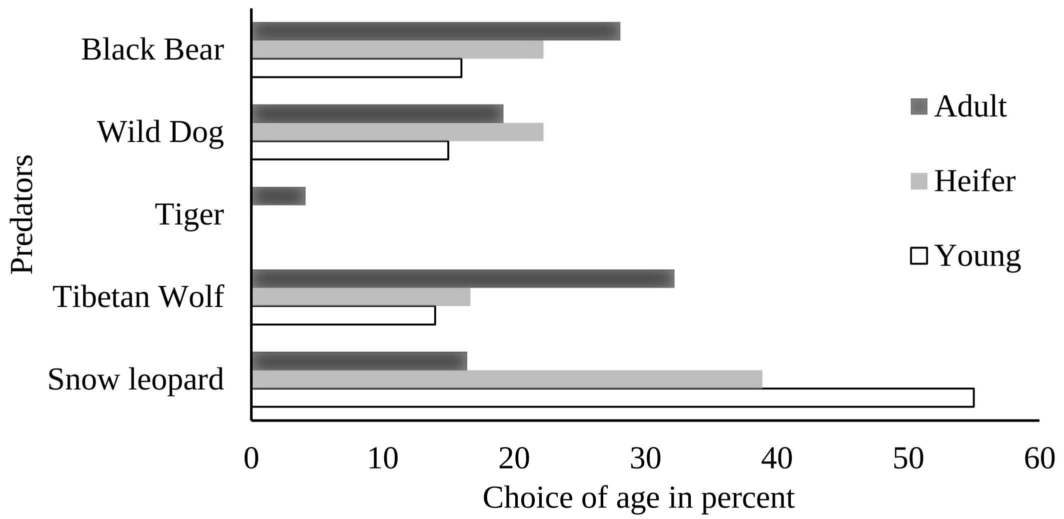

Figure 4.5: Percentage of livestock age depredated by predators

4.3.2 Depredation rate in two regions

The 67% (*n* = 433, *m* = 2.5, *SD* ± 1.6) of total yak kills are from Choekhortoe and only 32% (*n* = 192, *m* = 2.3, *SD* ± 1.6) from Dhur. However, sheep kills are all reported (*n* = 34) from Dhur region. Dhur lost average depredation of 4.9 (*SD* ± 3.3) sheep per herd. This is because Choekhortoe had only one herd rearing a small stocks of sheep and Dhur has two herds rearing a larger stocks of sheep. In addition the major portion of horses kill (71.4%, *n* = 5) are also reported from Dhur. Only 28.5% (*n* = 2) of horses lost are from Choekhortoe (Figure 4.6). The difference in mean livestock depredation between two regions are found highly significant t = -10.8, p <.05) (Annexure 2.18).

The 84.5% of the attacks in Choekhortoe happened in summer and only 6.9% during winter. The remaining attacks were during autumn (5.7%) and spring (2.9%). In Dhur, summer and winter had equal frequencies of attacks (43.3% each). Autumn had 11.1% and spring with only 2.2%. This is because in summer the frequencies in shift of grazing areas ranges from 3 - 7 times but only 3 - 4 times in winter. The depredation of yaks by Tibetan wolf and snow leopard occurred in spring to autumn, coinciding with livestock grazing in alpine pastures. In contrast, livestock depredations by wild dog occurred mostly in winter when livestock migrate to winter pastures in lower latitude.

