CONSERVATION AND MANAGEMENT OF SNOW LEOPARD AND CO-PREDATORS WITH SPECIAL REFERENCE OF LARGE CARNIVORE-HUMAN CONFLICTS IN THE SELECT AREAS OF WESTERN HIMALAYAS

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CHAPTER - 1: INTRODUCTION

1.1. Mountains of Asia and the Himalaya

The Central and Southern Asian mountains provide an amazing array of essential ecosystem services to mountain inhabitants as well as to the people in the plain lands and around the globe. These services include the storage and release of fresh water, watershed protection, forest products and land for food production, habitat for flora and fauna of local and global significance, the regulation of natural hazards and climate, natural areas for leisure and recreational activities. Also, these mountains ranges are crucial to the maintenance of natural and agricultural global biodiversity and provide a profound sense of place, a source of inspiration and a rich cultural heritage. (Gurung et al., 2006;Sharma and Xu, 2007).

The main mountain range of Central and Southern Asia is the Himalaya and its adjacent mountain ranges such as Karakoram, Tien Shan, Kunlun Shan and Pamir. The Himalaya, the highest mountain range on Earth is an example of a continent-to-continent collision. This immense mountain range began to form when two large landmasses, India and Eurasia, driven by tectonic plate movement, collided. Because both landmasses have about the same rock density, one plate could not be sub ducted under the other. The pressure of the colliding plates could only be relieved by thrusting skyward. The folding, bending, and twisting of the collision zone formed the jagged Himalayan peaks (Gansser, 1979).Home to a wide diversity of flora and fauna, this mountain range has fostered human civilisations and cultures across ages. The Himalayaextends about 2500 km in length from Afghanistan in the west and Namcha Barwa in the east (Burga et al., 2004). The Himalaya encompass a number of unique features, including glaciers, wetlands, and the source of several rivers truly making it the water tower of south Asia. As such, it is imperative to conserve this unique range of mountain ecosystems for the future well-being of many natural species, including humanity.

In South Asia, the Himalaya separates the lowland plains of the Indian subcontinentand the highland Tibetan Plateau. In India, the Himalaya and its associated hill rangesspans across 12States namely, Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, northern regions of West Bengal and hill ranges of Assam(Nandy et al., 2006).

The Himalaya comprises of three zones: the outer Himalaya (ranging from 900 to 1,500 m), the Middle Himalaya (up to 4,000 m) and the Greater Himalaya (up to 8,800 m) (Wadia, 1978; Jhingran, 1981). The Trans-Himalaya or the high altitude cold desert is situated north of Greater Himalaya and is represented by the Tibetan Plateau, Zanskar and Ladakh, Lahul and Spiti, very little portions in Uttarakhand, and north Sikkim. The Shiwaliks are uplifted glacial debris that extend up to about 1,000m at some places run parallel to the Outer Himalaya on the southern side and to the north of the Indo-gangetic plains. The Middle Himalaya is represented by the Pir Panjal in Jammu and Kashmir, and Dhaula Dhar in Himachal Pradesh and are characterised by undulating hills that are cut steeply by flowing torrents and rivers. The Greater Himalayan range consists primarily of igneous formations with patches of sedimentary rocks and bulk of this region is covered with huge glaciers and peaks, with relatively arid, cold valleys in their fold (Sathyakumar and Bhatnagar, 2002).

The Biogeographic classification of India by Rodgers and Panwar (1988) and later modified by Rodgers et al.(2000) demarcates the Himalaya into two Biogeographical zones, viz. the Trans-Himalaya (Zone 1) and the Himalaya (Zone 2). These two Zones are further categorized into Biotic Provinces, viz. Ladakh Mountains (1A), Tibetan Plateau (1B), North-West Himalaya (2A), Western Himalaya (2B), Central Himalaya (2C) and Eastern Himalaya (2D).

The West Himalaya ranges from Sutlej to the Gandak in Nepal, with generally drier climate and harsher winter (Rodgers and Panwar, 1998). Though less diverse, it too has an interesting vegetation zonation along the altitude, demarcated as Temperate, Subalpine and Alpine. The Temperate zone (2,500 to 3,000m) comprises of conifer and broad-leaved forests mainly oak and associated species (Singh and Singh, 1987). The Subalpine zone (3,000 to 3,350m) consists of high altitude oak, birch and *Rhododendron* forests below the ‘tree line’ and fringing the alpine meadows (Mani, 1974). The Alpine zone (3,300 to 4,500m) is characterized by dwarf *Rhododendron* and juniper scrub that grades into alpine meadows, rock and perpetual snow (Rawat, 1998).

1.2. The Snow leopard as Flagship Species of Central and South Asian Mountain Ecosystem

The snow leopard (*Panthera uncia*) is an Endangered Asian big cat found in high altitude ecosystems of Asia across 12 range countries (Figure 1.1).The species like other large predators is intrinsically rare, and even though it inhabits a large geographical range (almost 1.8 million km^2), its global population is estimated at 3,920-6,390 (Snow leopard working Secretariat, 2013, Table 1.1). However, these population estimates are not robust and are based on approximations. The secretive nature of the animal, rugged mountain topography and inherently low density of snow leopards make estimation of abundance and density using robust mark-recapture methods particularly challenging (Jackson et al., 2006; McCarthy et al., 2008).

Positions at the top of food chains make predator species, such as snow leopard, good indicator of the health of high altitude ecosystems in central and southern Asia. Wide diversity, high abundance and regular presence of predators are sure signs of good availability of broad range of prey species and other biodiversity within ecosystems. The snow leopard serves as an indicator species for Asia's high mountain ecosystems and, requires large home ranges. Therefore, by protecting the snow leopard, entire high altitude ecosystem can be protected (Snow Leopard Working Secretariat, 2013)

The fact that the snow leopard has a wide distribution in the Trans-Himalaya and that it is the apex predator in most of this region enables the species to be used as a ‘flagship species’ and an ‘umbrella species’ to guide conservation efforts in the region, as was recognized by the Government of India in the 1980’s (Anon. 1988).As a ‘flagship’ species the elusive snow leopard can be a unifying biological icon that can rally the regional players in the conservation arena, and become a symbol for international cooperation in regional conservation (Bhatnagar et al., 2002). As an ‘umbrella’ species, the ecological and behavioral requirements of snow leopards will also help to conserve the other facets of biodiversity in the alpine eco-regions of the highest mountain ranges in the worldSnow Leopard Working Secretariat, 2013.

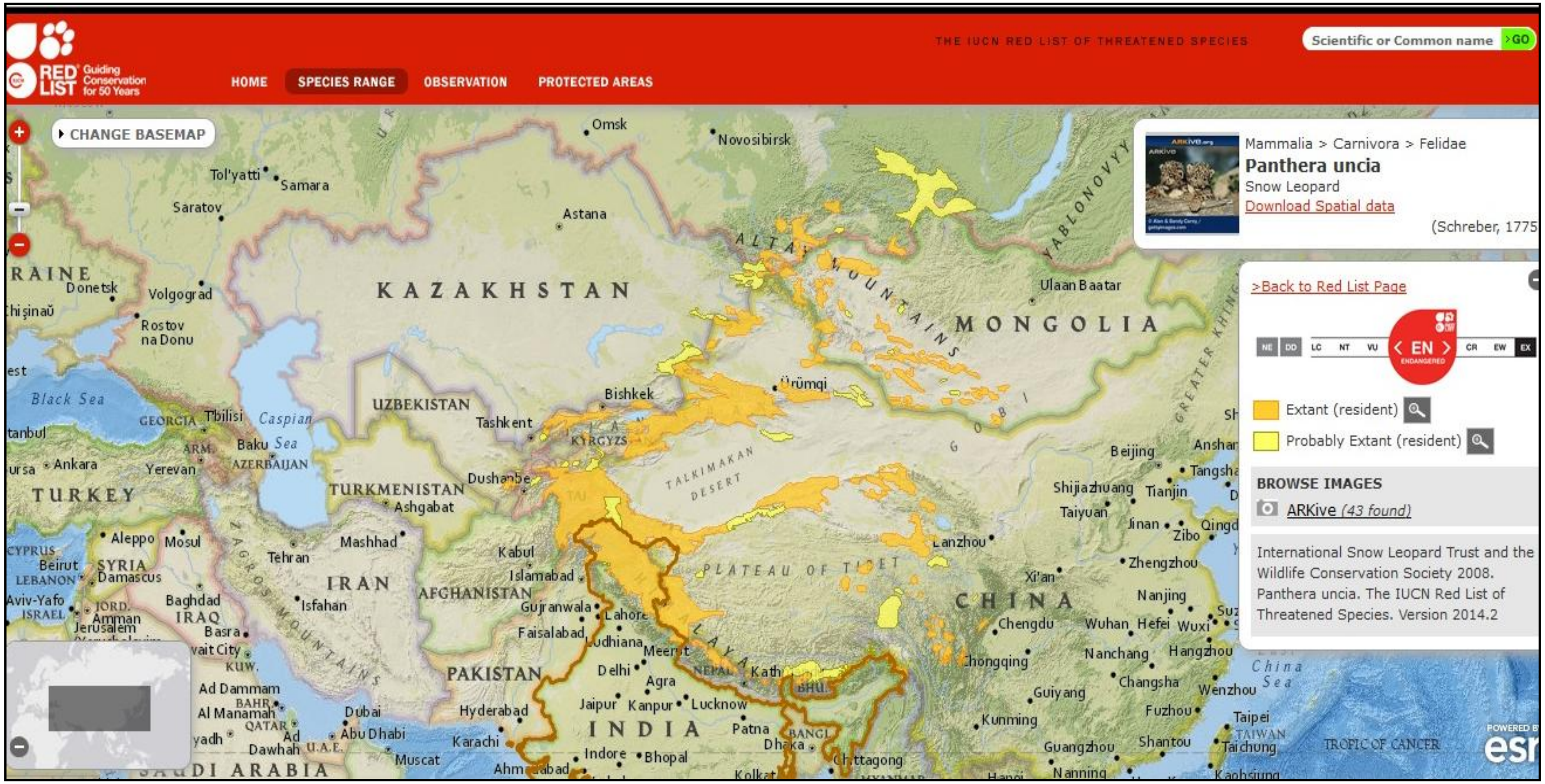
The snow leopard can be a focal species for landscape conservation planning in the Central and South Asian mountain ecosystem including high altitude Himalaya, as elephants (*Elephas maximus*), rhinos (*Rhinoceros unicornis*), and tigers (*Panthera* *tigris*) have done for other landscapes elsewhere in South and Southeast Asia (Bhatnagar et al., 2002).

Table 1.1. Estimated area inhabited and population size of snow leopards in the 12 range countries

Range Country	Estimated Area (km²)	Estimated Population	Year of Evaluation
Afghanistan	50,000	100—200	2003
Bhutan	15,000	100—200	1994
China	1,100,000	2,000—2,500	2003
India	75,000	200—600	1994
Kazakhstan	50,000	100—110	2001
Kyrgyz Republic	105,000	150—500	2001
Mongolia	101,000	500—1,000	2000
Nepal	30,000	300—500	2009
Pakistan	80,000	200—420	2003
Russia	60,000	70—90	2012
Tajikistan	100,000	180—220	2003
Uzbekistan	10,000	20—50	2003
Totals	1,776,000	3,920-6,390	

Source: Snow Leopard Working Secretariat, 2013

Figure 1.1. Map showing the global distribution of snow leopard.



Source: IUCN/SSC 2014

1.2.1. Literature Review on the Snow leopard

The snow leopard, up to 1970's remained unstudied in the wild. Then information concerning snow leopard in the wild were accrued from anecdotal observations, often made by big game hunters roaming remote areas in search of wild sheep and goat trophies (Hemmer, 1972; Guggisberg, 1975; Roberts, 1977; Schaller, 1977). Schaller (1977) carried out surveys in the Himalaya and summarized natural history information in his book 'Mountain Monarchs'.

The first successful radio – telemetry ecological study was carried out by Jackson et al. (1988a and b) in Nepal. Subsequently, radio –telemetry studies were conducted by Oli et al. (1994) in Nepal; Chundawat (1989, 1990, 1992) in India; Schaller et al. (1994) and McCarthy (2000) in Mongolia. Furthermore, studies were also carried out on the status and distribution, identifying conservation actions and snow leopard – human conflicts by Mallon, 1984; Koshkarev, 1984; Schaller et. al., 1987; Schaller and Junrang, 1988; Schaller et al., 1994; Fox, 1989; Buzurukov and Muratov, 1994; Chundawat, 1989 and 1990; Fox, 1994; Jackson and Ahlborn, 1984; 1988a and b; Jackson et al., 2006 and 2008; Oli et al.,1994; Hussain, 2003; McCarthy, 2000 and McCarthy et al., 2005; Bischof et al., 2013; Li et al., 2013a and b; Lovari et al., 2013; Suryawanshi et al., 2012, 2013 and 2014; Sharma et al., 2014 and Lyngdoh et al., 2014.

In India, studies on snow leopard had been carried out on habitat selection, camera trapping, food habits, associated co – predators, prey species, large carnivore – human conflicts as well status and anecdotal notes by Dang, 1960 and 1961; Nath, 1982; Mallon, 1984 and 1991; Green, 1982;Chundawat, 1989 and 1990; Chundawat et al.,et al., 1988; Chundawat and Qureshi, 1999; Fox et al., 1991; Mishra, 1997 and 2000; Bhatnagar et al.,1999; Jayapal, 2000; Sathyakumar, 1993 and 2003a; Sathyakumar and Qureshi, 2002; Sathyakumar et al., 2009; Raghavan et al., 2003; Jackson et al., 2003 and 2005; Suryawanshi et al., 2013 and 2014; Maheshwari and Sharma, 2010a and b; Maheshwari et al., 2012;Lyngdoh et al., 2014.In India, snow leopard studies have been focused in the Trans-Himalayan region of Spiti Valley (Himachal Pradesh) and Ladakh region (Jammu and Kashmir).

With the exception of a few status surveys and anecdotal information (Green, 1982; Sathyakumar, 1993; Vinod and Sathyakumar, 1999), the Greater Himalaya of

Uttarakhand, Himachal Pradesh and Trans-Himalaya of Kargil have remained unexplored for snow leopard and other wildlife values due to inaccessibility and its location at near to the International border (particularly Kargil). The proposed study is the first effort for collecting the base-line information about snow leopard and other wildlife in Kargil and also extensive surveys in the Greater Himalayan regions of Himachal Pradesh and Uttarakhand. In mid 2015, the Uttarakhand State Forest Department and Wildlife Institute of India made an assessment of the status of snow leopard and its prey in the high altitude regions of the State (Habib et al.,2016).

1.2.2. Taxonomy

The snow leopard is a member of the Felidae subfamily Pantherinae (Schreber, 1776; Nowak and Paradiso, 1983). DNA evidence suggested that the Pantherinae subfamily, including lions (*Panthera leo*), jaguars (*Panthera onca*), tigers, leopards (*Panthera pardus*), snow leopards and clouded leopards (*Neofelis nebulosa*) (big cats), diverged from their nearest evolutionary cousins, Felinae, which included cougars (*Puma concolar*), lynxes (*Lynx lynx*) and domestic cats (*Felis catus*), about 6.37 million years ago (Tseng et al., 2013). A phylogenetic analyses place the snow leopard within the genus Panthera, and being most closely related to the tiger with the divergence time estimated around 2 million years (Johnson et al., 2006).

As in other Pantherinae, the diploid chromosome number in snow leopards is 38 and the fundamental number is 36. There are 17 metacentric and 2 acrocentric chromosomes (Soderlund et al., 1980). The karyotypic banding pattern is almost identical to that in other Pantherinae (Gripenberg et al., 1982). There had been virtually no fossil record of snow leopard, the only positive identifications being upper Pleistocene remains from Altay caves (Hemmer, 1972). Recently, a well-preserved 4 to 6 million years old skull of a previously unknown species of prehistoric snow leopard from Tibet is the oldest big cat fossil ever found, according to palaeontologists in a joint study from China, Canada and the United States (Tseng et al., 2013).

1.2.3. Physical Attributes

The snow leopard is a large felid, with adult males weighing 45–55 kg and females 35–40 kg, a shoulder height c. 60 cm and head-body length of 1.8–2.3 m (Hemmer, 1972). With its smoky-grey pelage tinged with yellow and patterned with dark grey, open rosettes and black spots, the snow leopard is especially well camouflaged for life among bare rocks or patchy snow (Plate 1). It has a well-developed chest, short forelimbs with sizable paws, long hind limbs, and a noticeably long tail (75–90% of its head and body length), giving it an amazing agility for negotiating steep terrain or narrow cliff ledges (Sunquist and Sunquist, 2002). Adaptations for cold include an enlarged nasal cavity, long body hair with dense, woolly under fur (belly fur up to 12 cm in length), and a thick tail that can be wrapped around the body for added warmth while at rest. Mating occurs between January and mid-March, a period of intensified social marking and vocalization (Ahlborn and Jackson, 1988). In captivity, oestrous lasts 2–12 days, with a cycle of 15–39 days (Nowell and Jackson, 1996). One to five cubs are born after a gestation period of 93 to 110 days, generally in June or July. Age at sexual maturity is 2–3 years (Sunquist and Sunquist, 2002). There is no information on longevity in the wild. Litter size is usually two to three and exceptionally as large as seven. Dispersal is said to occur at 18–22 months of age, and sibling groups may remain together briefly at independence (Jackson, 1996). This may explain reported sightings of as many as five snow leopards in a group (Hemmer, 1972).

In general, snow leopard's average food requirement is estimated around 1.5-2.5 kg per day (Jackson and Ahlborn, 1984; Wemmer and Sunquist, 1988; Fox and Chundawat, 1988). Their most commonly taken prey consists of wild sheep and goats including blue sheep (*Pseudois nayaur*), ibex(*Capra sibirica*), markhor (*Capra falconeri*), argali (*Ovis ammon*) and urial (*Ovis orientalis*). Annual prey requirements are estimated at 20–30 adult ungulates, with radio-tracking indicating a large kill every 10–15 days (Jackson and Ahlborn 1984; Jackson, 1996). Domestic sheep and goats, donkeys and horses are also important constituents of snow leopard's diet throughout (Sathyakumar, et al., 2009; Maheshwari et al., 2010b; Lovari et al, 2013; Lyngdoh et al., 2014).

Snow leopards favour steep, rugged terrain well broken by cliffs, ridges, gullies, and rocky outcrops (Jackson and Ahlborn, 1989; Sunquist and Sunquist, 2002); however, in Mongolia and Tibet, they occupy relatively flat or rolling terrain when sufficient cover is available (Schaller, 1998; McCarthy, 2000). Home range size varies from 12 to 39 km^2 in productive habitat in Nepal (Jackson and Ahlborn, 1989) to 500 km^2 or more in Mongolia with its open terrain and lower ungulate density (McCarthy et al., 2005). Densities range from <0.1 to 10 or more individuals per 100 km^2, but current knowledge is insufficient for generating a reliable range-wide population estimate. The four telemetry studies to date reveal largely overlapping male and female home ranges, but with use of a particular area usuallyseparated temporally.

Plate 1: Photograph of snow leopard

1.2.4. Status and Distribution in India

The nationally approved Project Snow Leopard (Anon, 2008) estimated a total of about 1,27000 km² of Snow Leopard habitat in five States of India, namely, Jammu and Kashmir, Himachal Pradesh, Uttarakhand in the Western Himalaya (elevation ranges from 3000 to 5000 m) and Sikkim and Arunachal Pradesh in the Eastern Himalaya (elevation ranges from 4000 m to 5500 m; Table 1.2 and Figure 1.2). Within these states, coarse estimates suggest occurrence of 400 to 700 snow leopards in wild i.e. almost 10% of the total global snow leopard population.

Unfortunately, information on the distribution and abundance is as scanty as the animal itself. Snow leopard is less studied than any other large felid such as Bengal tiger (*Panthera tigris tigris*), Asiatic lion (*Panthera leo persica*) and common leopard (*Panthera pardus fusca*) in India. Its current range is poorly mapped due to the high and inhospitable terrain inhabited by snow leopard. Any attempt to study snow leopard in India started only in 1988 when Chundawat et al. (1988) estimated 95,000 km² as potential habitat for snow leopard in India, of which 72,000 km² was within Ladakh (includes about 20,000 km² within the disputed area between Pakistan and China). Hunter and Jackson (1997) estimated total potential habitat for snow leopard as 75,000 km² in India out of which only 14.4% area is protected.

Snow leopard has not been surveyed systematically in its range in India. Its presence is reported in Jammu and Kashmir and Himachal Pradesh (12 PAs in each State); out of which the status of the species in many protected areas is uncertain. Similarly, other states such as Uttarakhand with 06, Sikkim with 03 and Arunachal Pradesh with 01 PA have reported the presence of snow leopard.

In India, studies had been conducted in some of the protected areas of Jammu and Kashmir and Himachal Pradesh. But in rest of the States such as Sikkim and Arunachal Pradesh, the unprotected areas of snow leopard distribution range have been still unexplored. In Uttarakhand, wildlife surveys were conducted by Green, 1982; Sathyakumar, 1993 and 2003b; Rawat, 2005 and Kandpal, 2010. But specific surveys on snow leopard were lacking. Researchers documented snow leopard information while conducting other studies in various regions of Uttarakhand (Green, 1982; Sathyakumar, 1993 and 2003b; Rawat, 2005 and Kandpal, 2010). Though Uttarakhand has very little area under Trans-Himalayan Biogeographic zone i.e. ideal habitat for snow leopard, there are many areas which fall in the transitional zone of Trans-Himalaya and Greater Himalaya. Similarly, the Trans-Himalayan zone of Himachal Pradesh, Lahaul-Spiti and Pangi Valley were studied for snow leopard and wildlife values by Bhatnagar, 1997; Bhatnagar et al., 1999 and 2008; Saberwal, 1996; Vinod and Sathyakumar, 1999 but some of the areas of Himachal Pradesh have poor information about snow leopard.

Similarly, from Kargil, Jammu and Kashmir there have been a few studies conducted on snow leopard in Zanskar by Spearing, 2002, on Himalayan brown bear by Sathyakumar and Qureshi, 2002 and Sathyakumar 2003a and livestock depredation by Jayapal (2000) in the Zanskar and Suru Valleys of Kargil District and in general, there was very poor information on the occurrence and distribution of snow leopard and associated species and human-wildlife conflicts in Kargil.

Therefore, realising gaps in the available information on snow leopard in Kargil (Jammu and Kashmir) Uttarakhand and Himachal Pradesh, this study was proposed to identify potential habitats for snow leopard conservation in three States of the Greater and Trans-Himalaya.

In India the potential snow leopard habitat is estimated at 128,757 km2: 92% is in the western Himalayan Mountains, which provide habitat for 400-700 snow leopards (Anon, 2008). Unfortunately the information available on distribution and suitable habitat for snow leopard in western Himalaya is very sparse.

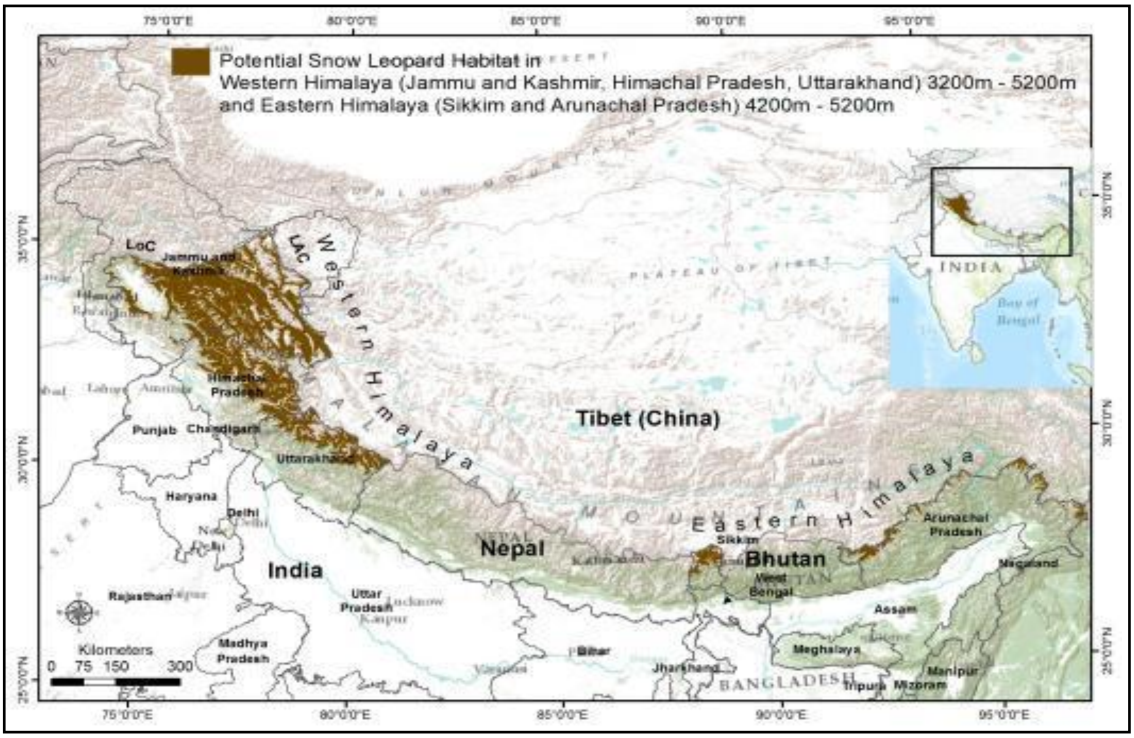
Recently developed tools (i.e. Species Distribution Modelling; [SDM], geospatial tools) can be used to predict the potential distribution and suitable habitat of carnivore species which have large spatial requirements (Rodriguez et al., 2007; Singh et al., 2009). The output may be used in developing effective species conservation measures (Ferrier, 2002; Olsson and Rogers, 2009; Adhikari et al., 2012). Recently Phillips et al. (2004, 2006) developed Ecological Niche Modelling (ENM) tools based on Maximum Entropy (MaxEnt) is a machine learning technique for making predictions from incomplete information, as in using presence-only data for predicting potential distribution habitat of species with ecological and environmental variables such as topography, temperature, precipitation, soil, vegetation, and landcover (Phillips and Dudik, 2008; Elith et al., 2011; Razgour et al., 2011). Maxent has great promise and is ranked as the best performing algorithm, recently compared with different SDM frameworks to predict distribution of rare species (Kumar et al., 2009; Elith et al., 2006). Therefore,Maxent modelling was adopted to predict the potential distribution of snow leopard in its native range in the western Himalayan region to identify key areas suitable for long-term survival of this species.

Table 1.2. Snow leopard range in the five Himalayan states* of India

State	State's Area(km^2)	Potential Area Under PSL (km^2)	% of total area of State
Jammu and Kashmir**	1,52,582	76,601	50
Himachal Pradesh	77,060	28,843	37
Uttarakhand	71,648	14,271	20
Western Landscape	3,01,290	1,19,716	
Sikkim	9,075	2,390	26
Arunachal Pradesh	1,05,173	4,736	05
Eastern Landscape	1,14,248	7,126	
Total	4,15,538	1,26,842	31

*The figures for the Western Himalaya include areas above 3,200 m and those for the Eastern Himalaya are above 4,200 m. Estimates are based on Digital Elevation Model from Shuttle Radar Topography Mission (SRTM). **Includes area only within the 'Line of Control' and the 'Line of Actual Control'.Source: Anon, 2008

Figure 1.2. Map showing the snow leopard distribution in India.



Source (table and map): Snow Leopard Working Secretariat, 2013

1.2.5. Threats to Snow leopard

Several factors are adversely affecting snow leopards throughout their ranges. These factors show regional variation and are sometimes inter-connected (Theile, 2003):

- Major threat to snow leopards is the increasing loss of their natural prey, which is partly due to hunting for meat and wild prey out competed by livestock graze in the snow leopard habitats.
- With less natural prey to feed on and with a rapidly growing numbers of domestic animals being grazed in their hunting territories, snow leopards have increasingly adapted to prey on livestock. This brings them into conflict with local people which lead to retaliatory killing of snow leopards and associated species.
- Snow leopards are also decimated by the trade related hunting for their fur, bones and other body parts, which are considered valuable in international illegal wildlife trade markets such as Asian traditional medicines and also used for some religious proposes.
- Possible impacts due to climate change.

Major threats to snow leopards and their habitat

Across the snow leopard range, threats are similar but their severity and magnitude vary county to country. Sometimes they are interlinked, which makes it a challenge to mitigate. For example, traditional hunting practices of wild ungulates for meat consumption eventually lead to loss of natural prey for snow leopard and killing of wild ungulates to reduce competition with domestic livestock also lead to depletion of natural prey base for snow leopards. Thirst for infrastructure development (primarily roads, hydroelectricity dams and mining industry) leads to unsustainable extraction of natural resources and heavy destruction of alpine and sub-alpine eco-zones with which Snow Leopards are closely associated.

