STUDY OF LEOPARD MENACE, FOOD HABITS AND HABITAT PARAMETERS IN MANDI DISTRICT, HIMACHAL PRADESH.

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By

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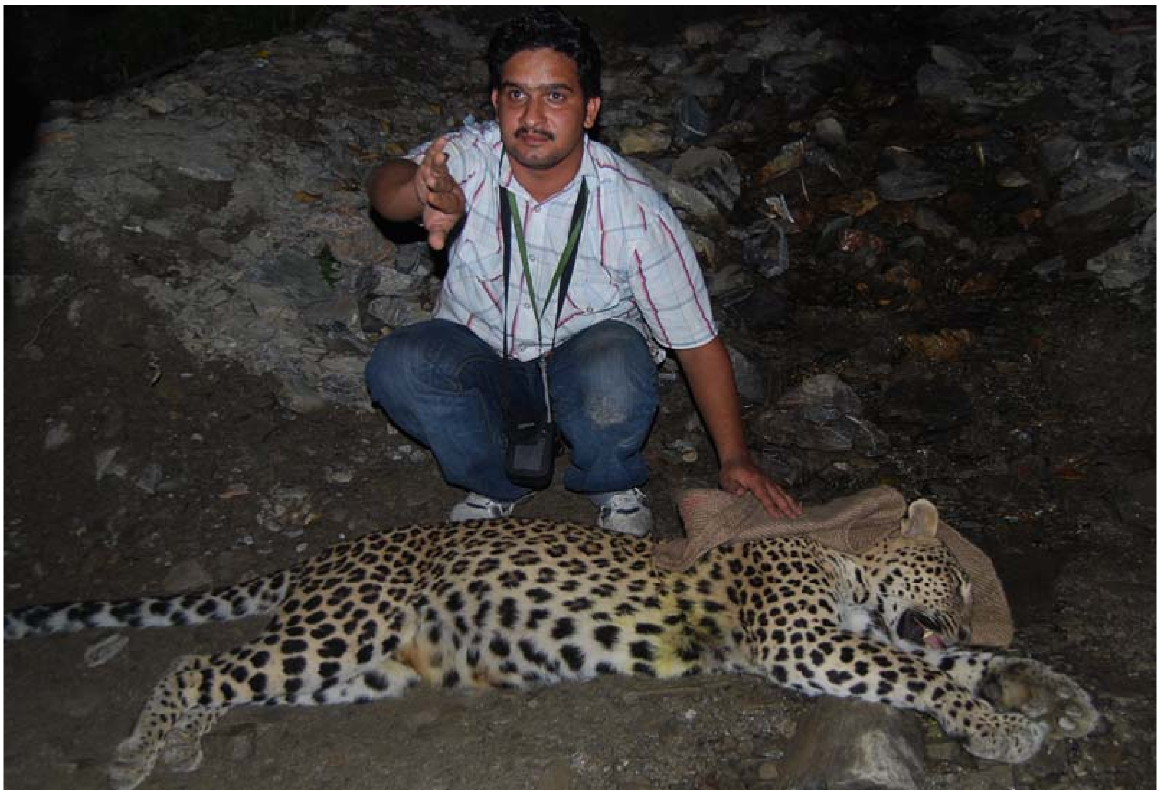

This Ph.D. Thesis

is

Dedicated to my beloved father

Photo credit: Leopard photographs

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Summary

The leopard (*Panthera pardus*) is the most widely distributed of all the wild cats in the world. Wide distribution of the leopard reflects the diverse adaptability of the species. Leopard is adapted to live well in Sevannah, rain forest, mountain elevation, dense vegetation, low scrub and thickets and even quite close to human habitation. Leopard is placed under 'Least Concern' category of International Union for Conservation of Nature (IUCN) (2002) Red List of threatened animals. Today, there are no true wilderness areas left where nature holds sway without at least some humans influence. However, a surprising amount of wildlife has survived, including most of the large herbivore species and large carnivore species. To maintain and restore, in coexistence with people, viable populations of large carnivores as an integral part of ecosystems and landscapes, reintegrating them into some of their former habitats, the landscapes is very important. Leopard populations have been greatly reduced over their vast former range due to several reasons. Thus, the preservation of carnivores becomes an important consideration in the discipline of conservation biology.

Leopard can surely be described as the most perfect of the big cats and graceful in its movements. It has been considered one of the most ferocious and cunning member of the larger cat family. Leopard is often considered to epitomize the features and behaviour of the larger cats. Secretive, silent, smooth, and supple as a piece of silk, it is an animal of darkness, and even in darkness it travels alone. In the Indian subcontinent, leopard is the most widely distributed large carnivore ranging from the Himalayas in the north to Sri-Lanka in the south. Leopard is known to occupy

all kinds of niches from Thar Desert. Leopard is found throughout the sub-continent with the exception of deserts and the Sundarbans mangroves. In Himalaya the leopard presence has been reported up to 3400 m in Trans-Himalayan regions. Leopard's ability to feed on a broad spectrum of prey also makes them most successful predator among big cats, its size gives it the ability to feed on a variety of prey species ranging in size from a young buffalo to smallest rodent. The leopard with territories in the proximity of human population has been known to hunt close to dwellings and prey on livestock. Due to increasing human population, loss of habitats and poaching, leopard population has been adversely affected. They are endangered through much of their range

Leopard is regarded as nuisance animal in the hills of Himachal Pradesh. They have created very formidable image among the people of Mandi district. In Mandi district, the habitat available to leopard is highly disturbed, fragmented, unprotected, and interspersed with villages, small townships, and agricultures fields. Thus there is a need to study ecology, behaviour, habitat use pattern, food habits of leopard, human-leopard conflict and socio-economic aspects of conflicts in highly affected areas in Himachal Pradesh.

Himachal Pradesh a state in north India is almost wholly mountainous with altitudes ranging from 350m to 6,975m above the main sea level. The district is situated in the lower Himalayas and is entirely hilly except some fertile valley in-between. The land use pattern in Mandi district comprises of forests, barren and un-culturable land, permanent pastures and other grazing land, land under miscellaneous tree crops and grooves, culturable waste, fallow land and agricultural area. The climate is temperate. The temperature varies from mild hot to cold with some areas under snowing winters. Physiographically, the district can be divided into three zones, namely, wet sub-temperate (Jogindernagar area), humid sub-temperate zone (some parts) and humid sub-tropical zone (major parts). Climatically, the area is divided into three distinct seasons viz. rainy season (June-September), winter (October-February) and summer (March-May). Variation in altitude, topography, precipitation, vegetation cover resulted into climatic variations from place to place.

The vegetation met within different parts of the district ranges from sub-montane to montane and alpine type. The vegetation of the study area is sub-tropical at lower elevations and sub-temperate at higher elevations. In the lower elevations upto an altitude of 1200m, mixed dry deciduous type of forests are represented, particularly in the areas adjoining the river Baes and its tributaries on the dry and exposed ridges. The mammalian species commonly found in the district are leopard, sambar, barking deer, wild pig, jackal, hill fox, rhesus macaque, common langur, porcupine, and hare. Black bears are common in the higher valleys.

Chapter 1 deals with the Introduction, problem statement and objectives of the study on leopard. The chapter 2 and 3 deal with the Review of literature and the Study area respectively.

Chapter 4 deals with the study of status, distribution and relative abundance of leopard in relation to habitat characteristics. Estimation of status of leopard population and its distribution become more important in an area when a species is highly threatened due to continuous habitat degradation and loss of habitat due to the increasing human population. Many carnivore species are rare or elusive, and documenting their distribution is difficult. Habitat requirement is also one of the most important factors which influence the distribution and abundance of a species, therefore habitat evaluation is a vital step in the formulation of carnivore management in an area. Large carnivores need large areas of relatively wild habitat, which make their conservation challenging. Estimating population abundance of large carnivores has always been controversial and reliable data on carnivore populations even today is questionable.

In previous studies, several different methods have been used to document carnivore distribution including track counts and signs indices. Large scale habitat evaluation has become possible due to the development of remote sensing techniques and the availability of Geographic Information System. For a species management, the ability to model spatial distribution grid changes in distribution of a species is of considerable importance. Therefore, using Geographic Information System has become an actable trend in ecological-studies. In Mandi district, human-leopard conflict is on the increase and situation has become alarming. In this chapter, the baseline information is generated on the distribution and relative abundance of leopard in Mandi district.

In the habitats available in the Mandi district, information from the local people and indirect evidences on forest trails and outside of leopard was used for estimating its population abundance and distribution. Through village survey and interview and direct and indirect evidences, information on status of leopard and its distribution was collected. Based on the shape and size of tracks, most frequently moving leopard to edge habitat were classified into males or females. Trails monitoring was carried out in the morning to get direct sighting of leopard. The relative abundance of leopards was estimated by walking on forest trails. To estimate the relative abundance, 31 trails of 1-2 km each covering various habitat types and landuse categories were walked three times over a period of one year in different seasons. In Mandi district, leopard den sites were located and identified as active sites and temporary ones. Besides location of direct sightings, scat collection, indirect evidences and also leopard attacks on humans and livestock were also marked to know the distribution of leopards in the districts. Across the intensive study areas of Mandi district, altogether 98 leopard den sites were identified. Among these 85 den sites were found to be actively used by leopards and rest 11 were used occasionally.

Along the 31 forest trails covering various habitat types and landuse categories, the leopard population abundance has been calculated in the Mandi district. Although all the transects were walked three times over a period of one year in different seasons, but the data was not indicative because of only a few sightings for estimating leopard population. Along transects in 372 walks, only 4 leopards were seen in 3 sightings in the study area. Average leopard encounter rate during each walk was very low i.e. 0.01. A total of 389 scats were collected out of which 131 collected in winter, 140 in summer and 118 in monsoon. Based on availability of scats, the mean encounter rate of leopard in Mandi district was found to be 1.04±0.39 (SD). During summer, monsoon and winter season, the mean encounter rate of leopard is 1.12±0.47, 0.95±0.43 and 1.05±0.54 respectively.

The landuse categories of the Mandi district identified on the basis of tone, texture and pattern in the satellite imageries showed that each landuse category was distinct with the specific characteristics. Altogether 16 landuse categories were initially identified. To make it more meaningful and convenient, these were finally reduced to 10 categories. The landcover and landuse pattern in Mandi district were studied through generation of maps with vegetation, habitation and agriculture, water distribution, road network, elevation, aspect and biotic pressure layers. Based on the vegetation and habitat features classification in the study area, 10 major habitat classes, namely, Pine forest, Mixed deciduous forest, Agricultural land, Deodar dominated forest, Oak dominated forest, Scrub, Grassland, Snow, Water bodies and Bare surface were recorded. Among all the landuse categories, Bare surface covered the maximum area (1101.8 km2, 27.9%). The habitat suitability map resulted from ENFA shows that only 17.15% of total geographic area of Mandi district was identified as highly suitable. Smaller suitable patch where leopard presence was occasionally recorded was identified as moderate suitable area which was around 39.98% of total geographic area, 31.01% of RNP was area identified as a least suitable while around 11.86% is unsuitable

The Chapter 5 deals with the assessment of nature and extent of man leopard conflict in relation to land use pattern. Carnivores exert a profound influence on biological communities via predation and interspecific competition. Human-carnivore conflict is considered to be a major conservation and rural livelihood issue because many carnivore species have been heavily persecuted due to elevated conflict levels with communities. One of the main contributors to human-wildlife conflict in Bhutan is predation of livestock by wild mammalian carnivores. Leopards are the most widely distributed wild cat in India. But due to expansion of human influence and ever-increasing pressure on natural resources, the issue of human-leopard conflict has been greatly intensified in a wide variety of situations.

Leopard is regarded as nuisance in hills of Himachal Pradesh. They are common in the forests across the state, and their food comprises of wild prey species such as goral, barking deer, wild boar, monkey, langur and jungle fowl. Due to severe human pressure mainly from hunting, cattle grazing, fire wood collection, forest fire, deforestation and habitat alteration, most of these prey species are either locally extinct or their numbers are too low to sustain the existing number of leopards. In this chapter, we have documented about the enormity of the problem, problem areas and human casualties and livestock depredation with respect to places of occurrence, season, time and circumstances of attack. It would help plan mitigation of leopard problem, besides conservation and future scientific management of the species.

To study the human-leopard conflict, a reconnaissance survey was done in the Mandi district. Information on the human casualties, livestock killing and circumstances was collected in specially designed questionnaire formats from the forest department and by interviewing the affected villages. Similarly the information on the livestock killing by the leopard, time and place of incidence and age class was collected. Human casualties and livestock killings by leopard occurred to varying extent in five forest divisions of Mandi district during 1988-2007. Based on information collected from the forest department and by interviewing local people, a total of 162 human casualties were reported in different villages situated in Mandi, Sundernagar, Jogindernagar, Karsog and Nachan forest divisions. In Mandi district, human casualties by leopard occurred every year from 1988 to 2007. Number of human casualties varied from 1 to 22 cases in these years. Out of the total of 162 cases, 13 people were reported to be killed and remaining 149 people were injured. Number of male casualties (n=99) was more than the female casualties. The frequency occurrence of human casualties was found to 38.9%, 30.2% and 30.9% during winter, monsoon and summer seasons respectively.

In Mandi district, victims of leopard were found to be from different age groups. Among the victims, middle age group people suffered the most. Out of total 162 human casualties, highest number of human casualties occurred in the age group of 25-30 years. Highest number of casualties occurred in the evening time during 1601-2200 hours. There were 37, 22 and 12 human casualties occurred during morning (0401-1000h), daytime (1001-1601h) and night time (2201-0400h) respectively. Compensation or ex-gratia amount was paid by the forest department to all the victims of leopard attacks or their relatives in Mandi district.

Chapter 6 deals with the food habits of leopard in relation to prey species availability. Leopards are considered as ecological generalist rather than specialist and can survive by feeding on large or small prey. They can be efficient scavengers. Food habits comprise one of the major determinants of various life history strategies in carnivores including pattern movement and habitat selection, social structure and geographical distribution. Leopards hunt by stalking, taking their prey opportunistically and mostly at night, especially in human dominated landscapes. Studies on leopards in other countries also showed that they preferred mainly medium sized prey. Leopards are well known for the use of habitat edges and its ability to live close to human habitation where livestock are available. Variation in diet of the leopards between areas was most likely due to its opportunistic behavior, resulting in a diet that that closely link prey consumption with availability.

The Mandi district, the study area, has a very low density of wild ungulates. So it was not possible to obtain absolute density estimates for the prey of the leopard. The relative estimate (abundance) of wild and domestic prey species was based on their direct sightings and indirect evidences along the forest trails or transects in the study area. The encounter rates were calculated on the basis of diurnal sightings of wild and domestic prey species. To determine the food habitat of a carnivore, availability of prey species is an important factor. A total of 390 scats were collected opportunistically as well as systematically from different habitats including den sites all over the study area as and when encountered during the field work or walking on forest trails (transects) or during village survey work during 2004 to 2008. To check for the stability of percent frequency of occurrence in the diet, all scats were randomized and the percent frequency of occurrence of each prey item in the diet was plotted. Leopard scats, broadly the occurrence of prey items were determined. These scats were processed for analysis. These scats were subsequently washed in flowing water through a fine sieve. Reference hair samples were collected from all domestic livestock species representing the study area. The hair sample of each species was than studied with respect to medullary and cuticular patterns. The frequency of occurrence (proportion of total scats in which an item was found) and percent occurrence (number of times a specific item was found as a percentage of all items found) were calculated. Accordingly, we also followed these regression equations to calculate the relative biomass consumed and relative number of species consumed. The relative number of each species consumed was obtained by dividing relative biomass by the average weight of the prey species. The frequency of occurrence of different species was calculated along with their bootstrap confidence intervals.

The relative abundance of wild and domestic prey species was based on their direct sightings and indirect evidences or a sign along the forest trails or transects in the study area. The indirect evidences such as diggings of wild pig, pellets of hare and quills and digging signs of porcupine were recorded. Similarly the indirect signs of the presence of buffalo, cattle and horse/mule were in the form of dung, and goat and sheep were pellets and dog were the faecal matter.

Among the wild prey species, monkey, langur, wild pig, hare, monitor lizard, mongoose, porcupine and birds were sighted on walking trails (n=31) during the field work. The mean encounter rates i.e. number of individuals per km of different wild prey species. The observed mean encounter rate of monkey was highest as compared to other prey species. The mean encounter rates of monkey did not show significant variation across seasons; it was 4.42 in winter, 3.24 in monsoon and 3.76 in summer. The mean encounter rate of hare on the basis of direct sighting was 0.29±0.18. The observed encounter rate of sheep was relatively high, followed by goat, cattle, buffalo, horse/mule and dog. On the basis on direct sighting, the observed mean encounter rate of sheep was 5.04±5.59. The encounter rate of sheep varied significantly in different seasons; it was 9.38 in winter, 2.14 in monsoon and 3.61 in summer. Whereas the mean encounter rate of horse and mule based on direct sighting was 0.78±0.85 and it showed no significant variation across seasons; it was 0.95 in winter, 0.66 in monsoon and 0.74 in summer.

Different prey species including wild and domestic were found out through identification of the food remains and hairs present in the scats. A comparison of the hair medullary and cuticular characteristics were compared with reference slides showed presence of both wild and domestic prey species in the diet of leopard. An analysis of total 390 scats, comprising of 132 scats of winter season, 118 scats of monsoon season and 140 scats of summer season, showed 13 different prey species in the diet of leopard in Mandi district. Out of which, 11 were mammals, one was reptile and others were birds. Birds were considered as one prey item in the leopard diet. All these prey species constituted parts of its diet throughout the year. But the rodents, sheep, goat, cattle and birds were frequently eaten by leopard, followed by langur, hare, buffalo, wild pig, reptile, dog, porcupine and mongoose.