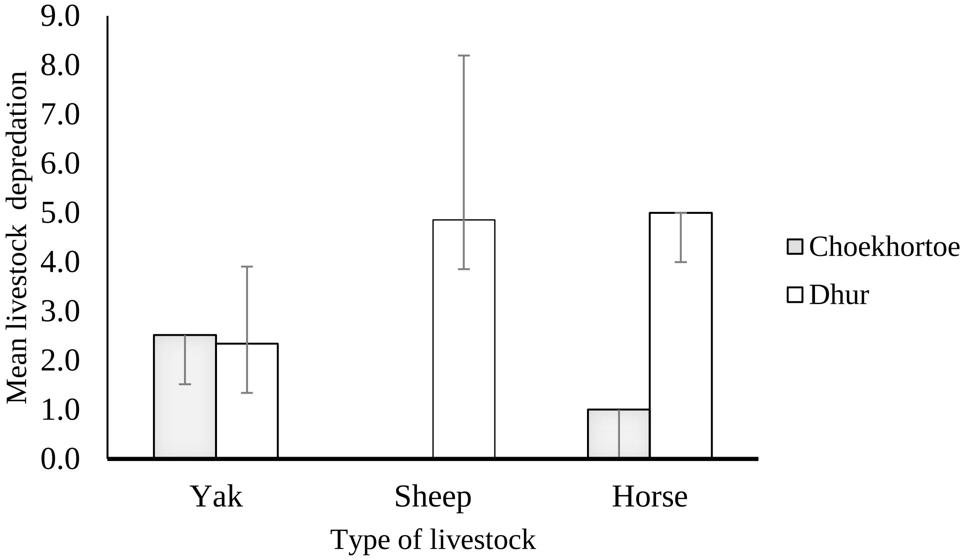

Figure 4. 6: Livestock depredation rates in two regions

The 84.5% of the attacks in Choekhortoe happened in summer and only 6.9% during winter. The remaining attacks were during autumn (5.7%) and spring (2.9%). In Dhur, summer and winter had equal frequencies of attacks (43.3% each). Autumn had 11.1% and spring with only 2.2%. This is because in summer the frequencies in shift of grazing areas ranges from 3 - 7 times but only 3 - 4 times in winter. The depredation of yaks by Tibetan wolf and snow leopard occurred in spring to autumn, coinciding with livestock grazing in alpine pastures. In contrast, livestock depredations by wild dog occurred mostly in winter when livestock migrate to winter pastures in lower latitude.

The time of kill by predators mostly happened during night in Choekhortoe (68.4%) and mostly during day (41.4%) in Dhur. Considerable amount of respondent are also not knowing the exact timing of attacks in both the regions. It is however found that there are no significant relationship between the preference of time by predators in both the region (r_s = .029, p >.05) (Annexure 2.19).

4.3.3 Livestock Losses in 2016

Herders reported a total of 124 (4.4% of total livestock population) livestock's killed by predators in the period of one year. Only yaks and sheep were reported to be killed of which yak formed 97.9% (n = 121) and sheep formed 2.1% (n = 3).The kill comprised of 43.8% adult, 48% young and 8.3% heifer. The average loss per herd is 3.26 heads which is relatively higher than that of JSWNP where mean loss per household was 1.29 head of livestock (Wang and

Macdonald, 2006) and higher than predation mentioned in Toebesa Gewog of Punakha Dzongkhag where reported mean loss is 0.21 head of cattle per household (Katel et al., 2014). The difference in mean could be explained by difference in number of livestock holding, livestock herding practice and also availability of prey species. The livestock kill can vary by site, livestock type and presence and absence of herder (Jackson, 1999). The majority of livestock's kills were reported during summer season (77.1%) followed by autumn and winter (8.3% each). The least kill (6.3%) was reported during spring season. The 85.4% (n = 106) of the total case were reported from herders of Choekhortoe and 14.5% (n = 18) were reported from Dhur. Statistically, it showed no significance difference in number of livestock's killed between two regions (F (46) = 2.50, p >.119) (Annexure 2.20). It must have been influenced by number of livestock holdings. The livestock population in Choekhortoe (n = 1,593) is greater than Dhur (n = 1222) and thus the higher frequency of depredation in Choekhortoe did not make much differences with Dhur.

The 38.7% (n = 48) of livestock kills in 2016 is attributed to Snow leopards and 19% (n = 24) to Tibetan wolves. High predation levels on livestock by snow leopard and wolf have been reported from other parts of their range as well (Schaller, 1977; Fox and Chundawat, 1988; Mallon, 1988; Oli et al., 1994; Nowell and Jackson, 1996). However the predation rate here is not as high as northern Nepal where they estimated 159 animals killed by snow leopard each year, equating to an annual predation rate of 15.1% (Wegge et al., 2012). The remaining 41.9% of the kill is attributed to black bears (n = 35, 28.2%), wild dogs (n = 24, 12.9%) and tiger (n = 1, 0.8%).

Tibetan wolves predated only on yaks, whereas snow leopard predated on both yak (37.9%) and sheep (2.1%). Mostly yaks and horses are being depredated by snow leopard as reported by Sangay and Vernes in 2008. This is because the cattle are not reared in the high mountains where snow leopard occur. The 55% of the snow leopard attacks were during the day and 35% during the night. The herders were not sure about timing for 10% of its attacks. The 45% of Tibetan wolf attacks were during the day and 18.1% during the night. The 36.6% of its attacks could not be traced whether attacked during day or night. The unsupervised grazing during the day gives chance to snow leopard and Tibetan wolves to depredate on those livestock's during the day. During the night, the adult livestock's are kept near their herds and younger ones are kept inside the corals where it provides very less chance for predators to prey on those livestock's. All snow leopard and Tibetan wolf kills were identified through the indirect signs left by predators on or near carcasses. Snow leopard kills are normally identified through the distinct canine mark left on neck of an animal. It can also be identified through its pugmark, scrape and scats left nearby the carcasses.