The following major threats provide detailed information on each threat.

Increasing livestock and overgrazing: loss of natural prey base and retaliatory killing of snow leopards and associated species

Though human density in the snow leopard's habitat is relatively low but the communities residing in these habitats are primarily agro-pastoral and depends on the natural resources. With growing human population and rising demand for cashmere, milk and its products livestock herds have greatly increased in size. This is resulting overgrazing which leads to degradation of pastureland, wildlife habitats and serious soil erosion and the decrease in their regenerative capacity, along with a reduction in vegetation production and biomass, and depletion of soil fertility (Steinfeld and Wassenaar, 2007). On the Qinghai-Tibetan Plateau, excessive livestock grazing is reported to have caused vegetation degradation and created barren soils over some 70319 km^2 (Shang and Long, 2007).

Increasing livestock population also leads to killing of wild ungulates (ibex, blue sheep and markhor) to reduce competition between domestic and wild ungulates that impact loss of natural prey base for snow leopards. It altogether results into livestock depredation by snow leopards which eventually lead to protective or retaliatory killing of snow leopards. About 3 to 18% of local livestock holdings are reportedly lost to snow leopards annually (Oli et al., 1994; Mishra, 1997; Jackson and Wangchuk, 2001; Namgail et al., 2007; Maheshwari et al., 2010a and b). These damages could amount to upto 56% of the local average per capita income (Mishra, 1997; Ikeda, 2004). Large losses sometimes create such level of hatred towards the snow leopard that local communities lose complete tolerance of the cat and view total extermination of this cat as the only solution to the conflict (Oli et al., 1994; Suryawanshi et al., 2013).

Habitat fragmentation and degradation

Habitat fragmentation and degradation has emerged as one of the most significant threat to the snow leopard and its habitat in the previous decade. The recent developmental activities such as resource extraction (especially precious mineral and fossil fuels) in the snow leopard central Asian range counties, building road network and hydroelectricity power facilities across most of the snow leopard’s range are increasingly fragments the historic range of the species (Snow leopard Working Secreteriat, 2013). Even urbanization is rapidly increasing in the remote locations of the snow leopard’s range. Altogether these human encroachments may restrict snow leopard’s historic movements.

Lack of Awareness

Snow leopard is less studied and lesser known Pantherinae amongst lion, tiger, jaguar, leopard. Across most of the snow leopard’s range indigenous communities are not even aware about their ecological importance, national wildlife protection laws and legislation which hamper the conservation efforts. Even in general, all levels of society within and outside the snow leopard range countries, from local people to leaders of governments and from the private sector to the general public have poor knowledge about Snow Leopards which restricts general attention and understanding about this elusive cat.

Weak Trans-Boundary Cooperation

Snow leopard cover large distances and data from camera trapping and radio collaring have provided substantial evidence of snow leopard crossing International borders. Therefore, without trans-boundary cooperation amongst snow leopard range countries, conservation goals cannot be achieved. Also, for a landscape conservation approach and providing protection to the snow leopard and associated species, strong trans-boundary policy and political will is crucial. For example, snow leopard covers both India and Pakistan and the Siachen and Kargil is in the species’ core area (Jackson, 2002). Therefore, promotion of the snow leopard as a ‘flagship species’ could become an important symbol representing fragile trans-boundary mountain ecosystem across central and southern Asia.

Trade and Poor Law enforcement

Pelt appears to be the main snow leopard product in demand, whereas other body parts, found in trade, include bones, nails, meat, and sexual organs of male cats. There is also evidence of demand for live animals for private zoos and circuses. Snow leopard bones are known to be valued for traditional Asian medicine similar to those of tiger bones. Evidence of trade in snow leopard bones has been reported from China and Nepal. Nevertheless, it is not clear if bones are sometimes the primary incentive for killing snow leopard or a by-product of the skin trade. Demand for snow leopard products is at the national and international level and consumers are reported to have included powerful and privileged in the central Asian range countries, Mongolia, Pakistan and Russia, while the Middle East and Europe were cited as destinations for skins outside the snow leopard's range.

1.3. Aim of the Study

The study aims to investigate occurrence, distribution of snow leopard, co-predators and their prey in Kargil, and some gaps areas in Greater Himalayan region of Himachal Pradesh and in Greater Himalayan and Trans Himalayan regions in Uttarakhand.

1.4. Objectives

Considering gaps in the knowledge on snow leopard in the Western Himalaya, this study focused on the following objectives

1. Determine conservation status and distribution of snow leopard and co-predators in Kargil, Uttarakhand and Himachal Pradesh
2. To assess occurrence and estimate density of prey species in Kargil
3. To asses food habits of snow leopard in Kargil, Uttarakhand and Himachal Pradesh
4. To assess snow leopard-human conflicts in Kargil, Uttarakhand and Himachal Pradesh
5. To Predict habitat suitability of snow leopards in the western Himalaya.

CHAPTER - 2: THE STUDY AREA

The Himalaya, a land of superlatives, is endowed with a variety of flora and fauna. The Indian Himalayan region ranging from Jammu and Kashmir to Arunachal Pradesh is one of the major repositories of biodiversity. It comprises of five biotic provinces *viz*. Trans-Himalaya (cold deserts in Ladakh region of Jammu and Kashmir, Lahaul and Spiti of Himachal Pradesh and North Sikkim), North West-Himalaya (Jammu and Kashmir and Himachal Pradesh), Western Himalaya (Himachal Pradesh and Uttarakhand), Central Himalaya (Sikkim and Darjeeling district of West Bengal) and East Himalaya (Arunachal Pradesh) (Rodgers et al., 2000). The present study was carried out in three States of the West Himalaya (Jammu and Kashmir, Himachal Pradesh and Uttarakhand).

Keeping the vast area and available resources in view, the study area was divided into intensive and extensive study sites. The intensive study site was Kargil in Ladakh range of Jammu and Kashmir where major work was undertaken with repeated sampling and the extensive study sites were Uttarakhand and some areas of Himachal Pradesh where one time sampling efforts were conducted in the form of sign-surveys.

2.1. Intensive Study Site: Kargil, Ladakh, Jammu and Kashmir

Kargil drew attention particularly late 1990s during military conflict and war between India and Pakistan. From a historic perspective, India and China fought a war in 1962, in which the eastern border of Ladakh was one of the main fronts (Lamb, 1991). In the wake of this war, a motorable road was built connecting Ladakh with the Kashmir valley to the west, and government spending in the area greatly increased. Since the early 1960s, there has been a massive army presence in Ladakh. Subsequent wars and skirmishes with Pakistan have meant that Ladakh has continued to be of crucial strategic importance to the Indian Government. As a result, government and army activity, as well as the building of the road and the opening of Ladakh to tourists from 1975 have combined to bring enormous economic changes to the area (Lamb, 1991).

One of the most significant changes has been the growth of government and employment opportunities in the tourism sector and army, mainly around Leh, which was the administrative headquarters of Ladakh for the first three decades of Independence since 1947. In 1979, Kargil was made into a tehsil in its own right with its headquarters at Kargil town, and similar to Leh, there was more government activity and employment in Kargil (Lamb, 1991).

Kargil was the battlefield of India during late 1990s. In the summer of 1999, Pakistan and India engaged in high altitude combat in Kargil, a region in the disputed state of Jammu and Kashmir. Pakistani forces occupied peaks in Indian-held territory, dominating the lone road that connected India to the remote reaches of the state. The Indian Army faced the formidable task of defeating an enemy entrenched atop commanding heights. A campaign that lasted more than two months and cost each side more than a thousand casualties concluded with India in control of the peaks around Kargil. The high altitude environment determined the nature of the conflict and shaped the conduct of the campaign.

Such military conflicts of course have detrimental impact on the natural ecosystem at landscape level. Very little is known about the general status of wildlife in Kargil before the military conflict of late 1990s. Such lack of information restricts knowledge to assess any changes in the status and distribution of wildlife over a period of time.

2.1.1. Location and Area

Kargil district in state of Jammu and Kashmir, India (Figure 2.1.1) was once known as ‘Purig’. The region called Purig included the areas around Kargil town, the Suru Valley, Shaghar Chiktan, Pashkum, Bodh Kharbu and Mulbek. Kargil is also a town, which serves as the headquarters of Kargil District. It is located at 37.57° North to 76.1° East, 60 km from Drass and 230 km from Srinagar, 234 km from Leh, and 240 km from Padum, Zanskar**.** The total area of Kargil is almost 14,000 km² within this the intensive study area was selected was east and west Kargil ranges of about 1,000 km² in total. There are 12 wildlife sanctuaries proposed in Kargil (Chundawat and Qureshi, 1999).

2.1.2. Physiography

Kargil district is a mountainous desert. The topography of the district is mountainous with little or sparse vegetation. Kargil is connected from the rest of the State by high mountains which are crossed through passes at various points. The District is divided into four high level natural Valleys namely the Suru Valley, the Drass Valley, the Indus Valley and the Upper Sindh Valley of Kanji Nallah Valley. Zojila and Fotula passes situated at the height of 3567 and 4192 m are called gateways for Kashmir Valley and Leh District for entry in Kargil District (Maheshwari et al., 2010b). General elevation ranges between 5934 m to 8510 m with average elevation of 3400 m (Figure 2.1.2).

In Zanskar ranges, permanent glacial bodies exist because of higher elevation of these ranges. Almost all the rivers are flowing through deep valleys. The important major rivers draining in Kargil district are Drass, Suru, Zanskar and Indus. Suru valley constitutes a major part of the Kargil district which is surrounded by hills of soft mixture of clay and sand stone. Suru valley has comparatively at lower altitude and most of the villages are located in this valley (Central Ground Water Board, Jammu, year N/A).

2.1.3. Climate

Kargil lies on the rain shadow side of the Himalaya where dry monsoon winds reaches Kargil after being robbed of its moisture in plains and in the Himalayan mountains. Precipitation is very low with annual precipitation of 15 cm mainly in the form of snow (Figure 2.1.3). Heavy snowfall is experienced in winter. During winters, mercury drops to minus 48° C at Drass, Kargil, which is the second coldest inhabited place in the world after Siberia (Central Ground Water Board, Jammu, year N/A).

Another important climatic factor is wind factor in this district where winds are very strong with velocity of wind ranging between 3 km / hr to 20 km / hr during November to April and 18 to 35 km /hr during May to October respectively. Wind velocity is preferably low during winter. In Kargil area surface wind flowing in the direction between WNW to NNW made the condition on the northern slopes of mountain conducive for accumulation of large quantity of snow (Central Ground Water Board, Jammu, year N/A).

Average relative humidity in Kargil district is between 29% and 73%. Maximum percentage of relative humidity available in the air between December to May and minimum value correspond to June to October. Low temperature as well as high relative humidity prevails during November to March favour heavy snowfall over the entire area as a form of precipitation.

The habitat types of Kargil include temperate forests and alpine rangelands. The four distinct seasons are spring (March–May), summer (June–August), autumn (September–November) and winter (December–February).

2.1.4. Geology and Soils

Geology of Kargil district is complicated due to its severe collision of Indian plate with Eurasia plate resulting into elimination of most of the geological records. Undifferentiated central crystalline rocks (Lioned/ Kilar formations) are the oldest rocks exposed in the Kargil district. These are mainly Garnetiferous mica-schists, Kyanite schists with thin bands of quartzite and marble. These crystalline are overlain by a thick belt of sedimentary rocks designated as Phe formation of upper proterozoic age. They comprised of silt stone/arenite, black pyritous and carbonaceous shale with limestone bands. The Phe formation is directly overlapped by a thin strip of basic volcanic rocks of lower permean age designated as Ralakung volcanics which are homotaxially correlatable with Panjal volcanics of Kashmir. Lilang group of rocks of Perma-triassic age comprising grey splintery shales and thick sequence of inter-bedded ferruginous limestones with Cephalopods overlie the Ralakung volcanic formations. Cretaceous volcanic known as Drass volcanic are intrusive ultrabasic rocks consisting of succession of volcanic, pyroclastic, volcano-clastic sediments with Gabbro and Doleite dykes. Isolated serpentinite lenses are also present. It is thrust over the molasses or the Indus formations in the northern part. The mountains are of sedimentary rocks and are in process of disintegration due to weathering. The terrain being hilly, available land for agriculture is meager (Central Ground Water Board, Jammu, year N/A).

The summer being short, only one crop of local gram or wheat is grown. The soil in Kargil is sandy to loamy in nature and deficient in organic matter and availability of phosphorus and potashes low and mixed with stones and gravels. It is shallow in formation, weak friable and being sandy it is vulnerable to all types of erosion. Soils developed on river terraces highly porous and coarse grained in nature. Fertility of the soil varies from place to place and crop growing season is very short during summers. Kargil has some deposits of chromed at Drass and around it. Copper is also found in Lungnak, Zanskar and Suru Valley. Besides, deposits like lime stone, marble and building material also exist in the soil (Central Ground Water Board, Jammu year N/A).

2.1.5. Flora and Fauna

The study area falls majorly in the Suru Valley of greater Himalaya. The only information available on wildlife is from the Zanskar and Suru Valley is about the status of brown bear-human conflicts (Sathyakumar and Qureshi, 2002) and wildlife conservation status and planning of a protected area network in Ladakh (Chundawat and Qureshi,1999), livestock depredation by predators in Zanskar Jayapal,2000. These rapid surveyshave reported snow leopard, Tibetan wolf (*Canis lupus chanco*), Himalayan brown bear (*Ursus arctos isabellinus*), Asiatic ibex, Ladakh urial (*Ovisorinetalis vignei*), musk deer (*Moschus spp.*), pika, hare and other associated species.

2.1.6. Human Use

Kargil district has an agro-pastoral community of approximately 1,40,000 people, who cultivate the land along the course of the drainage system, wherever artificial irrigation from mountain streams is possible. As per 2011 census, the district has a population of 1,40,802 persons, with density of population 10persons/ Km^2. Kargil is one of the sparsely populated district in India and settlement pattern is just along the river valleys and few broad valleys formed as terraces in Greater Himalayan ranges due to erosion activities of glaciers. The male and female population in the district is of 77,785 and 63,017 respectively with a male/female sex ratio of 810. The schedule caste population in the district is 139 persons i.e. 1.16% of the total population and Scheduled Tribe population is nil in this district. There was change of 18.02% in the population compared to population as per 2001. During 1991-2001 population growth was recorded as 36.89%. The decadal population growth rate during 1961-71 was 18.88%, during 1971-81 was 23.58% and during 1981-91, it was 32.89% (www.kargil.gov.in).

Figure 2.1. A Map of northern India showing the State of Jammu and Kashmir and Kargil the intensive study area

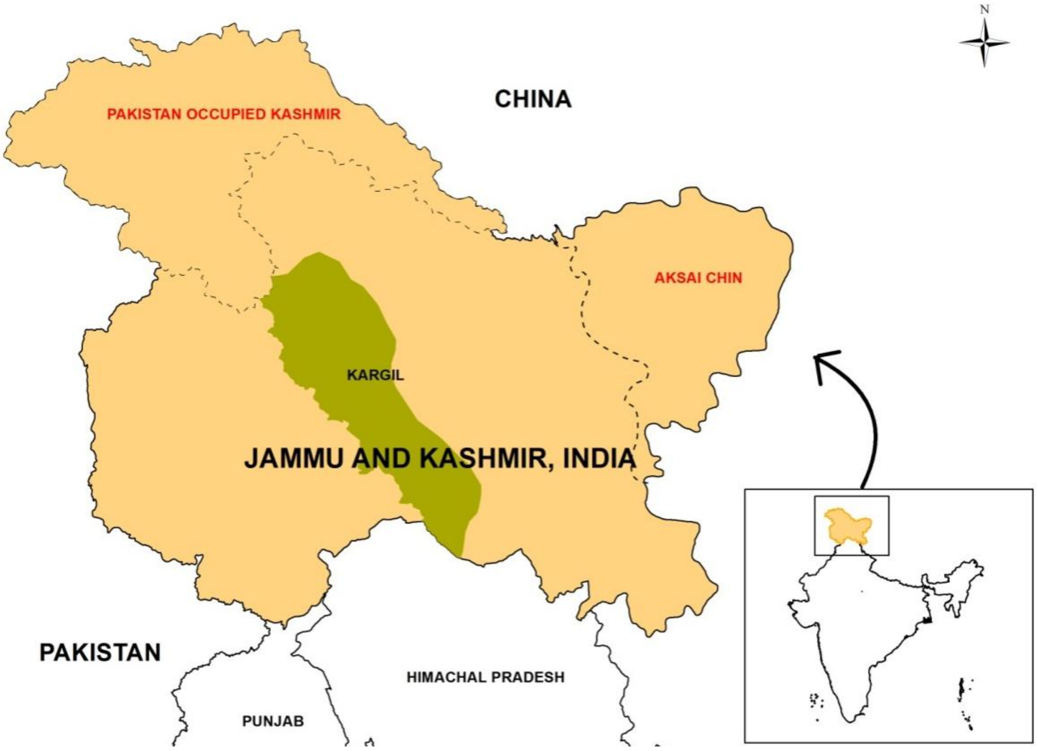


Figure 2.2. Map of Kargil showing various altitudinal categories

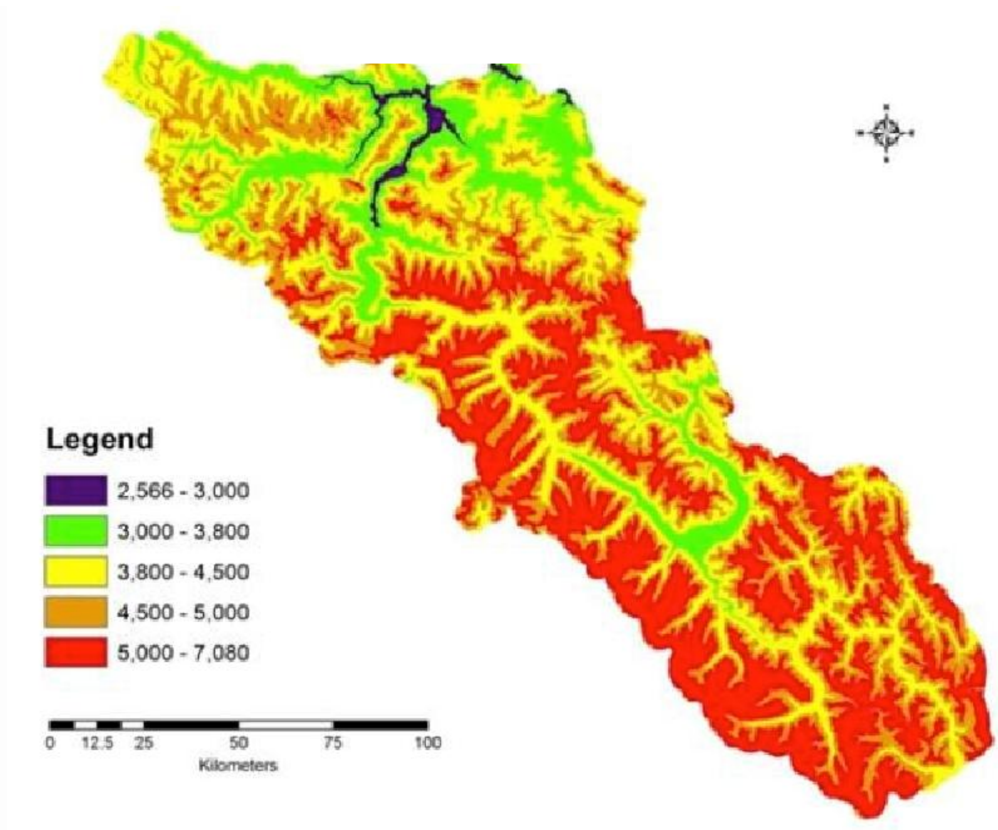


Figure 2.3. Map of Kargil showing various precipitation levels during October, 2009

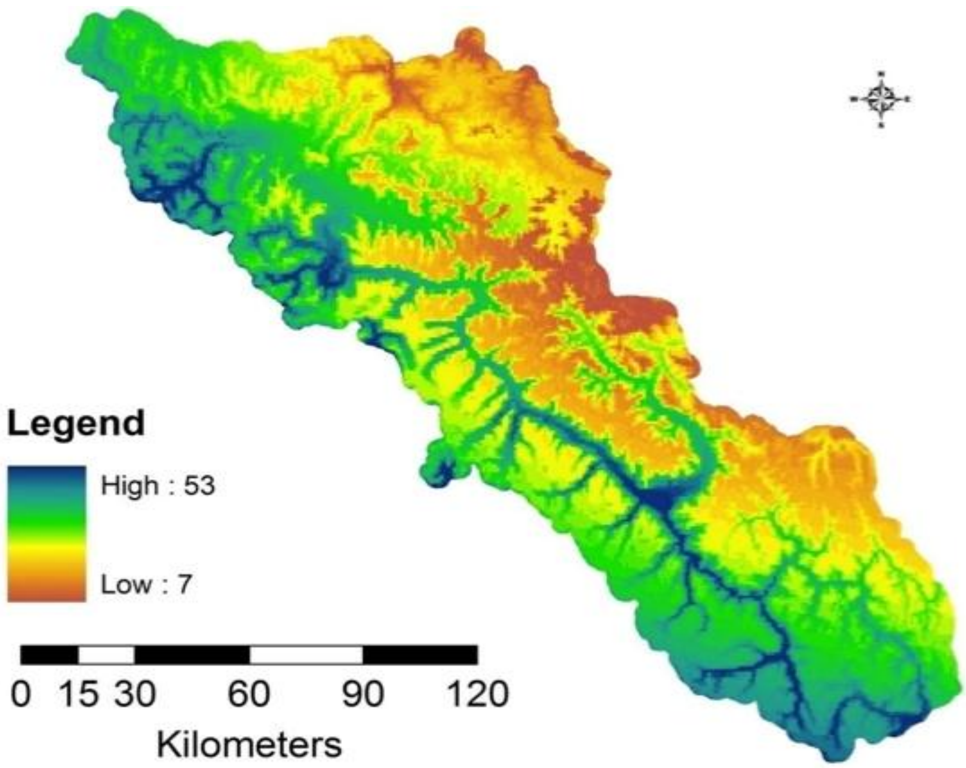
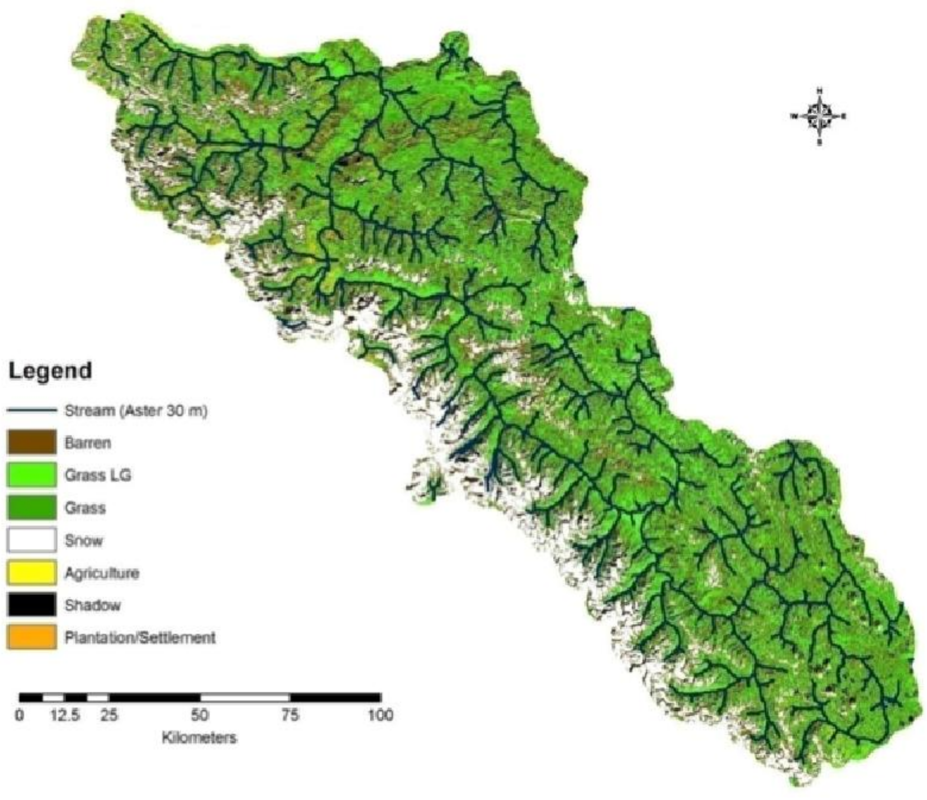


Figure 2.4. Map of Kargil showing land use and land cover



2.2. Extensive Study Sites: Uttarakhand and Himachal Pradesh

The snow leopard habitats for surveys were selected based on the information available and discussion with experts. The consultative process towards Project Snow Leopard, 2006 (PSL, 2006) was also of help in deciding the areas for survey.

2.2.1. Uttarakhand

In the precursor meeting of PSL in 2006, Uttarakhand Forest Department proposed six districts for snow leopard conservation. These were Uttarkashi, Tehri, Rudraprayag, Chamoli, Pithoragarh and Bageshwar. Existing five PAs, *viz.*, Gangotri National(NP), Govind NP and Wildlife Sanctuary (WLS), Kedarnath WLS, Nanda Devi Biosphere Reserve (BR) and Askot WLS within these districts were included for PSL. All these PAs were taken into consideration and surveyed in this study (Table 2.1), except Kedarnath WLS and Pindari region in the buffer zone of Nanda Devi BR as these areas have been surveyed in detail in the past (Green, 1982;Sathyakumar, 1994; Kandpal, 2010). On the other hand additional areas - Dung and Valley of Flowers National Park were included after detailed discussions with biologists who reported the presence of prey species such as blue sheep from these areas (Figure 2.5).

2.2.2. Himachal Pradesh

Similarly in Himachal Pradesh, Himachal Pradesh Forest Department proposed the inclusion of all areas above 3000 m in the PSL (PSL, 2006). These were Lahaul, Spiti, Pangi, Kinnaur, Upper Chamba, Upper Kangra, Upper Kullu and Upper Simla. These districts include the following eleven PAs: Pin Valley NP, Kibber WLS, Great Himalayan NP, Sainj WLS, Tirthan WLS, Lippa Asrang WLS, Bandi WLS, Kugti WLS Tundah WLS, Dhauladhar WLS and Sangla WLS. Of these, gap areas were identified were, Great Himalayan NP, Kugti WLS Tundah WLS, Sangla WLS and Lippa Asrang WLS. But due to limitations of time and resources three PAs were studied during the study period namely, Kugti WLS, Sangla WLS and Great Himalayan NP (Table 2.1).