Among wild prey species, the frequency occurrence of rodents was 28.89% in the diet, followed by birds, langur and hare, wild pig and reptile, porcupine and mongoose. The diet of leopard was found to have higher proportion of domestic prey species than wild prey. Among wild prey species, the mean percent occurrence of rodents was 33.3% in the diet, followed by birds, langur and hare, wild pig and reptile, porcupine and mongoose. An analysis of 140 scats of summer, 118 scats of monsoon and 132 scats of winter season showed some variation in the dietary pattern of leopard in different seasons. Although the prey species found were the same in different seasons, but the frequency occurrence of these items showed differences in summer, monsoon and winter seasons.

Domestic prey species contributed more biomass (66.3%) to the diet of leopard as compared to the consumption of wild prey biomass (33.7%). The large size prey species (cattle, buffalo) contributed 26.4% of the prey biomass to the diet of leopard, medium size prey (sheep, goat, dog, wild pig and langur) contributed 44.0% of prey biomass and small prey (hare, rodents, porcupine, mongoose, reptiles and birds) provided 29.6% of biomass consumed. Sheep contributed the maximum biomass (23.4%) to the diet of leopard. Large wild prey species were not present in the diet of leopard and medium wild preys were not contributing significantly to the consumed biomass of leopard.

Chapter 1

Study of leopard distribution and abundance, human-leopard conflict, food habits in Mandi district, Himachal Pradesh.

1.1 Introduction

Of the 36 species of cats extant in the world, Indian has fifteen of them, including five of the large sized cats: the tiger (*Panthera tigris*), the lion (*Panthera leo*), the leopard (*Panthera pardus*), the snow leopard (*Uncia uncial*) and the clouded leopard (*Neofelis nebulosa*) (Edgaonkar and Chellam, 1998). Of all the wild cats, the leopard is the most common and widely distributed species (Nowell and Jackson, 1996). It is found in almost every kind of habitat, ranging from the rainforests of the tropics to desert and temperate regions (Kitchener, 1991) as well as degraded areas (Pocock, 1939; Prater, 1971; Bailey, 1993 and Daniel, 1996). It is known to occur from across Africa to South Asia northwards to Central Asia and east to the Amur Valley in Russia (Bailey, 1993 and Edgaonkar and Chellam, 1998). In India, it has a wide range of distribution, except the arid regions of Rajasthan, the mangrove forests (Daniel, 1996) and above the tree line in the Himalayas. Besides natural habitats, leopard's elusiveness and behavioural flexibility (Daniel, 1996), allow it to survive near villages and human settlements (Nowell and Jacknson, 1996 and Edgaonkar and Chellam, 2002).

The leopard (*Panthera pardus*) is the most widely distributed of all the wild cats in the world (Bailey, 1993 and Nowell and Jackson, 1996). Wide distribution of the leopard reflects the diverse adaptability of the species (Turnbull-Kemp, 1967; Guggisberg, 1975; Bailey, 1993 and Daniel, 1996). Leopard is adapted to live well in Sevannah, rain forest, mountain elevation, dense vegetation, low scrub and thickets and even quite close to human habitation (Scott, 1988; Seidensticker *et al*., 1990 and Bailey, 1993). Leopard is placed under ‘Least Concern’ category of International Union for Conservation of Nature (IUCN) (2002) Red List of threatened animals.

Today, there are no true wilderness areas left where nature holds sway without at least some humans influence. However, a surprising amount of wildlife has survived, including most of the large herbivore species and large carnivore species. To maintain and restore, in coexistence with people, viable populations of large carnivores as an integral part of ecosystems and landscapes, reintegrating them into some of their former habitats, the landscapes is very important. Thus, the preservation of carnivores becomes an important consideration in the discipline of conservation biology (Eisenberg, 1986; Ginsberg, 2001 and Gittleman *et al*., 2001).

1.2 History and distribution

The geographical distribution of leopard extends throughout Africa, central Asia, and south-east Asia with scattered populations in China and north Amur valley in Russia. Leopards were once ranged from northern region and south of Sahara in Africa, Sinai Peninsula north to west Caspian through Arabia, across Turky, Iran and Afghanistan in middle east and throughout India south to Sri Lanka north to North Central China, far east Russia (Siberia and Korea) and into southeast Asia, including Indochina and the islands of Java (Bailey, 1993). At the turn of this century leopards have been extinct in several countries due to several reasons (Turnbull-Kemp, 1967; Guggisberg, 1975; Ilany, 1986; Green, 1987; Martin and De Meulenaer, 1988 and Bailey, 1993).

During the Pleistocene, leopard inhabited Africa, Asia and Europe as far west as England - a vast area that included nearly the same area as that inhabited by the lions and tiger (Fisher *et al.*, 2003). In Europe, many different subspecies of fossil leopard were recognized. Leopards entered Europe earlier than the lion in the early middle Pleistocene. These unspecialized leopards resembled the jaguars of the North American Pleistocene. A separate subspecies of leopard from south-eastern Europe spread to central Europe at the end of the Riss glacial (100,000 years ago). Again, the repeated glaciations and isolation during the Pleistocene has resulted in a complicated pattern of speciation and sub-speciation. At the turn of this century, the range of leopard included Africa and stretched north across Asia from the Cauasus mountains in southern Russia eastward through southern Turk Mania and southwestern Tadzhikestan to the Amur river in eastern Siberia. These leopards were once reported as far north as 52° N latitude near Khaborovsk (Stroganov, 1969). Fossil evidence, some as old as 1.5 to 2.0 million years, suggests leopards were once more widely distributed than today (Hemmer, 1976a and Brain, 1981).

By the middle of the Pleistocene, the leopard had spread to eastern and south eastern Asia. In Southern Asia leopards occurred throughout the forested regions of India, the Indo-China Peninsula, Southern China, and Island of Srilanka (Turnbull-Kemp, 1967 and Guggisberg, 1975). The oldest known leopard remains are from the Indian Shivaliks (Late Villa Franchian, approximately two millions years ago). Local populations in southern China become isolated and evolved into forms which are said to resemble modern Chinese leopards. The leopard’s historical presence on the Islands of Sumatra is doubtful, although fossils of leopards occurred there as well as further south in Java (Seidensticker, 1986). Leopards are also known from the early middle Pleistocene of java (one million plus years ago).

Currently, leopards are distributed in the Africa (south of the Sahara in the north to Cape Province in the Republic of South Africa in the South), Morocco, Algeria and Tunisia, further east to Turkey, Sinai, Israel, Arabian Peninsula, Transcaucasia, Iraq, Iran and neighbouring regions of Turkmeniya in USSR, Afghanistan, Pakistan, India with Sri Lanka to Indochina and south China, Malayan Peninsula, Java and Thailand (Guggisberg, 1975; Ilany, 1986; Khan, 1986; Khan and Beg, 1986; Santiapillai and Ramono, 1992; Bailey, 1993 and Korkishko and Pikunov, 1994).

Leopard populations have been greatly reduced over their vast former range due to several reasons (Santiapillai *et al*., 1982; Ilany, 1986; Green, 1987; Bailey, 1993 and Daniel, 1996). Among eight subspecies declared endangered by the IUCN, Amur leopard (*Panthera pardus orientalis*) is critically endangered and the population is estimated at approximately 50 mature individuals (Miquelle *et al*., 2003).

1.3 Taxonomy

The felidae forms a monophyletic family of 21 genera and 37 species (Bekoff *et al*., 1984). Felids are found in all continents except Australia. On the basis of physical characterstics, four species were put under the genus Panthera (Wozencraft, 1993). These species are the tiger (*Panthera tigris*), lion (*Panthera leo*), jaguar (*Panthera onca*) and leopard (*Panthera pardus*). Fossil evidences suggest that leopards were there 1.5 to 2.0 million years ago (Hemmer, 1976 and Bailey, 1993).

Leopard is classified under the kingdom Animalia, phylum Chordata, class Mammalia, order Carnivora, family Felidae, subfamily Felinae, genus *Panthera* and species *pardus* (Linnaeus, 1758). Twenty seven subspecies of leopard have been reported based on phenotypic and geographic variation, though not all of these are accepted as distinct by all authorities (Miththapala *et al*., 1996). Many subspecies may be the result of regional variations in coat pattern and spot or rosette size (Ellerman and Morrison-scott, 1966 and Miththapala *et al*., 1996). Miththapala *et al*. (1996) analyzed molecular data by using various phylogenetic methods to resolve genetic differentiation below species level in leopard population across the globe. Study revealed phylogenetic distinction of six geographically isolated groups of leopard viz. African, Central Asian, Indian, Sri Lankan, Javan and East Asian. So in order Miththapala *et al*. (1996) recommended revised taxonomy of leopard which comprised of eight subspecies, namely, *Panthera pardus pardus* (Africa), *Panthera pardus saxicolor* (Central Asia), *Panthera pardus fusca* (Indian subcontinent), *Panthera pardus kotiya* (Sri Lankan), *Panthera pardus melas* (Java), *Panthera pardus orientalis* (Amur), *Panthera pardus japonensis* (Northern China) and *Panthera pardus delacouri* (Southern China).

The leopard has fourteen recognized races in the checklist of Palaeartic and Oriental mammals (Ellerman and Morrison-Scott, 1951). Among the races that are recognized, especially in captive populations, are the following: Javan leopard (*melas*), Amur leopard (*orientalis*), Indian leopard (*fusca*), North Chinese leopard (*japonensis*), Somali leopard (*nanopardus*), Zanzibar leopard (*adersi*), Sinai leopard (*jarvisi*), Sri-Lankan leopard (*panthera*), Persian leopard (*saxicolor*), Arabian leopard (*nimr*), Anatolian leopard (*tulliana*), Caucasus leopard (*ciscaucasica*), and Indo-Chinese leopard (*delacouri*). They recognized four races from the Indian subcontinent are the Indian leopard (*Panthera pardus fusca*) (Meyer, 1974), the leopard of Sikkim and Nepal (*Panthera pardus pernigra*) (Gray, 1868), the Sind leopard (*Panthera pardus sindica*) and the Kashmir leopard (*Panthera pardus millardi*) (Pocock, 1930).

1.4 Physical description

The leopard show great variation in appearance and behaviour. The Indian leopard (*Panthera pardus fusca*) is a sleek short-haired animal with a fulvous or bright fulvous coat marked with small close-set black rosettes (Turnwell-Kemp, 1967; Bailey, 1993 and Prater, 1997). These rosettes are smaller and have no dark spots in the middle but are black circles broken into 2 to 5 parts. The head, lower limbs and belly are spotted with solid black spots (Pocock, 1939). The coat colour varies from pale yellow to deep gold. Animals from the desert zone are paler. Leopards from Kashmir have soft deep-furred grey buff coats with small, thick-rimmed rosette. The coat colour and rosettes patterns are broadly associated with surrounding habitat types (Pocock, 1939). Coat patterns differ between individual leopards and from one side of the body to the other in the same individual (Henschel and Ray, 2003 and Khorozyan, 2003).

One of the most striking features is melanism, the leopard being totally black. Melanism is a common coat colour mutations in cats, and not a subspecies (Miththapala *et al*., 1996). It has been recorded in leopards, lions, tigers, jaguars, caracals and servals (Robinson, 1970, 1976 a; Ever, 1973; York, 1973). Melanism in leopard and domestic cats is usually due to a recessive gene at the agouti locus for coat colour, and is probably the case in all cats. Melanistic leopards or black panthers are very common in the rain forests of southern Asia, especially in India and south-east Asia (Kingdon, 1977). Leopard in Iran and central Asia have a lighter colour and a long-haired winter coat (Bailey, 1993).

Leopard has an elongated body and limbs of moderate length. The paws are broad, rounded and the ears are short. The tail is longer in comparison with body, and assists its movements. The throat, chest, belly and insides of the limbs are white. The backs of the ears are black with a white central spot but there are various aberrant coat patterns. The skull is relatively elongated but flat on the upper surface.

The leopard is well known its versatility and shows a number of morphological adaptations (Turnbull-Kemp, 1967; Prater, 1971 and Guggisberg, 1975). Leopard body size varies across it range. Size of leopard varies according to the geographic region (Stuart, 1986; Norton *et al*., 1986 and Bailey, 1993). The larger subspecies of leopard are found in Iran and West Africa and the smaller subspecies occur in Somalia and Java (Bailey, 1993). Average body length of the leopard length is 7 ft. (215 cm), females about 1 ft. (30 cm) less. There is much variation in size in various parts of India. Adult body weight for male ranges from 50-70 kg and female ranges 29-54 kg (Nowell and Jackson, 1996). An exceptionally large male may reach 8 ft. (245 cm). According to Jenny (1996) and Bailey (1993), average leopard weight reported is 58 kg for male and 37.5 kg for female. Exceptionally large males weighing over 91 kg have been reported from Kruger National park, South Africa (Turnbell-kemp, 1967). The smallest male weighing 30-31 kg has been reported from the Cape Province and Judean desert of South Africa

(Ilany, 1986; Norton *et al*., 1986 and Stuart, 1986). The smallest female weighing 23 kg has been reported from Judean desert (Ilany, 1986). Bailey (1993) reported that old adult males were 70% heavier and 10% longer than females (n=30).

Like other felids, leopards have morphological adaptations for leaping and grasping prey with their sharp, retractile claws and long sharp canines (Hopwood, 1947 in litt.). Leopard's scapula is adapted for the attachment of powerful muscles that raise the thorax, enhancing its ability to climbs trees (Hopwood, 1947 in Litt.). The skull is massive, giving ample room for attachment of powerful jaw muscles. The species whiskers are particularly long and there are often several extra hairs in the eyebrow, protecting the eyes and assisting movement through vegetation in the darkness (Skinner and Smithers, 1990). Despite its relatively small body size, the leopard is still capable of taking large prey (Kingdon, 1977; Robinowitz, 1989; Karanth and Sunquist, 1995; Seidensticker *et al*., 1990; Bailey, 1993 and Henschel *et al*., 2005).

1.5 Ecology and behaviour

Leopard can surely be described as the most perfect of the big cats and graceful in its movements (Guggisberg, 1975). It has been considered one of the most ferocious and cunning member of the larger cat family. Male leopards are very resentful of intrusions of others of their kind in the area.

Fights between leopards are unusual because they invariably keep to their own areas (Corbett, 1947).

Leopard is often considered to epitomize the features and behaviour of the larger cats. Secretive, silent, smooth, and supple as a piece of silk, it is an animal of darkness, and even in darkness it travels alone. Leopard, because of their furtive habits, are almost impossible to see (Edey, 1968). Hearing, vision, scent all the higher senses, are highly developed in carnivores, particularly in those tribes which live habitually by hunting, such as the cats.

In the Indian subcontinent, leopard is the most widely distributed large carnivore ranging from the Himalayas in the north to Sri-Lanka in the south (Prater, 1997). Among secondary consumer of trophic levels, leopard or panther (*Panthera pardus*) protected under Schedule I of the Wildlife Protection Act (1993 amended) by law in India is most common and widely distributed species among larger cats across the country occupying a great variety of habitats ranging from prime forest to degraded areas (Pocock, 1939, Prater, 1997 and Daniel, 1996). Leopard is known to occupy all kinds of niches from Thar desert (Robert, 1977) to hilly tracts in Himalayan regions (Green, 1987 and Johnsingh *et al.,* 1991; Illany, 1986; Khan and Beg, 1986 and Bailey, 1993). Leopard is found throughout the sub-continent with the exception of deserts and the Sundarbans mangroves (Khan, 1986 and Johnsingh *et al.*, 1991). In Himalaya the leopard presence has been reported up to 3400 m in Trans- Himalayan regions (Green, 1987). Exceptionally leopards range up to 5700 m was observed by Guggisberg (1975).

In African subcontinent, leopard is the only cat species which occupies both rainforest and arid desert habitats (Bothma and Le Riche, 1984). The leopard has been successfully adapting to human modified landscapes (Hamilton, 1986; Seidensticker *et al*., 1990 and Daniel, 1996). Leopard's ability to feed on a broad spectrum of prey also makes them most successful predator among big cats, its size gives it the ability to feed on a variety of prey species ranging in size from a young buffalo to smallest rodent (Daniel, 1996). The leopard with territories in the proximity of human population has been known to hunt close to dwellings and prey on livestock (Hamilton, 1986 and Seidensticker *et al*., 1990). Leopards not only adapt well to drier areas with low cover (Seidensticker *et al*., 1990) but they have also been to shown to be independent of free water sources, using it when it is available (Hamilton, 1976 and Bothma and Le Riche, 1984). Leopards obtain their water requirement from prey (Bothma and Le Riche, 1984). Leopards are more tolerant than tigers of temperature extremes and dry environments (Bailey, 1993).

Leopards breeds throughout the year across their range except in the tropics (Prater, 1997). They have no particular breeding season. In Africa, most courtships (49%) among leopards were observed during January to March (Bailey, 1993). Breeding in Amur leopard was reported during June-July (Shibnev, 1989 in Litt.). In Sri Lanka, breeding was reported during dry season i.e. May to July (Santipillai *et al*., 1982).

Mating in leopards takes place for 4 to 5 days. The males become sexually mature at 2-3 years of age, where the females become sexually mature at about 3 years (Bailey, 1993). Female leopards appear to grow rapidly than males. Females are sexually receptive at 3-7 week intervals and the period of receptivity lasts for a few days. At this stage females become cyclic, and studies on captive leopards indicate an average oestrous period of 6 to 7 days and an inter-oestrous period of 45.8 days (Sadlier, 1966). Bailey (1993) reported oestrous cycles of about 46 days in captive females. The gestation period varies from 90 to 110 days (average 96 days). Normally 2 cubs per litter are born, occasionally 3 or 4. Leopard may give birth to litter of 1-6 cubs (Turnbull-Kemp 1967). The mean litter size varies between 2 to 3 (Turnbull-Kemp, 1967; Santiapillai *et al*., 1982; Seidensticker *et al*., 1990 and Bailey, 1993). Cubs are born in a den or under bushes (Bothma and Le Riche, 1984; Seidensticker *et al*., 1990 and Bailey, 1993). The young weights 400-700 gm at the time of birth and open their eyes after 7-9 days (Ewer, 1973 and Hemmer, 1976a). The cubs were weaned at the age of three months when they begin to accompany their mother on hunts (Bothma and Le Riche, 1984 and Bailey, 1993). The cubs remain with their mother for 12 to 18 months. Then they become independent and established territories of their own (Eisenberg and Lockhart, 1972; Muckenhirn and Eisenberg, 1973 and Bailey, 1993). Mortality among cubs is frequently observed by Seidensticker *et al*. (1990) in Chitwan National Park, Nepal. Male cubs have higher mortality rare than females (Bailey, 1993).