On contrary, Tibetan wolves normally attack on the legs of livestock's. The kills are also being identified through its scat and pugmarks. All tiger attacks were during the day and black bear attacks during night. The predation by black bear is found unique comparing to other predators as it mostly predated during night times as reported by Kinga in 2013. The majority of wild dog attacks (60%) also happened during the night and rarely 20% during the day. The herders were not sure about the timing of remaining 20% of its attack.

The depredation of yaks by Tibetan wolf and snow leopard occurred mostly in summer and autumn, coinciding with livestock grazing in alpine pastures. The 85% of snow leopard attacks were during summer. Only 10% during autumn and 5% during winter. It was also reported that predation by snow leopards peaked earlier during the summer months of June and July, and spanned a limited period from April through to September, with no predation reported at other times (Sangay and Vernes, 2008). Snow leopard and Tibetan wolf attacks in winter could have happened due to leaving of yaks unsupervised by herders while they migrate to their winter habitat. Wolves attack were even more in summer (90.9%) and autumn (9.1%). The 60% of snow leopard kills were young livestock's and only 15% heifer and 25% adult. This is just the opposite with Tibetan wolf which has 63.6% of its attacks on adult yaks and only 36.4% on young ones (Table 4.6). All tiger attack were during the day and black bears attacks happened only during night.

Table 4.6: Livestock depredation by predators in 2016

Predator	Young			Heifer			Adult		
	Sum	Mean	SD	Sum	Mean	SD	Sum	Mean	SD
Snow leopard	31.0	2.6	1.1	8.0	2.7	2.1	9.0	1.8	.8
Tibetan Wolf	5.0	1.3	.5				19.0	2.7	1.5
Tiger							1.0	1.0	
Wild Dog	12.0	4.0	5.2	1.0	1.0		3.0	3.0	
Black Bear	12.0	3.0	1.4				23.0	3.3	1.1

4.3.4 Economic valuation of losses due to depredation in 2016

The total loss of 124 heads of livestock was valued at Nu.17, 19,000.00, of which the majority (97.9%, Nu. 17, 13,000.00) were yak loses. Although Snow leopards were held responsible for the majority of predation, however the majority of monetary loss is attributed to black bears (41.5%, Nu.71, 4,000.00). This is because black bears killed only adult ones. Only 17.5% (Nu.302, 000) of monetary loss is attributed to snow leopards which is less than the loss in

Manang district of Nepal (Oli et al., 1994). Here the total loss by snow leopard depredation attributed to 1.4% of total annual income.

With only one adult kill, monetary loss to tiger attributes to Nu.30,000.00. Wild dog is responsible for livestock depredation worth Nu.117,000.00 (Figure 4.7). Overall, each household lost an estimated Nu.45,236.00 from depredation (approximately 8.5% of the annual household cash income). The average losses calculated were higher than the average depredation loss of JSWNP (Wang and Macdonald, 2006) and average loss of Tsarap valley in North India (Spearing, 2000). It has found that there are no significant difference in loss of income by different predators in the study area (t (47) = -5.639, p <.05) (Annexure 2.21).

Choekhortoe lost a sum of Nu.13, 19,000.00 (m = 37685.71, SD ± 47684) and Dhur lost Nu.400, 000.00 (m = 30,769.23, SD ± 33,209.32) from depredation. The loss per herd is estimated at Nu. 34,710.00 for Choekhortoe which is 8.6% of annual household income and Nu. 23,529.00 for Dhur which is equivalent to 5.07% of total annual income. Statistically it showed no significant differences in total livestock value loss due to depredation (F (1) = .230, p >.05) in two regions (Annexure 2.22).