Table 2.1. Study sites surveyed in Uttarakhand and Himachal Pradesh

Protected Area (PA) (total area in km²)	Lattitude / Longitude of PAs	Study Sites Surveyed
Govind NP and WLS(481 km²)	77° 45' - 78° 37' N / 30° 55' - 31° 18' E	Osla, Har ki Doon, Jamdar Gl, Mandal lake, Ruinsara
Gangotri NP(2200 km²)	30° 50' - 31° 12' N / 78° 45' - 79° 02' E	Gaumukh, Tapoban, Shivling, Nelong, Jadon, Sonam, Tripani
Askot WLS(599.93km²)	29° 30' - 29° 45' N / 80° 20' - 80° 25' E	Bundi, Gunji, Kalapani, Nabidhang, Om Parvat
Nanda Devi BR(5148km²)	30° 17' - 30° 41' N / 79° 40' - 80° 5' E	Sundardhunga glacier, Milam, Dung, Sumna, Lapthal, Chudang, Laha, Rimkhim
Valley of Flowers NP(87.5 km²)	30° 41'- 30° 48' N /79° 33' - 79° 46' E	Kunt Khal, Tipra Glacier
Great Himalayan NP(755 km²)	31° 38' - 31° 45' N / 77° 20' - 77° 52' E	Kobri, Rolla
Sangla WLS(304 km²)	-	Dumti
Kugti WLS(379 km²)	32° 20' - 32° 35' N / 76° 35' - 76° 55' E	Duggi, Baggi

Figure 2.5. Map showing extensive study area in Uttarakhand and Himachal Pradesh

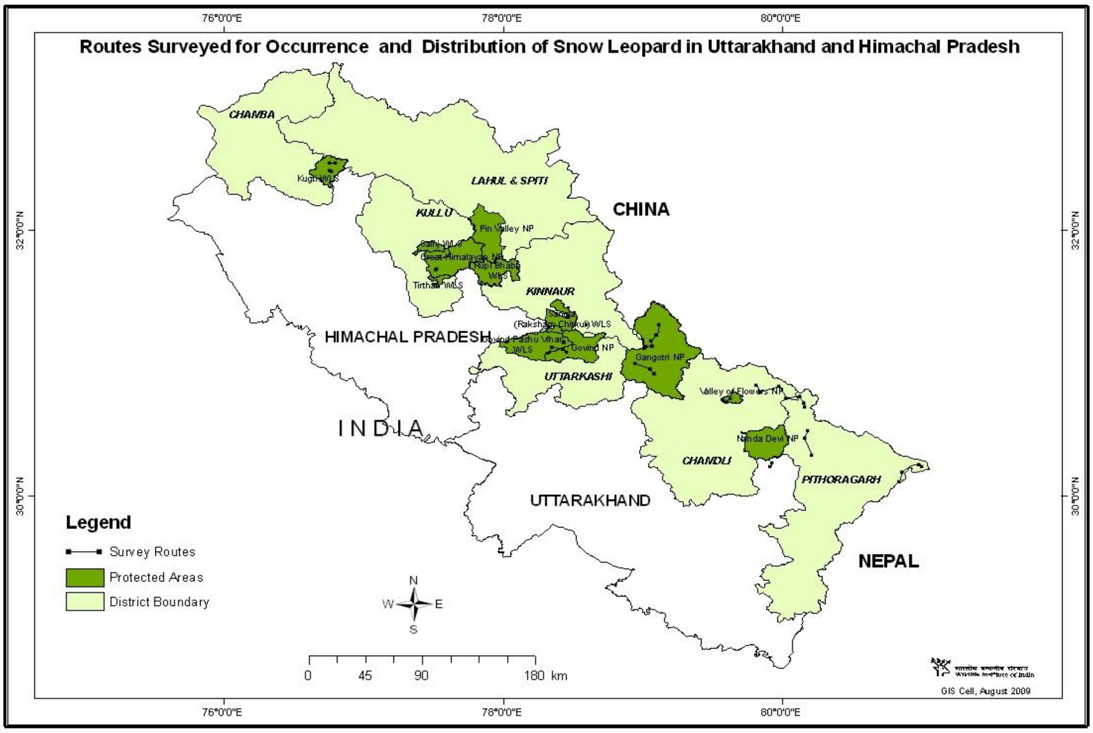


Plate 2.1: Pictures showing intensive study are, Kargil: a) Wakha, b) Mulbek, c) Sanku, d) Umba, e) Sapi, f) Kanji

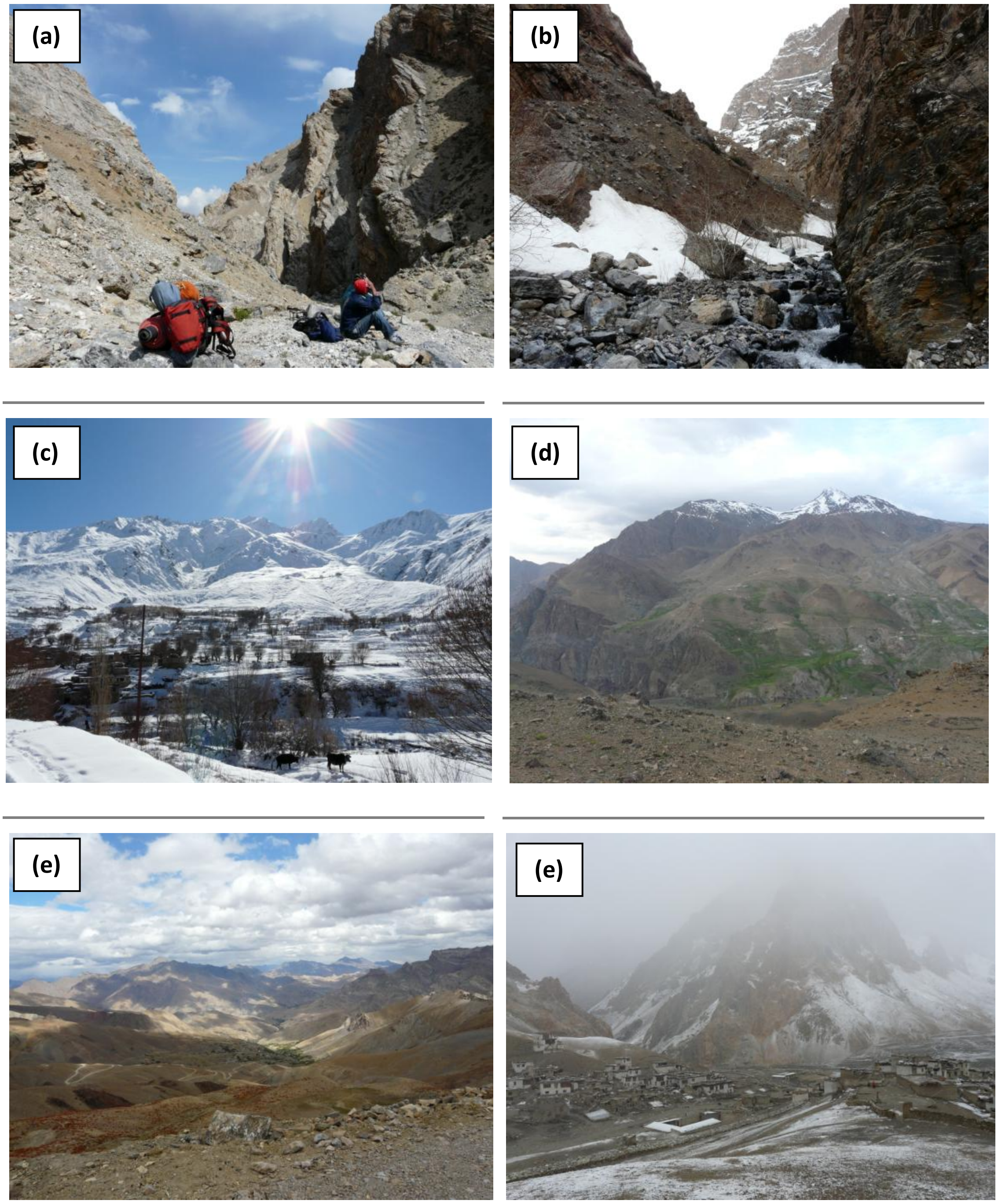


Plate 2.2: Pictures showing extensive study are, Uttarakhand: a) Askot WLS, b) Govind NP and WLS, c) Dung, d) Sundardhunga glacier, e) Gangotri NP

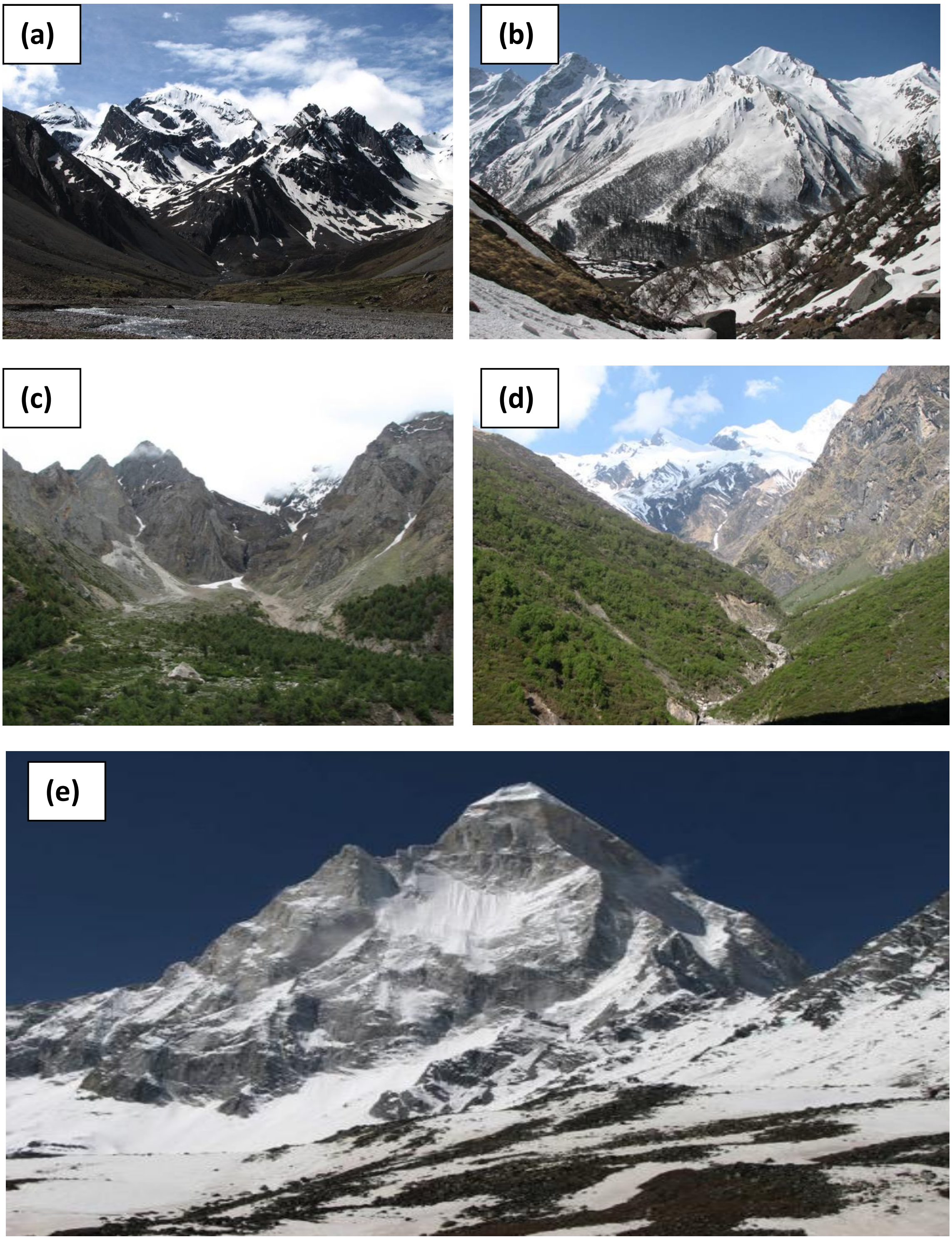
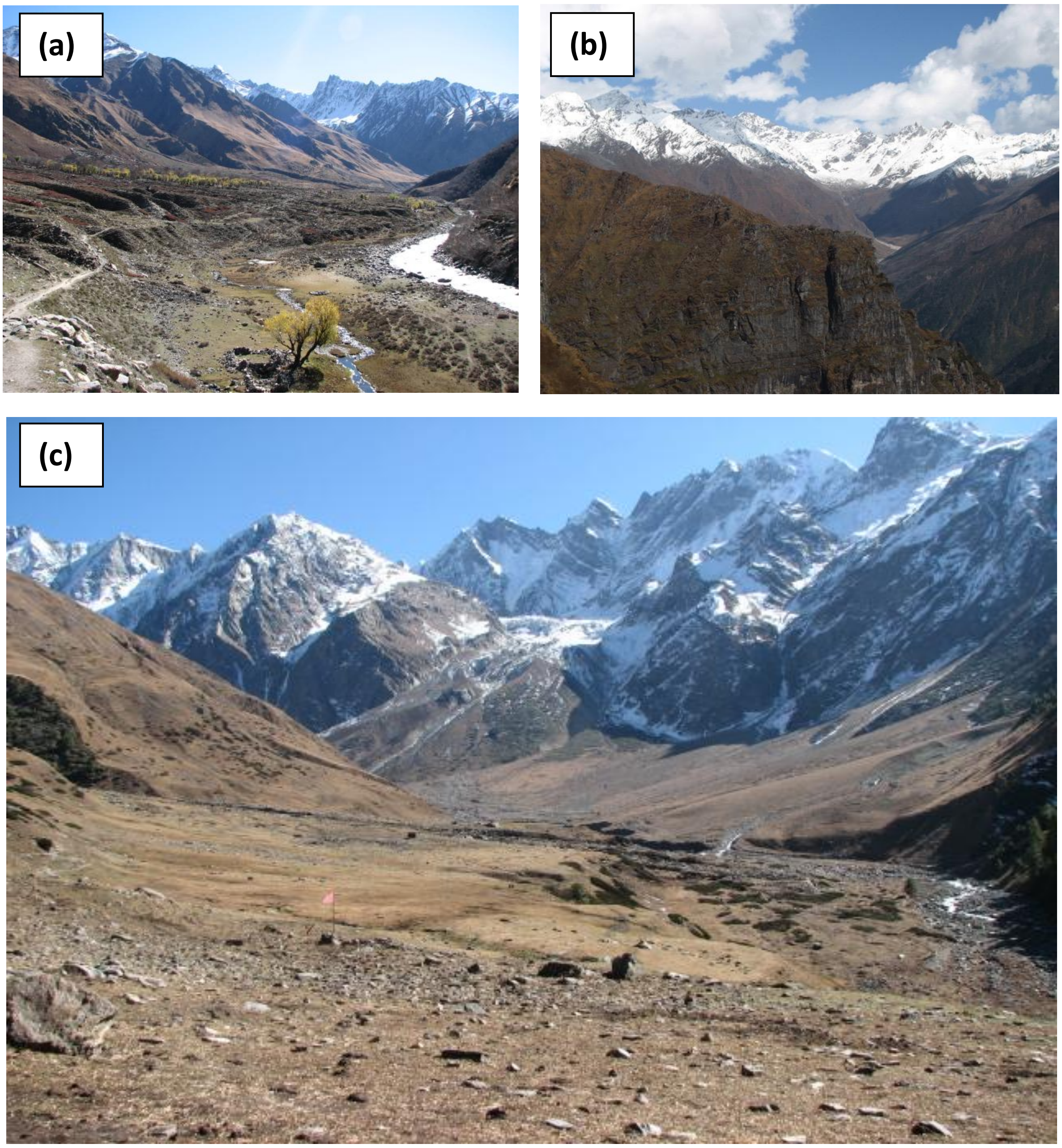


Plate 2.3: Pictures showing extensive study are, Himachal Pradesh: a) Sangla WLS, b) Great Himalayan NP, c) Kugti WLS



CHAPTER - 3: METHODOLOGY

3.1. Introduction

Conservation priorities and strategies are based upon understanding and assessments of general ecology of the concerned species. Mammalian carnivore study interest dates back to the origin of humans. Snow leopards in particular have not been well studied due to their inhospitable terrain and challenging climatic conditions where they are found. With a limitation of literature on snow leopard research, the present study was aimed at assessing the conservation status and distribution of snow leopard and towards mitigation of snow leopard-human conflicts in the unexplored areas of western Himalaya using basic techniques.

Due to remote, steep and rugged high altitude areas, infrastructure is poor in most of the Trans-Himalaya of these three states therefore, all field activities were carried out in the form of field surveys and involved camping in different areas (above 3000 m) of Kargil, Himachal Pradesh and Uttarakhand, one field survey was usually 05-20 days.

3.1.1. Study Period

The present study was initiated in April, 2008 with an aim to identify potential snow leopard habitats in the Western Himalaya.Field work in Uttarakhand and Himachal Pradesh was conducted from April to November, 2008 and Kargil work was conducted from April, 2009 to December, 2012 (Data could not be collected in 2010 due to natural disaster, heavy cloud burst in Ladakh).The study area was divided into extensive and intensive study sites based on available resources and primarily surveyed for snow leopard signs, co-predators and prey species and interface with human. Based on the literature review and the prior knowledge of the experts, sites were identified for conducting sign surveys which were followed by interventions towards mitigation of snow leopard-human conflicts in Kargil, Jammu and Kashmir.

3.1.2. Equipment Used

Basic equipment were used during the study e.g. Garmin GPS-72 GPS (for the locations and navigation) was used to record the location of direct and indirect evidence of target animals, villages, kills, starting and ending points of trails. Suunto Vector was used to record temperature, elevation and compass purposes. Nikon 8X50 binocular and Nikon 8309 Prostaff Spotting Scope 16X-48X-65 MM 25X Angled Eye Piece were used for scanning landscapes, observing animals during vantage sampling. Bushnell Sport 850 4x 20mm laser rangefinder was used to measure distance during sampling. A digital camera of Panasonic Lumix FZ200 was used to take photographs of animals, landscapes, indirect evidence and other associated objects.

3.1.3. Field Work Schedule

The entire (intensive) study area, Kargil (1000 km²) was systematically covered once in two months during the study period. Each trail and vantage pointwere monitored once in two months for signs and sightings. Trail monitoring and scan sampling was done in the mornings. Extensive study sites, Uttarakhand and Himachal Pradesh were surveyed once and all the data was collected in single time efforts. For snow leopard – human interaction assessment questionnaire surveys were carried out in both intensive (Kargil) and extensive (Uttarakhand and Himachal Pradesh) study sites.

3.2. To Determine Conservation Status and Distribution of Snow leopard and Co-Predators

Snow leopard Information Management System (SLIMS) developed by Jackson and Hunter (1996) and further refined by McCarthy et al. (2008), a standardized approach widely used in snow leopard research,were followed to determine occurrence and distribution of snow leopard, co-predators and their prey. SLIMS are designed for ease–of–use, presence–absence surveys are a scientifically valid approach to determine the general status of snow leopards in broad geographic areas. Assuming it is impossible (or at least impractical) to survey entire regions, the surveys rely upon the presence of snow leopard sign at strategic search locations.

3.3. To Assess Occurrence and Estimate Density of Prey Species

Population distribution and behaviour of prey influence the quality of a predator's habitat and the health of predator populations. Therefore, knowledge about the prey species of any predator is a must to understand the ecology of the predator. As the area is undulating in nature, to ensure uniform coverage of the entire study area, vantage points were selected to estimate abundance of prey species (Chundawat, 1992; Bhatnagar, 1997;Namgail, 2006; Namgail et al., 2004; Ale, 2007 and Suryawanshi et. al., 2012). In addition, observations were recorded while surveying trails/transects. This helped in gathering information about group size of ungulates, preferred habitats and support sign – survey dataset.

3.4. To Assess Food Habits of Snow leopard

During the study period, scats were collected on all trails/transects and opportunistically wherever they were encountered. Random searches were also carried out on trails (Anwar et al., 2011). Food habits were investigated after species identification using DNA based analysis (Janecka et al., 2008; Karmacharya et al., 2011).

3.5. To Assess Snow leopard-Human Conflicts

The increasing interface between humans and large carnivores is resulting in a world-wide escalation of large carnivore-human conflicts (Madhusudan and Mishra,2003; Trevesand and Karanth,2003; Maheshwari et al., 2014). Carnivores often cause serious economic losses. Livestock depredation by snow leopard has been reported throughout its range (Bhatnagar et al.,1999; Hussain, 2003; Oli et al.,1994; Jackson and Hunter,1996; Mishra, 1997; Jaypal, 2000; Jackson et al.,2003; Sathyakumar and Qureshi, 2002;Maheshwari et. al., 2010a and b;Li et al.,2013; Suryawanshi et al., 2013; Sathyakumar et al., 2016). Inadequate understanding of ecological and social issues of such conflicts makes the resolution of such conflicts more critical. Keeping this in view, information gathering of snow leopard-human conflicts was made an integral component of the study.

Plate 3a: Field work in the form of expeditions.

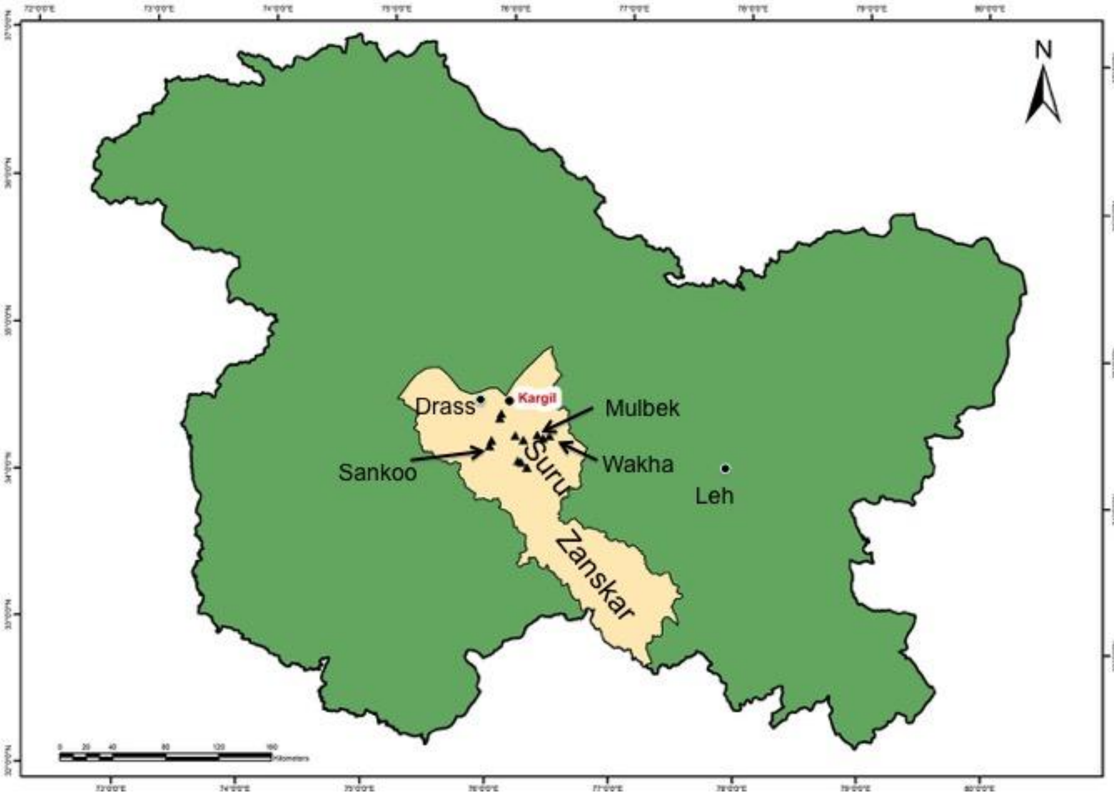
Plate 3b: Camping site in the snow leopard habitat in Uttarakhand.

CHAPTER - 4: CONSERVATION STATUS AND DISTRIBUTION OF SNOW LEOPARD, ASSOCIATED SPECIES, AND LARGE CARNIVORE-HUMAN CONFLICTS IN KARGIL

4.1. Introduction

Kargil was the battlefield of India during late 1990s, thus being politically senstitive there has not received much attention for wildlife studies due to its proximity to International boundary between India and Pakistan. Very few information on wildlife such as Sathyakumar (2003a) on the occurrence of Himalayan brown bear from Zanskar and Suru Valley, PA management in Ladakh by Chundawat and Qureshi (1999) and livestock depredation by predators in Zanskar by Jaypal (2000). But there was very poor information on the conservation status and distribution of snow leopard and associated species and conflicts with human in Kargil. Therefore, this study was felt needed to establish the current conservation status of snow leopard and associated species in Kargil. The study area covers the Suru Valley, Sanku, Wakha, Mulbek (Figure 4.1) and extendover almost 1000 km^{2}out of 14000 km^2 of Kargil.

Figure 4.1. Map of Kargil showing major places in the study area.



4.2. Objectives

This chapter deals with the following objectives:

a) Determining conservation status and distribution of snow leopard and co-predators
b) Assessing occurrence and estimating density of prey species
c) Assessing food habits of snow leopard and Tibetan wolf
d) Assessing snow leopard-human conflicts

4.3. Methods

4.3.1. Determining Conservation Status and Distribution of Snow leopard and Co-Predators

In total 13 trails were marked (trail length from 4km to 6.5km) to establish the current distribution of snow leopard, co-predators and their prey in Kargil. SLIMS (Jackson and Hunter, 1996; McCarthy et. al., 2008) were followed to conductsign surveys in the snow leopard habitats above 3000m in Kargil. Four types of signs were recorded:

a) **Scat** - snow leopard scat tends to be uniform in diameter (an average 1.8 cm) and comprises of several slightly constricted cords or connected with blocky segments (up to 8-10 cm; Janecka et al.,2008) with blunt ends

b) **Pug-marks** (*i.e.* tracks)

c) **Scrape** – a mark with hind paw consisting of an oblong depression with a pile of earth at one end

d) **Spray/urine** (scent-mark on rock surfaces by spraying them with urine)

Trails were marked in potential snow leopard habitats (such as ridgelines, cliff edges) were used where snow leopard signs are most likely to be found. These routes were walked by a single observer and all signs of snow leopard and co-predators (such as common leopard, Asiatic black bear (*Ursus thibetanus)*, Himalayan brown bear (*Ursus arctos isabellinus)* and Tibetan wolf (*Canis lupus chanko*) were recorded. At each site, information on location, date, elevation, slope, aspects, land ruggedness, habitat types, distance from human habitation and nearest water point were recorded with the help of GPS and ocular estimation. The habitats where snow leopard evidence were found; classified based on the parameters (such as landforms and habitats) of the SLIMS.

Since, it was difficult to distinguish the scats of sympatric carnivores such as snow leopard and Tibetan wolf. Therefore to minimise the chance of error of wrong identification of scats, species identification was done on the basis of genetic analysis of scats collected from study area.

4.3.2. Assessing Occurrence and Estimating Density of Prey Species

In total eight vantage points were marked to assess occurrence and estimate density of major prey species of snow leopard.From the vantage points, once animals were visually encountered, the place was observed carefully with 8x40 binocular and spotting scope 16X-48X-65 MM 25X Angled Eye Piece and habitat parameters were noted and distance was estimated with ocular estimation. Each observation was treated as one group or sighting, irrespective of number of individuals seen. For each observation, the following information was recorded: Date and time, species of animal, group size, age and sex classification (number of males, females, sub adult males – females and young ones; wherever possible), activity (e.g. feeding, foraging, resting, others), GPS location of the point on the trail from where animals were sighted, (wherever possible) slope angle, distance to cliff, aspect, terrain type (e.g. slopes, rocky outcrops, escarpments, valley bottoms, smooth slopes), vegetation type, distance to ridgeline and any other remarks. Densities were calculated for each ungulate species using the number of observations and the area covered from all vantage points (Nievergelt, 1981; Suryawanshi et. al., 2012).

4.3.3. Assessing Food Habits of Snow leopard and Tibetan wolf

All scats were stored in polybags with information on GPS location, place and habitat. After the species identification using DNA based analysis (snow leopard, n=59; Tibetan wolf, n=53) scats were oven dried and then teased out for the indigestible material like hairs, hooves, bones and other remains (Mukherjee et al., 1994; Maheshwari and Khan, 2006). The scats were crushed and observed carefully for the presence of indigestible macro elements like claws, feathers etc. and six hairs were collected randomly per scat (Chundawat and Rawat, 1994) This size of hair collection per scat were be standardized by analyzing 20 scats.

The hairs were kept in xylol (xylene and ethyl alcohol) for 24 hours. Slides were prepared with three hairs per slide i.e. two slides for each scat, by mounting hairs in DPX. All the slides were examined under microscope. These hairs were compared with known reference slides which were prepared from the hairs collected from different kills of wild ungulates and domestic livestock also. Reference hairs were also taken from different parts of the body such as belly, hind and neck portion to minimize the bias of any unknown hair extracted from the scat as there is a considerable difference of different hairs within the body, microscopically. The hairs were identified on the basis of structural differences like medullary portion, cuticle, cortex and pigmentation in the cells (Koppikar and Sabins, 1975). The long hairs such those of Asiatic ibex, yak and cow were cut in to three pieces of proximal, middle and distal and then examined under microscope. The total number of prey species which were examined (i.e. total number of all prey species whenever they recorded) was cross-checked through taking the frequency in percentage at interval of 10 scats.