The reported inter birth interval is 20 to 21 months (Seidensticker *et al*., 1990 and Bailey, 1993). Females in captivity have produced offspring at the age of 19 years, but the average age of last reproduction was 8.5 years (Bothma and Le Riche, 1984 and Bailey, 1993). The maximum life expectancy for wild leopard is 12 years, whereas leopards have lived up to 20 years (Bailey, 1993).

1.6 Conservation threats

Due to increasing human population, loss of habitats and poaching, leopard population has been adversely affected. They are endangered through much of their range (Roberts, 1977; Santiapillai *et al*., 1982; Ilany, 1986; Green, 1987; Khan, 1986; Bailey, 1993 and Daniel, 1996), though the species is not yet threatened with extinction except in certain areas (Myers, 1976). The wide geographic distribution of leopards is also attributed to their ability to co-exist with other large carnivores (Hamilton, 1976 and Seidensticker *et al*., 1990). In South Asia, leopard has an advantage over tiger due to its ability to survive outside protected area (Seidensticker *et al*., 1990).

There is declining trend in leopard population in many parts of Africa and south Asia due to habitat loss and depletion of prey (Santiapillai *et al*., 1982; Khan, 1986; Ilany, 1986; Green, 1987 and Bailey, 1993). Leopard populations have declined throughout much of West Africa (Martin and De Meulenaer, 1988). In Bangladesh, as recently as 1940, leopard occurred over the entire country and in all kind of habitats except a major portion of Sunderbans and coastal forests. But situation over the years has changed and leopards are now confined to one isolated habitat block (Khan, 1986). The number of leopards has been reduced in mountains of northern Pakistan (Roberts, 1977). In Sri Lanka, the numbers of leopards have fallen by 75% since the turn of century (Santiapillai *et al*., 1982). Small size and insularity of protected areas or wildlife habitat, widespread reduction in the prey base and indiscriminate killing by man are well known causative factors for local extinction of a carnivore species from an area.

Leopards continue to get killed for socio-economic reasons, as demand for bones and skin is high (Hamilton, 1981; Bailey, 1993 and WWF Report, 1997). Edey (1968) and Myres (1976) reported that alone in Africa, thousands of leopards were being killed per year due to the demand for their skin. Hamilton (1981) reported that the poaching for the fur trade has substantially reduced the leopard population in Kenya. In Africa at many places, leopard populations are increasingly threatened due to prosecution by local people to protect livestock (Myres, 1976). Due to excessive hunting for their valuable skins and depletion of prey species, leopard have becomes rare in the Savanna and West African rain forest zones (Myres, 1976; Norton *et al*., 1986 and Martin and De Meulenaer, 1988). Human pressure has reduced leopard population dramatically and in many areas, like Zanzibar, leopards are now extinct (Bailey, 1993). In the Java island of Indonesia, high commercial value of leopard pelt poses a serious threat to the species (Santiapiallai and Ramono, 1992). The greatest threat to the species in Java comes from the increasing use of poison. In Middle East, many leopard populations have become quite small and are increasingly vulnerable to disruption of healthy population dynamics (llany, 1986). In Russia, the leopard decreased dramatically between 1970 and 1983 due poaching and depletion of wild prey species and is threatened by small size of population (Ilany, 1990 and Korkishko and Pikunov, 1994).

The leopard is a Schedule I animal in Wildlife (Protection) Act, 1972 that gives highest level of protection to the species in India. But still the killing incidences and illegal trades of body parts of leopard have been reported to be high compared to tiger or other large felid (Athreya *et al.,* 2004). Data on seizures of tiger and leopard parts compiled by TRAFFIC-India indicates that against every tiger killed, over five leopards are being poached, and leopards distributed in northern India are facing danger of extinction (WWF Report, 1997). In the hill region of Northern India, leopards are being killed due to their confrontation with the human (Negi, 1996 and WWF Report, 1997).

Leopard habitat in India was continuous in past but most of the present population is confined to smaller insularized protected areas or forest patches (Rodgers and Panwar, 1988; Johnsingh *et al*., 1991 and Daniel, 1996). Conservation threats to leopard are the same i.e. fragmentation of habitat into smaller pockets and loss of wild prey population (Santiapillai *et al.,* 1982 and Green, 1987). Leopards are threatened due to depletion of wild prey base in many areas (Hamilton, 1981; Johnsingh *et al*., 1991; Chellum and Johnsingh, 1993; Korkishko and Pikunov, 1994 and Negi 1996). Leopards are persecuted when they resort to livestock depredation (Hamilton, 1981; Korkishko and Pikunov, 1994 and Daniel, 1996). In several areas, leopards are facing threats from its carnivorous competitors (Scheller, 1972 and Bailey, 1993). Although the species is not yet threatened with extinction except in certain areas and its prospects of survival are better than the lion and cheetah (Myers, 1976). In the recent past attrition of leopard range has been accelerating trend due to changes in land use pattern, encroachment and continuous mounting pressure on these habitats due to high human population.

Most of the protected areas and managed forests within the geographical range of leopard have well defined habitat edges where natural forests or grassland merges with plantation forests, scrub forest or cultivation. Larger cats are adapted to thrive well in the edge habitat or small forest patches outside the protected areas leading to plantation or tea garden or scrub in certain parts of the country which provide cover to predate on domestic species (Santiapillai *et al.,* 1982; Seidensticker *et al.,* 1990 and Sabarwal *et. al.,* 1994). Changes in leopard behavior to become extremely bold have been noticed due to habitat disturbance and degradation and loss of forests to plantation of monoculture timber species and rubber, coffee and tea plantation and decline in wild prey species (Johnsingh *et al*., 1991; Chellum and Johnsingh, 1993 and Daniel, 1996). With the result, there has been an increase in human-leopard conflict on the forest edges and in this process, irate farmers killed a number of leopards by poison, snare or shot dead. The decline of leopard populations in many areas has been due to frequent killing of alleged man-eaters (Johnsingh *et al*., 1991; Daniel, 1996 and WWF-report, 1997).

The leopard has survived from its ability to adapt a variety of environmental situations (Guggisberg, 1975; Seidensticker *et al*., 1990; Bailey, 1993 and Daniel, 1996). They also appear to be very successful at adapting to altered natural habitat (Turnbull-Kemp, 1967; Guggisberg, 1975; Martin and De Meulenaer, 1988 and Daniel, 1996). Although facing the same threats, leopards are more successful than tigers because of their ability to live in different environment and the flexibility in their diets (Seidensticker *et al*., 1990 and Bailey, 1993). They are considered most useful and perfect predator because of its ability to adapt and remain elusive and unseen in the most adverse of habitats, and flexibility of behavior with respect to boldness and timidity. They are also found to be tolerant to habitat modifications. Such abilities made leopard used to human beings and to live in the vicinity of human settlements (Seidensticker *et al*., 1990).

1.7 Conservation efforts

The leopard is placed in Appendix 1 in the Convention of the International Trade in Endangered species (CITES) which prohibits trade of leopard or it's body parts. Under the CITES treaty, use of leopard's pelts or body parts for commercial purposes is banned. But in the absence of effective public relation campaign, leopard killing for commercial purposes could not be checked (WWF Report, 1997).

Alarmed at the rate at which leopard are being killed for socioeconomic purposes, the International Union for Conservation of Nature listed its eight sub-species as endangered or critically endangered. In India, leopard is a schedule-1 species and its hunting is banned since 1972 after implementation of Wildlife (Protection) Act 1972. Leopard is protected along with co-existing carnivores within protected areas. But there is no clear cut management strategy for leopard conservation residing outside the protected areas. Thus, there is a strong need to have management plan for conserving species especially in human dominated landscapes.

1.8 The Preamble: Present study

All India tiger census data shows that leopard population is stable or has increased in the states of Bihar, Orissa, Karnataka, Tamilnadu, Madhya Pradesh, Maharashtra, Gujarat, Rajasthan, Himachal Pradesh, Uttar Pradesh, Uttarakhand, Assam, Arunachal Pradesh, Mizoram and Tripura between 1984 and 1993, and thereafter its population has been showing fluctuating trend. Green (1987) has also opined the same view. It is very difficult to conclude whether leopard population has increased during last one decade, but definitely it requires understanding of ecology of leopards including population dynamics, reproductive biology and population regulating factors.

Leopard is common in the forests across Himalayas, and its food consists of wild prey species such as goral, barking deer, wild boar, jungle fowl and langur. Due to severe biotic pressure mainly for cattle grazing, fuel wood collection, forest fire, deforestation and habitat alteration, most of these prey species are either locally extinct or their numbers are too low to sustain the existing number of leopards. Increase in the frequency of confrontation between leopard and humans during last decade may be due to accelerating trend in habitat fragmentation, scarcity of wild prey base and high toll of livestock depredation and to some extent may be due to increase of local leopard population.

Now a day's human-leopard conflict is on the increase and this requires immediate attention, not only to resolve the conflict but also for the conservation of this vulnerable species. Human-leopard conflict has been reported from Great Himalayan National park and Mandi and Hamirpur districts of Himachal Pradesh (Chauhan 2003). Leopard attacks on human and livestock is on the increase in Garhwal and Kumaun region of Uttarakhand state (Negi, 1996; Mohan, 1997; Chauhan, 2002, 2003 and Chauhan, 2009). Although leopard attacks on humans are not new in this region, but the frequency has increased during the last decade (Negi, 1996). Leopards are not uncommon in this region as their food consisting of a number of wild prey species has been historically common (Corbett, 1957). But due to severe human pressures mainly due to hunting, cattle grazing, fire wood collection, forests fires, deforestation and habitat alteration on habitat, most of these prey species have either become locally extinct or their numbers have become too low to sustain the existing number of leopards. Incidents of tea workers being mauled has also been reported in northern Bengal, because leopards have been found to use the cover for seeking shelter and sometimes raise their litters in the deep drains under the tea bushes (P.C. Dass, in litt, 1987 and D.K. Lahiri Choudhery, in litt. 1987). Cobb (1981) reviewed the conservation of leopard and reported that a disproportionate number of nuisance leopards were adult males.

Leopard is regarded as nuisance animal in the hills of Himachal Pradesh. They have created very formidable image among the people of Mandi district. In Mandi district, the habitat available to leopard is highly disturbed, fragmented, unprotected, and interspersed with villages, small townships, and agricultures fields. Thus there is a need to study ecology, behaviour, habitat use pattern, food habits of leopard, human-leopard conflict and socio-economic aspects of conflicts in highly affected areas in Himachal Pradesh. Most of the studies on leopard have been undertaken within the protected areas, whereas there is a need to understand responses of animal to changes in habitat attributes especially outside protected areas in human dominated landscapes. Therefore, the present study is first attempt to provide base line information on leopard ecology outside protected areas. This will be helpful in planning effective conservation and management strategies for the leopard whose status is vulnerable and precarious in these areas. The Ph.D. proposal envisages the study of various ecological and management aspects of problematic leopard in Mandi district. The study will also provide a basis for developing an action plan to mitigate the human-leopard conflicts effectively and on a long-term basis. While the study is site-specific, the outcome would have the potential of application to similar habitat situation elsewhere in India.

1.9 Significance of the study

1. The study on human-leopard conflict is of high research priority in Himachal Pradesh in India.

2. Leopard is an endangered species in India. It has wide distribution and its habitat is continuously encroached upon and degraded by the human beings. In Mandi district, forests are highly fragmented and interspersed with villages and agricultural crop fields. Leopard seems to have developed aberrant behaviour. As a result, human-leopard conflict has been increasing and now attained alarming proportion in most of the man-altered protected areas-village interface situations.

3. Though leopard attacks on human and cattle lifting are not new in the Mandi district, frequency of conflicts with human has increased in past couple of years. Consequently, the conservation efforts for the leopard, an endangered species, are badly affected.

4. A few studies conducted on leopard focus on only ecological aspects. There is no information available on human-leopard conflict, ecology of leopard and human dimension, and no proper strategy to deal with this kind of problem in Himachal Pradesh. The proposed study is entirely different and focuses on management of problematic leopard.

5. Why leopards are venturing into human habitation, and why there are increased confrontations with human which results in conflict in this part of the country? The problem needs to be tackled by collecting systematic data on ecology of leopard in order to understand its changed behaviour, and to plan a proper strategy to reduce human-leopard conflicts.

6. Although a similar site-specific study on human-leopard conflict has been conducted on problematic leopard in Pauri Garhwal, but due to varying situations, the findings of this study may not applicable in Mandi area for scientific management of leopard population and mitigation of the human-leopard conflict.

7. The study on man-leopard conflict, ecology and behaviour of leopard, habitat use pattern, food habits, and socio-economic impacts of leopard menace is also very necessary in the highly affected areas in Mandi district. The study will also ascertain causes of human-leopard conflict.

8. It is for the first time that an in-depth systematic scientific probe on ecology and management of problematic leopard has been done in Mandi district. This will provide a basis for developing an action plan for conservation and management of leopard in the state and to mitigate the human-leopard conflict effectively and on a long-term basis.

1.10 Objectives

The study was carried out with the following objectives:

1. To study current status, distribution and relative abundance of leopard in relation to habitat characteristics (terrain and vegetation).

2. To study nature and extent of man-leopard conflict in relation to land use pattern.

3. To study food habits in relation to prey species (wild and domestic) availability.

4. To suggest measures to minimize/contain human-leopard conflict in hills of Mandi district, Himachal Pradesh.

1.11 Organization of chapters

The Ph.D. thesis comprises of seven chapters. The chapter one deals with the introduction of the problematic leopards and objectives of the study. The chapter two covers the review of literature. The chapter three is all about the study area. The chapter four is dealing with the Status, distribution and relative abundance of leopard;; chapter five with the Nature and extent of man-leopard conflict, chapter six with the Food habits in relation to prey species availability, and chapter seven with the Mitigation strategies for human-leopard conflict. The results and discussion will be given separately for each chapter from IV to VI. Besides, the thesis includes acknowledgements, summary, content table, list of tables, list of figures, list of maps, list of photographs, references and appendices.

Chapter 2

2.1 Review of literature

Leopards are exceptionally secretive and elusive. Till 1970, leopards remained essentially unstudied in wild (Bailey, 1993). Their behavioral studies by direct sightings are very difficult even in undisturbed areas where this felid is relatively common than other large cats (Karanth and Sunquist, 2000 and Khorozyan, 2003). To understand ecology and behaviour of leopards, several studies have been conducted on habitat use, home range, activity pattern, reproductive biology, food habits, distribution and relative abundance of wild and domestic prey species, responses of leopards to changing landuse and landcover and human-leopard interactions.

It is not always possible to carry out the study on the whole animal population (Sutherland, 1996). There may be several constraints like lack of manpower and resources as well as temporal and spatial discontinuity. So it is always better to focus in one area or population considering it as a cluster of samples, and study each sample separately. This type of study design always yields significant results to indicate the population parameters (Sutherland, 1996). Therefore, it is easier to survey an area to determine whether the predators or prey animals are present or not (Henschel and Ray, 2003). For certain large scale surveys, the easiest and least expensive way is to walk along the forest trails or roads throughout the area, and search for the predator signs such as tracks or scats. Normally scats and scrapes can be encountered on a regular basis if predators are present. Estimation of proportion of area occupied by predators can be calculated by dividing the area into grids (eg. 10 km^2) or any other form of sampling unit. Relative abundance estimates can be derived from quantitative indices of abundance that have a direct relationship to the densities (Seber, 1982 and Karanth and Nichols, 2002). Examples of such indices may include number of leopard signs encountered per unit distance or number of leopard pictures per unit effort. If it is not possible to obtain the density estimates, monitoring programmes based on relative abundance data can indicate whether a leopard population is increasing, decreasing or relatively stable (Hart *et al.,* 1996; Henschel, 2001; Ray and Sunquist, 2001 and Henschel and Ray, 2003). Relative abundance index can be expressed as encounter rate (eg. number of tracks or scats per kilometer walk) (Karanth and Nichols, 2002 and Henschel and Ray, 2003). The most efficient way to estimate relative abundance of leopards is to quantify all tracks or scats encountered along forest trails or roads. Study in Namibia on large carnivores revealed a strong correlation between track counts along trails and roads and population density (Stander, 1998).

Identification of individual large cats in a population is possible through careful measurements of their tracks (Smallwood and Fitzhugh, 1993; Grigione *et al.,* 1999; Lewison *et al.,* 2001 and Miller, 2001). With a series of measurements especially for hind foot tracks, individuals can be identified using ‘Discriminant Function Analysis’ test (Smallwood and Fitzhugh, 1993). The main drawback of this approach is that it needs a high number of track sets, ideally 20 prints of a same paw, to determine discriminating variables for any given population (Henschel and Ray, 2003). The accurate measurement and quality of the track print depends on the soil condition of different regions (Henschel, 2001 and Karanth *et al.,* 2003). Karanth (1995) and Karanth *et al.* (2003) raised the doubt on the validity of "Pugmark Census" method used in India to derive density estimation for tigers, stating the point that even though individual tracks can be discriminated statistically, the essential next step to derive population estimates in a general sampling framework has not been done. But this method requires less economic and logistical support to carry out the study.

Little is known about population composition and behavioural ecology of leopard in Asia. In earlier times, leopards have been mostly studied incidentally while studying other wild animals sharing the same habitats (Schaller, 1967, 1972, 1976; Kruuk, 1972 and Muckenhirm and Eisenberg, 1973). In Rajaji national park, the status survey of tiger and leopard was done (Johnsingh and Negi, 2003). Daniel (1996) made a review of various ecological studies conducted on leopards.

Among a few detailed studies conducted on the leopard in Asia, the species has been studied by direct observations or by monitoring radio-collared animals. Some behavioral studies were conducted on leopards in Sri Lanka by Chambers and Santipillai (1982). Eisenberg and Lockhart (1972) conducted detailed study on distribution, relative density, home range, activity pattern and breeding biology of leopards in Wilpattu national park, Sri Lanka.