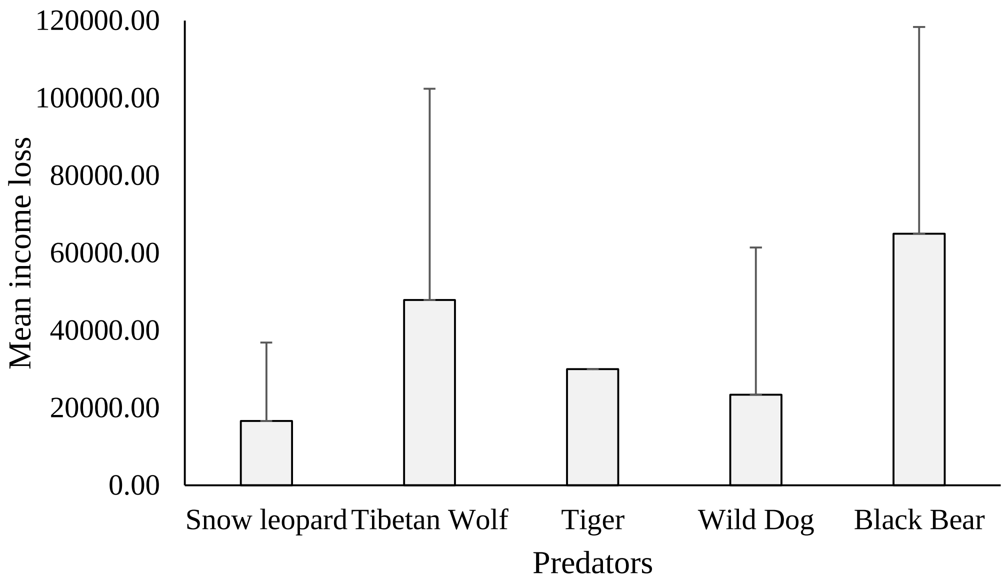

Figure 4.7: Mean income loss caused due to depredation by predators

4.3.5 Income loss due to depredation in last 5 years

The total yak loss attributed to snow leopard in last 5 years is Nu. 14,55,500.00 of which Nu.565,000.00 was lost in 2015 alone. The minimum loss was reported in 2013 with monetary value worth Nu.84,000.00. Snow leopards caused mean annual loss of Nu.7,660.00 which is equivalent to 1.44% of the total annual income. Tibetan wolves were responsible for total yak depredation worth Nu.35,01,000.00 which amounts to Nu.18,426.00 per herd and 3.47% of total annual income. Tiger, black bear and wild dog were held responsible for depredation of yaks worth Nu.4,80,000.00, Nu.19,40,000.00 and Nu.28,44,000.00 respectively (Figure 4.8).

Sheep was depredated by only snow leopard and black bears. Snow leopard is held responsible for total monetary loss of Nu.45,000.00 equivalent to 0.05% of herder's annual income. Black bear being blamed for sheep depredation worth Nu.20,000.00 which is 0.02% of herders total annual income. Only snow leopards and Tibetan wolves preyed on horses. The amount accounts to Nu.48,000.00 (1.44% of total annual income) by snow leopards and Nu.20, 000 (Nu.0.02% of total annual income) by Tibetan wolf.