4.3.4. Assessing Snow leopard-Human Conflicts

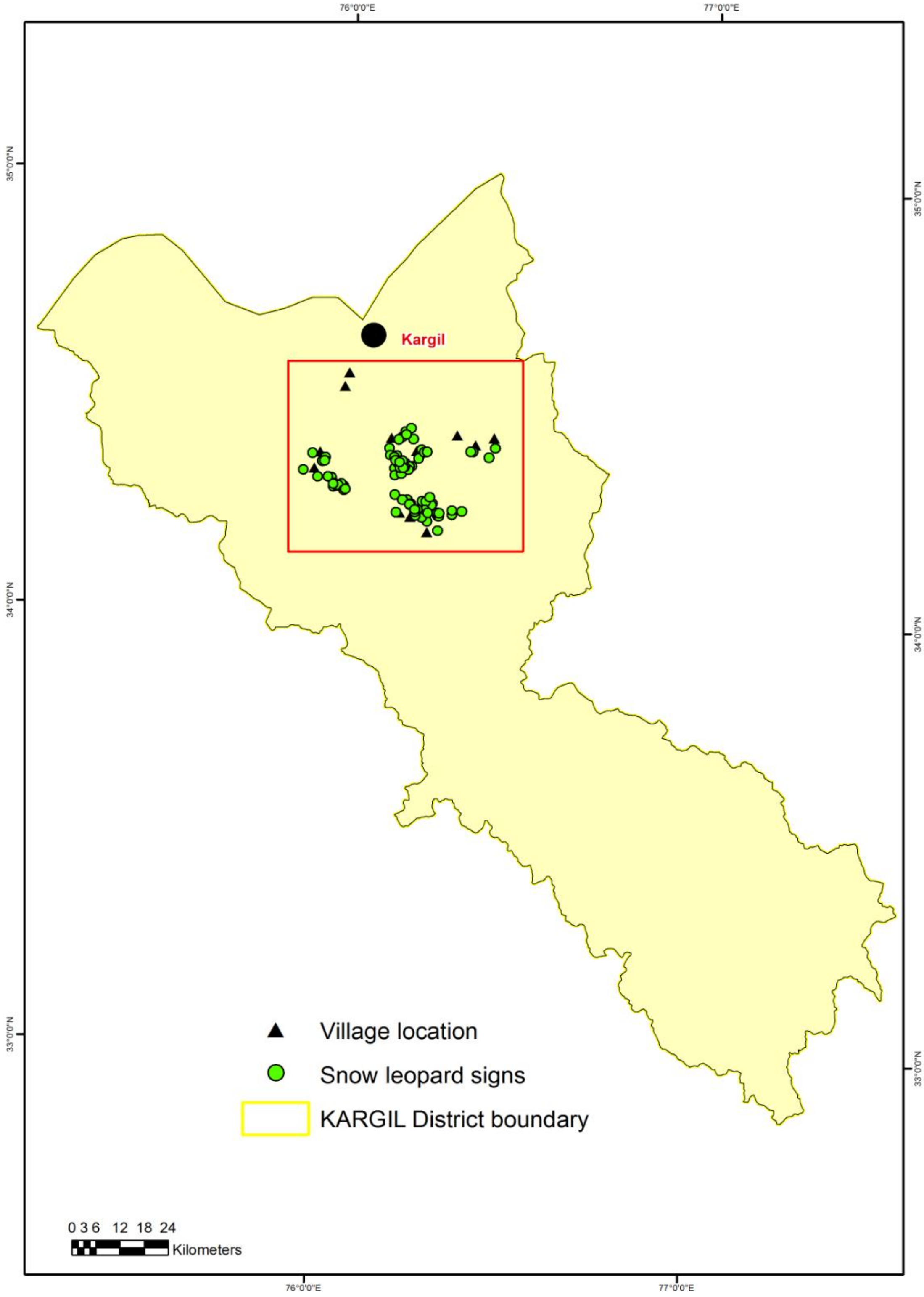
During the field work, demographic information of the stydy area such as human population, number of housholds, details about livestock, number and composition of the livestock was collected in the semi-structured questionnaire format (Appendix 4). Further,attacks on livestock and site of the attack wasalso collected from all the shepherds who graze their livestock in the snow leopard habitat.

4.4. Results

4.4.1. Occurrence and Distribution of Snow leopard and Associated Species in Kargil

A total of 13 transect or trails were sampled (1100 km effort) in Kargil to record evidences of snow leopard and associated species based ondirect and indirect evidences, and excluded unidentified signs from analysis. Snow leopard was visually encountered once in Kargil in 2009 and on five occasions in other areas of Ladakh during the study period. A total of 115 evidences of snow leopard(Figure 4.2) (scat=59, scrape=44, pugmark=11, fresh kill=1) were recorded from 3635 m to 4205 m (Table 4.1). Habitat use by snow leopard was assessed based on indirect evidence (n=115). There was no significant difference in the use of aspect (χ^2=3.26, $P < 0.05$). The eastern aspect was used (n=38) followed by northern (n=28), southern (n=26) and western (n=23). Amongst landform ruggedness categories, very broken terrain (n=65) was used more than the cliffs (n=30) and terrain with relatively smooth surface i.e. rolling (n=11) and terrain forms a level surface i.e. flat land was used least (n=9); and this difference was highly significant (χ^2=56.72, P < 0.05). The steep slopes (20°-40°) were used more (n=56) than gentle (0-20°; n=34) and very steep (n=25°). There was a significant difference in the use of various slopes as well (χ^2 = 13.27, P < 0.05) (Plate 4.1).

Figure 4.2. Locations of evidences of snow leopard in Kargil, 2009-2012



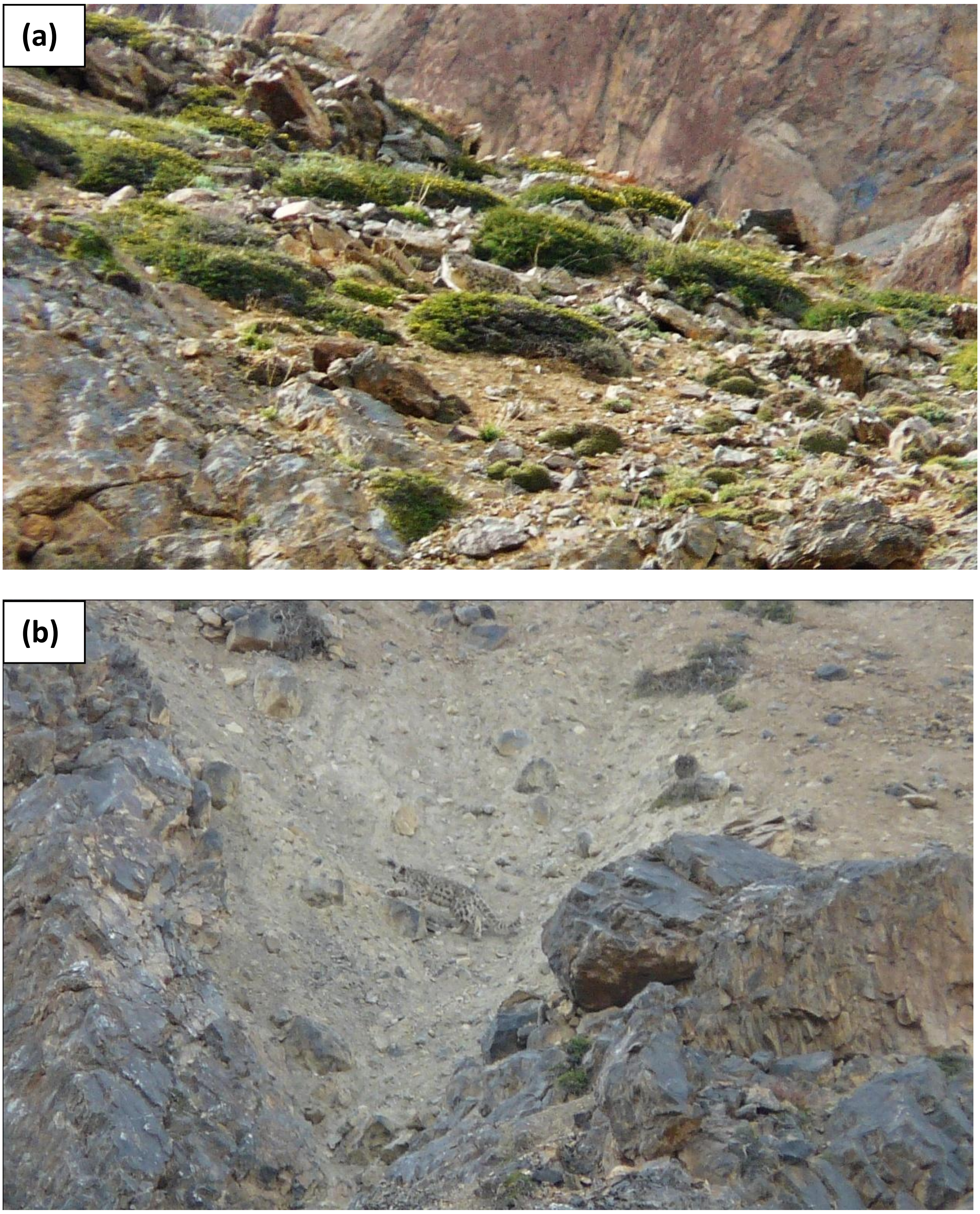
Tibetan wolf and Himalayan brown bear were the two main co-predators of snow leopard in Kargil. Amongst all the wild large carnivores in Kargil Tibetan wolf was visually encountered the most(n=24) and so were its signs (scat=53, tracks/spoor=74). Habitat use by Tibetan wolf was assessed based on the visual encounters and allindirect evidences (N=151) recorded during field work. There was no significant difference in the use of aspect (χ^2=0.07, P > 0.05). Similarly, there was no significant difference in use of various landforms (χ^2=0.023, P > 0.05). However, there was a significant difference in using various slopes (χ^2=35.46, P > 0.05) and gentle slopes were used more (0-20°; n=84) than the steep slopes (20°-40°; n=40) and more steep slopes (>40°; n=27).

It was easy to identify indirect evidences of Himalayan brown bear because it is the only bear species present in Kargil. A total of 72 evidences of brown bear (5 sightings, 19 scats, 48 tracks) were recorded. These evidences were recorded from elevation 3600 to 4750 m. There was no significant difference in the use of aspect (χ^2=0.72, P < 0.05). Most of the evidences were recorded in the shrublands (n=60) followed by near rivers or steams (n=12) and it was significantly different (χ^2=32.0, P < 0.05). All the evidences were recorded on a gentle slopes ranging from flat land to maximum 20° slope.

Table 4.1. Summary of total number of direct and indirect evidences of snow leopard and co-predators in Kargil, Jammu and Kashmir, 2009-2012

Large Carnivores	Sightings	Scats	Pugmark/Tracks	Scrapemarks	Kills	Total
Snow leopard	1	59	11	44	1	116
Tibetan wolf	24	53	74	-	-	151
Himalayan brown bear	5	19	48	-	-	72
Unidentified carnivores	-	70	74	-	20	164

Plate 4.1: Snow leopard habitat – a) Rugged terrain with snow leopard in the centre b) Snow leopard habitat – Slopes and rocky outcrops with snow leopard in the centre



4.4.2. Occurrence and Density of prey species

A total of eight vantage points were selected and data was collected on the main prey species found in Kargil i.e. Asiatic ibex and Ladakh urial. It was note worthy that Ladakh urial has restricted distribution only in Nindum areas of Kargil. A total of 54 groups of Asiatic ibex (n=445; with a mean group size of 8.24 ± 0.89) and 31 groups of Ladakh urial (n=360; with a mean group size of 11.61 ± 2.28) were recorded(Figure 4.2).

The overall density (#/km²) estimated for Asiatic ibex and Ladakh Urial was 0.45± 0.34 and 0.36 ± 0.88 respectively based on scan counts in the study area. Observations were also made along transects/trails and a total of 40 groups (n=222) with a mean of 5.55 ± 1.65 of Asiatic ibex were sighted and 12 groups (n=110) with a mean of 9.16 ± 2.9 of Ladakh urial (Table 4.3). These observations also helped in gathering data on the group composition (Table 4.2 and 4.3) of the two main prey species of snow leopard in the study site. Comparison of mean values with 95% Confidence limit (CI) of prey species along transects and vantage sampling was also evaluated and summarised in Figure 4.4. Asiatic ibex was recorded from all the vantage points but Ladakh urial was recorded only from the vantage point in Nindum Valley.

Figure 4.3. Map of the study are showingobservation points of two major prey species in Kargil, 2009-2012

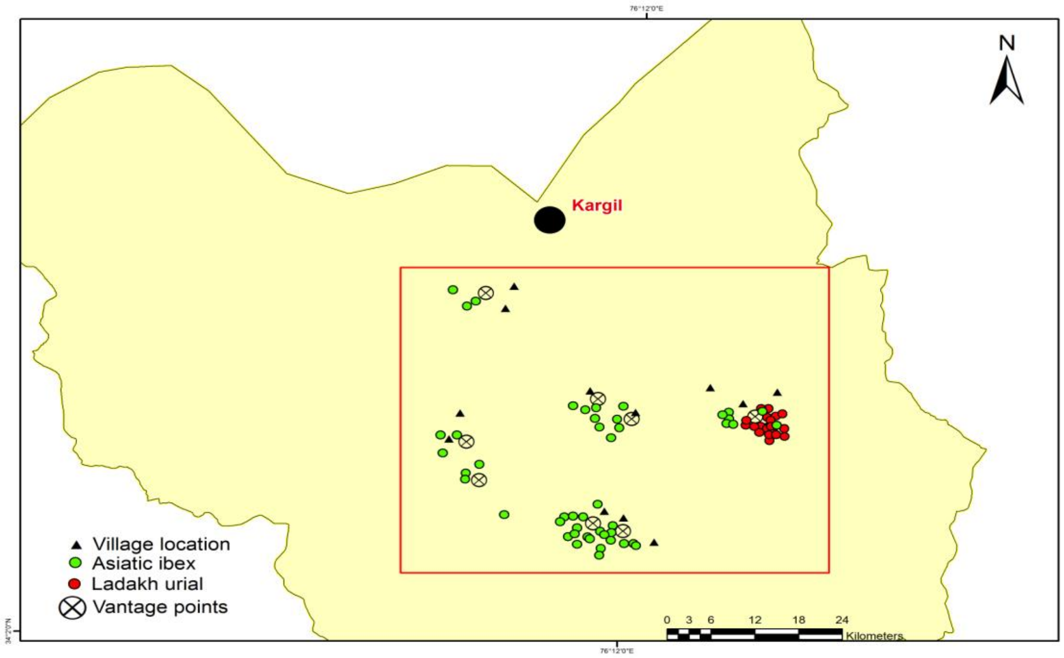


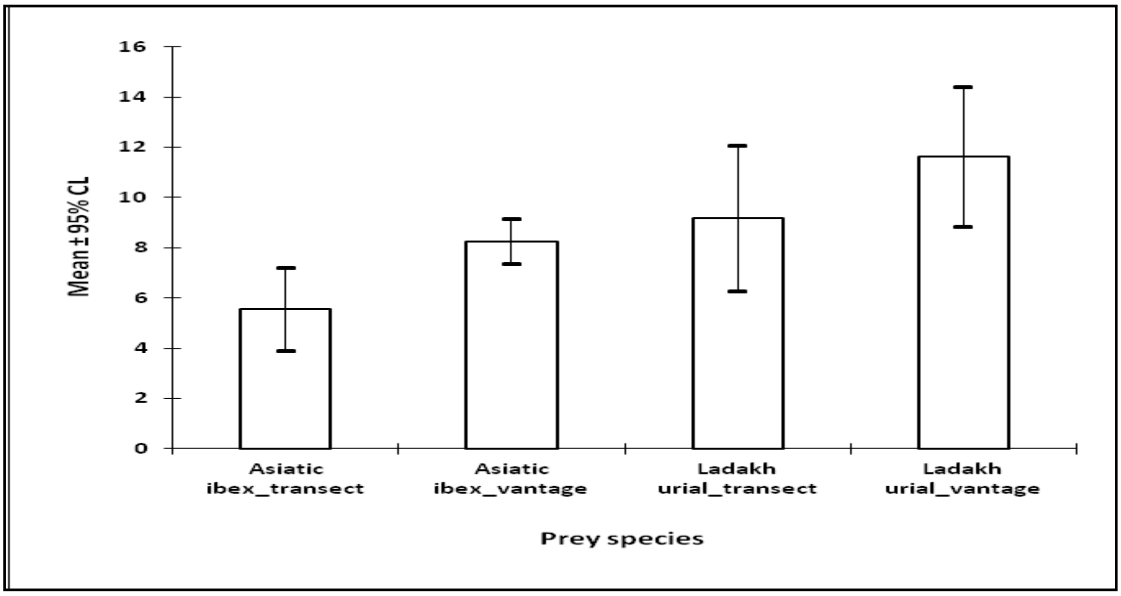
Table 4.2. Group composition of wild ungulates recorded from vantage points in Kargil study area, 2009 to 2012

Prey species	Male	Female	Sub-adult male	Sub-adult female	Young one	Uniden tified	Total
Asiatic ibex	80	101	42	85	44	93	445
Ladakh urial	62	90	35	40	78	55	360

Table 4.3. Group composition of wild ungulates recorded along trails in Kargil Kargil study area, 2009 to 2012

Prey species	Male	Female	Sub-adult male	Sub-adult female	Young one	Unident ified	Total
Asiatic ibex	53	79	22	15	33	20	222
Ladakh urial	18	33	15	12	11	21	110

Figure 4.4.Mean values of group size with 95% CI of two major prey species of snow leopard in Kargil study area (2009 to 2012).



4.4.3. Landform-use by Major Wild Prey Species in Kargil

In total, 87 groups (n=1051) of Asiatic ibex and 52 groups of Ladakh urial (n=628) were recorded during trail walk and scan smapling. This information was analysed to assess the landform use by two major wild prey species of snow leopard (Figure 4.5).

Elevation: both the prey species were recorded from elevation ranging from 4000-4500 m more than other elevation range. Asiatic ibex was recorded from elevation range 4000-4500 m (55%) followed by 4500-5000 m (12%), 3500-4000 m (22%) and 3000-3500 m (11%). Similarly, Ladakh urial was recorded from elevation range 4000-4500 m (52%) followed by 4500-5000 m (24%), 3500-4000 m (19%) and 3000-3500 m (5%).

Slope: Almost (55%) observations ofAsiatic ibex were recorded from very steep slope (angle 41-60^o) followed by steep slope 21% (angle 21-40^o), slope angle >60^o(16%) and gentle slope 8% (0-20^o). In contrast, Ladakh urial was recorded from gentle slope (51%) followed by steep slopes (32%) and very steep slope (17%)(Plate 4.2).

Dominant topographic feature: Asiatic ibex were recorded from cliff (38%) followed by hill slope (23%), valley floor (14%), ridgeline (13%), stream bed (9%) and rolling slopes (3%). In contrast, Ladakh urial were recorded from rolling slopes (41%) followed by stream bed (19%), hill slope (16%), valley floor (14%), ridgeline (6%) and cliff (4%)(Plate 4.2).

Habitat: both the prey species were recorded from shrubland than other habitats. Asiatic ibex was recorded from shrubland (50%) followed by grassland (36%) and barrenland (14%). Similarly, Ladakh urial were recorded from shrubland (48%) followed by grassland (31%) and barrenland (21%).

Figure 4.5. Landform used by snow leopard in Kargil [Asiatic ibex: n=87 (1051) and Ladakh urial: n=52 (628)]: Left to right - a) Elevation, b) Slope, c) Dominant topographic feature and d) Habitat type

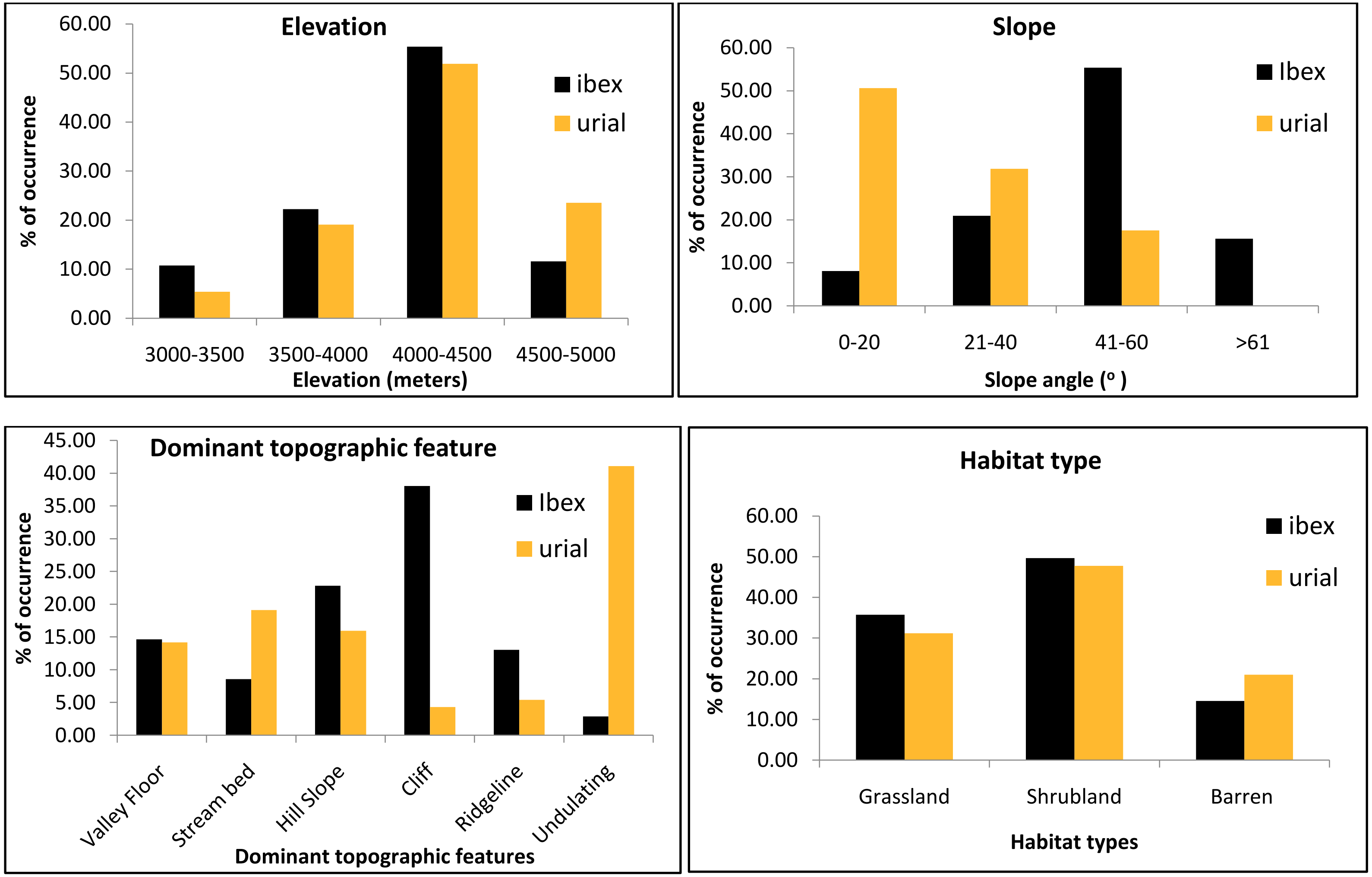
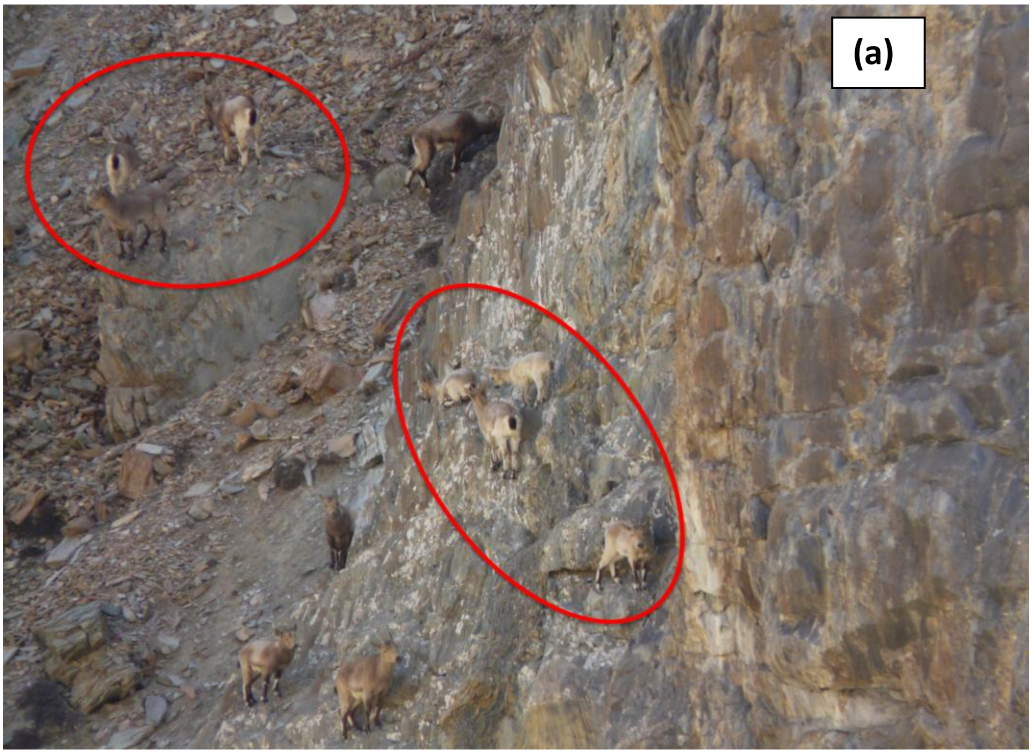


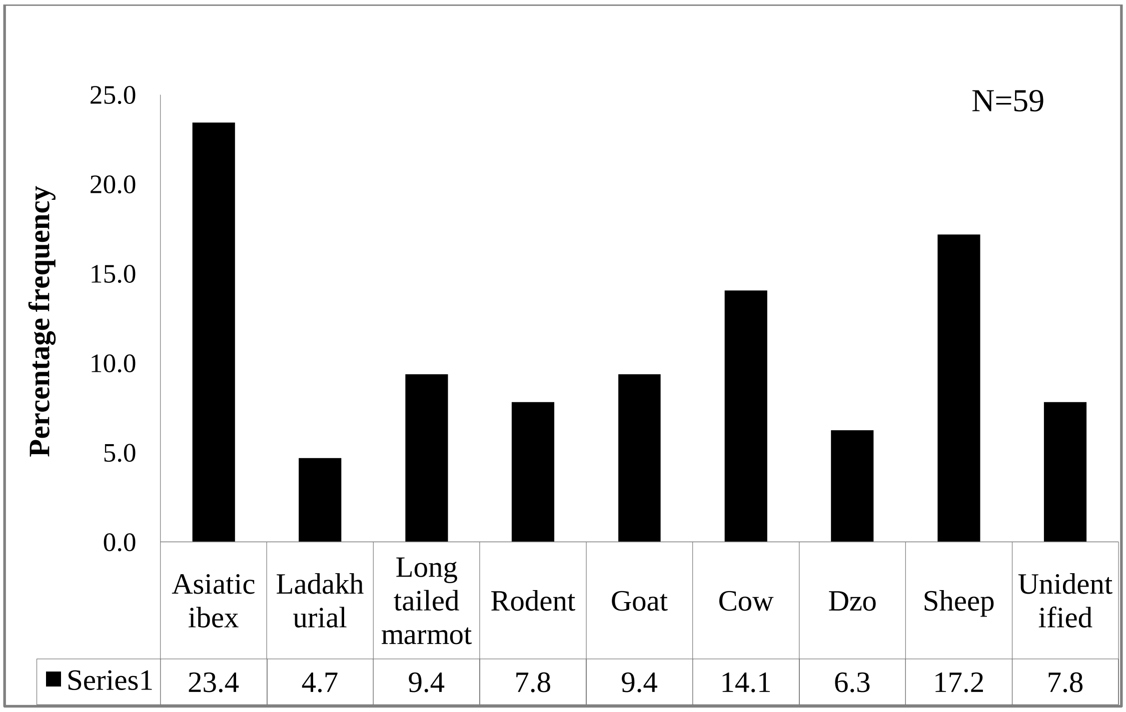
Plate 4.2: Major prey species habitat – a) Asiatic ibex at the broken terrain with rocky outcrops and very steep slope and cliffs, b) Ladakh urial at the rolling slopes



4.4.4. Food Habits of Snow leopard and Tibetan wolf

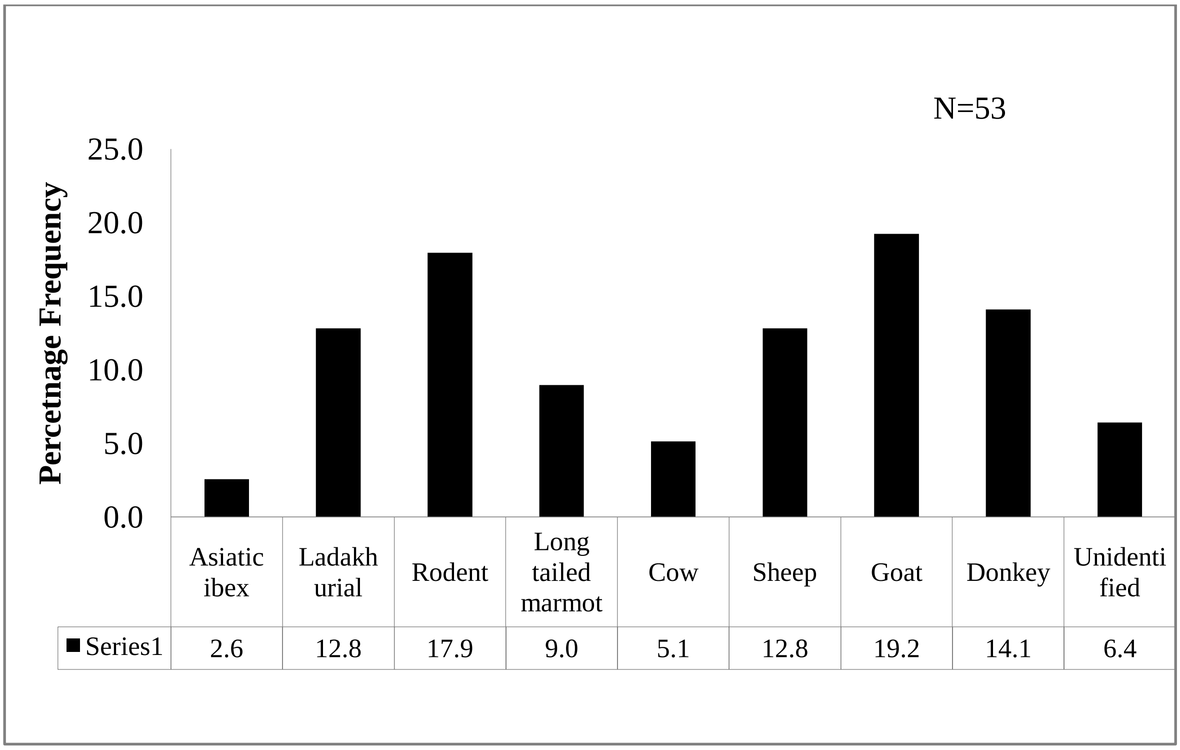
A total of 59 scats were genetically identified of snow leopard and analysed for assessing food habits. A total of nine prey species were identified on the basis of unique medullar and cuticle pattern of the hair. Among 59 scats, 32 scats were comprised of single prey, 19 scats of two prey and 08 scats of three prey species. Asiatic ibex contributed towards 23% of the diet followed by long tailed marmot (9%), rodent (8%) and Ladakh urial (5%). Livestock contributed almost 47% in the snow leopard diet. There were some unidentified vegetation and animal material (8%) also recorded in the snow leopard diet. The other details are summarised in the Figure 4.6.