The estimated overall density of leopard around one animal per 30 km^2 in Wilpattu National Park and also stated that it may rise to one per 8 to 10 km^2 prime in habitats. Social structure and food habits of leopards were also studied by monitoring radio-collard animals in Rahuna national park, Sri Lanka (Santiapillai *et al.*, 1982). Robinowitz (1989) studied the home range and food habits of leopards in dry tropical forest of Huai Khaeng wildlife sanctuary, Thailand. Direct observations were made on kills to study food habits of leopards. The density of leopards was around one leopard per 25 km^2 (Rabinowitz, 1989). In Royal Chitwan national park, Nepal, leopards were radio-collared and monitored for a long time to study their home range and food habits in relation to composition and distribution of preys (Sunquist, 1983 and Seidenssticker *et al.*, 1990). In China, food habits of leopards were studied through analysis of scats for about seven years in Wolong reserve, Sichuan (Johnson *et al.*, 1993).

Leopards are extensively studied in African continent during the last two decades (Scheller, 1972; Hamilton, 1976; Bothma and Le Riche, 1984; Bailey, 1993; Mizutani and Jewell, 1998; Spong *et al.*, 2000). Information on ecology and biology of leopards was first given by Schaller (1972) while studying lions in Serengeti national park. Hamilton (1976) intensively studied the movement pattern of radio-collard leopards in Tsavo national park. Bothma and Le Riche (1984, 1986), Norton and Lawson (1985), Norten *et al.* (1986) and Norton and Henley (1987) conducted detailed studies on behavioural ecology, biology and food habits in Africa. Bailey (1993) monitored leopards for a long time in Kruger national park and provided valuable information on ecology, biology, behaviour and population structure of leopards. Leopard abundance and ranging pattern were also studied by monitoring radio-collared leopards in Lolldiaga hills in Kenya (Mizutani and Jewell, 1998). In Namibia, information on ecology of leopard was collected by monitoring of radio-collared animals for three years (Stander, 1998). Spong *et al.* (2000) studied the population structure and history of leopard by using molecular tools in Tanzania. Among other intensive studies, Bothma and Le Riche (1984, 1986), Norton and Lawson (1985), Norten *et al.* (1986) and Norton and Henley (1987) collected information on behavioural ecology, biology and food habits in Africa.

2.2 Status and distribution

Several studies have been conducted in Indian subcontinent for the estimation of abundance and biomass of wild and domestic prey of predators (Schaller, 1967; Eisenberg and lockhart, 1972; Seidensticker, 1976; Dinerstein, 1980; Johnsingh, 1983; Karanth and Sunquist, 1992 and 1995; Varman and Sukumar, 1995; Khan *et al.,* 1996; Biswas and Sankar, 2002 and Karanth *et al.*, 2004). Schaller (1967) studied tigers and their prey in Kanha national park. He estimated the ungulate densities and biomass using direct count and belt transect methods. The biomass of wild ungulate was in range between 937 to 1178 kg per km^2, but when the contribution of the domestic ungulates was considered, it went up to 3880 to 4103 kg per km^2. This showed the importance of the livestock contributing to the diet of the wild predators. Khan *et al.* (1996) estimated ungulate densities in Gir using road side counts and line transect method. Remarkably, this study revealed that the densities of all species, except nilgai (*Boselaphus tragocamelus*) and wild pig (*Sus scrofa*), had increased substantially due to the removal of livestock from the park area, which had reduced the competition of grazing between livestock and wild herbivores.

Johnsingh (1983) used direct counts to estimate the abundance of herbivores in Bandipur. It was observed that chital was the most abundant wild ungulate in the study area, with relatively high sambar (*Cervus unicolor*) density. Low gaur (*Bos gaurus*) density was attributed to the epidemic outbreak in the gaur population. Some studies had also incorporated trail monitoring method where line transect was not possible due to topographic conditions, especially in hills (Edgaonkar and Chellam, 2002 and Kawanishi, 2002). They had included trail monitoring method to estimate the encounter rates of the prey species through direct sighting as well as the indirect signs available there. In many studies, line transect method was used to estimate the densities of ungulates in different parts of India (Karanth and Sunquist, 1992; Varman and Sukumar, 1995 and Biswas and Sankar, 2002). Karanth and Sunquist (1992) monitored ungulate prey populations in Nagarhole national park since the mid 1980s. Varman and Sukumar (1995) evaluated the efficiency of different models and analytical techniques in prey base estimation in Mudumalai wildlife sanctuary. Their results suggested that transect data collected by vehicle have a wide biased estimates in comparison to those collected on foot.

Eisenberg and Lockhart (1972) estimated the abundance of the ungulates using direct and pellet count methods in Wilpattu, Sri Lanka. The study revealed that the ungulates biomass density in Wilpattu was one sixth of the biomass of steppe and savannah habitats of east Africa. The low density of ungulates was due to the competition for grazing with the livestock. In Nepal, ungulate densities were estimated by Seidensticker (1976) and Dinerstein (1980). Seidensticker (1976) used successive belt transects to estimate the densities of the large herbivores in the tall grassland and riverine forest areas in Chitwan national park. Dinerstein (1980) estimated prey densities based on pellet count method, vehicular transects and counts from observation platforms in Royal Karnali Bardia wildlife reserve. His study revealed that chital densities were higher in Bardia wildlife reserve than other reserves in the subcontinent. Whereas the densities of other cervids, namely, hog deer (*Axis porcinus*), swamp deer (*Cervus duvaucelli*), barking deer (*Muntiacus muntjak*) and wild pig (*Sus scrofa*) were similar or lower than the densities found in other protected areas of Nepal and India. The study on prey selection and kill monitoring was carried out on Namibian leopard by Stander *et al.* (1997).

2.3 Food habits

Almost every feature of a cat’s body is related to the way it detects and catches its prey. Cats have no option but to be efficient hunters because they are the most exclusive of meat-eaters, and compared with other food resources, meat is in limited supply with in a given area (Gittleman and

Harvey, 1982). Unlike other carnivore, cats cannot supplement their diet with plant matter because their gut physiology is so specialized for a diet of meat. Cat hunt either by patrolling their home ranges until they come across a potential victim, or by waiting in ambush for them to pass by (Kruuk, 1986). They need keen senses to detect their prey before being detect themselves, and must be we concealed while staking or waiting to strike in order to maximize their chance of getting close enough to capture a potential prey animal. Cats must be able to move quickly and quietly as they approach to capture and kill their prey. The need to overcome all of these problems as reflected in specializations in the form and structure of cats. Cats show a number of specializations of their claws, teeth and jaws for both killing and eating their prey (Ewer, 1973; Gonyea and Ashworth, 1975; Savage, 1977; Wrogemann, 1975 and Alexander *et al.*, 1986).

Leopards are considered as ecological generalist rather than specialist and can survive by feeding on large or small prey (Bailey, 1993). They can be efficient scavengers. The food habits of leopard are influenced by distribution and abundance of preferred prey species and cover. Food habit is one of the major aspects of leopard ecology that has been studied worldwide (Emmons, 1987; Wemmer and Sunquist, 1988; Rabinowitz, 1989; Stander *et al.,* 1997; Mizutani, 1999 and Ray and Sunquist, 2001). A leopard weighing 45 kg requires 1.5-2.5 kg of food daily (Emmons, 1987; Wemmer and Sunquist, 1988; Mizutani, 1999). Average prey weight ranges between 5-70 kg (Rabinowitz, 1989; Stander *et al.*, 1997; Ray and Sunquist, 2001) and usually less than 50 kg (Seidensticker *et al.*, 1990 and Johnsingh, 1992). Food habits of leopards were studied on the Mundanthurai plateau by Sathyakumar (1992) and in Bandipur by Andheria *et al*. (2007) and Johnsingh (1983). Johnsingh (1992) studied food habits of leopards along with other coexisting carnivores like tiger (*Panthera tigris*) and dhole (*Cuan alpinus*) by observing their kills in Bandipur tiger reserve. In Sariska tiger reserve, food habits of leopard were studied by Sankar and Johnsingh (2002).

Prey selection by leopards in relation to prey availability was assessed alongwith tigers and dholes in Nalkeri reserve forest area of Nagarhole national park (Karanth and Sunquist, 1995). The study conducted by monitoring of radio-collared leopards and tigers showed that they selectively killed different prey in terms of species, size and age-sex classes which behaviourally contributed to their successful coexistence in Nagarhole national park (Karanth and Sunquist, 2002). A study on food habits of leopard conducted in Gir national park showed no considerable difference in the seasonal dietary pattern (Aishwarya Maheshwari, 2006). The home range and activity pattern of leopards were studied by monitoring radio-collared animals, and food habits were studied by direct observations and through scat analysis in Sanjay Gandhi national park, India (Edgaonkar and Chellam, 1998). The study on feeding ecology through scat analysis and standardization has been done by Mukherjee *et al.* (1994) and (Sankar and Johnsingh, 2002) in India. The study also included aspect of biomass consumption and scat produced in captive leopards and lion.

In fragmented and disturbed areas, they are increasingly preying upon domestic stock, a behaviour that brings them into direct conflict with humans. Studies conducted in south Asia showed that leopard had more diverse diet ranging from lower size classes of animals to medium size wild species usually weighing less than 50 kg (Eisenberg and Lockhart, 1972; Santiapillai *et al.,* 1982; Rabinowitz, 1989 and Seidensticker *et al.,* 1990). Wild ungulates constituted only one fourth of the leopard kills found outside the park, and switched to the wild prey of the same size classes more inside the park (Seidensticker *et al.,* 1990). Prey items of leopards varied a lot, with a range from small reptiles, crustaceans to large ungulates (Bertram, 1982; Daniel, 1996 and Stander *et al.,* 1997). Studies conducted in Nagarhole tiger reserve revealed the average weight of prey being 38 kg (Karanth and Sunquist, 1995; 2000). Prey species killed by leopard in Chitwan national park were in the range of 25-50 kg with the average of 28 kg (Seidensticker, 1976 and Seidensticker and Lumpkin, 1991). Mean prey weight of leopard in forests in Zaire was found to be 25 kg with ungulates and primates being the most common prey items (Hart *et al.,* 1996). This variation in the biomass of the prey species of leopard was due to its co-existence with other sympatric carnivores like tigers, dholes etc. (Johnsingh, 1983 and Karanth and Sunquist, 1995; 2000). But in places where leopard was the only large predator, the prey biomass was found to be much higher (Seidensticker and Lumpkin, 1991). The study conducted in Dachigam national park, Jammu and Kashmir showed that the leopards were found to predate upon large mammals like hangul (*Cervus elaphus hanglu*), Asiatic black bear (*Ursus thibetanus*), Himalayan brown bear (*Ursus Arctos isabellinus*) (Inayatullah, 1985; Iqbal, 2005). The world's largest antelope eland (*Taurotragus oryx*) was also reported to be predated upon by leopard (Bertram, 1982). In Thailand, primates constituted an important part of the diet of leopard (Rabinowitz, 1989), whereas in other places, rodents and medium size ungulates were mostly consumed by leopard (Rabinowitz, 1989 and Khorozyan and Malkhasyan, 2002).

In Itury forest of Zaire, Matopos national park in Zimbabwe and Lope national park of Gabon Africa, diet of leopard was studied by analyzing scat contents and observing leopard kill (Grobler and Wilson, 1972; Hart *et al.*, 1996 and Henschel *et al.*, 2005). Among other intensive studies, Bothma and Le Riche (1984, 1986), Norton and Lawson (1985), Norten *et al.* (1986) and Norton and Henley (1987) collected information on behavioural ecology, biology and food habits in Africa. Food habits of leopard were studied in Nepal (Seidensticker *et al*., 1990), in Pakistan Himalayas (Schaller, 1977) and in Sri Lanka (Muckenhirn and Eisenberg, 1973). A study on food habits of Asiatic leopards (*Panthera pardus fusea*) conducted by analysis of feces in Wolong reserve, Sichuan, China showed a varied diet pattern over a 7-year period (Kenneth *et al*., 1993).

Leopards have been reported to kill medium-sized prey, mainly impala (*Aepyceros melampus*), but also take a very wide variety of small animals including hyrax, civet and mongoose in Kruger National Park in South Africa (Bailey, 1993). A wide spectrum of the potential prey available in the Tai National Park, Ivory Coast, with about thirty species recorded (Hoppe-

Dominik, 1984). In the Kalahari desert leopards have been known to take small prey like bat-eared foxes (*Otocyon megalotis*), jackals (*Canis spp*), genets (*Genetta spp.*), hares (*Lepus spp*), duiker (*Cephalopus spp*) and porcupines (*Hystrix spp*) (Bothma and LeRiche, 1984). Mills (1984) studied the prey selection and feeding habits of the large carnivores in the Southern Kalahari and concluded that predators generally have a small impact on their prey population. The leopard kill data showed 65% of springbok while hartebeest calf, steenbok, black-backed jackal, gemsbok calf, ostrich, duiker, wild beast calf, bat-eared fox, cape fox, aardwolf, wild cat, ground squirrel, cheetah, aardvark and mice comprised of 35% to the leopard diet. In the richer hunting ground of the Serengeti, a very varied diet of leopard has been recorded, but the main prey item is male Thomson's gazeller (Kruuk and Turner, 1967 and Schaller, 1972).

Bothma and LeRiche (1994) studied the food habits and defecation in northern Cape leopards in Augrabies Falls national park and found that dassie (*Procavia capensis*) remains were present in nine scats, springhare (*Pedetes capensis*) and gemsbok (*Oryx gazelle*) remains in two scats each, and silver fox (*Vulpes chama*) remains in one scat. Of the 40 leopard scats from the Kalahari, porcupine (*Hystrix africaeaustralis*) remain were found in 12 scats (30%), duiker (*Sylvicapra grimmia*) and gemsbok remains in 10 scats (25%) each, springhare and black-beched jackal (*Canis mesomelas*) remains in 6 scats (15%) each, plant material, including the gemsbok cucumber (*Acanthosycios naudianus*) in 4 scats (10%), steenbok (*Raphicerus campestris*) and springbok (*Antidorcas marsupialis*) in two scats each. No evidences of small rodents were found in any scat from the Augrabies Falls or the Kalahari Gemsbok national parks.

Hart *et al*. (1996) studied leopard and African golden cat in Ituri forest of Ziare and found that felids consumed predominantly mammalian prey. Ungulates comprised 53.3% and primates 25.4% of prey items identified in leopard scats; mean prey weight estimated from scats was 24.6 kg. Hoppe-Dominic (1984) has analyzed 215 scats of leopard in Le Pare National de Tai in the Ivory Coast. More than 30 different prey species were found in the diet, which included duikers, monkeys, rodents and other carnivores. Some degree of dietary separation between pumas and jaguars has been noted, with jaguars tending to take slightly larger prey and more peccaries (Emmons, 1987).

Mahar *et al*. (1990) studied the diet of Florida Panthers (*Felis concolor coryi*) in southwest Florida during 1977-1989. Seven vertebrate species were identified as kills, and fourteen species were identified in scats. The frequency of occurrence in scats indicated that wild hog (*Sus scrofa*) was the most common prey, followed by white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), and 9-banded armadillo (*Dasypus novemcinctus*) and there was no seasonal variation in the diet.

Schaller *et al*. (1985) found that diet of leopards was constituted mostly (85.1%) of tufted deer (*Elaphodus cephalophus*) in Wolong reserve, Sichuan, China. Although leopards occasionally consumed young giant pandas, they were a small component (0.6%) of the diet. Later the study conducted by Johnson *et al*. (1993) in Wolong reserve showed 15 species of large and medium-sized mammals constituting the diet of Asiatic leopards. There was dominance of pheasants, livestock, grasses in the diet of leopards, and soil being eaten occasionally. In Royal Chitwan National Park, prey includes wild pig, sambar, chital, hog deer, muntjac and domestic cattle (Seidensticker, 1976). In Wilpattu National Park in Sri Lanka, 60% of the 51 observed preys were axis deer (Muckerhirm and Eisenberg, 1973). Most of the rest of the diet comprised wild pigs, but other prey included buffalo, calves, sambar, muntjac, langur, porcupine, squirrel, hare and birds.

In Wilpattu leopards took chital, wild pig (*Sus scrofa*), sambar, langur, hare, porcupine and domestic buffalo calves (Muckenhirn and Eisenberg, 1973). In Nepal, wild pig, sambar, chital, hog deer (*Axis porcinus*), muntjac and domestic cattle were part of their diet (Seidensticker *et al*., 1990). In the Pakistan Himalayas, leopards took mainly wild goats (*Capra aegagrus*) but also preyed on livestock, hare and porcupine (Schaller, 1977). Alan Robinowitz (1989) studied the behaviour of large cats including leopard in dry tropical forest mosaic in Huai Kha Khaeng wildlife sanctuary, Thailand during 1987- 1989. The major prey of the leopards was barking deer, although wild pigs, sambar, porcupine and hog badger were important secondary prey items. In another study on food habits of Indochinese leopards (*Panthera pardus delacouri*) in Kaeng Krachan national park, Petchaburi Province, Thailand, scat analysis revealed that feces were dominated by hog badger, *Arctonyx collaris* (44%), barking deer, *Muntiacus muntjak* (19.5%) and wild pig, *Sus scrofa* (7.3%) (Grassman, 1999).

In India too, dietary studies have found that leopards take a range of prey. Some food habit studies have been conducted on single species (Bagchi *et al*., 2003; Biswas and Sankar, 2002; Edgaonkar and Chellam, 2002 and Reddy *et al*. 2004), and there is information on diet selection and overlap between multiple species including tigers, leopards and dholes from southern India (Johnsingh, 1983 and Karanth and Sunquist, 1995), and on leopards and tigers (Sankar and Johnsingh, 2002) and lions and leopards (Chellam, 1993) in western India. Johnsingh (1992) found that out of 58 kills by leopard, 66% were of chital and 5% samber in Bandipur tiger reserve. Besides, cattle and village dogs were also killed by leopard. Sixty nine percent of leopard kills were found to weigh less than 50 kg. In Sariska tiger reserve leopard scats contained rodents (Sankar and Johnsingh, 2002). The leopards on the Mundanthurai plateau in Kalakad-Mundanthurai tiger reserve have been preying mainly on sambar (Sathyakumar, 1992). Black-naped hare (*Lepus nigricollis nigricollis*) and chital remains in scats accounted for 16.2% and 9.3% respectively. Although five of the nine leopard kills were of livestock, only 6.9% of scats contained livestock remains. Vegetation (grasses) was present in 4.6% of the scats. Whereas in Bandipur, the leopard kills were mainly chital (Andheria *et al*., 2007 and Johnsingh, 1983).