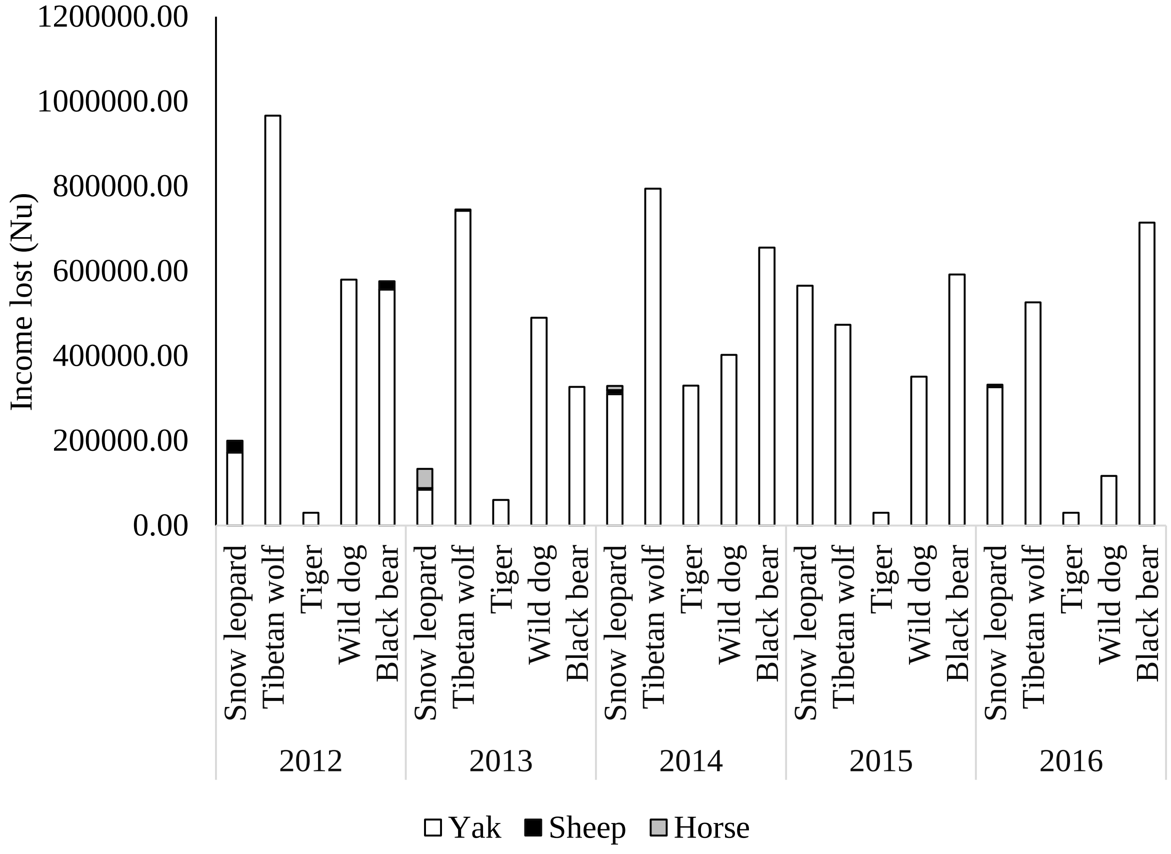

Figure 4.8: Economic valuation of reported livestock kill by predators in the study area

4.4 Dietary composition of snow leopard and Tibetan wolf

4.4.1 Diet composition of snow leopards

A total of 90 scats were analyzed from which four species of wild mammals and two species of domestic mammals were identified. Blue sheep (*Pseudois nayaur*) dominated the diet of snow leopard which consisted 36.5% of the identified prey items (Figure 4.9). Blue sheep was most frequently eaten prey by snow leopard even in Shey and Lapche of Nepal and Taxkorgan reserve and Shule Nansham in China (Shaller, 1977). In Ladakh, blue sheep remains were encountered in 23% of the scat analyzed (Chundawat and Rawat, 1994). 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.

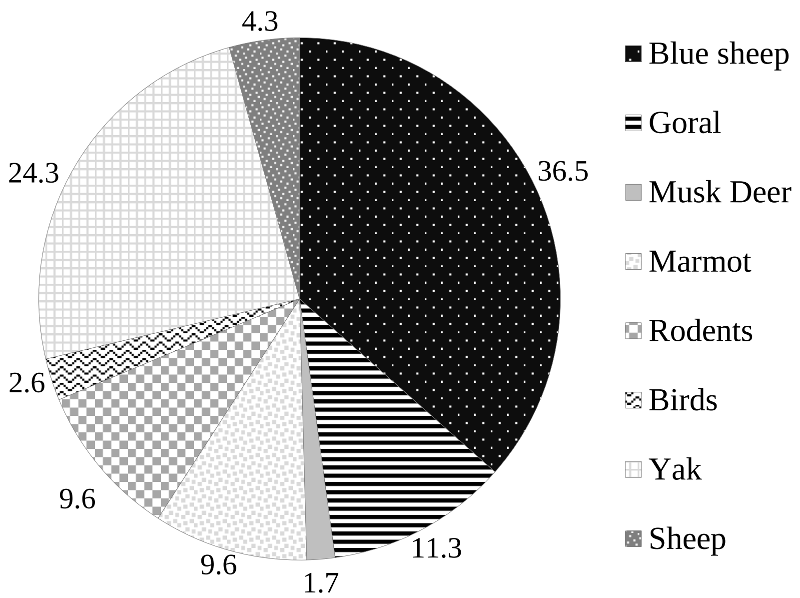

Figure 4.9: Dietary composition of snow leopard

Goral (11.3%) were also frequently eaten next to blue sheep and the marmot and rhodent were the third most frequently found species in the diet of snow leopards (Annexure 3). Shaller et al. (1977) reported that marmots also form a part of snow leopard diet in most of its range. Considerable amount of birds (2.6%) were also found in scat. Although the species of birds present in the scat could not be identified, it was believed that they were blood pheasants, monal pheasants, hill partridge and Tibetan snowcock as these were only large birds found in the area. The birds were also found in the diets of snow leopard in Shey Phoksundo National Park (Devkota, 2010).