Figure 4.6. Percentage frequency (%) of prey species in the diet of snow leopard in Kargil study area, 2009-2012



During surveys, 53 scats (genetically identified) of Tibetan wolf analysed. Results revealed that nine prey species were present in the diet of wolf out of which single prey species was found in 18 scats, two prey species in 26 scats and three prey species in 09 scats. The highest contribution in the diet of Tibetan wolf was by domestic goats (19%) followed by rodents (18%). Amongst wild prey, Ladakh urial contributed 13% followed by rodents, long tailed marmot (9%) and Asiatic ibex (3%). The rest of the prey species are summarised in Figure 4.7. Similar to snow leopard some unidentified material (6%) in the form of vegetation, animal and insectswere also recorded in the scats.

Figure 4.7. Percentage frequency (%) of prey species in the diet of Tibetan wolf in Kargil study area, 2009-2012



4.4.5. Demographic Information of the Study Area in Kargil and Availability of Domestic Prey to Snow leopard and other Large Carnviores

A total of 12 villages fall under the areas surveyed in Kargil. Total human population of these villages was 5232 with 664 households. The villagers owned various types of livestock including goat, sheep, cow dzo-dzomo, donkey, horse and yak. There were about 13356 total livestock reported in the 12 villages surveyed in the study area in Kargil (Table 4.4).

Table 4.4. Demographic information of the study area collected during the study period in Kargil

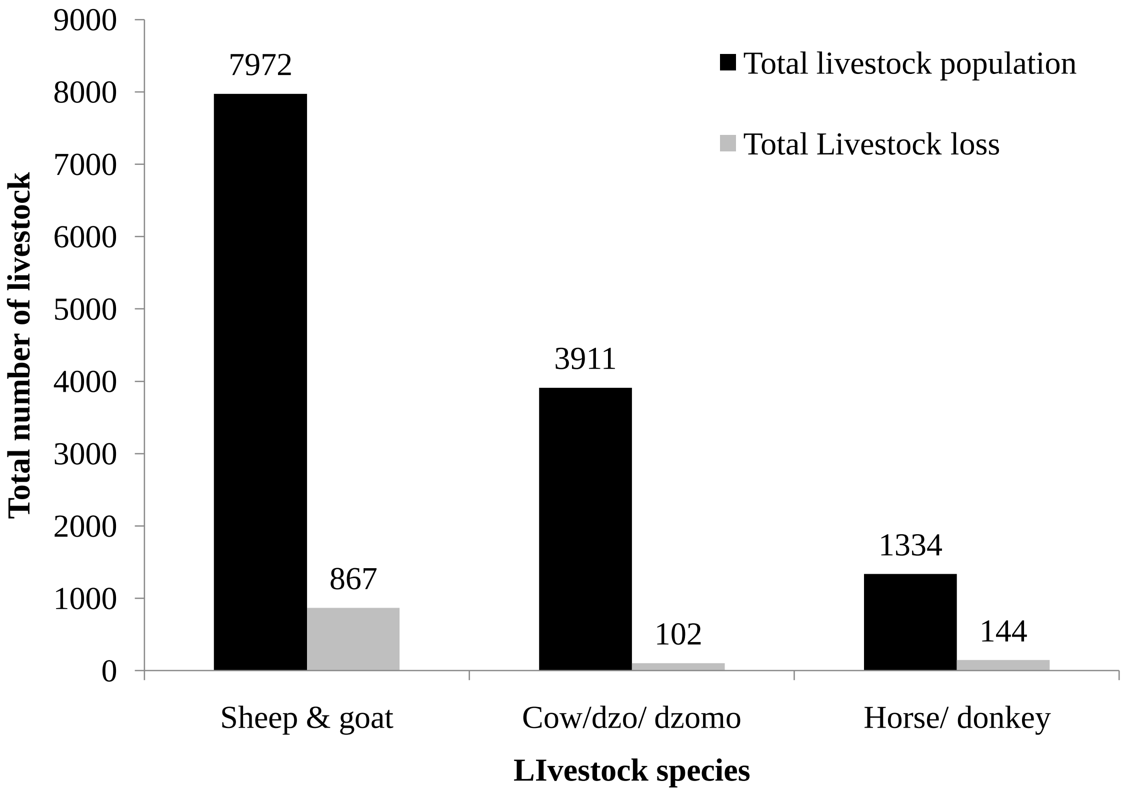
Village	House-holds	Human population	Goat and sheep	Donkey/horse	Cow	Dzo/dzomo	Yak	Total livestock population
Bartoo	79	878	375	458	526	67	2	1428
Pangbar	20	134	325	4	70	90	1	490
Yarkashing	20	122	325	2	70	90	0	487
Bilching	30	234	350	4	100	130	1	585
Umba	100	967	1760	433	389	87	25	2694
Ichoo	18	123	266	62	21	38	0	387
Mulbek	176	1340	1345	131	337	250	14	2077
Shergandi	30	254	341	0	68	40	3	452
Fokar	48	336	948	105	199	250	20	1522
Kanji	50	267	678	61	430	300	38	1507
Sapi	90	560	1069	57	102	230	18	1476
Shangla	3	17	190	17	20	7	17	251
Total	**664**	**5232**	**7972**	**1334**	**2332**	**1579**	**139**	**13356**

4.4.6. Large Carnivore-Human Conflicts

Livestock depredation by large carnviors was the major component of the large carnivore-human conflicts in Kargil, therefore, it was crucial to identiry the main predator species involved in livestock depredation. Identification of predator was done based on the description provided by the villagers under the guidelines developed by Maheshwari et al., (2014), such as; have you seen the predator, description of the predator, number of livestock killed, place of depredation, how the predator was identified if not seen (indirect evidence).

In total, goat and sheep population was 7972 in the 12 villages surveyed out of which large carnviores killed 867 i.e. almost 10.8% loss during 2009-12 (Plate 4.3). Similarly, 10.7% loss was reported in the horse/ donkey population followed by 2.6% loss was reported in the cow/ dzo/ dzomo population during the study period (Figure 4.8).

Figure 4.8. Percentage of livestock loss against total livestock population due to large carnviores during 2009-12 in Kargil.



Livestock depredation was recorded in all the 12 villages surveyed over three years of monitoring. Out of all 12 villages surveyed, 198 sheep and goats, 21 cows/ dzo/

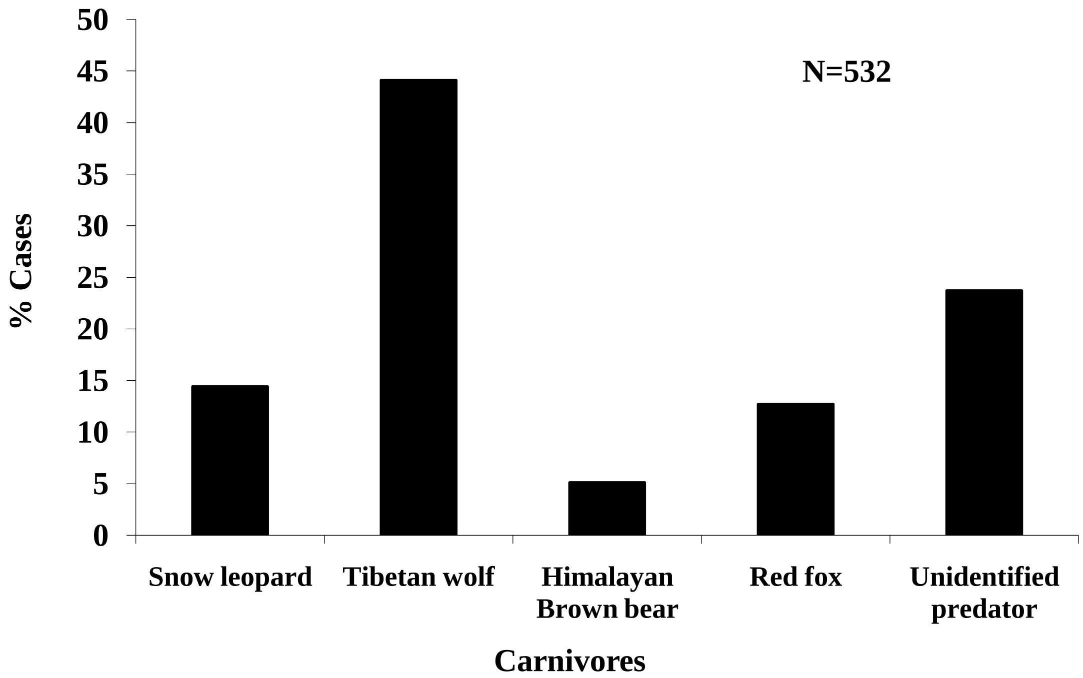
dzomo (yak hybrid) and 21 horses/ donkey were lost to snow leopard over three years. Detail livestock depredation by snow leopard and associated carnivores is summarised in Table 4.5. Villagers reported that red fox was also involved preying upon young ones of sheep and goat and poultry. In total 74 young ones of sheep/goat were killed by red fox and over 100 domestic fowls were also lost to red fox.

Table 4.5. Livestock depredation by large carnivores in Kargil over three years (2009, 2011 and 2012)

Large carnivores	Goat/sheep	Cow/dzo/ dzomo	Horse/ donkey	Total livestock loss
Snow leopard	198	21	21	240
Tibetan wolf	386	32	68	486
Himalayan brown bear	37	0	0	37
Unidentified carnivores	246	49	55	350
Total	**867**	**102**	**144**	**1113**

Amongst large carnivores, snow leopard and Tibetan wolf were the two main wild predators in Kargil. Out of 12 villages surveyed in Kargil, total 532 depredation cases were reported by villagers due to large carnivores during 2009, 2011 and 2012(Figure 4.9).Almost 44% livestock depredation cases were reported of Tibetan wolf followed by unidentified predator (28%). In case, villagers could not identiy the predator involved in depredation were considered as unidentified predator. Altogether, 8.3% livestock was lost to the large carnviores in the 12 sampled villages during the study period.The impact of livestock depredation by snow leopards and other sympatric carnivores such as the Tibetan wolf on the local herding communities was considerable.

Figure 4.9. Cases of livestock depredation (%) by large carnivores reported in Kargil from 2009 to 2012.



Furthermore, livestock depredation tended to be slightly site specific, out of total livestock depredations cases reported (n=532), 8.8% cases (n=47) were reported when they were in the open range or during unsupervised grazing whereas 36.7% cases (n=195) were reported due to negligence of the guard/ shepherd and almost 54.5% cases (n=290) were reported from corralled sheep, goat and young ones of horse/ donkey, cow, yak, dzo/ dzomo.

Plate 4.3: Photographs of co-predators and key prey species of snow leopard in the study site - a) Tibetan wolf, b) Himalayan brown bear, c) Red fox d) Asiatic ibex,e) Ladakh urial, f) Long tailed marmot

(a)

Tibetan wolf photograph © Basant Kumar Sharma

(b)


2010-11-08 7:39:56 AM M 2/2
-15°C
(c)
KARGIL
RECONYX


(d)

4.5. Discussion

Similar to previous studies (Sathyakumar, 2003; Jaypal, 2000), this study also confirmed the snow leopard presencein Kargil areas of Ladakh. Previous studies were fairly rapid ones and helped in designing the present study. This study stands the first attempt in providing comprehensive information about snow leopard, co-predators, their prey and interaction with the local communities in Kargil. Snow leopard depredation on Asiatic ibex was observed during the sighting of this elusive cat. The overall duration of the sighting was 17 minutes in which snow leopard chased a group of Asiatic ibex (n=32) but could not hunt and rested over a ridge. The scats, tracks and fresh scrapes were observed and collected at sighting site but a high percentage of this track could not be traced due to a rocky terrain. Nevertheless, it helped in acquiring substantial information about the main study species.

In this study, the principal prey of snow leopard, Asiatic ibex were found mostly across the rugged and broken terrain and snow leopard evidence were also collected from similar habitats. Further, Asiatic ibex contributed (23%) in the snow leopard diet. Thus, it seems that the distribution of snow leopard coincided with the presence of major prey species. Overall, it was found that the snow leopard had specific habitat preferences. It appears that the characteristic features of snow leopard habitat in Kargil is shrub land with rugged and broken terrain.

In contrast, Tibetan wolf was found to be opportunistic, as there was no significant difference in the various habitat parameters (except slope) from where evidences were recorded. Tibetan wolf was the most visually encountered (n=24) large predetor during the study period in Kargil. Out of 24 sightings, 15 sightings occurred near the human habitation (0.4 to 1.5 km from villages). Further, dietery analysisrevealed dependency of Tibetan wolf on variety of food items with very less preference to any specific prey species. Unlike snow leopard diet was inclined towards Asiatic ibex.

The diet of a carnivore reflects the availability of prey and the morphological and physiological adaptations of the carnivore to the location to capture and digest the prey species. Blue sheep is reported as one of the major prey species of snow leopard in Hemis NP, Leh (Chundawat and Rawat, 1994) but in the areas sampled of Kargil, blue sheep is not present and this niche is filled by Asiatic ibex, which was reflected in the diet of snow leopard in this study. The presence of vegetation in snow leopard scats has been reported earlier by Chundawat and Rawat (1994) who reported 41% plant material in snow leopard diet including an interesting observation of snow leopard feeding on *Myricaria* plant.

In the diet analysis, domestic livestock comprised 47% of the diet of snow leopard while for Tibetan wolf domestic livestock comprised 51.2% of the diet. It showed the high proportion of livestock depredation and represents the extreme of large carnivore-human conflicts in Kargil. This should be mitigated to ensure the better survival of imperial large carnivores of these areas.

Local communities of the study area were primarily agro-pastoral and livestock is the major source of their income. Thus,loss of livestock by predators such as snow leopard, Tibetan wolf and Himalayan brown bear instigate the retaliatory killing of these carnivores (Oli et al., 1994; Mishra, 1997; Jackson and Wangchuk, 2004).About 3 to 18% of local livestock holdings are reportedly lost to snow leopards annually (Oli et al., 1994; Mishra, 1997; Jackson and Wangchuk 2004; Namgail et al., 2007; Maheshwari et al., 2010). Similarly, this study reported about 8% livestock loss to the large carnviores of the study area.

This study was conducted in the remote villages of Kargil and during interviewing the villagers on the large carnivore-human conflicts, initially the villagers were expecting compensation from us and therefore they seemed to quote very high losses of livestock during the questionnaire surveys. To overcome this bias, the motive of surveys and institutional information was provided to the local communities. It was much clear that there is no scope of paying compensation but the view of locals will be taken to decision makers through findings of these surveys (Maheshwari et al., 2014).

The Nindum valley has a population of the Ladakh urial and nowhere else in the study area Ladakh urial were recorded neither reported by the local communities. Also, Ladakh urial are inhabitants of rolling slopes (Fox et al. 1991).

The primary objective of this study was to identify gaps in the existing knowledge on snow leopard, gather base-line information on snow leopard and associated species, identify potential snow leopard habitats and best use of this all information by providing inputs in the Ministry of Environment, Forests and Climate Change's (MoEF&CC) Project Snow Leopard.

Findings of this study can be utilized to plan a more specific study for future conservation interventions of wildlife in Kargil with special emphasis on mitigation of carnivore-human conflicts. Further, there is great need to do some more intensive studies in Kargil on snow leopard and associated species in the remaining areas to understand the population dynamics and more importantly mitigate the carnivore-human conflicts.

Plate 4.4: Photograph of livestock killedby snow leopard in the traditional corral in Kargil

CHAPTER- 5 : CONSERVATION AND MANAGEMENT OF SNOW LEOPARD AND CO-PREDATORS WITH SPECIAL REFERENCE TO SNOW LEOPARD-HUMAN CONFLICTS IN UTTARAKHAND AND HIMACHAL PRADESH

5.1. Introduction

Continuous efforts have provided meaningful information on Trans-Himalayan wildlife in Uttarakhand such as Green (1982 and 1985), Fox et al. (1988); Fox (1994); Kala and Rawat (1999); Rawat (2005); Sathyakumar(1993, 1995, 2004); Maheshwari et al. (2013); Habib et al., (2016) but a comprehensive information was lacking on snow leopard from the Greater and Trans-Himalayan region of the State.

Similarly, in Himachal Pradesh studies have been focused on snow leopard and associated species in the Trans-Himalaya such as Great Himalayan National Park by Vinod and Sathyakumar (1999); and major studies conducted in Spiti, Kibber areas of Himachal Pradesh by Bhatnagar (1997); Mishra (1997, 2000); Mishra et al. (2003 and 2010); Suryawanshi et al. (2012, 2013 and 2014) but Greater-Himalayan region was lacking on information on snow leopard.

Keeping this all in view, this study was conducted in the Great and Trans-Himalayan region of Uttarakhand and Greater-Himalaya of Himachal Pradesh (Table 5.1).

5.2. Objectives

This chapter deals with the following objectives:

a) To determine occurrence and distribution and landform use by snow leopard

b) To assess food habits of snow leopard

c) To determine occurrence of prey species of snow leopard

d) To assess snow leopard-human conflicts

5.3. Methods

Extensive field surveys were conducted (Table 5.1) from April to November, 2008. Shepherd routes and defence patrolling routes were followed above 3000 m areas in Uttarakhand and Himachal Pradesh.

5.3.1. Determining Conservation Status and Distribution of Snow leopard and Co-predators

Shepherds routes and defence patrolling routes were followed to establish the current distribution of snow leopard, co-predators and their prey in Kargil. Similar to sign-surveys in Kargil, SLIMS (Jackson and Hunter, 1996, McCarthy et. al., 2008) were followed to conduct sign surveys in the snow leopard habitats above 3000m in Uttarakhand and Himachal Pradesh. Unlike, sign-surveys in Kargil, two types of signs were recorded in Uttarakhand (scrapes and spray/ urine could not be found in Uttarakhand):

a) **scat-** snow leopard scat tends to be uniform in diameter (an average 1.8 cm) and comprises of several slightly constricted cords or connected with blocky segments (up to 8-10 cm; Janecka et al.,2008) with blunt ends

b) **pug-marks** (*i.e.* tracks)

Trails were marked in potential snow leopard habitats (such as ridgelines, cliff edges) were used where snow leopard signs are most likely to be found. These routes were walked by a single observer and all signs of snow leopard and co-predators (such as common leopard, Asiatic black bear (*Ursus thibetanus),* Himalayan brown bear (*Ursus arctos isabellinus)* and Tibetan wolf (*Canis lupus chanko*) were recorded. At each site, information on location, date, elevation, slope, aspects, land ruggedness, habitat types, distance from human habitation and nearest water point were recorded with the help of GPS and ocular estimation. The habitats where snow leopard evidence were found; classified based on the parameters (such as landforms and habitats) of the Snow Leopard Information Management System (SLIMS).

Since, it was difficult to distinguish the scats of sympatric carnivores such as snow leopard, common leopard and Tibetan wolf. Therefore to minimise the chance of error of wrong identification of scats, species identification was done on the basis of genetic analysis of scats collected from study area.

Table 5.1. Details of routes taken and survey efforts in Uttakhand and Himachal Pradesh

Route taken	Distance walked (Km)	
	Surveyed distance	Total distance walked
Govind National Park and Wildlife Sanctuary		
Sankri to Taluka	-	12
Taluka to Osla	-	15
Osla to Harki Doon	12	12
Harki Dun to Mandal lake	04 (*2)	08
Harki Doon to Osla	12	12
Osla to Ruinsara	10	10
Ruinsara Valley	04	04
Ruinsara to Osla	14	14
Osla to Taluka	-	15
Taluka a to Sankri	-	12
Gangotri National Park and Nelong Valley		
Gangotri to Bhojbasa	14	14
Bhojbasa to Tapovan	08	08
Tapovan	04	04
Tapovan to Bhojbasa	08	08
Bjojbasa to Gangotri	14	14
Bhairoghati to Sonam* (by vehicle)	42 (*2)	84
Nelong Valley	11	11
Nelong to Naga to Jadon	13 (*2)	26
Naga to Sonam	10	10
Sonam to Tripani	10 (*2)	20
Sonam to Hindoligad	27	27
Sundardhunga Glacier		
Khalidhar to Dhakuli	-	11
Dhakuli to Jatoli	-	15
Jatoli to Kothalia	-	16

Kothalia to Madtoli	5.5 (*2)	11
Kothalia to Khati	-	11
Khati to Khalidhar	-	22
Askot Wildlife Sanctuary		
Garbadhar to Bundi	-	19
Bundi to Gunji	15	18
Gunji to Nabidhang	18	18
Nabidhang to Om Parvat	5.5 (*2)	11
Nabidhang to Gunji	18	18
Gunji to Bundi	15	18
Bundi to Garbadhar	-	19
Munsiari-Dung		
Dummer to Rergari	-	15
Rergari to Relikot	-	16
Relikot to Milam	18	18
Milam to Dung	09 (*2)	18
Milam to Relikot	18	18
Relikot to Lilam	-	24
Lilam to Selapani	-	09
Nanda Devi Biosphere Reserve		
21 Point to Sumna	-	05
Sumna to Lapthal	14	14
Lapthal to Chudang	08	08
Chudang to Lake	02	02
Chudang to Laha	04 (*2)	08
Chudang to Lapthal	08	08
Lapthal to Sumna	14	14
Sumna to Rimkhim	14	14
Rimkhim to Sumna	14	14
Sumna to 21 Point	-	05
Valley of Flowers National Park		
Govindghat to Ghangharia	-	13

Ghangharia to Kunt Khal	07 (*2)	14
Ghangharia to Tipra Glacier	07 (*2)	14
Ghangharia to Govindghat	-	13
Great Himalayan National Park		
Gushaini to Rolla	-	10
Rolla to Nada	-	12
Nada to Kobri	08	08
Kobri to Rolla	08	20
Rolla to Gushaini	-	10
Sangla Wildlife Sanctuary		
Chitkul to Nagasti	-	03
Nagasti to Dumti	18	24
Dumti to Chitkul	18	27
Kugti Wildlife Sanctuary		
Dharol to Kugti	-	07
Kugti to Duggi	-	08
Duggi to Relang	3.5 (*2)	07
Duggi to Kugti	-	8
Kugti to Baggi	01	07
Baggi to Tal	2.5 (*2)	05
Baggi to Kugti	01	07
TOTAL	**504**	**987**

(*2): return track.

5.3.2. Assessing Occurrence of Prey Species

Survey routes were scanned carefully using an 8X40 binocular for presence of major prey species such as blue sheep, Asiatic ibex and marmot. On each sighting, animals were counted. The occurrence of many smaller prey species such as rodents, pika and hare was difficult to determine because of their habitat preference and behaviour.

5.3.3. Assessing Food habits of Snow leopard

All scats were stored in polybags with information on GPS location, place and habitat. After the species identification using DNA based analysis (snow leopard, n=09) scats were oven dried and then teased out for the indigestible material like hairs, hooves, bones and other remains (Mukherjee et al., 1994, Maheshwari and Khan, 2006). The scats were crushed and observed carefully for the presence of indigestible macro elements like claws, feathers etc. and six hairs were collected randomly per scat (Chundawat and Rawat, 1994).

The hairs were kept in xylol (xylene and ethyl alcohol) for 24 hours. Slides were prepared with three hairs per slide i.e. two slides for each scat, by mounting hairs in DPX. All the slides were examined under microscope. These hairs were compared with known reference slides which were prepared from the hairs collected from different kills of wild ungulates and domestic livestock also. Reference hairs were also taken from different parts of the body such as belly, hind and neck portion to minimize the bias of any unknown hair extracted from the scat as there is a considerable difference of different hairs within the body, microscopically. The hairs were identified on the basis of structural differences like medullary portion, cuticle, cortex and pigmentation in the cells (Koppikar and Sabins, 1975). The long hairs such those of Asiatic ibex, yak and cow were cut in to three pieces of proximal, middle and distal and then examined under microscope.

5.3.4. Assessing Snow leopard-Human Conflicts

During the field work, information on the attacks on livestock and site of the attack was gathered from all the shepherds who graze their livestock in the snow leopard habitat at more than 3000 m. Details about livestock such as number of livestock and animals owned by the family and were asked informally in the semi-structured questionnaire format (Appendix 4).

5.3.5. Assessing Threats to Snow leopard and its Habitat

During this survey, information such as evidence of human and livestock, developmental activity (road construction and hydroelectric dams), permanent or temporary human settlement present, construction of roads, tourism, signs of grass and tree cutting and lopping was collected. In addition, discussions were held with locals and forest department on the threats to snow leopard and its habitat. On the basis of the intensity of disturbances, these were categorized as high, medium and low – as described below:

Pressures*	High	Medium	Low
Grazing	10-15 livestock groups	6-9 livestock groups	<5 livestock group
Human settlements	26-50 households	15-25 households	<15 households
Tourism	75-200 tourists / day	20-74 tourists /day	<20 tourists/ day

*Pressures are further explained below:

Grazing: Average number of livestock in one group was 500. Only seasonal grazing takes place in snow leopard habitats

Human settlements: permanent / temporary

Tourism: Number of tourists per day and garbage material dumped by tourists

The intensity of pressures was analyzed with the Software *Miradi* Version 2.4 under three step analyses: scope, severity and irreversibility defined below:

I. Scope -Most commonly defined spatially as the proportion of snow leopard and its habitat that can reasonably be expected to be affected by a threat within ten years, given the continuation of current circumstances and trends.

Very High: The threat is likely to be pervasive in its scope, affecting the snow leopard and / or its habitat across all or most (71-100%) of the surveyed areas.

High: The threat is likely to be widespread in its scope, affecting the snow leopard and / or its habitat across much (31-70%) of the surveyed areas.

Medium: The threat is likely to be restricted in its scope, affecting the snow leopard and / or its habitat across some (11-30%) of the surveyed areas.

Low: The threat is likely to be very narrow in its scope, affecting the snow leopard and / or its habitat across a small proportion (1-10%) of the surveyed areas.

II. Severity - Within the scope, the level of damage to snow leopard and its habitat from the threat that can reasonably be expected, given the continuation of current circumstances and trends. For habitat, it is typically measured as the degree of destruction or degradation within the scope. For snow leopard, usually measured as the degree of reduction of its population within the scope.

Very High: Within the scope, the threat is likely to destroy or eliminate, or reduce snow leopard and / or its habitat by 71-100% within ten years or three generations.

High: Within the scope, the threat is likely to seriously degrade/reduce snow leopard and/or its habitat by 31-70% within ten years or three generations.