In Gir, 40 percent of leopard scats contained chital remains while langur remains were found in 25% of the scats (Chellam, 1993). In subsequent study in Gir, an analysis of leopard scats showed that chital formed the major prey (27.74%), followed by monkey (14.25%), porcupine (7.24%), peafowl (6.37%), sambar (5.87%), hare (4.59%), civet (4.60%), feral dogs (4.59%), livestock (12.50%) and others (12.06%) (Srivastava, 1999). Singh *et al*. (1999) also analysed 102 scats of leopard in the Gir proteced area and reported that 28% of the scats contained chital hairs and 14.7% contained the remains of monkey, about 10% of the scats contained feathers, presumably of peafowl, and nearly 8% contained the remains of civet cat and sambar. Leopard living near urban areas of Mumbai were found mainly dependent on domestic dogs and rodents (Edgaonkar and Chellam, 1998).

In a study conducted in the Shiwalik hills of Rajaji national park, diet of leopards was comprised of chital (65%), langur (15%), barking deer (11%) and rodents (11%), and proportion of goral, nilgai and wild pigs was negligible (Johnsingh *et al*., 1993). In the Himalayas, Schaller (1977) found that leopards fed mainly on wild goats, but livestock and porcupine were also important dietary components. Mukherjee and Mishra (2001) studied the food habits of leopard in Majhatal Harsang wildlife sanctuary and reported that cattle remains were found in 33% of the scats (n=47), followed by langur (30%), goral (30%) dog (23%). Remains of buffalo, rodents, goat and hare occurred in less than 15% of the scats. Fifty percent of the scats contained the remains of a single prey species, 33% contained 2 prey species and 17% contained 3 prey species.

Adgaonkar and Chellum (2002) studied the food habits of leopard by analyzing scats in Sanjay Gandhi national park, a small, isolated, prey-poor protected area abutting Mumbai city and concluded that the leopard were adapted to its prey impoverished habitat by feeding largely on domestic animals. The frequency occurrence of domestic dog was 63.7%, followed by domestic buffalo (14.8%), rodents (26.1%), primates (11.4%), cervids (9.1%) and others (5.7%). The relative biomass consumed by leopard was also highest for domestic dog (0.58) followed by domestic buffalo (0.14), rodents (0.05), primates (0.10) and cervids (0.11).

Sankar and Johnsingh (2002) analysed 125 leopard scats and found 61% scats contained single prey species, 33% contained two prey species, 5% contained three prey species and 1% contained four prey species. Remains of rodents (largely Indian gerbillle *Tatera indica*) and insectivore (grey musk shrew *Suncus murinus*) were found in 45.6% of the leopard scats, and chital, sambar and nilgai were found in 20.8%, 20%, and 7.2% of the leopards scats respectively. Sambar contributed the maximum (34.55%) biomass to the diet of leopard, followed by rodents and insectivores (23.19%), chital (19.32%) and nilgai (15.41%). Arivazhagan *et al*. (2007) studied the food habits of leopard (*Panthera pardus fusca*) in Singur and Thalamalai reserve forests of Tamil Nadu and found that chital (*Axis axis*) was the major prey of leopard in both areas. Chital was found in 40% leopard scats in highly disturbed area and 65% in the less disturbed area. Other important prey species were sambar (*Cervus unicolor*), blackbuck (*Antilope cervicapra*), black napped hare (*Lepus nigricolis*), Indian wild boar (*Sus scrofa*), Indian porcupine (*Hystrix indica*), common langur (*Semnopithecus entellus*), and Indian peafowl (*Pavo cristatus*). A study conducted on food habits of leopard in Dachigam national park revealed the presence of nine prey species in the diet (Shah *et al*., 2009). The major prey items were dog, langur, hangul and rodents with frequency occurrence of 21%, 21%, 18.4% and 15.7% respectively.

2.4 Human-leopard conflict

The expansion of human influence and ever-increasing pressure on natural resources has greatly intensified the issue of human-wildlife conflict in a wide variety of situations. Human-wildlife conflict has been defined as 'When the needs and behaviour of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact the needs of wildlife' (Recommendation 5.20, 2003 World Parks Congress) and now it has become a very common global phenomenon.

Carnivore-human conflict is a worldwide problem for the wildlife management (Rajpurohit and Chauhan, 1996; Linnell *et al.,* 1996; Mizutani, 1999; Butler, 2000; Bauer and Kari, 2001; Stahl *et al.,* 2001; Karanth and Madhusudan, 2002, Chauhan *et al.*, 2002, Hoogesteijn *et al*., 1993 and Hoogesteijn, date n.a.). Carnivores are involved in a wide range of conflicts including predation on human and livestock (Chakrabarti, 1992; Chellum and Johnsingh, 1993; Daniel, 1996; Woodroffe, 2000 and Ginsberg, 2001). All large cats' viz. lion, tiger, snow leopard and leopard are involved in conflicts with humans in India (Chakrabarti, 1992; Chellem and Johnsingh, 1993; Sabarwal *et al*, 1994; Daniel, 1996; Mishra, 1997; Jhala and Sharma, 1997; Jackson, 1999; Rangarajan, 2001; Linnell *et al.*, 2002; Mishra *et al.*, 2003 and Atherya *et al.*, 2004). When large cats live in proximity to humans, some level of conflict between them is inevitable (Sawarkar, 1986). In India, leopard has reported as the most common problematic carnivore among human-carnivore conflicts (Saberwal *et al.*, 1994; Rajpurohit and Chauhan, 1996; Negi, 1996; Daniel, 1996; Chauhan and Goyal, 2001; Chauhan *et al.*, 2002 and Athreya *et al.*, 2004). But the conflicts due to these carnivores have been mostly restricted in and around their ranges and their impacts were not as widespread as that of leopard. Many cases of human casualties caused by leopards have been reported from Maharastra, Gujarat, Himachal Pradesh, West Bengal, Karnataka, Orissa and Uttarakhand state of India (Das, in Litt; 1887; Choudhary, in Litt, 1987; Negi 1996; Athrya *et al.* 2004).

Larger cats are adapted to thrive well in the edge habitats or small forest patches outside the protected areas. Most of the conflicts caused by tigers, lions, and snow leopards are reported from the edges of the protected areas (Chakrabarti, 1992; Chellum and Johnsingh, 1993 and Mishra, 1997). Extent of human-leopard conflict is greater than other large cats as a large population of leopard is outside the protected areas (Daniel, 1996; WWF Report, 1997). The plantations or tea gardens or scrubland have been found to provide good cover to leopards to predate on domestic species (Santiapillai *et al.,* 1982; Seidensticker *et al.,* 1990 and Saberwal *et. al.,* 1994). Incidents of tea workers being mauled by leopards has been reported from Northern

Bengal (Das, in Litt, 1887; Choudhary, in Litt, 1987). Few incidences of man-eating have been reported from the adjoining human colony of Borivali national park, Maharashtra (Athreya *et al.*, 2004). In Junnar forest division, increasingly growing of sugarcane crop, habitat loss and the lack of wild prey were the most commonly factors for the increase in conflict over the years (Atherya *et al.*, 2004). After 2002, the conflict declined to pre-existing levels mainly because of the large-scale trapping and long distance translocation of the leopards from this division.

Leopards are not man-eater by nature. It is believed that leopards turn to man-eater due to problem pertaining to physical fitness, which makes them to turn to easier ones like human (Corbett, 1957). But this hypothesis does not seem to be true in present context. In the past leopards rarely turned to man-eater but now situation is different as they are killing human throughout the year. A change in leopard behaviour in which it is becoming extremely bold has been noticed in several regions (Johnsingh *et al.*, 1991; Daniel, 1996 and Negi, 1996). It is intriguing that leopard predation on human and livestock is on increase in hilly regions perhaps due to disturbance and degradation of habitat and depletion of wild prey species and loss of forests to plantation of monoculture timber species and rubber, coffee and tea plantations. Consequent of this increase in human-leopard conflict on the forest edges and in this process, irate farmers killed many animals by giving them poison or snaring or shooting (Cobb, 1981; Green, 1987; Seidensticker *et al.*, 1990 and Bailey, 1993).

In India, people have been mauled or killed by leopard while they were in forest for grazing their livestock or collecting non-timber forest produce or working on forest edges. Leopard attack on humans are not new in the Garhwal region of Uttarakhand and there has been human death by leopards in the past (Corbett, 1944, 1948 and 1957). In early 1990's nearly a thousand people were killed by leopards and a dozen of leopards were killed as man-eaters (1957). Among popular man-eaters, leopard of Rudraprayag killed more than 115 people over an eight-year period (Corbett, 1948). During 1982 to 1989, 170 people were reported to be killed by leopard in India, of which 111 cases were reported from Uttar Pradesh only (Johnsingh *et al.*, 1991). Most of the time, human casualties or livestock depredation cases were not even reported to the forest department (Negi, 1996). Between 1986 and 1996, sixty one human casualties occurred due to man-eating leopards, whereas 50 leopards were killed in Garhwal district of Uttar Pradesh. The problem of human-leopard conflict has recently increased during the last decade in the hill state of Uttarakhand in Northen India (Negi, 1996 and Mohan, 1997).

Human-leopard conflict was reported to be serious throughout the Garhwal district (Chauhan *et al.*, 2002). A total of 328 human casualties by leopard were reported in Pauri Garhwal during 1988-2001. Out of 328 cases, 146 people were reported to be killed and 182 injured. Female casualties were more than the male casualties. Besides, there were 463 livestock killings by leopard in Pauri during 1996-2001. Livestock depredation was on increase from 1996 onwards and it was found to be highest in 1999. Cow, bull and goat/sheep suffered maximum killings, i.e. 213, 123 and 93 cases respectively. There was distinct variation in the age group of livestock killings. Out of 463 livestock killings, 293 cattle were with the graziers, and 100 cattle were without graziers. Whereas Chauhan and Goyal (2001) have reported occurrence of only 141 human casualties by leopard in Pauri during 1988 to 2000. They reported that in the last few years, incidences of human casualties were on the increase, and every year 12 to 22 attack cases occurred. Leopard attacks varied across the seasons; rainy and winter seasons were more vulnerable periods. During rainy season, weeds such as *Lantana, Xanthium* or *Eupatorium* grew tall in the vicinity of the villages, which provided a good stalking cover to leopards till winter. Seventy eight percent cases occurred in areas having degraded forest or scrub vegetation. During these years, many leopards have been either killed as man-eaters or found dead or killed by villagers in Pauri Garhwal (Chauhan and Goyal, 2001). Since 1987, more than 90 leopards have been killed or found dead in Pauri Garhwal.

Various reasons have been put forward to explain about the increase in human-leopard conflict in different places. The main reasons were found to be depletion of the natural prey base and degradation or fragmentation of leopard habitat. The man-made changes of the landscape led to creation of suitable habitats for the leopard (e.g. sugarcane fields, tea plantation areas), which resulted in increase of local leopard populations (Seidensticker, 1986; Johnsingh *et al.,* 1991; Karanth, 1991; Rabinowitz, 1991; Bailey, 1993 and Daniel, 1996). In Pauri, occurrence of human-leopard conflict showed a positive correlation with number of livestock in affected villages. The areas having more livestock were highly affected (Chauhan and Goyal, 2001).

Factors like presence of domestic dogs, electricity, distance of forest from the villages etc. have been found to be correlated with levels of conflicts. A study by Mitzuani (1999) carried out in the ranches of Kenya showed that leopard attacks on livestock were substantially higher in ranges devoid of wild prey compared to ranges which supported sizeable populations of wild prey. Areas with good numbers of wild prey could face some degree of livestock depredation, and areas where natural prey had been depleted; livestock depredation was likely to be inevitable.

Livestock depredation and incidences of dog lifting by leopard have been reported to be quite common in the vicinity of villages (Gee, 1964; Prater and Barruel, 1971; Santiapillai *et al.,* 1982; Tikader, 1983; Johnsingh, 1992; Daniel, 1996 and WWF-India, 1997). In Majhatal wildlife sanctuary, Himachal Pradesh, a high rate of predation on domestic animals by leopard was found despite presence of wild prey species (Mukherjee and Mishra, 2000). There were about 17 villages in the sanctuary having a total of 750 houses with huge livestock population. Leopards were also reported to feed on dead and rotting carcasses (Seidensticker and Lumpkin, 1991). In disturbed areas, leopards were found to return to their kills, thus making them more susceptible to being poisoned.

Large carnivore populations have declined worldwide in the last centuary (Nowell and Jackson, 1996) primarily as a result of conflict with humans (Gittleman *et al.*, 2001). Human animal conflict might affect species conservation in an area (Saberwal *et al.*, 1994). Studies on human-animal conflict suggest that peoples attitude toward the conflict causing species from positive acceptance to negative acceptance has created problems in many areas (Saberwal *et al.*, 1994 and Jackson, 1999).

2.5 Reproduction

Leopard becomes sexually matured at between 2.5 to 3 years of age. At this stage females become cyclic and studies on captive leopards indicate an average oestrous period of 6 to 7 days in duration and an inter-oestrous period of 45.8 days (Sadlier, 1966). Leopard mates 4 to 5 days and breed all the year round. Gestation period varies from 87 to 94 days. Normally 2 cubs per litter are born, occasionally 3 or 4. Eyes open between the 4^{th} and 8^{th} day after the birth. Weaning occurs at about 4 months. In captivity, reproductive biology of leopards has been studied by Desai (1973). Genetic work was conducted for phylogeographic subspecies recognition of 27 subspecies of leopard by Miththapala *et al.* (1996) and same work carried out by Spong *et al.* (2000) on Tanzanian leopard.

Chapter 3

Study area

3.1 Area profile

Endowed with natural beauty, Himachal Pradesh a state in north India has geographic area of 55,673 km^2. The state is almost wholly mountainous with altitudes ranging from 350m to 6,975m above the main sea level. Its location is between latitude 30°22′40′′ N to 33° 12′ 40′′ N and longitude 75° 45′ 55′′ E to 79° 04′ 20′′ E.

The Mandi district has been selected for the present study as frequent man-leopard conflict has been reported (Chauhan, 2003). The Mandi district lies between 31^{0}13'30" N to 32^{0}04'22" N and longitude 76^{0}36'08" E to 70^{0}23'26" E. It has an area of 3,950 km^2. The district is situated in the lower Himalayas and is entirely hilly except some fertile valley in-between. **Map 1** shows the location and road network in the study area, Mandi district. It is bounded by Kangra district on the north-west, Hamirpur and Bilaspur district in the west, Arki tehsil of Solan district in the south Shimla district on the south west and Kullu district in the east. The study area comprises of five forest divisions of Mandi district, namely, Mandi, Sundernagar, Jogindernagar, Nachan and Karsog. Three wildlife sanctuaries, namely, Bandli wildlife sanctuary, Nargu Winch Camp wildlife sanctuary and Shikari Devi wildlife sanctuary have been established in the district for rare Himalayan animals.

The land use pattern in Mandi district comprises of forests (1,75,375 ha.), barren and un-culturable land (24,990 ha.), permanent pastures and other grazing land (96,383 ha.), land under miscellaneous tree crops and grooves (314 ha.), culturable waste (4,479 ha.), fallow land (8,948 ha.) and agricultural area (1,59,837 ha.). **Plate 1 and 2** show the study area, forests interspersed with human habitation.

3.2 History

The Mandi state takes its name from its capital, which is situated on the left bank of river Beas. Mandi is a Hindi word meaning ‘market’ and it may possibly be connected with the Sanskrit word ‘mandapika’, meaning ‘an open hall or shed’ and may also be derived from the Sanskrit word ‘mand’ meaning ‘to adorn or distribute’. If a conjecture as to the origin of the name may be offered, it probably took its rise from the fact that in ancient times, as at the present day, the place was a centre of trade on the main route from Yarkand and Ladakh to Hoshiarpur and the plains. The earliest mention of the town is on the inscription at the Trilok Nath temple in Old Mandi, which dates back to the year 2264 of the Kaliyuga era, and the Saka year 1442, corresponding to A.D. 1520. The Mandi district was formed with the merger of two princely states viz; Mandi and Suket in April 1948, which coincided with the formation of the state of Himachal Pradesh and it was named after the name of Mandavya Rishi.

3.3 Administration

The district headquarter is located at Mandi. The administrative setup of the district consists of six top sub-divisions i.e. Sadar, Sarkaghat, Sundernagar, Karsog, Gohar, Jogindernagar. There are nine tehsils, namely, Sadar, Thunag, Sundernagar, Sarkaghat, Padhar, Jogindernagar, Lad-Bhraol, Karsog and Chachyot, and seven sub-tehsils, namely, Kotli, Aut, Nihari, Baldwara, Dharampur, Sandhol and Balichowki in the district (http://hpmandi.nic.in/fact.htm). Recently, the number of tehsils has increased to nine, but we have worked in seven tehsils. **Map 2** shows different tehsils in the study area. The number of development blocks is ten (Sadar, Balh, Sundernagar, Karsog, Gopalpur, Dharampur, Chauntra, Drang, Seraj and Gohar), number of panchayats 473, backward panchayats 143 and 3,338 villages. The district holds ten assembly constituencies, namely, Karsog, Chachyot, Nachan, Sundernagar, Balh, Gopalpur, Dharampur, Jogindernagar, Drang and Sadar and one Parliamentary constituency.