Among the livestock, yaks were the main species found in the diet of snow leopard (24.5%). Yaks were also found in 13.62% of the scat in Annapurna Conservation Area, Manang, Nepal (Oli et al., 1994). However, in Ladakh, goat formed major livestock portion in the diet of snow leopard (Chundawat and Rawat, 1994). In Shey Phoksundo National Park, sheep formed major component (15%) of the snow leopard diet (Devkota et al., 2013). Sheep is found in 1.2% of total snow leopard scat in the study area (Figure 4.9). This depicts that snow leopards preys all the livestock types available at the site.

Diet composition of snow leopard did not differ largely among two different regions. In both regions, blue sheep and yak constituted a substantial amount of diet. Bluesheep constituted 43.8 % in Choekhor and 21.7% in Dhur. Among livestock yak dominated the diet of snow leopard in both Choekhortoe and Dhur by 23.3% and 23.9% respectively. Snow leopard preyed least on bird and sheep (1.4% each) in Choekhortoe and on bird (4.3%) in Dhur.

4.4.2 Prey preferences of snow leopard

Snow leopards in study area exhibited high preferences to domestic sheep (*D* =1) and blue sheep (*D* =0.7) and significantly avoided birds (*D* =-0.8). Unlike in south Gobi in Mongolia, Siberian ibex (70.4%), domestic goat (17.3%) and argali sheep (8.6) were found to be the preferred species of snow leopard (Shehzad et al., 2012). Overall the ungulates comprised the dominant part of the diet. Goral and Himalayan marmot were other species preferred by snow leopards. Jacob index also shows that yak and rhodents are being avoided by snow leopard (Figure 4.10) although the relative occurrence of yak in snow leopard scat was found high. The availability of yak in the study area during survey period was found high which has influenced the index value while calculating the preferences.

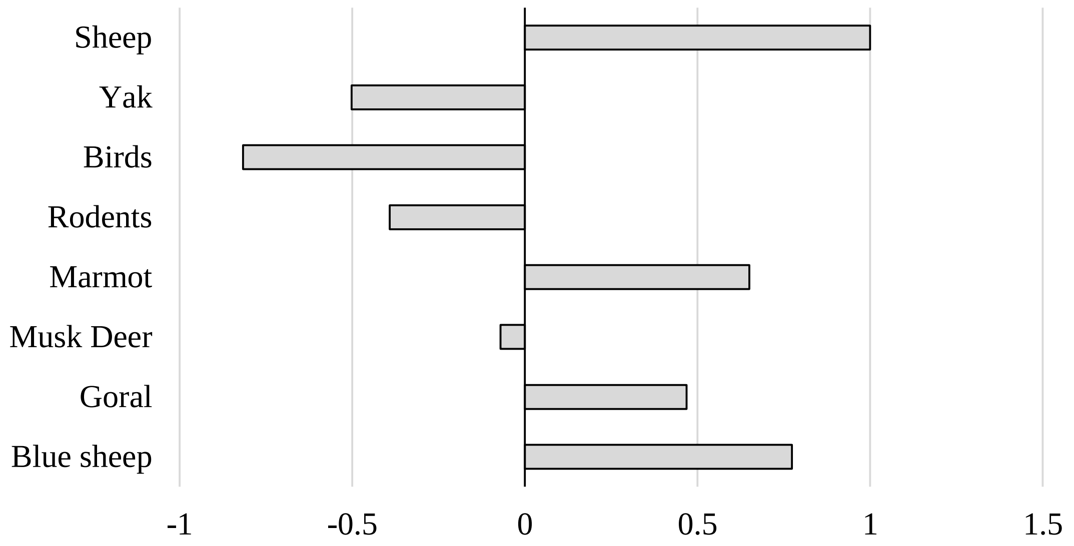

Figure 4.10*: Jacob's index values for prey species of snow leopard in the study area
*The resulting value range from +1 (maximum preference) to -1 (maximum avoidance)

4.4.3 Diet composition of Tibetan Wolf

A total of 54 scats of Tibetan wolf were analyzed for dietary remains. Wild mammals constituted substantial amount of wolf diet, principally blue sheep (50%) which frequently encountered. Infrequently, it also preyed on goral (6.06%), rhodents (7.58%) and birds (1.52%). Among livestock's, it preyed frequently on yaks (28.7%). Even in Pamirs of Northwestern China, wolf scat contained majority of large prey items (61.7%) of which more than half were wild ungulates (32.4%) (Wang et al., 2014). However, in central Himalayas, small mammals were most common food category found in wolf scats (41%) followed by plain dwelling ungulates (31%) (Chetri et al., 2017).