Medium: Within the scope, the threat is likely to moderately degrade/reduce the target or reduce snow leopard and/or its habitat by 11-30% within ten years or three generations.

Low: Within the scope, the threat is likely to only slightly degrade/reduce the target or reduce snow leopard and/or its habitat by 1-10% within ten years or three generations.

III. Irreversibility (Permanence) - The degree to which the effects of a threat can be reversed and the snow leopard and/or its habitat affected by the threat restored.

Very High: The effects of the threat cannot be reversed and it is very unlikely the snow leopard and/or its habitat can be restored, and/or it would take more than 100 years to achieve this (*e.g.*, habitat converted to a reservoir).

High: The effects of the threat can technically be reversed and the snow leopard and/or its habitat restored, but it is not practically affordable and/or it would take 21-100 years to achieve this (*e.g.*, wetland converted to agriculture).

Medium: The effects of the threat can be reversed and snow leopard and/or its habitat restored with a reasonable commitment of resources and/or within 6-20 years (*e.g.*, grazing by livestock).

Low: The effects of the threat are easily reversible and the snow leopard and/or its habitat can be easily restored at a relatively low cost and/or within 0-5 years (*e.g.*, hunting of prey base of snow leopard).

Target-Threat Rating - Miradi calculates threat ratings using a rule-based system for combining the scope, severity, and irreversibility criteria. These procedures involve specifying rules as to how different parameters should be combined with one another.

5.4. Results

5.4.1. Occurrence, Distribution and Landform-use by Snow leopard

A total of 13 evidence of snow leopard were found during the survey. These evidences were in the form of scats (9) which were genetically identified and pugmarks (4) (Figure 5.1). Out of 13 snow leopard evidence, nine were recorded from Gangotri NP, two from Nanda Devi BR and one each from Govind NP and WLS and Askot WLS.

Snow leopard evidences were recorded from 3190 to 4115m with mean altitude of 3783 m. Almost 53.9% evidences were recorded from shrubland habitat and 21.4% evidence were recorded from grassland and barren land. About 31% of the snow leopard evidences were recorded at a slope of 35°. About 39% of the evidences were found on the hill-slope followed by valley floor (30%) and cliff (15%). Details about land form and habitat use by snow leopard is shown in Figure 5.2.

Figure 5.1. Map showing locations of evidence of snow leopard in Uttarakhand, 2008

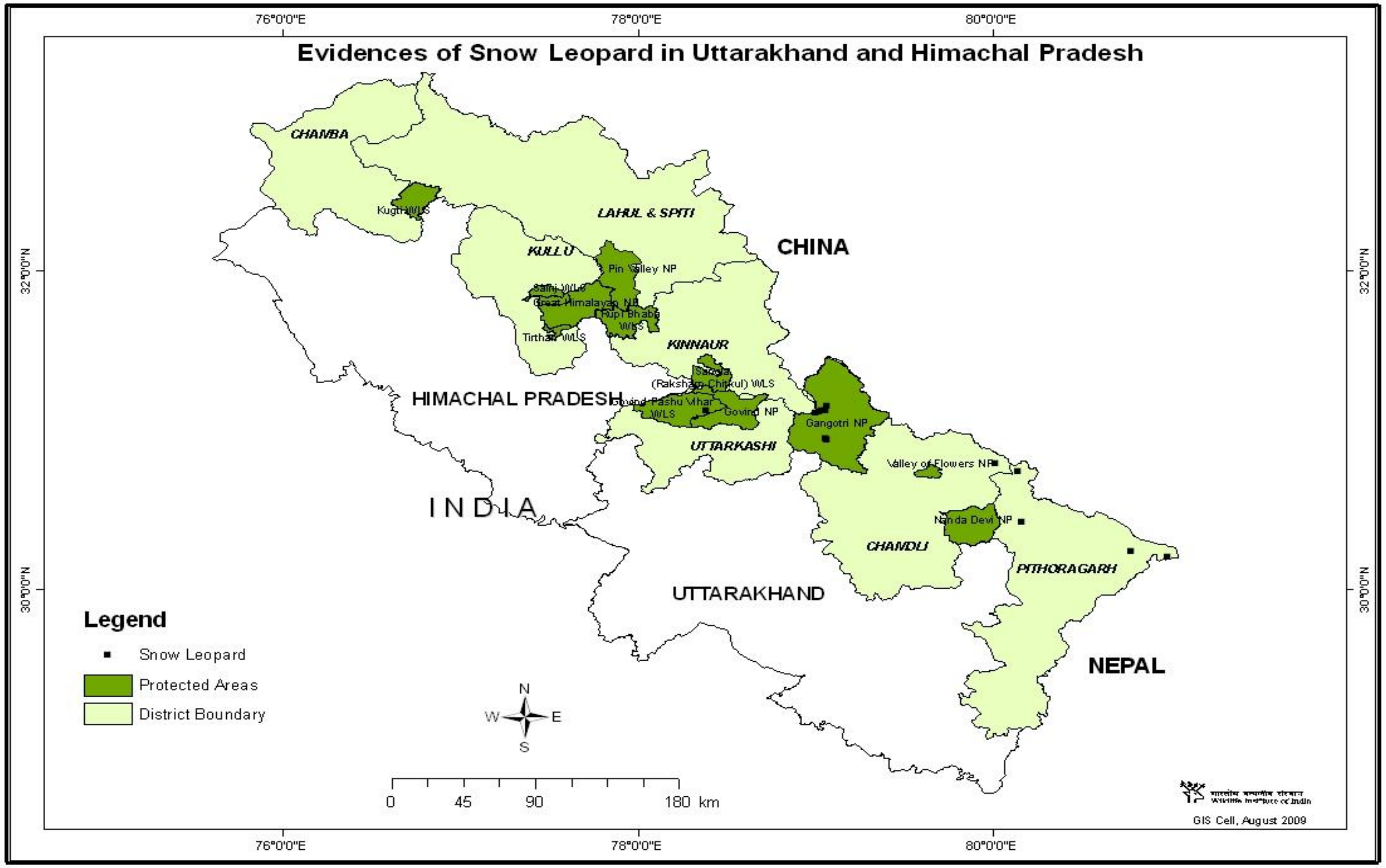
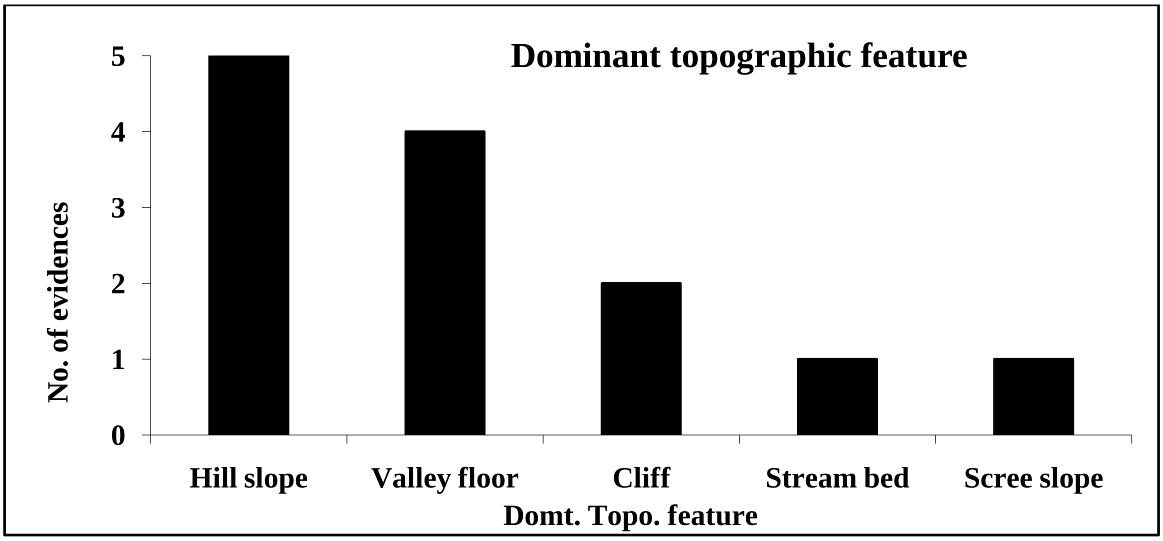
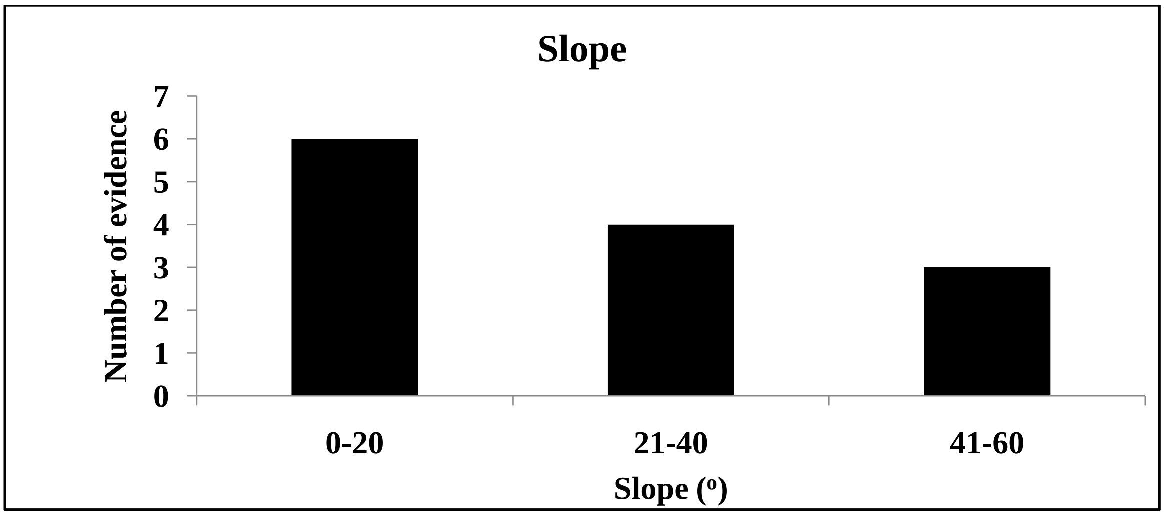
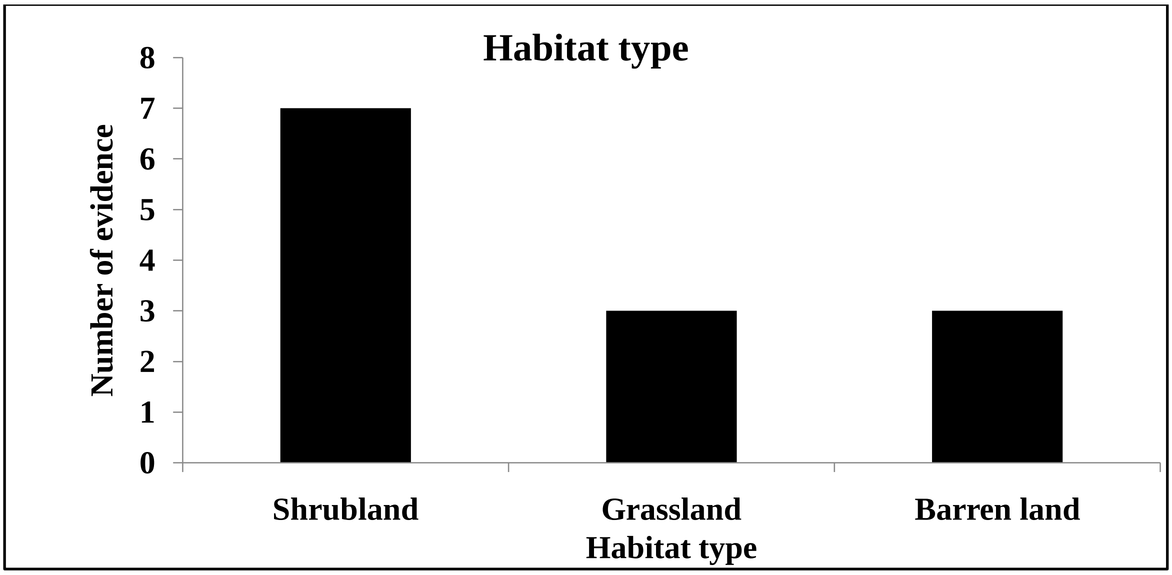
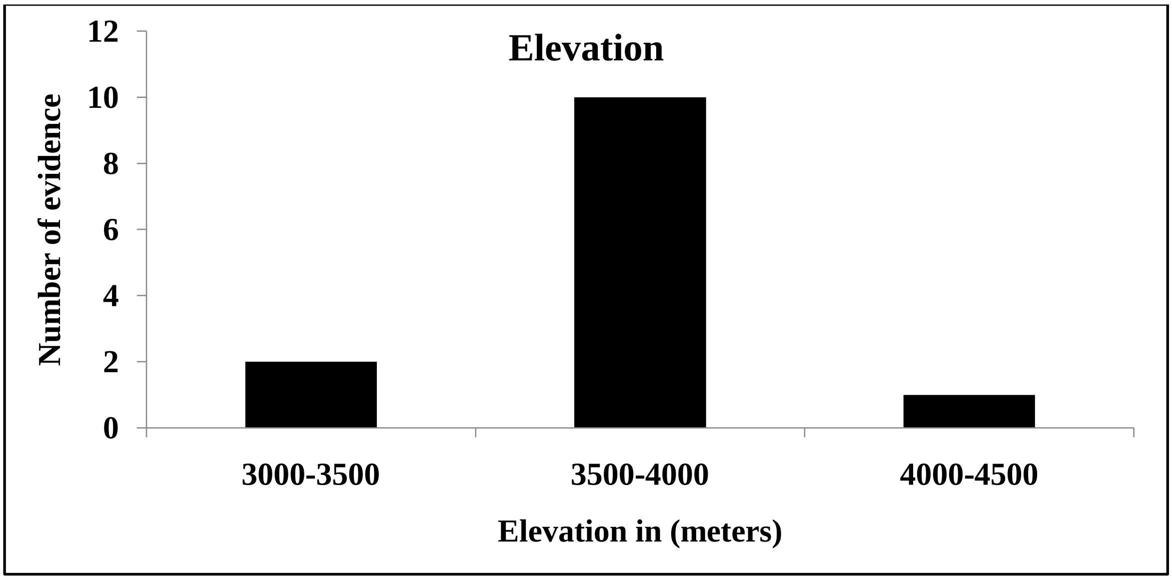


Figure 5.2. Landform use by snow leopard (n=13) in Uttarakhand and Himachal Pradesh, 2008





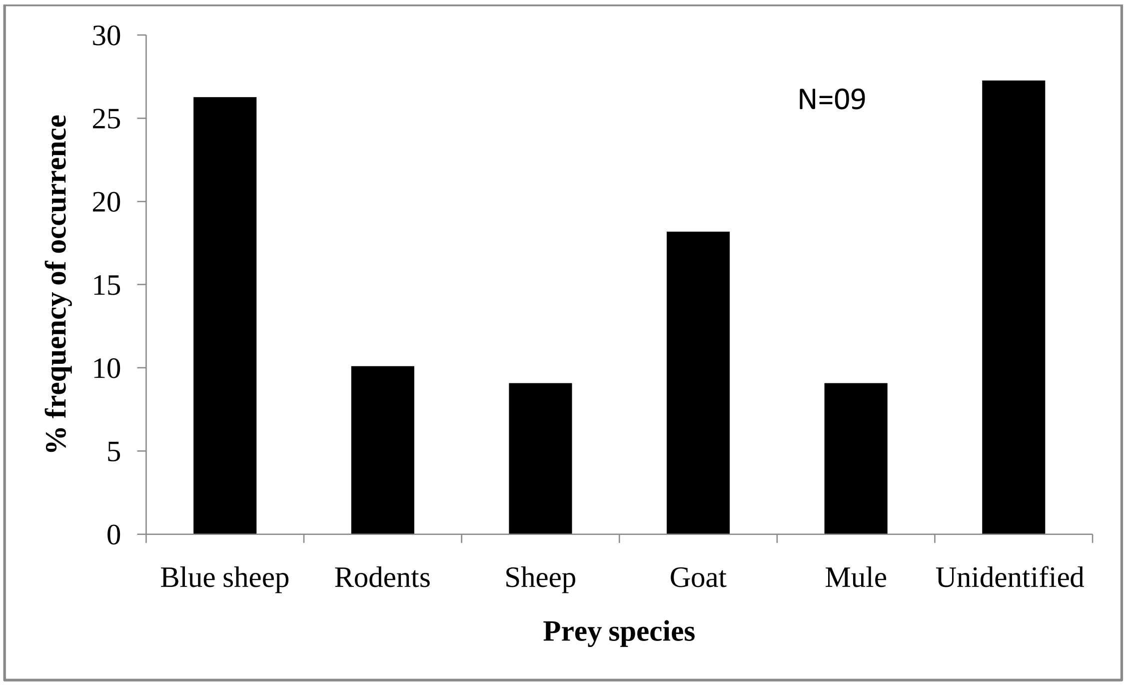




5.4.2. Food Habits of Snow leopard

A total of nine scats were identified genetically from the survey were analysed for assessing the food habits of snow leopard. Each prey item was examined under microscope and recorded for the cuticle and medullar pattern of hairs. A total of six prey species were identified in the scats (Figure 5.3) while three prey species could not be identified. Some plant material was also found in the scats. About 80% of the scats had single prey and 20% of the scats consisted two prey species. Scat analysis showed that 36% of snow leopard diet comprised of domestic livestock (mule, goat and sheep) followed by blue sheep (18.2%) and rodents (18.2%).

Figure 5.3. Percentage frequency (%) of occurrence of prey species in the diet of snow leopard in Uttarakhand, 2008



5.4.3. Occurrence of Major Prey Species of Snow leopard

The most common wild prey species found was bharal or blue sheep. A total of 340 individuals were recorded in 23 groups from Gangotri NP, Nanda Devi BR, Askot WLS and Sangla WLS. Almost 73% sightings were recorded from open areas or areas classified as grasslands, 17% from shrub land and 10% from riverine patches. Another wild prey species recorded was Himalayan marmot along three survey routes in Askot WLS and Gangotri NP. A total of eight individuals were recorded from grasslands. One group of Asiatic ibex was recorded from Kugti WLS Himachal Pradesh with five individuals in shrubland habitat.

5.4.4. Snow leopard-Human Conflicts

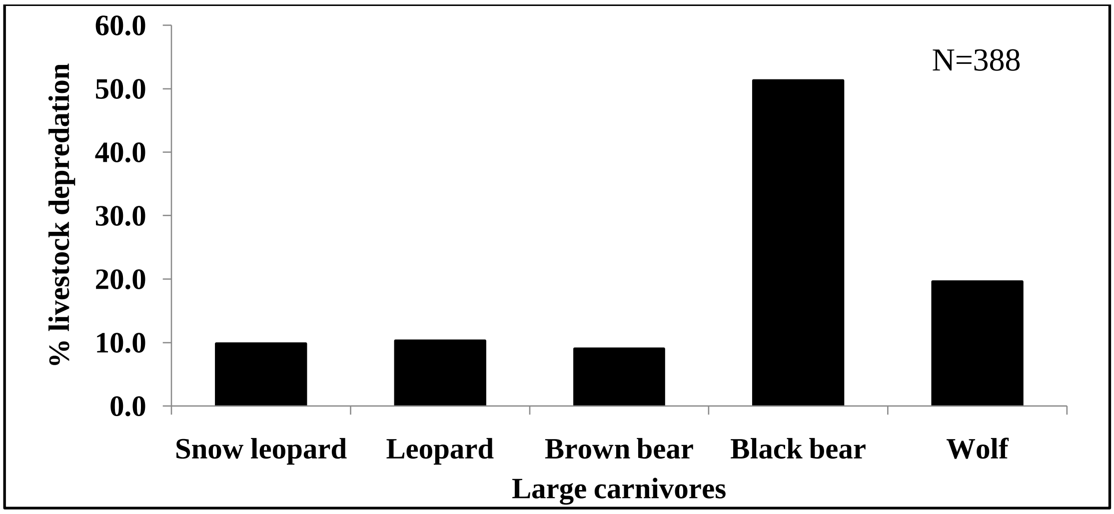
A total of 16 shepherds were interviewed in Govind NP and WLS, Askot WLS and Sundardhunga Glacier and Dung areas of Munsiari region of Nanda Devi BR where livestock population total was almost 8000 and comprised of goat, sheep, horse and mule. Livestock depredation was recorded as the only component for snow leopard-human conflicts and it varied. Snow leopard was reported to kill 22 livestock in Govind NP and WLS followed by 36 and five in Askot WLS and Dung areas respecitively. All depredations occurred during summers when these shepherds visit the higher ranges of snow leopard habitats in Uttarakhand.

Table 5.2. Livestock depredation by snow leopard in 4 regions of Uttarakhand, 2008

Area	Number of Shepherds Interviewed	Total Livestock Population	Livestock loss to snow leopard
Govind NP and WLS	4	1365	22
Askot WLS	4	4630	36
Sunderdhunga Glacier	3	740	0
Dung (Munsiari)	5	1270	5
TOTAL	**16**	**8005**	**63**

Thisstudyfound that the shepherds are primarily concerned about the livestock depredation and there were very few permanent human settlement in the snow leopard habitats (>3000 m elevation) in Uttarakhand. In total, 194 cases (n=388) were reported killed by large carnivores including snow leopardwere Asiatic black bear (51.3%) followed by, wolf (19.6%), common leopard (10.3%) and brown bear (9%)(Figure 5.4).

Figure 5.4. Shepherd responses (n=16) on livestock depredation (%) by large carnivores in Govind NP and WLS, Askot WLS and Nanda Devi BR, 2008



5.4.5. Biotic Pressures on Snow leopard and its Habitat

The intensity and occurrence of threats (grazing, developmental activities, tourism and human settlements) varied among areas surveyed. Overall, 68.1% of the area surveyed in Uttarakhand and Himachal Pradesh is under grazing and 12.3% area faces threats from tourism and defence activities (Figure 5.5). The details about these threats are given below:

Tourism posed low threat to snow leopard habitat because tourism is confined to definite treks such as from Gangotri temple to Bhojbasa at Gangotri NP and Kailash-Mansarovar track at Ascot WLS.

Fire was considered a threat because it leads to burning of alpine meadows when shepherd move down after grazing livestock. While this promotes grass growth in the next season, does not leave grass for wild ungulates. Fire was recorded from two areas namely Sundardhunga Glacier and Kugti WLS and found as low threat for snow leopard habitat.

Developmental activities such as road construction categorized as medium threat to snow leopard habitat at Nelong Valley, Ascot WLS and Nanda Devi BR. There is a great need for providing basic amenities to the local people and defense personnel of the areas such as at International Border areas of Uttarakhand and Himachal Pradesh. But many of the activities, such as construction of road is causing many side effects that need to be dealt immediately. At Nelong valley it was observed that gorge was blasted through to make the road and with the widening and newer roads being built the possibility of landslides. The other important issue is the influx of labor from outside areas in large numbers who largely depend on natural resources for survival and some of them also involve in illegal activities effecting wildlife.

Grazing was presently found as low threat to snow leopard habitat. Grazing was recorded from almost all snow leopard habitats except Gangotri NP, Valley of Flowers NP and Great Himalayan NP where it was not allowed by Forest Department. The severity of grazing was medium. It was thoroughly common practice that in Govind NP and WLS, Askot WLS, Dung (Uttarakhand) and Kugti WLS, Sangla WS (Himachal Pradesh) several families drive their unproductive livestock to sub-alpine and alpine areas for unsupervised grazing during the snow free period (May to October).

Human settlements posed low threat to snow leopard habitat because there were very few human settlements and settled in snow free period and utilizing natural resources. Human settlements (locals) were recorded from Govind NP and WLS, where one village was settled at snow leopard habitat, Askot WLS three villages settled at snow leopard habitat which provide shelter forKailash-Mansarovar tourists and Munsiari to Dung areas two villages were settled at snow leopard habitat.

Defence settlements, was another human settlement that was recorded at along the International Border with China and Nepal such as Gangotri NP, Askot WLS, Nanda Devi BR and Sangla WLS. Unlike human settlements these settlements were permanent and occupying snow leopard habitats but not depend on the natural resources therefore, posed low threat to snow leopard habitats.

Figure 5.5. Summary of threats to snow leopard and its habitat in the surveyed areas of Uttarakhand and Himachal Pradesh, 2008 (Miradi 4.2)

THREATS	Snow leopard	Snow leopard habitat	Summary Threat Rating
Tourism		L L L Low	Low
Snow leopard-human conflict	L L L Low		Low
Human settlement		L L L Low	Low
Grazing		H M L Low	Low
Fire		L L L Low	Low
Developmental activity		M M M Medium	Low
Summary Target Rating	Low	Low	Low

5.5. Discussion

This study covered four PAs and buffer zones of a Biosphere Reserve (BR) in Uttarakhand and three PAs in Himachal Pradesh. These PAs were Govind NP and WLS, Gangotri NP, Askot WLS, and Valley of Flowers NP, buffer zones (Sundardhunga Glacier and Dung) of Nanda Devi BR in Uttarakhand, The Great Himalayan NP, Sangla WLS and Kugti WLS in Himachal Pradesh.

In general, this Himalayan belt represent similar habitat for the high proportion of high altitude wildlife located above forests (Rawat, 1998 and 2005; Sathyakumar, 2003 and 2003b). There is a vast tract of mountains and plateaus immediately north of the Greater Himalayan chain, comprising the Trans-Himalaya. These mountains lie in the rain-shadow areas of the Himalaya and some of them are cold deserts such as higher areas (>4000m) of Nanda Devi BR, Gangotri NP, Askot WLS and Sangla WLS and mostly consists of subalpine scrub, alpine meadows and vast areas under permafrost, glaciers and rock faces.

Snow leopard presence coincides with the presence of prey species such as blue sheep and Asiatic ibex and it also helped in selecting the areas for snow leopard surveys (Maheshwari et al., 2013). Furthermore, on the basis of these preliminary results, Uttarakhand Forest Department initiated camera trapping in Nanda Devi BR and captured images of snow leopard.

Livestock depredation is emerging as a significant problem across the snow leopard’s range in the Himalaya and the other mountains of Central Asia (Oli et al., 1994; Jackson and Hunter, 1996; Mishra, 1997; Jayapal, 2000; Jackson and Wangchuk, 2001; Sathyakumar, 2003). These surveys suggested that shepherds are primarily concerned with their livestock depredation by snow leopard at Govind NP and WLS, Askot WLS and Munsiari areas. It seems that snow leopard-human conflicts can be a manifestation of habitat degradation due to over-harvesting of the natural resources by humans. Conservation education efforts can help to enhance the under-standing of the value of sustainable use of natural resources and importance of wildlife and help in mitigating these conflicts. The findings of snow leopard scat analysis are similar in some aspects with Chundawat and Rawat (1994) who reported that almost 96% scats consisted of single prey species. Here, 80% scats were with single prey species. They reported 23.4% blue sheep (this study recorded 18.2%) in snow leopard diet followed by 12.5% domestic livestock (yak, goat and sheep) in Ladakh. But due to low sample size this study is not able to document the food preference of snow leopard.

This study also showed that livestock grazing is at present a low threat to snow leopard habitat. But over-stocking of livestock may lead to habitat degradation. In general, this study suggests that some areas need to be earmarked to be grazing free where wild ungulates can thrive without competition. Surveys showed that road construction at Nelong Valley, Askot WLS and Nanda Devi BR may threaten existence of snow leopard, if not adequately planned. Roads cause habitat fragmentation and open the inaccessible areas to people and this often results in increased illegal activities (including hunting of snow leopard and its prey). It is suggested that while roads are planned, care should be taken to minimize habitat destruction.

There is a great need to provide basic amenities to the local people and defence personnel in areas along the international borders in Uttarakhand and Himachal Pradesh. But such activities including but not limited to construction of roads are causing side effects that need to be dealt with immediately. With the widening of existing roads and building of newer ones the threat of landslides have multiplied. The other important issue is the influx of labour from outside areas in large numbers who largely depend on natural resources for survival and some of them are also involved in illegal activities affecting wildlife.