3.4 Demographic features

According to Census of India 2001, human population in Mandi district is 9,01,344, out of which, 4,47,872 were males and 4,53,472, were females. The population of scheduled castes is 2,61,233 and scheduled tribe is 10,564. The district has 60,982 urban and 8,40,362 rural populations. The sex ratio of district is 1,013 female/male. The human population density is 228 persons/km^2 **(Table 1)**. Literacy rate of the district is 75.8% with male and female literacy 86.6% and 65.3% respectively. The district is next to Kangra with regards to population. In terms of area, it ranks seventh in the state. Mandi has 14.8 percent of the state population and 7.1 percent of the total geographical area of the state. The population of the Mandi district increased from 6,44,827 in 1981 to 7,68,446 in 1991 recording a growth rate of 20.40 percent. The population of the district further increased to 9,01,344 in 2001 with a growth rate of 16.05 percent. **Plate 3 and 4** show the study area, forests interspersed with human habitation.

3.5 People and their dependency

Generally, the rural people of the area are poor. Economy of these people is mainly based on agriculture. Livestock is the chief wealth next to agriculture of a predominant population of the district. Every house invariably has a few cows or buffalos, ox, sheep, goats, pigs and ponies. In addition, some people (shepherd) have large flock of sheep and goats. People depend on these livestock for their income, which is not enough, to meet their day to day requirements. Further leopard frequently raid the cowsheds and kill their livestock, as a result they are put to more hardships. In order to meet their daily needs, they depend on the forests and forest produce. In search and collection of these resources, people go to the forest where some time leopard attack on them which further add to their problems and anxiety. Although the forest department provides compensation to the victims of leopard attack or their families but that is not sufficient. Many people have lost their lives, their body parts and their livestock. This has resulted in aggressive resentment among local people.

3.6 Livestock population

Livestock is another indispensable asset to the farming as well as non-farming community of the district as it provides nutrition and livelihood also. According to livestock census (http://hpagrisnet.gov.in/animal-husbandry) conducted by the state animal husbandry department in 2007, the total population of livestock was 9,41,489. The livestock wealth of Mandi district includes mainly cattle population (51.6%), goat (24.1%), sheep (15.0%) buffalo (8.6%) and other (0.7%). Other livestock includes horse, mare, mule and donkeys etc. Cattle and buffalo reared mainly for milk, whereas goat and sheep are reared for wool, meat and milk purposes. The changes in livestock over the three decades have been presented in the **Table 2**. In Mandi district, there was a huge decline in sheep population over the three decades. The sheep population declined from 1,80,954 in 1977 to 1,40,837 in 2007.

3.7 Geography and physical features

The district is entirely hilly except Balh area in Sundernagar tehsil and Chauntra in Jogindernagar tehsil, which are fertile valleys. The geological configuration consists of four prominent ridges viz.:

Dhaula Dhar: This range runs with the eastern boundary of the district, from north to south. Nargu is the highest peak with an elevation of about 4400 meters. This range reaches the river Sutlej and runs towards north-east and joins the Kullu hills. This range is thickly wooded.

Ghagar Dhar: This being the second biggest range of the area enters the district at Harabag in Joginder Nagar tehsil. It contains the salt quarry at Gumma and Drang, and is well wooded and fertile.

Sikandra Dhar: This range can be divided into two sub-ranges, i.e. Kamlah range and Lindi range. It runs from north-west boundary of Suket and Bilaspur.

Dhar Vairket: The range started from Revalsar and extends to Suket. Some of its shoots join Kangra and Sikandra Dhar.

3.8 Soil types

The soil in the district can be classified into brown hill and sub-mountain soil. The rocks of the central zone consist of slates, conglomerates and sandstones. The brown hill soil occurs in Chauntra, Drang, Mandi Sadar, Revalsar, Dharampur, Gopalpur, Chachyot and Sundernagar development blocks, whereas the sub-mountain soil predominantly occurs in Seraj and Karsog blocks. The sub-mountain soil is rich in organic carbon, poor in availability of phosphorus and medium in potash contents. The brown hill soil is medium in the organic carbon, normal in potash but deficient in phosphorus contents. The former is too acidic in soil reaction and loamy in texture, whereas the later is slightly acidic in soil reaction and sandy loam in texture.

3.9 Drainage pattern

The Beas drainage system flows through Mandi district; the river originates near the Rohtang Pass, enters the district from close to Bajaura, at the boundary of Kullu and leaves the district at Sandhol. For the greater part of its length, it runs between high banks and as it is never of great width, though the current is swift, especially during the rains when numerous streams running from the mountains join the river but principal tributaries on the north bank are Uhl, Luni, Rana and Binu and on the south bank are the Hanse, Tirthan, Parvati, Harla Sainj, Bakhli, Jiuni, Suketi, Ranodi, Son and Bakar. The river Sutlej forms the boundary of the district in the East and South. There are three main lakes, namely, Rewalsar, Prashar and Kamrunag situated at 1000m, 2600m and 3050m respectively (Singh, 1999).

3.10 Slope gradients

The slope characteristics of the study area are shown in **Map 3.** Reclassified slope map containing six major classes indicates that only a small part of the study area has plain to gentle slope while most of the area falls under steep slope above 30^0.

3.11 Aspect

The aspects derived from DEM of Mandi district are shown in **Map 4**. It displays eight directions i.e. north, north-east, east, south-east, south, south-west, west and north-west. Since the topography of the area is very undulating, different aspects play a major role in the distribution of vegetation types and other land cover types.

3.12 Climate and season

The climate is temperate. The temperature varies from mild hot to cold with some areas under snowing winters. Physiographically, the district can be divided into three zones, namely, wet sub-temperate (Jogindernagar area), humid sub-temperate zone (some parts) and humid sub-tropical zone (major parts). Climatically, the area is divided into three distinct seasons viz. rainy season (June-September), winter (October-February) and summer (March-May). Variation in altitude, topography, precipitation, vegetation cover resulted into climatic variations from place to place. The altitude in the area ranges from 500m above mean sea level at Dehar to about 4042m in Nargu dhar**.** Precipitation occurs both in the form of snow and rains. The average annual rainfall is about 1568mm. Maximum rainfall occurs in the months of June to September, followed by January to March whereas least rainfall occurs in the month of November, followed by December, October and April (**Figure 1**). About 63 percent rainfall occurs in monsoon season i.e. from June to September. Snowfall at higher elevations starts in the mid of December and continues up to mid of February. The average total snowfall at 3000m elevation is about 3m. The temperature rises to about 40ºc in summer (District agriculture plan, 2009).

3.13 Forest types

Forests play an important role in the economy of the district. Forests provide valuable timber for export as well as for construction purposes, fuel wood, grazing land and grasses for the animals and habitats for wild animals. The percent of forest cover in the district is around 42.35 as compared to 26.35 in the state (www.fsi.nic.in, 2009). Interestingly, the area under forest cover has shown increasing trends over the years 1991-92 to 2002-03 (**Table 3**). The principal marketable forest products are timber, bamboo, resin and katha in the lower areas of the district (District agriculture plan, 2009).

3.14 Flora

Corresponding to climate and topography, the vegetation met within different parts of the district ranges from sub-montane to montane and alpine type (Singh, 1999). Variations in different factors like altitude, topography, precipitation, aspect, rock, soil, elevation and microclimate, etc. influenced the normal limit of vegetation type. The vegetation of the study area is sub-tropical at lower elevations and sub-temperate at higher elevations. Based on elevations, climate varies from sub-tropical to alpine type which have been recently applied to the Himalayan mountains as sub-montane (upto 1000m), montane (1000-3000m) and alpine (>3000m) zones. In general the following types of vegetation are encountered in the area.

In the lower elevations upto an altitude of 1200m, mixed dry deciduous type of forests are represented, particularly in the areas adjoining the river Baes and its tributaries on the dry and exposed ridges. The important tree species met in these areas are *Albizia chinensis*, *Bauhinia variegate*, *Bombax cieba*, *Cassia fistula*, *Dalbergia sissoo*, *Emblica officinalis*, *Grewia optiva*, *Mallotus philippensis*, *and Toona ciliate etc*. Scattered trees *of Albizia lebbeck*, *Butea monosperma*, *Litsea monopetala*, *Oroxylum indicum*, *Ougeinia oojeinensis*, *Terminalia chebula* and *Termenalia tomentosa* are also distributed. In Balh valley, *Ulmus villosa* is especially dominated by large population. Between an altitude of 900-2000 m in some nalas and along river Beas between Aut and Bajaura, good patches of Alder forest (*Alnus nitida*) are also found to occur.

The shrubs commonly occurs in the area are *Berberis spp*., *Caesalpinia decapetala, Carrisa opaca*, *Cassia spp*., *Murraya koeinghii*, *Randia tetrasperma*, *Reinwardtia indica*, *Rubus ellipticus* and *Zanthoxylum armatum*. *Euphorbia royleana* occurs in degraded and overgrazed areas. Common climbers occurring in the study area are *Caesalpinia sepiaria*, *Cissampelos pariera*, and *Tinosperma cordifolia*.

The ground flora consists of herbs and grasses which included the common species like *Achyranthes aspera*, *Ageratum conyzoides*, *Arenaria* *serphyllifolia*, *Artemisia spp*., *Bidens bipinnata*, *Boenninghausenia albiflora*, *Campanula pallida*, *Cannabis sativa*, *Euphorbia spp*., *Flemingia macrophylla*, *Inulla cappa*, *Micromeria biflora*, *Oxalis corniculata*, *Rumex hasatus* and grasses such as *Apluda mutica*, *Arundineria nepaensis*, *Chrysopogon serrulatum*, *Cymbopogon spp*., *Cynodon dactylon*, *Dicanthium annulatum*, *Digitaria setigera*, *Heterpogon contortus*, *Imperata cylindrical*, *Oplismensus spp*., *Poa annua*, *Pollypogon spp*., *Setaria gauca, Sorghum haepense* and *Themeda anathera* etc.

Chir forests are found to occur between 700-2200m in all ranges. The dominant component is *Pinus roxburghii*. Other scantily associated trees are *Lyonia ovalifolia*, *Rhododendron arboreum*, *Quercus leucotrichophora* and *Myrica esculenta* mainly on the shady places. The undergrowth consists of scattered bushes and grasses. *Berberis spp*., *Capillipedium assimile*, *Carrisa opaca*, *Cyperus niveus*, *Galium asperifolium*, *Prinsepia utilis*, *Rosa brunonii* and *Rubus ellipticus* are commonly occurring plant species. *Adhotota zeylanica*, *Aechmenthera gossypina*, *Carrisa*, *Dodonaea*, *Heteropogon contortus*, *Hoarrhena*, and *Ziziphus oxyphuylla* are main shrubs and herbs found in these scrubs. Acacia catechu associated with *Dalbergia sissoo* is found along river Satluj. In the Panarsa range, above Panarsa and towards Jwalapur, Olea cuspidate scrubs are found mainly on flatter alluvial ground. The trees have mostly been cleared for cultivation.

Ban-oak (*Quercus leucotrichiphora*) forests occur between altitudes of about 1000-2500 m. These forests are found to be composed of species like

Lyonia ovalifolia and *Rhododendron arboreum.* In some forests, *Acer oblongum*, *Myrica esculenta*, *Neolisea pallens* and *Querucus glauca* also grow mixed with it. In upper zone ban-oak gets mixed with *Qurecus floribunda* and *Qurecus semecarpifolia*. The undergrowth is not generally thick except in nalas and at places where the canopy is broken. Main species forming the undergrowth in these forests are *Berberis spp*., *Daphne papyracea*, *Indigofera heterantha*, *Myrsine africana*, *Prinsepia utiis*, *Rubus niveus and Viburnum cotinifolium* etc. and climbers like *Hedera napaensis*. Moru-oak (*Querecus floribunda*) occurs in the moist zone of main Himalayan zones between 2000-2700m in Seraj, Nachan and Barot ranges. Kharsu-oak forests (*Ouercus semecarpifolia*) are one of the characteristic features of the hills (2200-3000m) of the district and found along Nagru-Tunga dhar top of Ghogar dhar to the north of Barot, Deokana dhar and adjoining Kamrunag, Shikari dhar. Purses tan of Kharsu-oak, the second storey is generally absent and undergrowth consists of scattered bushes of *Cotoneaster affinis*, *Desmodium spp*., *Indigofera spp*. and *Viburnum cotonifoium*. The herbaceous flora is very thin.

The most beautiful type of montane mixed coniferous forests with mixture of *Abies pindrow*, *Picea smithiana*, *Pinus wallichiana* and *Cedrus deodara* together, associated with evergreen and deciduous board leaved trees are found to occur between 2000-3000m. Deodar (*Cedrus deodara*) grows mainly occur between 1500-2200m with some *Pinus wallichiana* trees along the spurs and an under storey of *Picea smithiana* along water channels and cooler sites. The undergrowth is generally poor because of heavy grazing and consists mainly of *Artemisia indica*, *Berberis spp.*, *Daphne papyracea*, *Plectranthus rugosus*, *Desmodium*, *Indigofera*, *Sarcococca saligna* and ferns are found to occur. The herbaceous growth is generally thin and consists mainly of *Ainsliaea aptera*, *Boennighausenia albiflora*, *Fragaria vesca*, *Salvia nubicola*, *Thymus serphyllum*, *Viola spp*. and a number of ferns and grasses. Common climbers met in the zone are *Clematis montana*, *Hedera nepalensis*, *Parthenocissus himalayana* and *Rosa brunonii*.

Sub-alpine and Alpine forests occur in the northernmost part of the district along Nagru-Hathipur ridge. The forest vegetation in this zone situated beyond 3200 m above mean sea level is characterized by the upper timber limit. The main elements are high altitude fir (*Abies pindrow*) with scattered admixture of *Pinus wallichiana* and *Quercus semicarpifolia*. *Viburnum nervosum*, *Skimmia anquetilia*, *Rohododendron campanulatum*, and species of *Salix*, *Spiraea*, *Juniperus*, and *Cotoneaster* are the common shrubs. Sometimes scattered trees of *Betula utlis* and *Prunus cornuta* in isolated pockets are also there. Ground flora consisting predominantly of species of *Anaphalis*, *Androsace*, *Anemone*, *Aster*, *Astragalus*, *Gentiana*, *Geranium*, *Myosotis*, *Oxyria*, *Polygonum*, *Primula*, *Potentilla*, *Renunculus*, *Saxifraga*, *Sedum*, *Selinum*, *Stearia*, *Swertia*, *Thalictrum* and several members of *Brassicaceae* and *Poaceae*.

Alpine pastures and meadows in between fir forests occur mostly above 3300m in uppermost part of Nagru sanctuary, Hathipur and Tunga Devi dhar, Samehnidhar and near Shikari Devi. These are high grasslands with scattered trees of kharsu, maple and bird cherry or silver fir. The ground cover is full of flowers in spring. The main species found here are grasses with *Anaphalis triplinervis, Anomone obtusiloba, Delphinium spp., Primula denticulate, Polygonum, Ranunculus* and *Iris spp., Cotoneaster* and *Vibrinum cotonifolium* are also found to occur. Among main grasses which are found in these areas are *Themeda spp., Heteropogon spp., Chrysopogon spp., Agrostis vineais* and *Dactyysis glomerata*. The common elements of meadows are the species of *Iris*, *Gentiana*, *Aconitum*, *Androsace*, *Arenaria*, *Corydalis*, *Germanium*, *Lactuca*, *Pedicularis*, *Saxifraga*, *Selinum*, *Stellaria*, *Swertia*, *Tanacetum*, *Thalictrum*, *Picrorhiza*, *Rheum* and several members of *Brassicaceae* and *Poaceae*. Due to overgrazing, soil erosion is taking place at a very high rate in such pastures

The habitat available for leopard is highly patchy, degraded, fragmented and interspersed with villages with high human and cattle population. Optimum habitat that can support the population of leopard in these forests is completely lacking. Most of the forest fragments are bouldery with small hillocks, which offer suitable den sites for leopard.