Among livestock's, yak constituted a major portion of diet with 25% and horse with only 3.84%. Even in Pamirs of Northwestern China, yak formed relative larger portion of wolf diet (Wang et al., 2014). In Central Himalayas in Nepal, highest proportion of wolf scats are from goats, followed by horses , lulu cow, yak and sheep (Chetri et al., 2017). Thus it can deduced from here that wolf preys on both small and large mammals based on availability.

Blue sheep (51.9 %) dominated the diet of Tibetan wolf in Choekhortoe followed by goral (7.69%) and rhodents (5.7%). The 71.15% of scat remains were composed of wild preys and remaining 28.8% were livestock's. In Dhur, 64.2% of scat remains consist of wild preys and 35.7% with livestock's. Yak and blue sheep were the most dominant prey species and birds were the least dominant one in the scats.

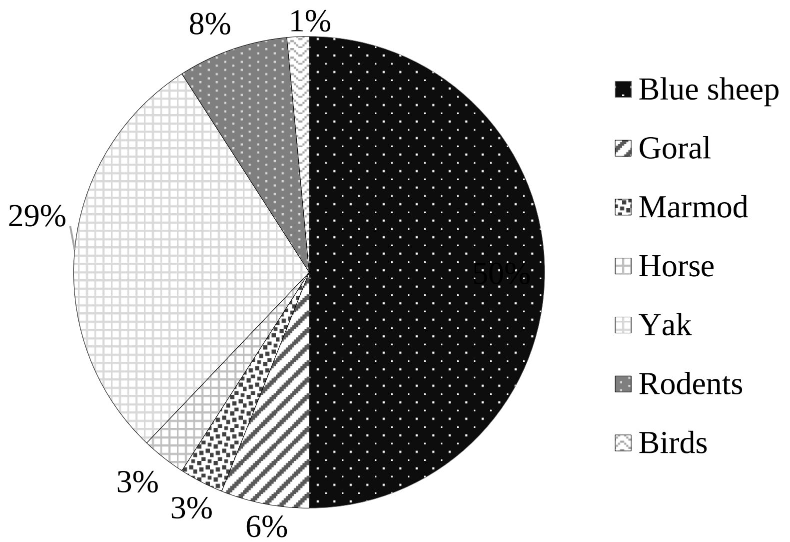

Figure 4.11: Dietary composition of Tibetan wolf

4.4.4 Prey preference of Tibetan wolf

Among wild preys, Tibetan wolf exhibits higher preferences to blue sheep (*D* = 0.3) and Himalayan marmot (*D* = 0.09) and lesser preferences to birds (*D* = -0.8), rodents (*D*= -0.4) and goral (*D* = -0.115). Horse is the most preferred among livestock (*D* = 0.09) and yak the least preferred (*D* = -0.24) (Figure 4.12). In central himalayas in Nepal, wolves exhibited a significant preference for plain dwelling ungulates and an avoidance of cliff dwellers, whereas livestock was consumed according to their availability (Chetri et al., 2017). The case is no different with the study area.