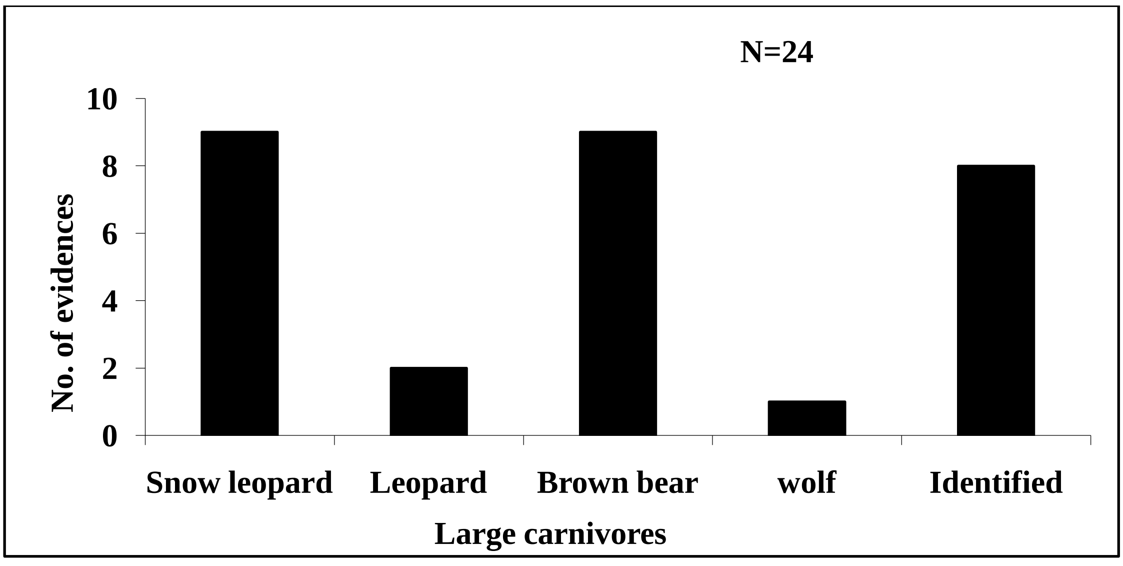
5.6. Detail findings of each study area surveyed in Uttarakhand and Himachal Pradesh

5.6.1. Govind National Park and Wildlife Sanctuary:

a. Snow leopard evidence

A total of 04 routes surveyed for collecting the information on status and distribution of snow leopard. One scat of snow leopard was identified from Govind NP and WLS at 3190 m from shrubland (habitat), seasonal grazing (rangeland-use) and in the high human disturbance area. The information about the other co–predators was summarised in the Figure 5.6.

Figure 5.6. Evidences of large carnivores in Govind NP and WLS, 2008



b. Snow leopard – human conflicts

Livestock depredation was reported from Govind NP and WLS. Four shepherds were interviewed and there was one shepherd who reported the livestock depredation by snow leopard. Overall, there was 6.25% livestock loss by snow leopard from Govind NP and WLS. Other large carnivores such as brown bear, wolf and leopard were also found involved in livestock depredation.

c. Grazing pressure and human disturbance

A total of 29 Km (n=04 routes) were surveyed for collecting information on grazing pressure and human disturbance. Grazing was recorded as medium disturbance to snow leopard habitat. Snow leopard-human conflicts were direct threat to snow leopard and categorized as low.

Figure 5.7. Summary of threats (Miradi 2.4) to snow leopard and its habitat in the surveyed areas of Govind Pashu Vihar NP and WLS

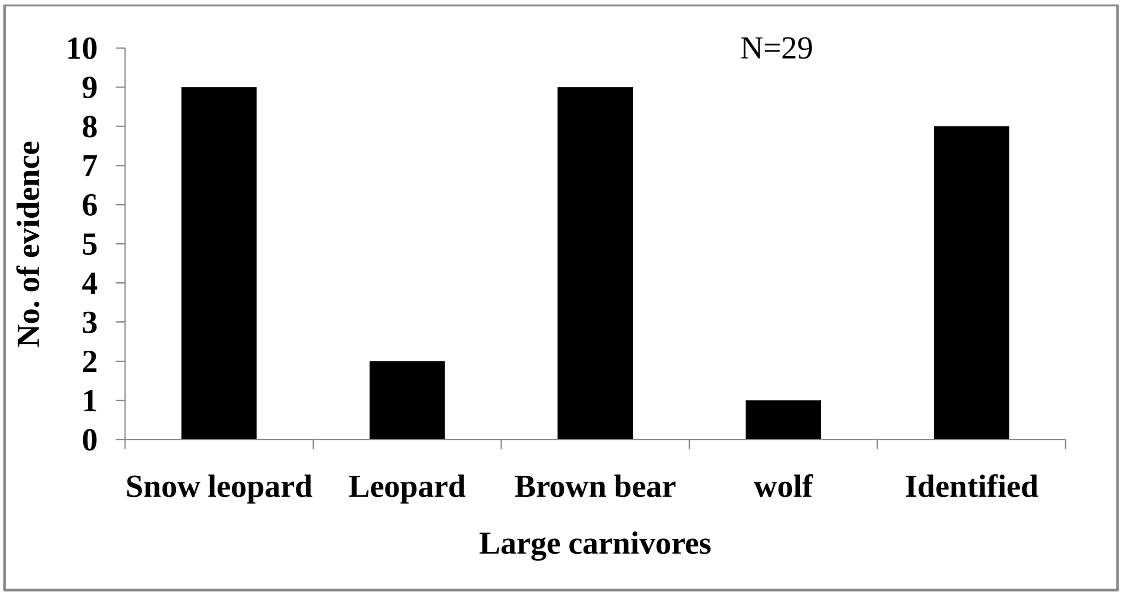
THREATS	Snow leopard	Snow leopard habitat	Summary Threat Rating
Developmental activity		N N N None	None
Fire		N N N None	None
Snow leopard-human conflict	N N N None		None
Tourism		N N N None	None
Grazing		H H L Medium	Low
Human settlement		L L L Low	Low
Summary Target Rating	None	Low	Low

5.6.2. Gangotri National Park:

a. Snow leopard evidence

A total of 29 evidence of large carnivores were found in the sampled area in Gangotri NP. Of these nine evidences (07 scats and 03 pugmarks) were of snow leopard out of which 03 evidences were recorded from Nelong Valley to Tripani along 10 routes. The altitude varies from 3580 to 4100 m in barren, grassland and shrubland habitats. The pressures were tourism and seasonal livestock grazing. The status of evidences of the co-predators has been summarised here in Figure 5.8.

Figure 5.8. Evidences of large carnivores in Gangotri NP, 2008



b. Grazing pressure and human disturbance

There was no permanent human settlement in Gangotri NP except in Bhojbasa and Defense settlements at Nilang Valley. Gangotri NP faces pressures of tourism but mostly was restricted up to GauMukh and tourist movements posed low threat for wildlife because number of tourist permitted per day was regulated, banned on mule movement inside the Gangotri NP and tourist sites were removed except Chirbasa and Bhojbasa. At Gangotri, hydroelectricity dam was under construction and categorized as medium threat to snow leopard habitat. In contrast, Nelong Valley faces grazing pressures and categorized as medium threat to snow leopard habitat. Construction and widening of roads in Nelong Valley was categorized as low threat to snow leopard and its habitat. The details about the grazing pressure and other human disturbance was given in Figure 5.9.

Figure 5.9. **Summary of threats (Miradi 2.4) to snow leopard and its habitat in the surveyed areas of Gangotri NP (top) and Nelong Valley (down)**

THREATS	Snow leopard	Snow leopard habitat	Summary Threat Rating
Fire		N N N None	None
Grazing		N N N None	None
Human settlement		N N N None	None
Snow leopard-human conflict	N N N None		None
Tourism		N N N None	None
Developmental activity		H H L Medium	Low
Summary Target Rating	None	Low	Low

THREATS	Snow leopard	Snow leopard habitat	Summary Threat Rating
Developmental activity		M L L Low	Low
Human settlement		N N N None	None
Snow leopard-human conflict	N N N None		None
Tourism		N N N None	None
Developmental activity	L L L Low		Low
Fire		L L L Low	Low
Grazing		H H L Medium	Low
Summary Target Rating	Low	Low	Low

5.6.3. Sundardhunga Glacier:

There was no evidence found of snow leopard during the study in this area. Extreme livestock grazing, human disturbance and seasonal grazing was high (100%) found at Sundar Dhunga glacier.

5.6.4. Askot Wildlife Sanctuary:

The Kailash-Mansarovar track was surveyed till Nabidhang and Om Parvat during June, 2008 in Askot WS in snow leopard base-line survey.

a. Snow leopard evidence

One scat of snow leopard was found at the height of 4000 m in shrubland habitat and one scat of black bear in Askot WLS.

b. Snow leopard – human conflicts

Based on the interview of four shepherds, it was found that total livestock depredation by snow leopard was 0.67% (i.e. 10 livestock out of 1525) in 2007 in the area surveyed of Askot WLS.

c. Grazing pressure and human disturbance

Seasonal grazing (80%) was one of the major threat and categorized as medium to snow leopard habitat in Askot WLS. In addition, Kailash-Mansarovar track and Aadi-Kailash are one of the pilgrim sites in Askot WLS. Permanent human settlements till Gunji offer shelter for pilgrims on these tracks. But tourists were restricted to these tracks and posed low threat to snow leopard habitat. Efforts from Forest Department were also minimizing these threats through awareness programmes for locals. Construction of roads was categorized as low threat to snow leopard habitat because it was started recently from Garbadhar and not yet reached at snow leopard habitat. Direct threat to snow leopard was conflict with human and categorized as low (Figure 5.10). Livestock depredation by snow leopard and co-predators was reported from Askot WLS.

Figure 5.10. Summary of threats (Miradi 2.4) to snow leopard and its habitat in the surveyed areas of Askot WLS

THREATS	Snow leopard	Snow leopard habitat	Summary Threat Rating
Fire		N N N None	None
Human settlement		M M L Low	Low
Snow leopard-human conflict	N N N None		None
Tourism		H L L Low	Low
Developmental activity		L L L Low	Low
Developmental activity	L L L Low		Low
Grazing		H H L Medium	Low
Summary Target Rating	Low	Low	Low

5.6.5. Nanda Devi Biosphere Reserve:

Snow leopard habitats surveyed in Nanda Devi BR, namely, Lapthal Rimkhim, Sumna and Niti, Munsiari and Dung Valleys were surveyed during June to September 2008, for collecting information on snow leopard along seven routes.

a. Snow leopard evidence:

A total of 220 km was walked out of which 128 km was surveyed *i.e.* above 3000 m in the snow leopard habitat. There was one fresh track of snow leopard recorded in the Rimkhim Valley at the elevation of 4000 m and two scats were collected from Lapthal and Dung Valleys; one scat from each valley.

b. Grazing pressure and human disturbance

In Nanda Devi BR grazing was recorded 100% in the areas surveyed and categorized as low threat to snow leopard habitat. Construction of roads categorized as medium threat to snow leopard habitat and roads were constructed at 21 Point *i.e.* 05 km before from Sumna. Defence posts were the only human settlements in Nanda Devi BR and posed low threat to snow leopard habitat (Figure 5.11).

Figure 5.11. Summary of threats (Miradi 2.4) to snow leopard and its habitat in the surveyed areas of Nanda Devi BR

THREATS	Snow leopard	Snow leopard habitat	Summary Threat Rating
Developmental activity		H H L Medium	Low
Developmental activity	L L L Low		Low
Fire		N N N None	None
Grazing		H M L Low	Low
Human settlement		L L L Low	Low
Snow leopard-human conflict	N N N None		None
Tourism		N N N None	None
Summary Target Rating	Low	Low	Low

5.6.6. Valley of Flowers National Park:

Two areas were surveyed in Valley of Flowers NP namely, Kunt Khal and Tipra Glacier during September, 2008.

a. Snow leopard evidence:

A total of 28 km was walked in the Valley of Flowers NP and there was no evidence found of snow leopard during the study in this area. One track was recorded of Asiatic black bear.

b. Grazing pressure and human disturbance

There was no grazing activity allowed inside Valley of Flowers NP. At the time of survey (September 2008) the tourist activity was very low and could not be treated as the human disturbance inside the Park. Thus there was no disturbance found in the Valley of Flowers NP during survey.

5.6.7. Great Himalayan National Park:

In Great Himalayan NP due to heavy land-slide in the month of September 2008 much of the high altitude snow leopard habitats were not accessible. Therefore, information was collected only from Kobri areas of Great Himalayan NP during September, 2008.

a. Snow leopard evidence:

No evidence of snow leopard were found in the areas surveyed of Great Himalayan NP during the study.

b. Grazing pressure and human disturbance:

Grazing was not allowed inside the Great Himalayan NP. Similarly, there was very minimal human disturbance recorded at survey duration since there was no permanent human settlement inside Great Himalayan NP.

5.6.8. Sangla Wildlife Sanctuary:

Dumti areas were surveyed (October, 2008) for snow leopard base-line survey in Sangla WS. There were no evidence recorded of snow leopard from Sangla WLS at survey duration.

5.6.9. Kugti Wildlife Sanctuary:

Duggi-Relang and Baggi-Tal areas were surveyed during November, 2008 for collecting direct and indirect evidences of snow leopard in Kugti WLS.

a. Snow leopard evidence:

No evidence of snow leopard could be found during survey duration from Kugti WLS. In total 13 evidences of Himalayan brown bear including one direct sighting were recorded from Kugti WLS.

b. Grazing pressure and human disturbance:

Grazing pressure was recorded 100% in areas surveyed of Kugti WLS and faced grazing from neighboring district (Lahul and Spiti) also. Unsupervised livestock grazing was also recorded from Kugti WLS and categorized as medium threat to snow leopard habitat. Burning of alpine meadows was observed in areas surveyed of Kugti WLS and categorized as medium threat to snow leopard habitat. There was no shepherd found at the duration of survey thus no information was available on snow leopard-human conflict from Kugti WLS.

Figure 5.12. Summary of threats (Miradi 2.4) to snow leopard and its habitat in the surveyed areas of Kugti WLS

THREATS	Snow leopard	Snow leopard habitat	Summary Threat Rating
Developmental activity		N N N None	None
Fire		H H L Medium	Low
Human settlement		N N N None	None
Snow leopard-human conflict	N N N None		None
Tourism		N N N None	None
Grazing		V H L Medium	Low
Summary Target Rating	None	Medium	Low

5.7. Potential habitats for snow leopard conservation in Uttarakhand and Himachal Pradesh

Selection of the potential habitats for snow leopard in Uttarakhand and Himachal Pradesh was done on the basis of direct and indirect evidences of snow leopard, co-predators, prey and biotic pressure recorded. As far as the wildlife is concerned, a very important characteristic of the Greater and Trans-Himalayan region of Uttarakhand is that it provides almost continuous wildlife habitat. Almost the entire landscape has large mammals, including snow leopard, common leopard, wolf, brown bear, Asiatic black bear, bharal, musk deer, Himalayan tahr and Asiatic ibex but the densities may vary depending on the quality of habitat. Snow leopard is threatened by grazing (leads to competition between wild and domestic ungulates), conflicts relating to crop and livestock depredation, and some levels of poaching of snow leopard, co-predators and prey species. On the basis of overall analysis (area profile) this study proposes the following areas have good potential for snow leopard conservation

1. Gangotri National Park

2. Askot Wildlife Sanctuary

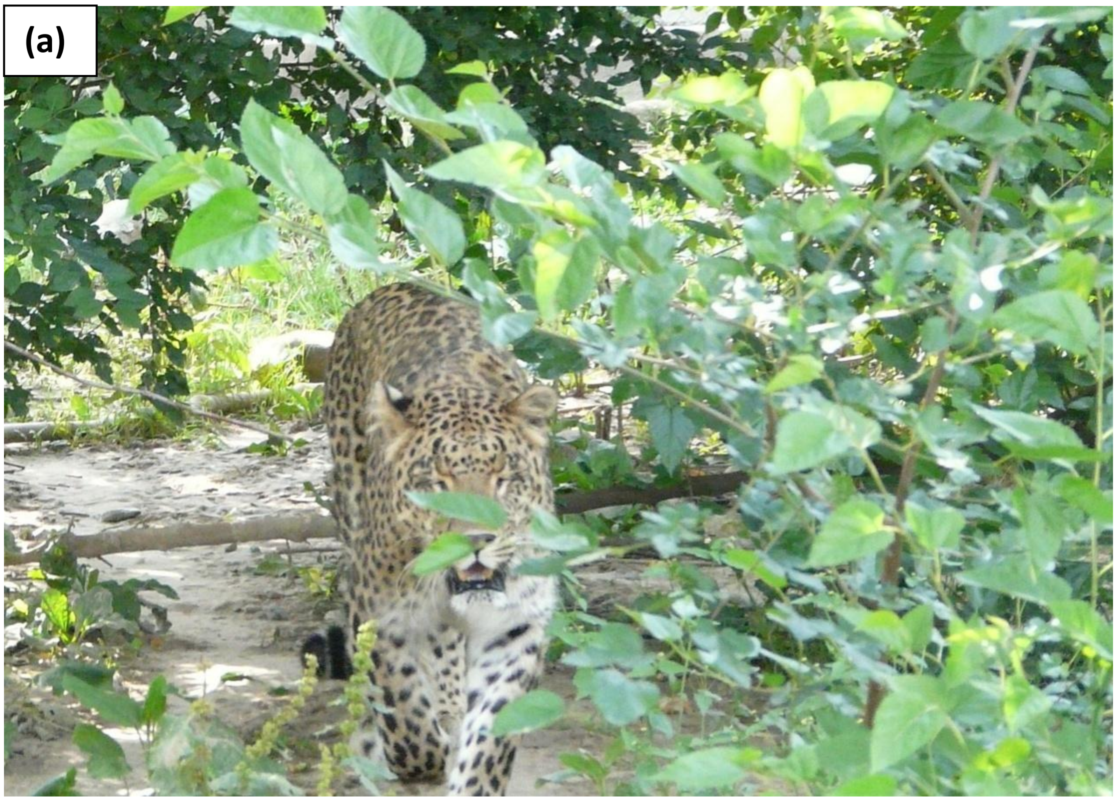
3. Nanda Devi Biosphere Reserve.

There are some other areas which also represent the potential habitat for snow leopard but due to the unfavorable climatic conditions, inadequate time for the sampling in the snow leopard habitat and limitation of time available, these could not be properly surveyed or not surveyed at all. These areas should be surveyed to get a better picture of conservation status of snow leopard.

1. Valley of Flowers National Park

2. Great Himalayan National Park

Plate 5.1: Photographs of co-predators and key prey species of snow leopard in Uttarakhand and Himachal Pradesh (a) Common leopard (b) blue sheep



CHAPTER - 6: HABITAT SUITABILITY MODELING AND CONSERVATION AND MANAGEMENT PLANNING FOR SNOW LEOPARD IN THE WESTERN HIMALAYA

6.1. Introduction

A key issue in ecology and conservation biology is to determine how species are distributed in space. Since extinction risk is associated with range size, a significant reduction of a species range often determines change in conservation status (Purvis et al., 2000). The term habitat is defined as the place where an animal lives or, more specifically, the collection of resources and conditions necessary for its occupancy. It becomes imperative to evaluate the habitat suitability of an area where the study species is living. In a habitat there can be many factors or site specific characters, which are necessary for the survival of a species. According to Barnes et al. (1998) habitat integrates the effect of many interacting factors, and key species which may indicate the site condition.

Several statistical models exist to predict the distribution of a species (Franklin, 2009). Beyond classical regression methods (Resource Selection Function (Boyce and McDonald, 1999), Generalized Linear Models (McCullagh and Nelder, 1989), algorithmic modeling based on machine learning (for example Artificial Neural Networks (Ripley, 1996), Maximum Entropy MAXENT (Philips et al., 2006) have become increasingly popular in recent years. Among these, MAXENT has been described as especially efficient to handle complex interactions between response and predictor variables (Elith et al., 2006). This, as well as its extreme simplicity of use, has made MAXENT the most widely used Species Distribution Modeling (SDM) algorithm, therefore, MAXENT was used to predict the suitable habitat for snow leopard in the western Himalaya.

Agro-pastoralism are the predominant land uses and sources of local livelihood within snow leopard range (Snow Leopard Network, 2014), with seven range countries having over 25% of land area under permanent pasture, > 50% of their human population involved in agro-pastoralism, > 40% living below national poverty levels, and average per capita annual incomes of US$250-400 (Mishra et al., 2003). For centuries humans have co-existed with wildlife practicing nomadic or semi-nomadic pastoralism herding sheep and goats flocks, cattle, horses, yaks and camels. Although relatively few humans live in snow leopard habitat, their use of the land is becoming increasingly pervasive, resulting in escalating conflicts between conservation and livestock production even within protected areas (Jackson et al., 2010; Snow Leopard Network, 2014). The economic loss due to snow leopards and wolves in Spiti region has been estimated at US$ 128 per family annually, amounting to about half the per capita income of the state (Mishra 1997). Similarly, in the present studyreported about 8% livestock loss to the large carnviores in Kargil. Interviews of local communities revealed that they do not have proper infrrastructure to maintain the livestock and tradtional livestock corrals are prone to the large carnviors and sometimes lead mass depredation of the livestock.

The conservation and management of the snow leopard, its prey and habitat is contingent upon the understanding of the species ecology and conservation priorities at the landscape level. Reducing traditional threats such as retaliatory killing of snow leopards to minimize livestock depredation, poaching for skin and bones and emerging threats such as climate change need to managed on priority to ensure viable populations of snow leopards. In India, a flagship species recovery programme called the Project Snow Leopard (PSL, 2006) is already under implementation in the country aimed at strengthening the population status of the species and conservation of its habitats with active cooperation of the local inhabitants and scientific institutions. In addition, Global Snow leopard and Ecosystem Protection Programme (GSLEP) and National Snow leopard and Ecosystem Protection Priorities (NSLEP) are also under implementation at international and national level since their inception in 2013 (Snow leopard Working Secretariat, 2013).

6.2. Objective

This chapter deals with the following objectives:

a) To predict habitat suitability for snow leopards in the western Himalaya
b) To propose strategies for the management of snow leopard-human conflict in the western Himalaya

6.3. Methods

The methods used for predicting habitat suitability for snow leopard in the Western Himalaya followed the standard methods adopted by previous studies (Phillips et al., 2006; Elith et al., 2011). MAXENT is now a common SDM tool used by conservation practitioners for predicting the distribution of a species from a set of records and environmental predictors (Elith et al., 2011).

The principle of SDM is to relate known locations of a species with the environmental characteristics of these locations in order to estimate the response function and contribution of environmental variables (Philips et al., 2006), and predict the potential geographical range of a species (Elith and Leathwick, 2009). These models estimate the fundamental ecological niche in the environmental space (*i.e.* species response to abiotic environmental factors (Elith et al., 2011) and project it onto the geographical space to derive the probability of presence for any given area (Elith and Leathwick, 2009).

6.3.1. Predicting habitat suitability for snow leopards in the western Himalaya

A total of 129 observations (direct and indirect evidence) of snow leopards were used for predicting suitable habitat in the western Himalayan states of India (Jammu and Kashmir; Chundawat, 1992; Maheshwari et al., 2010); Himachal Pradesh (Sharma, 2009) and Uttarakhand (Maheshwari and Sharma, 2010). Coordinates for each data point were referenced from information provided in the literature or by using Google Earth 5.0.1 using geographic projection. Positional accuracy of the geographic coordinates assigned to the records was between 20 and 50 m. Spatial resolution of 1x1 km was used for the selected localities so the localities corresponded to the environmental data resolution (WorldClim). Only one locality was selected per 1km grid cell if > 1 observation was clustered in a grid (i.e., to avoid autocorrelation with low sample size; Phillips et al., 2006; Pearson et al., 2007).

6.3.2. Environmental variables

Series of bioclimatic environmental variables were selected and obtained from WorldClim database (Version 1.4, http://www.worldclim.org/bioclim.htm; Hijmans et al., 2005). These metrics are derived from monthly temperature and rainfall climatologies and represent biologically meaningful variables for characterizing a species range. A total of 23 environmental variables were used, (11 variables for temperature, 8 for precipitation variables, expressing spatial variations in annual means, seasonality and extreme or limiting climatic factors), and elevation interpolated climate surfaces at resolution of 30 arc-seconds approximately to ~1km^2 (0.008333 decimal degree; derived from monthly temperature and rainfall records worldwide; Hijmans et al., 2005; Hijmans and Graham, 2006). Elevation data was used to generate the slope and aspect data layers. Land cover was obtained from GlobCover V2.2 (ESA Globcover Project), a global land use dataset with a spatial resolution of 1 km^2 and a thematic resolution of 22 classes (http://www.esa.int/due/ionia/globcover). All the spatial data layers were resample to 1 km spatial resolution using the nearest neighbor re-sampling technique using ERDAS 9.3 and ArcGIS 9.2 software (ESRI, 2006). ENM Tools version 1.3 were used (Warren et al. 2010) to test multi-collinearity between 19 Bioclimatic predictor variables. ENM Tools output matrix of Pearson Correlation Coefficients (r) was used to drop variables with $r > 0.8$.

6.3.3. Niche modeling

MAXENT software package (version 3.3.3.e; Phillips et al. 2004; http://www.cs.princeton.edu/~schapire/maxent/) was used for ecological niche modeling that implements a maximum entropy algorithm, that generates a probability distribution of a targeted species across the landscape (Phillips et al., 2006; Elith et al., 2011). MAXENT is a machine learning algorithm used to predict robust ecological niches of a species, with presence records, even when only a few are available (Elith et al., 2006; Phillips et al., 2006; Papeş and Gaubert, 2007; Kumar and Stohlgren, 2009). This model has an advantage for species whose presence/available data are limited and absence and false absence in the surveys is a significant risk (Elith et al., 2006; Phillips and Dudik, 2008). The maximum number of background points was 10,000 and implementing linear, quadratic and hinge features was used (Phillips and Dudik, 2008). Other values were kept default and then ran 100 replicates for model building (Flory et al., 2012) and partitioned the occurrence locations randomly into two sub samples, using 75% of the locations as the training dataset and the remaining 25% for testing the resulting (partitioned) models. The accuracy of the model was using the area under the curve (AUC) of a receiver operating characteristic (ROC) plot (ranging from 0.5 = random to 1 = perfect discrimination) and to assess the variables importance we adopted a jackknife procedure (Yang et al., 2013). A total of 100 model predictions were averaged and produced a probability map of snow leopard presence. The Shape files of protected area boundaries within each state were downloaded from the World Database on

Protected Areas – WDPA (IUCN and UNEP, 2009) and other published maps (Palni et al., 2012).

6.4. Results

6.4.1. Model performance

The AUC score (SD) was high for the MAXENT model for the training data (0.994 ± 0.003; i.e., models having AUV scores > 0.75 are considered potentially useful and indicate excellent predictive ability; Phillips and Dudik, 2008). The low AUC standard deviation (0.003) suggests there was no overfitting around the presence data. The jackknife evaluation procedure revealed that nine variables contributed 99.5% towards the model (Table 6.1 and Figure 6.1). Altitude had the single largest influence on model predictions and contributes 34.5% to the snow leopard habitat suitability prediction. Based on the model predictions, the probability of occurrence of snow leopards increased with an increase in altitude >3,000 m and significantly decreased > 6,700 m (Figure 6.2-a). The precipitation during the driest quarter (Bio17), seasonal variation on precipitation (Bio15), precipitation of the wettest quarter (Bio16), and precipitation of the coldest quarter (Bio19) accounted for 39.4% of model performance, while mean diurnal range of temperature (Bio2), Isothermality (Bio3), LULCand mean temperature during the wettest quarter (Bio8) influenced the final model, with 25.6% (Table 6.1). The probability of snow leopard occurrence increased when precipitation during the driest and coldest quarter increases > 80 mm (Figure 6.2-b and c) and decreased with an increase in variation on seasonal precipitation (CV= 30%) (Figure 6.2-d). Snow leopard probabilities of occurrence also decreased with increase in temperature (Figure 6.2-e and f).