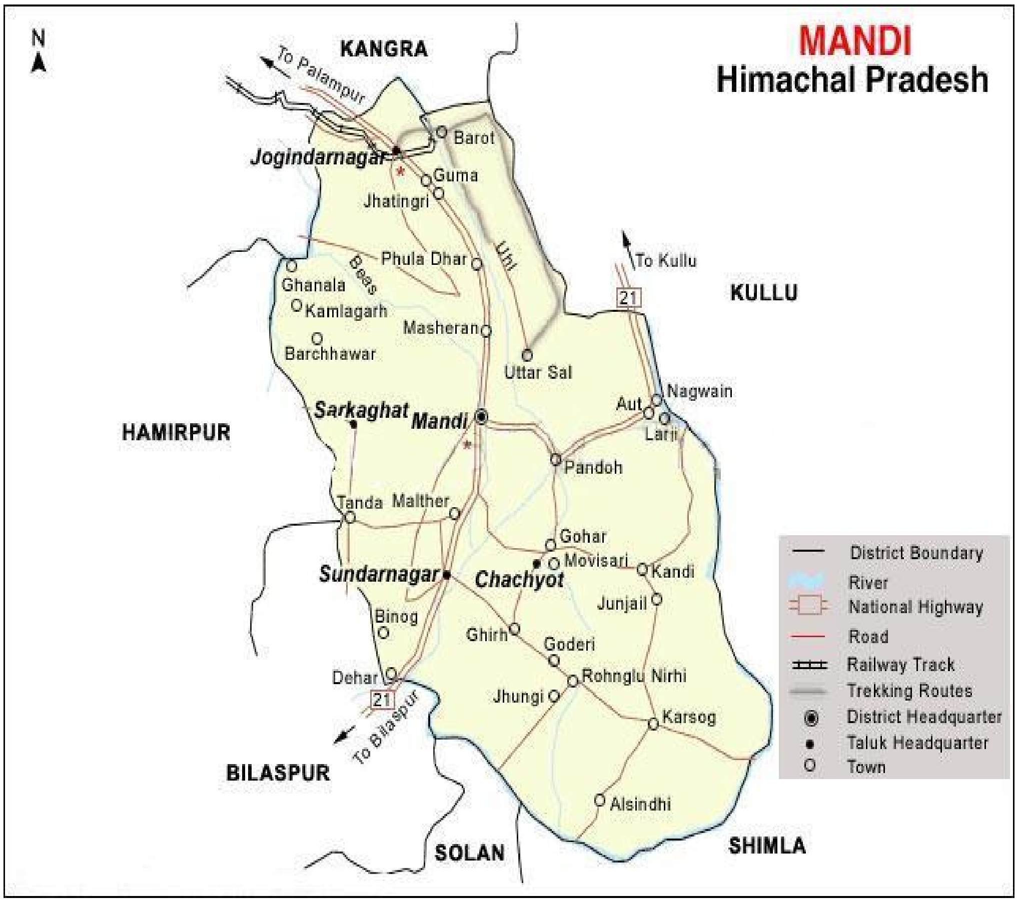
3.15 Fauna

The district is well diversified in animal community. Goral (*Nemorhaedus goral*) is frequently found at medium elevation. The mammalian species commonly found in the district are leopard (*Panthera pardus*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), wild pig

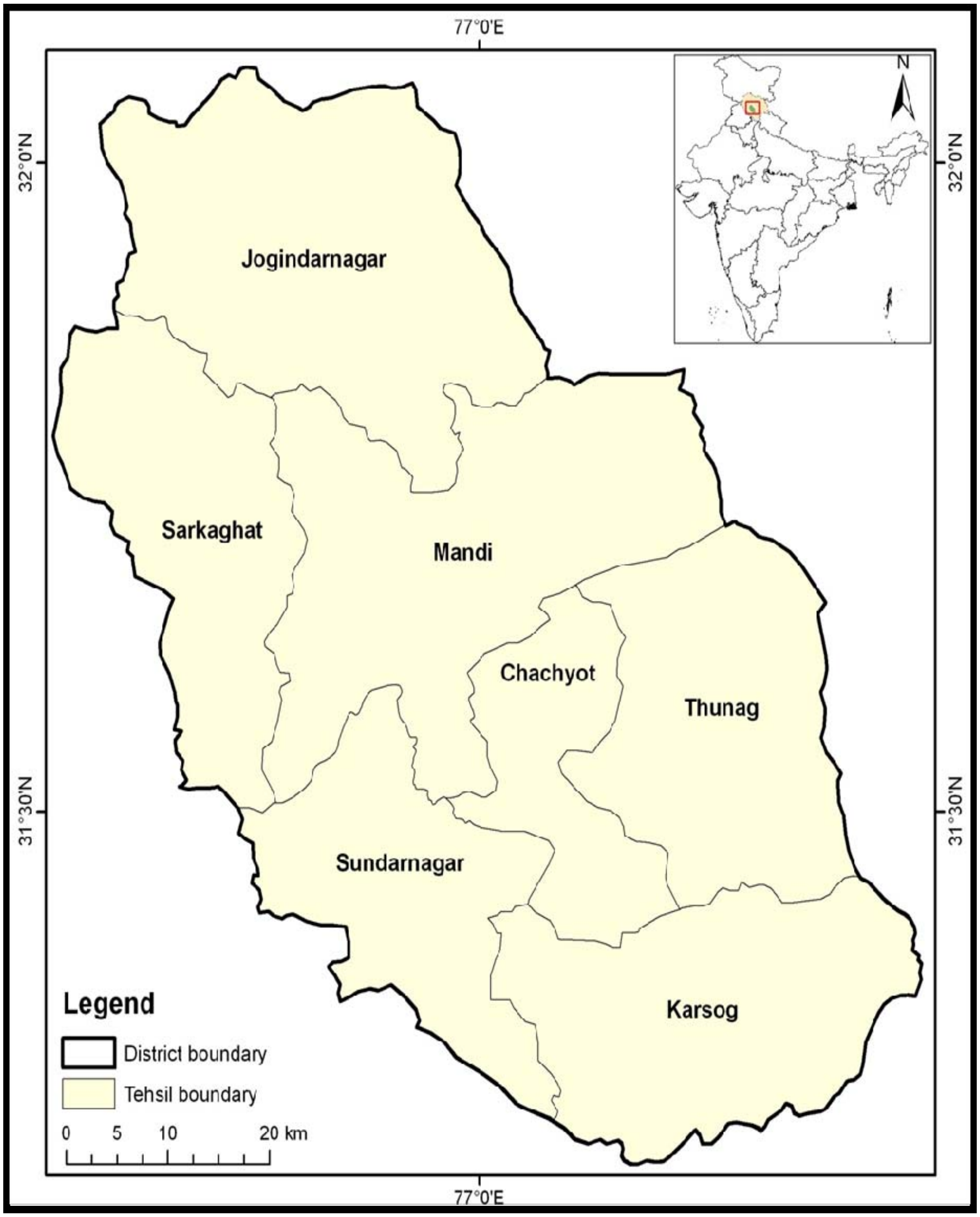
(*Sus scrofa*), jackal (*Canis aureus*), hill fox (*Vulpes bengalensis*), rhesus macaque (*Macaca mulatta*), common langur (*Presbytis entellus*), porcupine (*Hystrix indica*), and hare (*Lepus nigricollis*). Black bears (*Ursus thibetanus*) are common in the higher valleys. The musk deer (*Moschus moschiferus*) and serow (*Capricornis sumatraensis*) are also found in certain areas. In addition to leopard, other wild cats existing in the study area are Jungle cat (*Felis chaus*) and leopard cat (*Prionailurus bengalensis*). **Plate 5** shows a mother with cub in the study area.

Among the birds, black francolin (*Francolinus francolinus*and), gray francolin (*Francolinus pondicerianus*) and jungle bush-quail *(Perdicula asiatica*) are commonly found throughout the district. Among the pheasants, the peacock (*Pavo cristatus*), red jungle fowl (*Gallus gallus*) and kaleej pheasant (*Lophura leucomelanos*) are also found. Among vultures, Egyptian vulture (*Neophron percnopterus*), Indian white-backed vulture (*Gyps bengalensis)* Himalayan griffon (*Gyps himalayensis*) and red-headed vulture (*Sarcogyps calvus*) are also rarely seen.

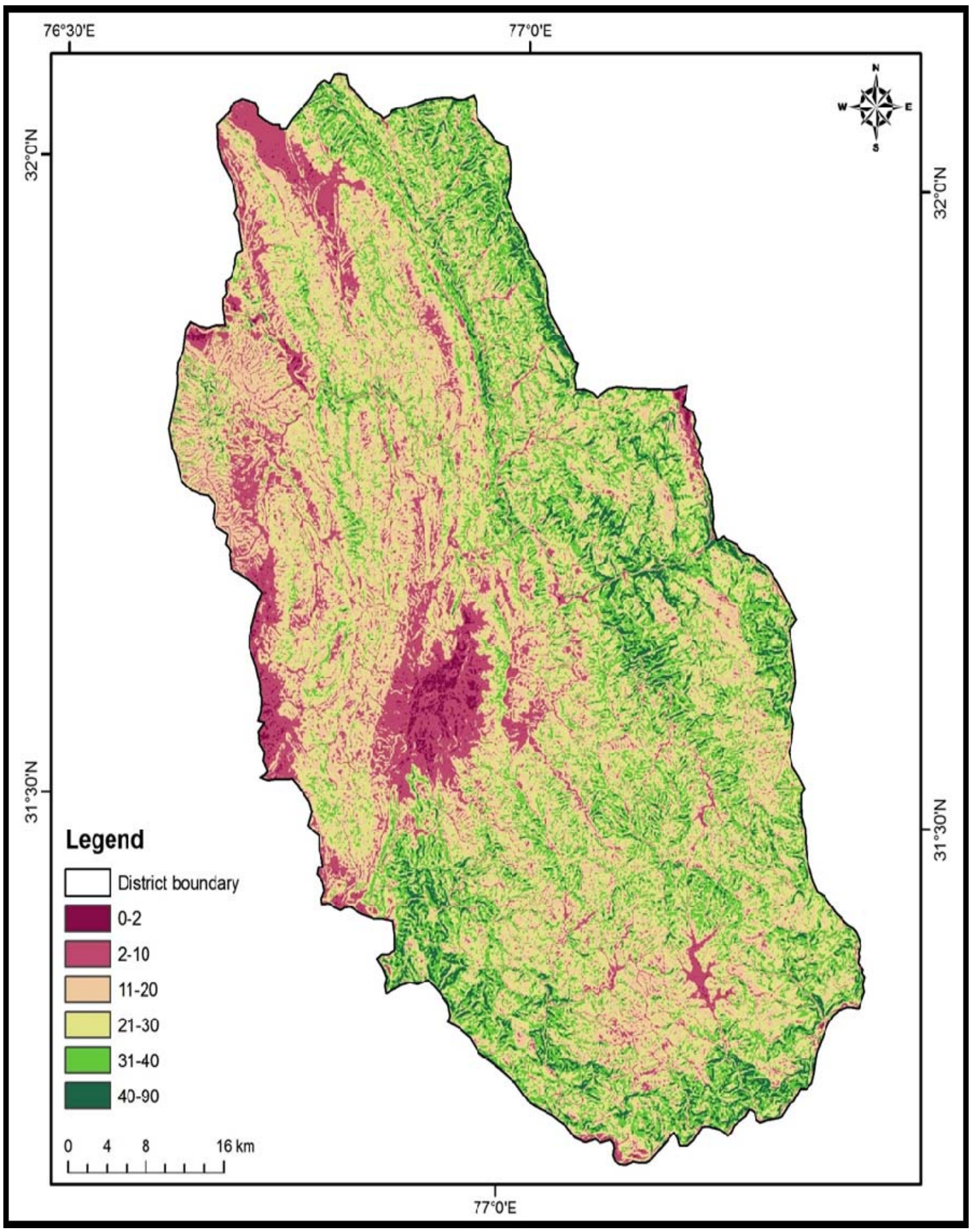
Map 1. Map of the study area, Mandi district showing road network.



Map 2. Location map of Mandi district showing tehsils.



Map 3. Map of Mandi district showing slope characteristics.



Map 4. Map of Mandi district showing aspects.

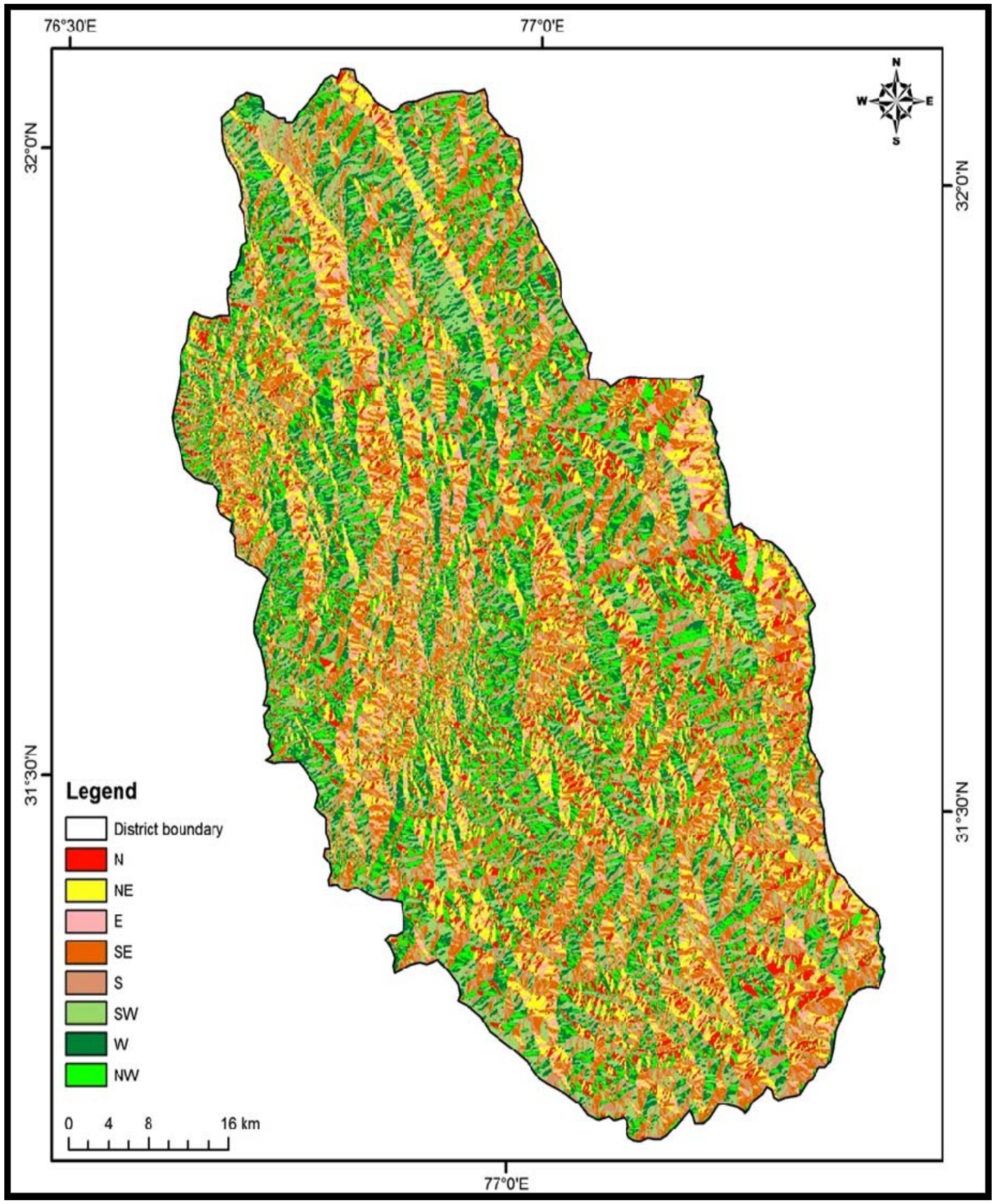


Plate 1. A view of study area, forests interspersed with villages.

Plate 2. A view of study area, forests interspersed with villages.

Plate 3. Leopard infested fragmented habitats in Mandi district.

Plate 4. Leopard infested areas in Mandi district.

Table 1. Decadal human population growth.

Year	Population	Males	Females	Sex ratio	Growth (%)	Density/km²	% to state
1981	6,44,827	3,22,575	3,22,252	999	24.46	163	15.06
1991	7,68,446	3,77,986	3,90,460	1,033	20.4	195	14.86
2001	9,01,344	4,47,762	4,53,582	1,013	16.05	228	14.83

Table 2. Change in livestock population over last three decades.

Year	**Cattle**	**Buffalo**	**Sheep**	**Goat**	**Others**	**Total**
1977	378752	87103	180954	200312	3002	850123
1992	430331	107676	196041	203270	5155	942473
1997	438050	108416	197769	202938	5317	952490
2003	437536	84301	129844	189745	7525	848951
2007	485895	81643	140837	226485	6629	941489
Total	**2170564**	**469139**	**845445**	**1022750**	**27628**	**4535526**

Table 3. Changes in forest land from 1990 to 2003.

Year	Forest land (%)
1990-91	42.44
1995-96	43.65
2000-01	43.84
2002-03	44.08

Figure 1. Year-wise rainfall in Mandi district from 1990-2003.

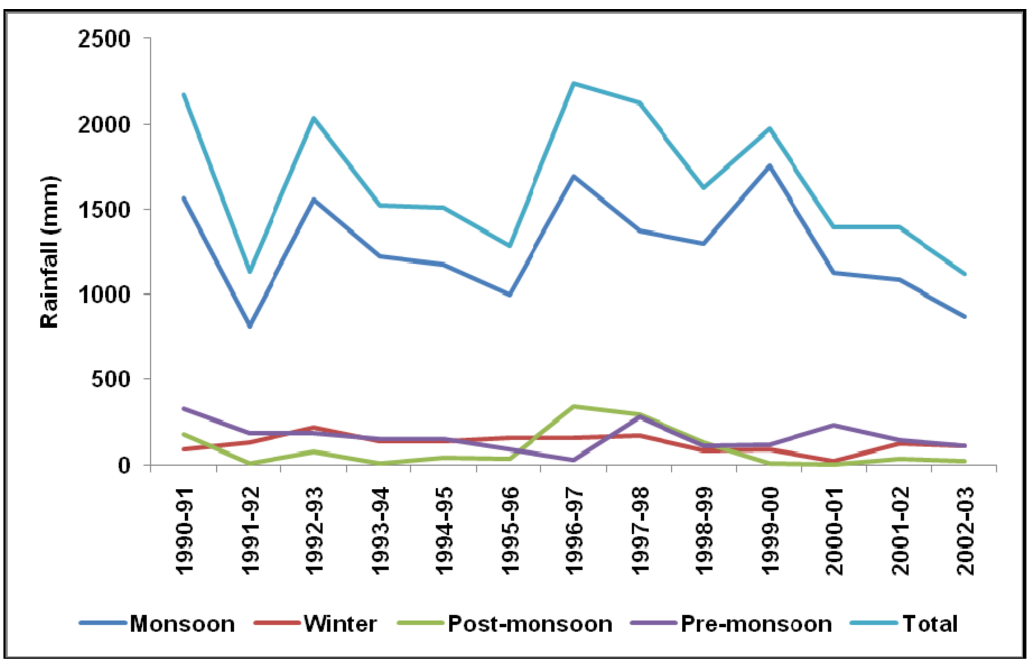


Plate 5. Mother with a cub.

Chapter 4

To study status, distribution and relative abundance of leopard in relation to habitat characteristics.

4.1 Introduction

Estimation of status of leopard population and its distribution become more important in an area when a species is highly threatened due to continuous habitat degradation and loss of habitat due to the increasing human population. In several countries, leopard population is increasingly threatened by habitat fragmentation and degradation, depletion of wild prey, as well as prosecution by local people to protect livestock (Myers, 1986; Nowell and Jackson, 1996 and Woodroffe, 2000). In spite of these threats, leopard is still most successful among all cats in terms of its distribution (Bailey, 1993). Leopard ecological and behavioural adaptation abilities are the main reasons for its sustained perseverance in areas where changes in landuse, prey base and habitat structure have caused the extinction of other large cats or less adaptive carnivores (Marker and Dickman, 2005).