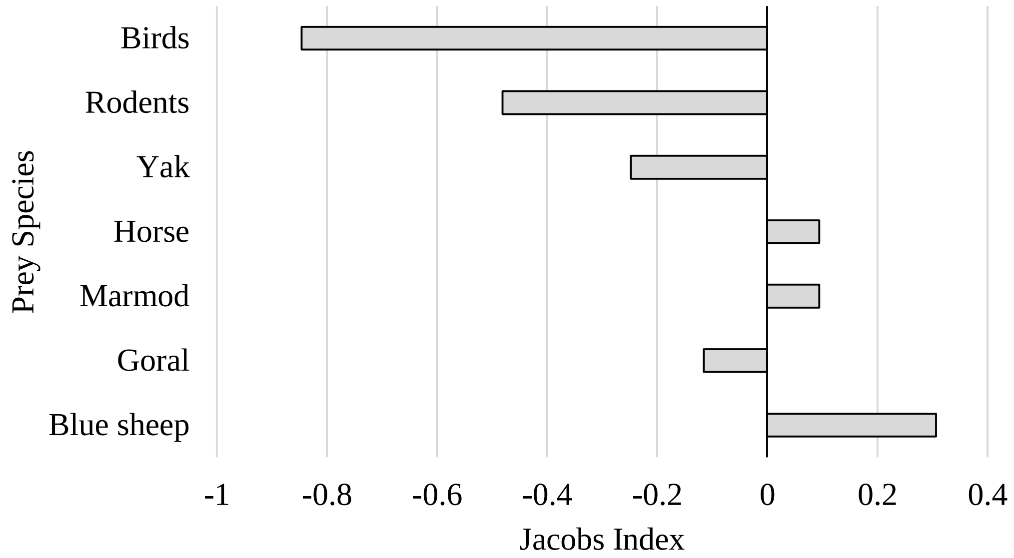

Figure 4.12*: Jacob's index values for prey species of Tibetan wolf in the study area

*The resulting value range from +1 (maximum preference) to -1 (maximum avoidance).

4.4.5 Dietary overlap

Overall, the scats of snow leopards consisted of 75% prey of wild origin and 25% of domestic animals. Among different categories of wild prey, cliff dwelling ungulate (blue sheep) dominated the diet of snow leopard in both Choekhor and Dhur region. Among domestic animals, the highest proportion in scats was from yak, followed by sheep. Blue sheep were also the most common food category found in wolf scats, followed by yak. The proportion of domestic animals was significantly higher in the scats of snow leopard than wolf scats ($p < .05$) whereas cliff dwelling ungulates did not differ significantly in both scats ($p > .05$). Pianka index value for Dhur was 0.83 and 0.96 for Choekhortoe, thus indicating that a large dietary overlap between the two species in both the regions. Six prey items were common in the diets of both species including; blue sheep, Goral, Himalayan marmot, rodent, birds and yak. Even in the Pamirs of Northwestern China, a larger dietary overlap was observed between snow leopard and wolf (0.87) (Wang et al., 2014). A relatively small diet overlap (0.44) between two species was also reported from Central Himalayas in Nepal (Chetri et al., 2017). A higher dietary overlap is observed because distribution of both of these carnivores overlap, raising the possibility of competition for natural prey.

Chapter Five
Conclusion and Recommendation

5.1 Conclusion

The 38 herders of central part of Wangchuck Centennial National Park reared a total of 2,815 heads of livestock with an average herd size of 74 head of stock. The herders have multiple source of income though mainly dependent on yak husbandry and Cordyceps collection and sale. The average annual income is estimated as Nu.5, 15, 219.00 for Dhur and Nu.5, 49,117.00 for Choekhortoe region.

Besides having a successful semi nomadic life, it was observed that there was a constant decline in herders as well as livestock population in the study area. The major reason for decline in livestock population and herders is aggregated to increasing number of predation in the recent years. Choekhortoe lost 8.6% of annual household income and Dhur lost 5.07% of annual household income through depredation. Snow leopards and Tibetan wolves were responsible for the maximum predation, being blamed for 56.8% and tiger, wild dog and black bear were responsible for remaining 43.2% of livestock loss.

To corroborate the livestock losses reported by herders and to understand more about the prey preference and composition, a dietary study was carried out. Yak and blue sheep were domestic and wild preys that dominated the diet of snow leopard in both the regions. However, Jacob's index indicate that snow leopard exhibits higher preference to domestic sheep and blue sheep and significantly avoided birds, rhodents and yaks. Similarly, wild mammals constituted substantial amount of wolf diet, principally blue sheep which frequently encountered. Among livestock's, it preyed frequently on yaks. Tibetan wolf exhibits higher preferences to blue sheep and Himalayan marmot and lesser preferences to birds, rodents and goral. Horse is the most preferred among livestock and yak the least preferred. A large dietary overlap was observed between two species in both the region consisting of six prey species in common.

5.2 Recommendations

The impact of livestock depredation by snow leopards and other sympatric carnivores such as the wolf on the local herding communities is considerable. This may activate herders to conduct retaliatory/preventive killings. Therefore, compensation for snow leopard predated livestock through livestock insurance scheme should be implemented in the Park. Compensation can change the attitude of people towards snow leopard conservation and at the same time provide income for households. For understanding more about the prey predator relationships, scat from all seasons from multiple years should be collected and analyzed to gain better understanding of the diet composition for both predators. Besides social threats, higher dietary and habitat overlap between snow leopard and Tibetan wolf is observed in study area which can affect both predators negatively. Thus a detail study has to be carried out to understand the prey density to device science based management for conservation of both species.

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