Table 6.1. Environmental variables used in the predicting the potential distribution of snow leopards in western Himalaya

Code	Environmental Variables	% contribution	Permutation importance
Alt	Altitude	34.5	87
Slo	Slope	0	0
Asp	Aspect	0	0

Bio1	Annual Mean Temperature	0	0
Bio2	Mean Diurnal Range (Mean of monthly (max temp - min temp))	8.8	4.1
Bio3	Isothermality (P2/P7) (* 100)	6.9	1.2
Bio4	Temperature Seasonality (standard deviation *100)	0	0
Bio5	Max Temperature of Warmest Month	0	0
Bio6	Min Temperature of Coldest Month	0	0
Bio7	Temperature Annual Range (P5-P6)	0	0
Bio8	Mean Temperature of Wettest Quarter	2.5	0.5
Bio9	Mean Temperature of Driest Quarter	0	0
Bio10	Mean Temperature of Warmest Quarter	0	0
Bio11	Mean Temperature of Coldest Quarter	0	0
Bio12	Annual Precipitation	0	0
Bio13	Precipitation of Wettest Month	0	0
Bio14	Precipitation of Driest Month	0	0
Bio15	Precipitation Seasonality (CV)	11.1	0.3
Bio16	Precipitation of Wettest Quarter	2.2	0.8
Bio17	Precipitation of Driest Quarter	16.7	0.8
Bio18	Precipitation of Warmest Quarter	0	0
Bio19	Precipitation of Coldest Quarter	9.4	2.1
LULC	Landuse/Landcover	7.4	2.1

Figure 6.1. The Jackknife test for evaluating the relative importance of environmental variables for snow leopard in the western Himalaya

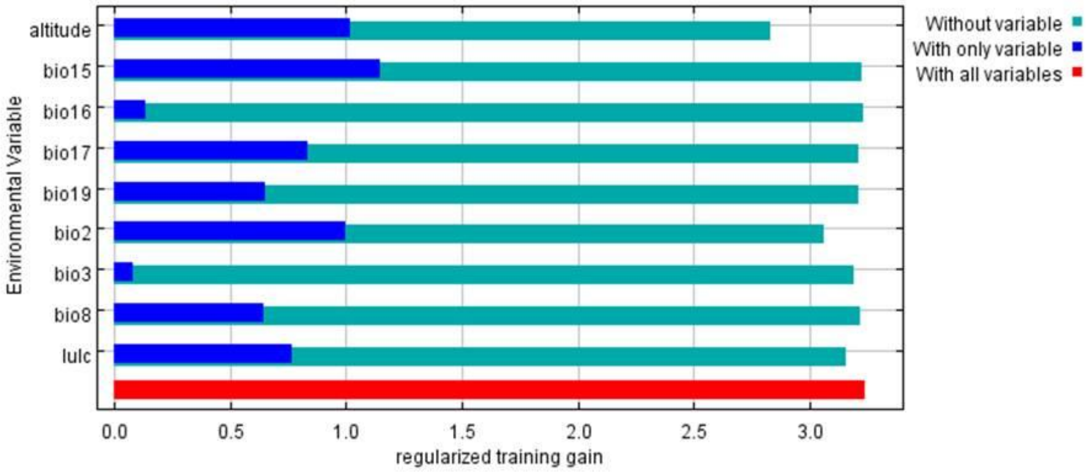
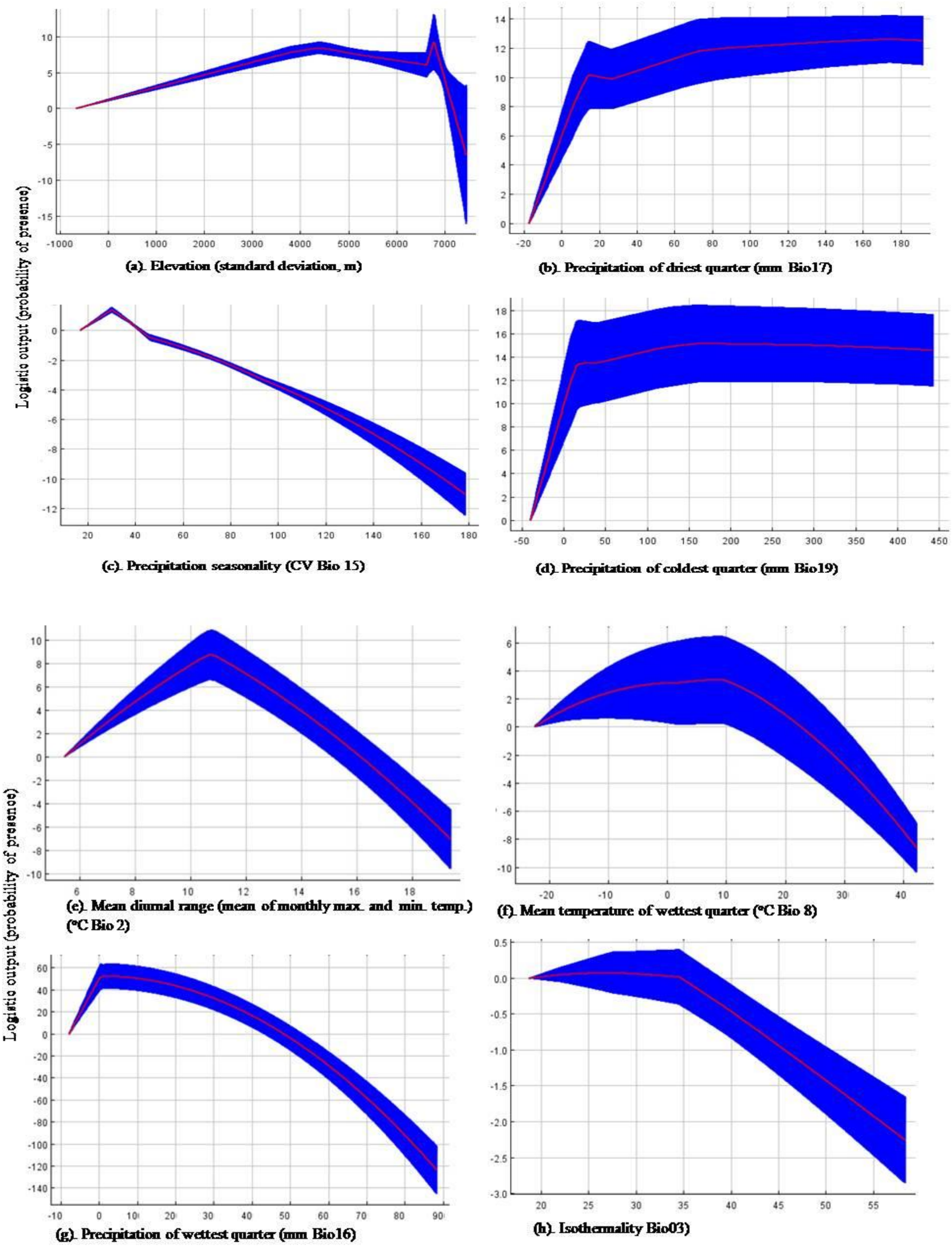


Figure 6.2. Relationships between top environmental predictors and the probability of occurrence of snow leopard in western Himalaya: a) Elevation, b) Precipitation of driest quarter, c) Precipitation seasonality, d) Precipitation of coldest quarter, e) Mean diurnal range, f) Mean temperature of wettest quarter, g) Precipitation of wettest quarter, h) Isothermality



6.4.2. Potential distribution area

Most (89.2%) of the presence records of snow leopards corresponded to areas where the probability of occurrence was >0.50 (Figure 6.3). The model predicted the potential distribution of snow leopard with a high suitability threshold in the higher elevation of the western Himalayan Mountains. If logistic probabilities assigned ≥ 0.50% (suggested by Elith et al., 2011) the ~ 42,432 km^2 land areas of the western Himalaya (Table 6.2) is predicted to be suitable for snow leopards (Figure 6.3). The prediction includes ~11,247 km^2 (26.5%) within the protected areas while other landscapes in the western Himalayans do not have protected status. Area of moderate suitability (0.30-0.50%) was 22,162 km^2 and 42,037 km^2 was classified as low suitability (< 0.30%) (Table 6.2).

Figure 6.3. Predicting potential distribution habitat for snow leopard in the western Himalaya

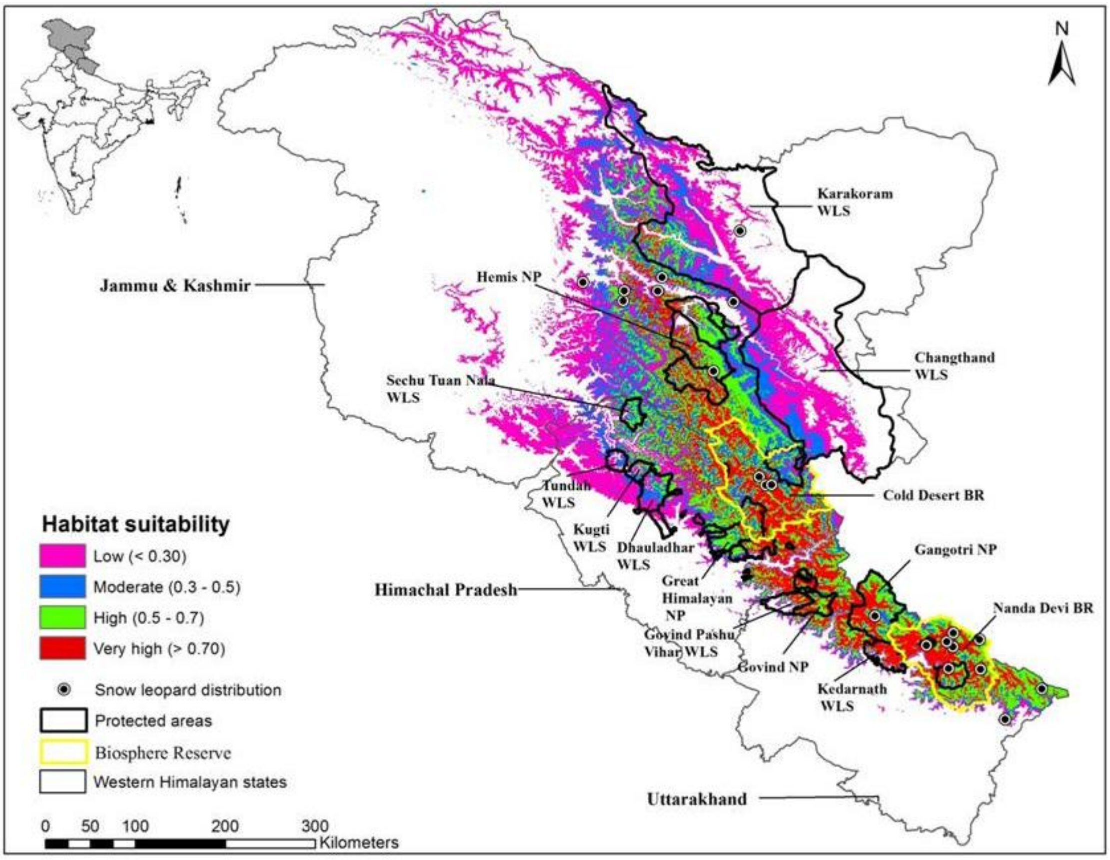


Table 6.2. Predicting the potential distribution habitat of snow leopard in western Himalaya

	Anon, 2008		Predicting suitable habitat area (km^2)			
State	**Total geographic area (km^2)**	**Potential area under Project Snow Leopard (km^2)**	**Very High suitable (> 0.70%)**	**High suitable (0.50 – 0.70%)**	**Moderate suitable (0.30-0.50%)**	**Low suitable (< 0.30-0.10%)**
Jammu and Kashmir	128,534	77,833	4,068	9,202	13,743	32,641
Himachal Pradesh	54,979	27,846	7,802	8,757	6,342	7,755
Uttarakhand	59,846	13,885	6,143	6,460	2,077	1,641
Total area	**243,355**	**119,564**	**18,013**	**24,419**	**22,162**	**42,037**

6.5. Management of Snow leopard-Human Conflicts in the Western Himalaya

People inhabiting the snow leopard habitats in India are primarily agro-pastoralists, with some regional variations where they are primarily nomadic herders. There have been suggestions that owing to development, traditional herders are increasingly leaving this occupation for alternatives, resulting in a decline in livestock numbers (Sabarwal, 1999). While this may be true in some regions, in others the reverse appears to be happening (Fox et al., 1994). Data suggests that, at least regionally, livestock holdings are increasing with holding patterns changing due to evolving market forces (Bhatnagar, 1996; Mishra, 1996; Mishra, 1997). In some areas, livestock densities may be as high as 1,500 per km^2 (Kothari et al.,1989).

Snow leopard-human conflict is a serious issue throughout their range (Bagchi et al., 2004; Mishra, 1997; Nowell and Jackson, 1996). Snow leopards often cause serious economic losses by preying on livestock (Mishra, 1997; Maheshwari et al., 2010; Suryawanshi et al., 2013). The antagonism arising from conflict with snow leopards pushes people toward retributive killings, which have a substantial impact on the snow leopard's populations and undermines conservation efforts. Sheep and goats are the primary livestock in the region owing to market demands for their wool, under-wool (*pashmina*), and meat (Fox et al., 1994).

In general, there are three management strategies in practice to mitigate the snow leopard-human conflicts in the western Himalaya:

1. Predator proof corrals in the west Himalaya: Predator proofing of livestock corrals has been one of the main measures for improving livestock protection (Bhatnagar et al., 1999; Jackson and Wangchuk, 2004).
2. Livestock insurance scheme in Spiti, Himachal Pradesh: Community based or locally managed system for monetary compensation and insurance for those herders losing livestock in Spiti Valley, HP (Mishra et al., 2003).
3. Sensitizing local communities and raising their awareness for snow leopard conservation: Awareness is a powerful tool in the local communities to mitigate the snow leopard-human conflicts. Over time, it would result in a change of behavior towards the snow leopards and reduce the level of conflict (Jackson and Wangchuk, 2004; Maheshwari et al., 2010).

This study implemented two of the management strategies in the intensive study area, Kargil. Livestock depredation by large carnivores was identified main root cause of the snow leopard-human conflicts in Kargil and retaliatory killing of snow leopard and co-predators can't be ruled out, however, this study could not record any evidence of hunting of snow leopard but one incident of killing of Tibetan wolf was recorded during the study period. During the study, two predator proof livestock corrals were supported in one of the conflict hotspot village in the study site in Kargil. This village reported livestock loss (n=19; sheep and goats-15, yak calves-3 and horse-1) out of total livestock (n=251) in 2009 and 2011. The first and second corral pens for sheep and goats were 20 X 30 and 10 X 15 feet in dimensions and with a 6-foot and 3-foot high stone wall respectively. Both had an open roof covered by 4 X 4 inch wire mesh and supported with wooden poles at every 5 feet. Each of the structures had two covered windows and a single closely-fitting iron door that can be securely locked at night (Photograph 6.1-a). It is interesting to note here that there was no depredation reported in 2012 after building the livestock corral.

To sensitize the local communities, district officials and other major stakeholders for snow leopard conservation, one high level meeting (with Ladakh Autonomous Hill Development Council, Kargil, Indian Army, Police, Department of Wildlife Protection and Forest Department) and eight meetings with local communities, shepherds, school teachers and students were organized during the study period in Kargil (Photograph 6.1-b). There were almost 500 participants in altogether in these meetings. Participants were briefed about the study and time-to-time updates and findings and helped in raising the awareness about the snow leopard and associated species amongst the local communities. Large depredation losses may create such levels of anger towards snow leopards, wolves and other large predators that local communities lose any tolerance and view predator extermination as the only solution to the conflict (Oli et al. 1994). Therefore, understanding and managing conflicts over livestock depredation and changing attitude of local communities for the snow leopards and associated species represent an important goal for effective snow leopard conservation action in the western Himalaya.

Plate 6.1: Photograph of wildlife conservation activities in Kargil: (a) Livestock corral (b) Conservation awareness workshop for the local communities in Kargil

6.6. Project Snow leopard

The Project Snow leopard is an Indian initiative for strengthening wildlife conservation in the Himalayan high altitudes. It aims to promote a knowledge-based and adaptive conservation framework that fully involves the local communities, who share the snow leopard's range, in conservation efforts.

Despite the ecological importance, the harshconditions, and the increasing threats to conservation in the region, the wildlife of the Himalayan high altitudeshas received little conservation attention. The Ministry of Environment, Forests and Climate Change (MoEF&CC), Government of India had initiated programme on a flagship Snow Leopard Scheme in1988, but it could not be launched (Anon., 1988). Later in 2006 (PSL, 2006) a concept paper was prepared together with the state Forest/ Wildlife Departments of five snow leopard range that outlined the project justification and its objectives. The goal of the project was articulated as "*To safeguard and conserve India's unique natural heritage of high altitude wildlife populations and their habitats by promoting conservation through participatory policies and actions.*"

The high altitude Himalayan landscape in India is spread over c. 130,000 km^2 including *c.* 35 existing protected areas (*c.* 31,000 km^2) (Anon., 2008). Given that this high altitude landscape is unique as the wildlife populations, though threatened, occur across the landscape and are not restricted to protected areas, an alternative, landscape-level conservation approach is needed. At the same time, this landscape continues to undergo traditional resource use in the form of livestock grazing and associated activities, and a participatory approach to conservation, that fully involves local communities, is urgently required (Anon., 2008). Keeping this broad philosophy in mind, the following are the objectives of the Project Snow Leopard (Anon, 2008):

1. Facilitate a landscape-level approach to wildlife conservation
2. Rationalize the existing protected area network and improve protected area management
3. Develop a framework for wildlife conservation outside protected areas and promote ecologically responsible development
4. Encourage focused conservation and recovery programmes for endangered species such as the snow leopard
5. Promote stronger measures for wildlife protection and law enforcement

6. Promote stronger measures for wildlife protection and law enforcement
7. Restore degraded landscapes
8. Promote a knowledge-based approach to conservation and an adaptive framework for wildlife management
9. Reduce existing anthropogenic pressures on natural resources
10. Promote conservation education and awareness

6.7. Global Snow Leopard and Ecosystem Protection Program (GSLEP)

The GSLEP is a joint initiative that aims to conserve the snow leopard within the broader context of also conserving valuable high mountain ecosystems. GSLEP unites all 12 range country governments, non-governmental and inter-governmental organizations, local communities, and the private sector around this aim.

In 2013 (Snow Leopard Working Secretariat, 2013) the 12 snow leopard range countries and partners signed the Bishkek Declaration in Bishkek and agreed to the goal of the GSLEP for the 7 years through 2020. The snow leopard range countries agree, with support from stakeholder and interested organizations, to work together to identify and secure at least 20 snow leopard landscapes across the snow leopard's range by 2020 or, in short – "Secure 20 by 2020."

Secure snow leopard landscapes are defined as those that contain at least 100 breeding age snow leopards conserved with the involvement of local communities, support adequate and secure prey populations, and have functional connectivity to other snow leopard landscapes, some of which cross international boundaries (Snow Leopard Working Secretariat, 2013).

India had proposed three landscapes from the Indian Himalayan Region, (http://www.globalsnowleopard.org/our-work/the-first-step-20-by-2020/) Hemis-Spiti landscape (29,000 km^2), Nanda Devi-Gangotri (12,000 km^2) and Kanchendzonga-Tawang (5,630 km^2).

6.8. National Snow Leopard and Ecosystem Protection Program (NSLEP)

The foundation of the GSLEP is 12 individual National Snow Leopard and Ecosystems Priorities (NSLEPs). These NSLEPs were developed by each country to incorporate a set project activities to be implemented to meet their national snow leopard and ecosystem protection goals. The NSLEPs are supported by five Global Support Components (GSCs) prepared by international organizations to address issues which transcend national boundaries and go beyond the capacity of any one country to address alone. The GSCs aim to support and assist the range countries, as needed, is the areas of wildlife law enforcement; knowledge sharing; trans-boundary cooperation; engaging with industry; and research and monitoring.

6.9. Discussion

This study predicted the potential distribution of snow leopards in the western Himalaya of India based on available presence records (collected during present study and published sources). The output of this model can assist conservation plans and serve as a bench mark for collection of presence and absence data on snow leopard. MAXENT models only identify regions with similar environmental conditions to occurrence localities across the species distribution range (Pearson et al., 2007). Altitude plays an important role in predicting the distribution of snow leopard, and this model output and previous field surveys revealed that the distribution of snow leopards in higher elevations ranged from 3,000 to 6,700 m characterized by a narrow range of precipitation (< 100 mm) and maximum temperatures during summer (<15^{o}C), characterized by low vegetation cover (< 15% vegetation cover, grassland and shrub cover) (Chundawat, 1992; McCarthy and Chapron, 2003; Mishra et al., 2003; Forrest et al., 2012).

The potential area protected for snow leopard was estimated at 119,564 km^2 in the western Himalaya (Anon, 2008); this model predicted similar potential snow leopard habitat (106,631km^2) under high, moderate and low suitable habitat classes in the western Himalaya. The model predicted that 39.8 % of the land area (probability > 0.50%) out of the total potential snow leopard habitat predicted in western Himalaya is highly suitable for snow leopards, which is distributed in Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. The highly suitable habitat areas were predicted for Himachal Pradesh (16,559 km^2) are followed by Jammu and Kashmir, and Uttarakhand (13,270 km^2 and 12,603 km^2, respectively).

Protected Areas (PAs) in Trans-Himalaya were identified to maintain and conserve a viable population of snow leopards as a flagship species, but the information about snow leopard presence is still missing for most PAs in the Indian Himalayan region (Bhatnagar et al., 2001). There are 23 PAs in the western Himalayan region having potential snow leopard occurrence (Fox et al., 1988; Bhatnagar, 1997; Bhatnagar et al., 2001), which covers an area of 27,323 km^2 (Bhatnagar et al., 2001). Current study estimated that only ~11,247 km^2 was suitable for snow leopards in the PAs of western Himalaya. Some protected areas (i.e. Karakoram WLS, Changthang WLS in the trans-Himalayan region have the largest extent covering 9,000 km^2, but have little wildlife value because most of the area is under permanent ice or glaciers with shear and large rock faces, thus further inflating the size, but not contributing to the wildlife values directly (Bhatnagar et al., 2001). This model did not predict potential snow leopard habitat in these PAs.

This model predicted that most of the potential habitats (73.5% ~31,185 km^2) for snow leopard are not protected and about 80% of the snow leopard population exists outside PAs explained by previous studies (Bhatnagar et al., 2001). To enhance the conservation initiative and make planning for snow leopards to occur outside the PAs, zonation of landscapes is the first step to making regional level conservation plans (i.e., identification of landscape at larger spatial scale units, which is > 1,000 km^2). Within these landscape units, small conservation units or core areas (National Park and Wildlife Sanctuary) with small buffer areas (Bhatnagar et al., 2001;Mishra et al., 2010) should be established. The Nanda Devi BR (area 6,407 km^2) and Cold Desert BR (area 7,770 km^2) are the best examples of conservation complexes for species conservation. They have different management practices (i.e., core zones [having no human interference], buffer zones [limited human activities] and transition zones (human involvement); Palni et al., 2012). Thus, knowledge about species distribution patterns is needed for effective management within landscapes including their relative abundance across different management regimes. Recent camera trap studies highlighted distribution of snow leopards in highly disturbed areas of Jammu and Kashmir (Maheshwari et al., 2012). Till date,density estimates oftwo populations of snow leopards have been reported from the western Himalayan region in India (Jackson et al., 2006; Sharma, 2009). In the core habitat region of Hemis National Park (4,100 km^2) there is protection status for snow leopards and their density was estimated to range from 4.45 to 8.49 individual/ 100 km^2 (Jackson et al., 2006) while in the buffer (area 3,843km^2) of Cold Desert BR with low protection status, the density was estimated 0.68 ± 0.40individual/100 km^2 (Sharma, 2009). Also, previous study on snow leopards (Maheshwari and Sharma, 2010) and recent study in the core and buffer zones of Nanda Devi BR suggest there is potential habitat for snow leopards (Habib et al., 2016).

Forrest et al., (2012) suggested climate change could lead to some loss of potential snow leopard habitat and current suitable habitat may change to forest tree stands in the near future. So, there is need for an integrated regional conservation strategy to protect these habitats. Protected areas <100 km^2 have little potential for long term maintenance of viable populations of snow leopard (Jackson and Ahlborn, 1989, Bhatnagar et al., 2001) for conservation. The most suitable habitat areas predicted in this study should be used as a base map to extend the boundaries of small PAs. Larger habitat blocks will allow expansion for the species and have potential to shift their distribution in the face of future climatic challenges. This study highlights the potential habitat of snow leopard and is a forward step to improve the conservation efforts for this endangered cat.

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Appendix I. Sign Survey for snow leopard and co – predators

Observer: Area: Starting time: Ending time: Date:

GPS location (St.): End: Whether:

Total distance walked (Km):

Sl. No.	GPS location	Species	Sign type	Elevation	Slope	Rangeland-use	Habitat type	Landform ruggedness	Site type	Sign age	Dominant topographic feature

Appendix II. Data sheet for scanning ungulates

Scat / Pellet group of ungulates

Date: **Time (St-Et):** **Area:**

Locality: **Total distance walked (km):**

Fire:

Grazing (Y/N):

GPS location	Time	Species	Total No.	Group Composition						Altitude (m)	Aspect	Slope °	Vej. Cover % G/C/S	Habitat (Vej.)	Distance from		Activity	Distance	Re mark
				M	F	Sm	Sf	Y	Un?						Escape terrain	livestock			

Vej. Cover: G (Ground), C (Canopy), S (Shrub)

Appendix III. Parameters recorded during the study (adopted from the SLIMS)

Rangeland-use

None	NON	Area receives no human use
Seasonal grazing	SGR	Area grazed seasonally by livestock
Year-round grazing	YRG	Area grazed throughout the year by livestock
Other	OTH	Other type of land-use (describe)

Habitat type

Barren	BAR	Less than 10% of the ground has vegetation cover
Grassland	GRA	Dominant vegetation is grassland
Shrubland	SHR	Dominant vegetation consists of shrubs
Woodland	WOO	Dominated by open trees and savanna
Forest	FOR	Tree cover exceeds 30%
Other	OTH	Other habitat type such as field (describe).

Landform ruggedness

Cliff	CLF	Terrain at site is very precipitous (slope more than 50o).
Very broken	VBR	Terrain heavily broken by cliffs, rocky outcrops, ravines, and gullies.
Rolling	ROL	Terrain has a relatively smooth land surface (e.g., rolling hills or alluvial fan).
Flat	FLA	Terrain forms a level surface (e.g., plain).

Dominant topographic feature

Cliff	CLF	Terrain at site is very precipitous (slope more than 50o).
Ridgeline	RID	Narrow crest of land sloping down on either side
Hill-slope	HIL	Side or slope of a hill.
Valley floor	VAL	Valley floor or adjacent slope.
Basin or bowl	BOW	Bowl-like depression.
Stream bed or	STR	Site with seasonal or permanent water flowing drainage through it.
Boulder field	BOU	Outcropping of large boulders.
Talus or scree slope	TAL	Accumulation of rocks and pebbles at base of a steep slope.

Rockfall or landslide ROC The mass of rocks at the base of a cliff.

Bluff BLU Steep slope bordering a stream or river.

Terrace TER Level raised area bordering a stream or river.

Glacier GLA Permanent ice-field.

Site type

Scrape Site

Non-relic 0 Usually only one scrape is present at the site or all the scrapes (and feces) are about the same age. No evidence of repeated use.

Relic 1 Usually there are numerous (3-10) scrapes present of various ages. Due to remarking, some or most scrapes have a sculptured appearance. Feces of many different ages may also be present.

Substrate type

Rock 1 Ground surface consists largely of rock.

Sandy soil 2 Sandy appearances with particles having a diameter of less than 2 mm.

Gravelly soil 3 Mixture of small pebbles (particle diameter more than 2 mm) and soil.

Fine or silty soil 4 Soil consists of fine or very fine particles (clay, silt, and dust).

Snow 5 Snow dominates.

Vegetation 6 Vegetation dominates.

Sign age or visibility

Scrape

Very old 0 Extensive weathering and disintegration, scrape features poorly defined, often with vegetation growth in the depression and on the pile (age 3 to 6 months)

Old 1 Moderate weathering and disintegration, with the scrape showing a rounded form, occasionally with vegetation in the depression or on the pile (age = several months or more).

Fresh 2 Slight weathering. Scrape has a well-defined form with “sharp” edges, is easily recognizable, and has no new vegetation growing in the scrape depression or pile (age = 1 to 4 weeks).

Very fresh 3 Little or no weathering has occurred, so that the scrape has a very sharp and "clean" form, is very easily recognizable, and has no vegetation in its depression or pile. (age = less than 1 week).

Pugmark

Old 0 Pugmark is very poorly defined, with an obviously "weathered" appearance (more than 2 weeks old).

Fresh 1 Pugmark has sharply defined edges and shape (several days, but less than one week old)

Appendix IV. Questionnaire format for assessing Snow leopard – Human Conflicts

Area: **Protected Area:** **GPS location:**

Date:

Village Name: **Block/ District:**

<table>
<tr><th rowspan="2">S. No.</th><th rowspan="2">Name of Respondent</th><th>Family members</th><th colspan="5">Livestock details</th><th colspan="5">Livestock killed: sp., No. and predator (which year)</th></tr>
<tr><td rowspan="2"></td><th>Goat</th><th>Sheep</th><th>Mule/Horse</th><th>Cow</th><th>Yak/ dzo/ dzomo</th><th>Snow leopard</th><th>Bear</th><th>Wolf</th><th>Red fox</th><th>Other</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th>General Wild Animals found in your area</th><th rowspan="3">Snow leopard seen (where, whem)</th><th colspan="2">Sign of snow leopard (Type, where, when)</th><th colspan="4">Attitude toward species</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><th>Snow leopard</th><th>Bear</th><th>Wolf</th><th>Red fox</th></tr>
</table>