Many carnivore species are rare or elusive, and documenting their distribution is difficult (Zielinski and Kucera, 1995). Monitoring their presence over the long term or identifying areas preferred or avoided by carnivores, however, is important. This is especially true for species that are endangered, valued as furbearers, or sometimes considered nuisances. Although assessing specific habitat needs of common habitat generalists is less important, such efforts are essential for rare habitat specialists, and research identifying their distribution and habitat preferences is a priority among biologists (Ray, 2000). The most basic information about the status of a species is its distribution (Linnell *et al*., 2000). Understanding factors that influence and predict species distribution and abundance is fundamental to conservation and population management (Mace *et al*., 1999). This is particularly for the endangered species, where knowing what determines distribution is a necessary precursor for schemes to mitigate decline or to create new populations (Rushton *et al*., 2004).

Habitat requirement is also one of the most important factors which influence the distribution and abundance of a species, therefore habitat evaluation is a vital step in the formulation of carnivore management in an area (Mladenoff *et al*., 1995 and Clevenger *et al*., 1997). Large carnivores need large areas of relatively wild habitat, which make their conservation challenging. Estimating population abundance of large carnivores has always been controversial and reliable data on carnivore populations even today is questionable (Srnallwood and Schonewald, 1996). However, methods used for population estimation of large carnivores have always been marred with one or the other problem on account of low numbers and poor detection probability of large carnivores which make it extremely difficult to arrive at a reliable estimate (Carbone *et al*., 2001). Reliable information on the status and population trend of large carnivores is lacking due to high cost of sampling across large geographical areas (Srnallwood and Fitzhugh, 1995).

In previous studies, several different methods have been used to document carnivore distribution including track counts and signs indices (Thompson *et al*., 1989; Raphael, 1994 and Srnallwood and Fitzhugh, 1995), density based habitat qualities (Fuller and Sievert, 2001 and Carbone and Gittleman, 2002), radio-telemetry (White and Garott, 1990; Karanth, 1995 and Van Schaik and Griffiths, 1996), smoked aluminum track plates (Barrett, 1983 and Raphael, 1994) and DNA analyses (Raphael, 1994 and Kohn and Wayne, 1997) and more recently camera trapping in a mark-recapture frame work have enabled the identification of elusive animals (Zielinski and Kucera, 1995; Karanth, 1995; Karanth and Nicholas, 1998; Carbone *et al*., 2001; Kawanishi, 2002, Moruzzi *et al*., 2002 and Wegge *et al*., 2004). Although cameras take considerable set up time and may produce biases in detection because of baits or other stimuli used to attract animals to the station, they appear to be the best compromise for assessing carnivore distribution over relatively large areas.

Large scale habitat evaluation has become possible due to the development of remote sensing techniques and the availability of Geographic Information System (GIS). For a species management, the ability to model spatial distribution grid changes in distribution of a species is of considerable importance (Scott *et al*., 1992). Once spatial distribution can be adequately modeled, the distribution and abundance can be monitored efficiently over time, and future changes can be predicted (Buckland and Elston, 1993). These spatial characteristics and relationship are often difficult to identify and hard to display with traditional ground surveys or statistical model. Therefore, using Geographic Information System (GIS) has become an actable trend in ecological-studies (Forman, 1995). Overall, distribution mapping using GIS and field survey data gives a clear understanding for carnivore distribution pattern that is otherwise difficult to obtain. These methods can not be efficiently applied in every ecosystem. Some landscape can be so remote, steep or so densely vegetated that only a few methods could be practicable. Sometimes the choice is limited not by technique efficiency, but by the field costs (Silveira *et al*., 2003).

Among these methods, sign (tracks, scats and mark or scrape) surveys are probably the most commonly used for monitoring large carnivores throughout the world (Kutilck *et al*., 1983; Fox *et al*., 1991 and Srnallwood and Fitzhugh, 1995). The track surveys are also efficient and usually involve low cost, but depend on suitable field conditions and trained personals (Srnallwood and Fitzhugh, 1995 and Silveira *et al*., 2003).

The use of Relative Abundance Indices (RAI) and their correlation (if any) with the real population is appears to be the most promising and cost effective techniques since it allow potentially to estimate the density from scat counts, track counts, and similar procedure without disturbing the target animals themselves (Khorozyan, 2003). However, because large carnivores typically occur at very low densities, tracks and signs are not found on many transects (Clevenger and Purroy, 1996 and Silveira *et al*., 2003). As carnivores mostly use the available habitat in a non-random fashion and favours certain routes, the probability of detecting carnivore can be increased by placing transects in area where they are most likely to pass (Srnallwood and Fitzhugh, 1995 and Beier and Cunningham, 1996). Studies suggested that the correlation between density and RAI does exist in carnivores (Fox *et al*., 1991; Srnallwood and Fitzhugh, 1995; Beier and Cunningham, 1996 and Stander, 1998). Photographic capture frequency may serve as an index to the population (Carbone *et al*., 2001) and this may not hold true for all species (Jennelle *et al*., 2002). Carnivore abundance in an area may also correlate with rainfall (Martin and De Meulenaer, 1988) and or prey biomass (Fuller and Sicvert, 2001 and Carbone and Gittleman, 2002), but such a relationship is possible only in prey-rich and low human population areas where anthropogenic pressures do not affect the predator abundance (Carbone and Gittleman, 2002 and Khorozyan, 2003).

To find the land cover and land use pattern and correlation of leopard population abundance and habitat use by them, Remote sensing and Geographical Information System (GIS) are the most vital tools in any area now days. The remote sensing technology captures the synoptic view of resources and GIS technology has made it is easier to integrate multi-theme information on spatial scales and to derive requisite information for planning and management (Akhtar, 2002 and Lal, 2007). These techniques are very helpful and deterring to formulate important national policy on environmental conservation, water, soil etc. Remote sensing techniques have helped in investigating and mapping of natural resources (Karale, 1992). Forest Survey of India (FSI) used remote sensing techniques for the first time for operational task at the national level in 1982 (Lal *et al*., 1991). The utility of the Indian remote sensing satellite data has been amply demonstrated for various resource applications through a number of recent studies (Tiwari and Kudrat, 1988; Tiwari *et al*., 1991; Akhtar, 2002; Lal, 2007; Gupta, 2007 and Joshi *et al*., 2001, 2006).

The vegetation maps provide location information along with distribution and abundance of plant species. The most important use of vegetation map is in various ecological application such as habitat mapping, biodiversity characterization, biomass estimation, change detection and long term monitoring.

Traditionally, forest is considered a renewable resource and integration of various aspects of the environment. However, the survival of the man existence is threatened due to exploitation of natural resources, including vegetation wealth. There has been growing concern for the preservation of primary or secondary forests. More and more attention is being drawn to conservation of all kinds of forests for protective regulation and their productive role in maintaining the earth's ecosystems. In Mandi district, preservation of forests is very important due the fact that most of the forests cover is under tremendous pressure from the growing human and livestock population. Leopard is ecologically dislocated and as a result, human-leopard conflicts are on the rise. Therefore, collection of information on spatial distribution of vegetation types, forest structure and composition in Mandi district was considered important. The data have been subjected to stratify random sampling to analyze community characters. Ground work carried out in homogenous vegetation strata has been used to derive information on stand density, composition, frequency, abundance, basal area etc of various species present.

In Mandi district, human-leopard conflict is on the increase and situation has become alarming. If the human-leopard conflict is not reduced now, the circumstances may pose serious threats to the survival of leopard as well as other wild animals. Reliable estimation of leopard population and knowledge about its distribution pattern are very essential for the field managers to develop mitigation strategy to combat man-leopard conflict on the long term basis. What is the distribution of leopard in Mandi district? Is distribution of leopard affected by habitat characteristics? What is the relative abundance of leopard in different human-leopard conflict categories? It is necessary to know the answers of all these questions. In this chapter, the baseline information is generated on the distribution and relative abundance of leopard in Mandi district.

4.2 Materials and Methods

If the purpose of a census is comparison than the data ought to be precise enough to detect differences (Rodgers, 1991). In many cases a simple index of density using dung counts may be the most efficient way to show changes. For example counting pellets or scats in a series of quadrates in two areas can be a way to show the differences in animal use of those two areas. Dung/scat is reliable indicator of animal presence (provided one can identify the species) and has frequently been used for estimating animal abundance (Rodgers, 1991). In certain situation, dung counts can lead the actual population estimates, but there are many assumptions to be met. However scat counts can easily be used as an index of population abundance. Two types of sample units are considered for sample counts of animals using actual sightings; counting within blocks, and counting along transect lines to know the presence of animal(s) or/and location of the den sites. Line transect is the robust method to estimate population of a species, in which animals are counted along the straight line and their number, distance and angular or perpendicular distance from the observer is recorded (Anderson *et al.,* 1979; Buckland *et al.,* 1993 and Burnham *et al.,* 1980).

In the habitats available in the Mandi district, information from the local people and indirect evidences on forest trails and outside of leopard was used for estimating its population abundance and distribution. The details are as follows:

4.2.1 Distribution and relative abundance

Leopard being solitary, nocturnal and elusive, it was difficult to obtain direct information. Through village survey and interview and direct and indirect evidences, information on status of leopard and its distribution was collected. Based on the shape and size of tracks, most frequently moving leopard to edge habitat were classified into males or females. Trails monitoring was carried out in the morning to get direct sighting of leopard. Each sighting of leopard was recorded. The study area, the Mandi district is all hilly, so it was not feasible to mark and monitor straight line transects. Therefore relative abundance of leopards was estimated by walking on forest trails. To estimate the relative abundance, 31 trails of 1-2 km each covering various habitat types and landuse categories were walked three times over a period of one year in different seasons (summer, monsoon and winter). Along the walking trails, leopard scats were collected, and these were also collected from all over the study areas. Trails were walked once in a season to record indirect evidences such as tracks and scats. Scats were collected along one meter strip on both the sides of the trails and old scats were removed immediately after data collection. Relative abundance of leopards was calculated based on the number of scats and trail/km walk by using the following calculation:

Encounter Rate (ER) = # of scats\distance covered (km)

Mean Encounter Rate (MER) = Σ ER $_{(1,2.X)/}$X

Where X =No. of monitored trails

4.2.2 Landuse and landcover mapping

In Mandi district, preservation of various forest types in different habitats is very important due the fact that most of the forests cover is under tremendous pressure from the growing human and livestock population. Leopard seems to be ecologically dislocated and as a result, human-leopard conflict is on the rise. Therefore, collection of information on spatial distribution of vegetation types, forest structure and composition and landuse pattern in the study area has been considered important.

For quantification or mapping of the landuse and vegetation, the 30m resolution Landsat TM image of the period from April and October 2010 was used. The entire six bands (1 to 5 and 7) except thermal band (band-6) were used for classification. Image classification method is based on initial isodata clustering into 45 classes which were later recoded in 10 major classes (Pine forest, Mixed deciduous forest, Agricultural land, deodar dominated forest, Oak dominated forest, Scrub, Grassland, Snow, water body and Bare surface). Scrub and grassland class were derived from October image while image from April was used for other classes. Derivation of classes is based on spectral properties of objects rather than standard landuse and landcover classes. **Map 1** shows different classes of the landuse and landcover in Mandi district.

4.2.3 Normalized Difference Vegetation Index

Normalized difference vegetation index (NDVI) derived from Landsat image of April month was used as surrogate of percent vegetation cover in the study area (**Map 2**). Since September is the peak vegetation growing season, images of this month was not used due to poor separation among different vegetation classes. Though the scale of NDVI ranges between -1 to +1, it was rescaled at 8-bit scale (0-255) before it was used for habitat suitability mapping.

4.2.4 Digital Elevation Model

Aster global Digital Elevation Model DEM with 30m resolution used in this study was downloaded from freely available online archive:

(http://www.gdem.aster.ersdac.or.jp).

The altitude in the study area ranges from 500m above mean sea level at Dehar to about 4042m in Nargu Dhar (Singh, 1999). The Digital Elevation Model of Mandi district is given in **Map 3**.

4.2.5 Terrain Ruggedness Index

Terrain heterogeneity is an important variable for predicting which habitats are used by species and the density at which species occur across a variety of environment. Topographic ruggedness index representing the landscape heterogeneity was calculated according to Riley *et al*. (1999). A large part of the study area is comprised of high elevation zones that greatly impacts landscape heterogeneity and thus is a very important factor for leopard distribution modelling. Terrain Ruggedness Index from low to high is shown in **Map 4**.

4.2.6 Topographic Position Index

Topographic Position Index (TPI) is a measure of where a location is in the overall landscape. That is, in relative terms, the topographic position of a place may be a hill top, or a valley bottom, or a slope, or an exposed ridge, or a flat plain, or other feature. The TPI algorithm used in this study is adapted from Weiss, 2001 which derives 10 different land form classes (1. Canyons, deeply incised streams; 2. Mid slope drainages, shallow valleys; 3. Upland drainages, headwaters; 4. U-shaped valleys; 5. Plains; 6. Open slopes; 7. Upper slopes, mesas; 8. Local ridges or hills in valleys; 9. Mid slope ridges, small hills in plains, and 10. Mountain tops, high ridges) from a digital elevation model. First three classes are features related to river valleys, but due to its low geographical representation, they were merged together. Last three classes which represent hill topes were also merged together. Overall six different land form classes were used for analysis (**Map 5**).

4.2.7 Drainage

The type and pattern of drainage in Mandi district is shown in **Map 6**. The Beas drainage system flows through Mandi district. During the rains, numerous streams and tributaries running from the mountains join the river but principal tributaries on the north bank are Uhl, Luni, Rana and Binu and on the south bank are the Hanse, Tirthan, Parvati, Harla Sainj, Bakhli, Jiuni, Suketi, Ranodi, Son and Bakar. The river Sutlej forms the boundary of the district in the East and South.

4.2.8 Major road network

From the point of view of transport and communication, the Mandi district occupies an important place because of the fact that National Highway (No. 21) passes from here and the narrow gauge Pathankot - Jogindernagar railway line also passes through the district. Major road network in Mandi district is shown in (**Map 7**) Most of the villages and all the towns are linked with the district and tehsil headquarters, by a network of motor able roads. Even the far off villages where it is not possible to construct motor able roads, footpaths and bridle paths have been constructed. The major road passing through study area can influence the wild-animal movements.

4.2.9 Human habitation

As per the 2001 population census, there are 3338 villages in 10 blocks of the district (http://hpmandi.nic.in/fact.htm). The Karsog block has highest number of villages (n=599), followed by Seraj (n=388), Sadar (n=365), Chachyot (n=334) and Darang (n=320). The forests are interspersed with villages which affect the habitat use by wild animals. **Map 8** shows the location of villages in the Mandi district.

4.2.10 Habitat Suitability Mapping

Despite a legally protected species, leopard population is under tremendous pressure due to decline of suitable habitats and increasing human-leopard conflict. Protection of leopard population in its natural habitat requires identification and delineation of areas where ecological conditions are suitable for this species. Habitat suitability (HS) mapping using GIS is a valuable tool to map the geographical extent suitable for a species.

4.2.11 Ecological Niche Factor Analysis

Among various models available for HS mapping, ecological niche factor analysis (ENFA) which uses presence data only was chosen for this study. The ENFA model is designed on the basis of Hutchinson's niche concept (Hutchinson, 1957). The fact that patchiness of the habitat does not necessarily restricts the movement of animal from one patch to another, they presumably do not occupy y*et al*l suitable regions. Absence data therefore do not necessarily reflect poor-quality habitat, a point which strongly advocates for the use of an analysis relying on presence data only (Hirzel *et al*. 2002).

ENFA summarises all variables into a few uncorrelated factors and compares the species distribution to the global (available) environment. It is built on the concepts of marginality (deviation from the global means of eco-geographical variables) and specialization (niche breadth). ENFA and HS map computations were facilitated within the program 'BioMapper' (Hirzel *et al*. 2004). Marginality (*M*) is calculated in the following way.

$$M = \_mG - mS/1.96\ \sigma G \qquad (1)$$

Where, *mG* = global mean, *m*S = species mean, σG = standard deviations of global distribution.

The specialization of a species is expressed by the fact that the species variance is lower than the global variance. Specialization indicates how restricted the species' niche is in relation to the study area (Hirzel *et al*., 2002). Specialization (S) is defined as the ratio of standard deviation of the global distribution (σG) to that of focal species (σS).

$$S = \sigma G/\sigma S \qquad (2)$$

The inverse of specialization is a measure of species 'tolerance'. Marginality and specialization are uncorrelated factors, with the major information contained within the first factor (Hirzel *et al.,* 2002). The marginality factor expresses the marginality of the focal species on each EGV. The negative coefficients indicate that the focal species prefers values that are lower than the mean with respect to the study area, while positive coefficients indicate preference for higher than mean values. The interpretation of the subsequent factors is different. The higher the absolute value, the more restricted is the range of focal species on the corresponding variable. The signs are arbitrary in these variables.

4.2.12 Eco-Geographical Variables

Eco-Geographical Variables (EGV) used for mapping the suitable habitat of leopard was derived from land cover map and the aster global digital elevation model (AGDEM). Both the data are available free from USGS online archive (http://glovis.usgs.gov/). Overall 16 variables were used for the habitat suitability mapping (**Table 3**), of which, six variables were derived from the land cover map while eight variables were calculated from the AGDEM. All the maps were rasterized using Arc View 3.2, SAGA and Arc Map (ESRI 2004). The NDVI was derived from Landsat TM image from the month of April 2010. All the variables used in this analysis were generated at 30m resolution. Proportion of cells for a given category is based on the area calculated within a circle of 1200m radius around the focal cell. Circle surface is ~5km^2 which is close to the mean home range area of leopard. Eisenberg and Lockhart (1972) estimated overall density of leopard around one animal per 30 km^2 in Wilpattu national park. It was also stated that it might increase to one per 8 to 10 km^2 prime in habitats. In dry tropical forest of Huai Kha Khaeng wildlife sanctuary, Thailand, density was around one leopard per 25 km^2 (Rabinowitz, 1989). Female leopard home ranges were found to vary from 6 to 30 km^2 in

Africa (Bailey, 1993) and an average 17 km^2 in Nepal (Odden and Wegge, 2005). So 5 km^2 was considered as a conservative estimate of the area in which presence could be assumed in the forest grid. Distance data express the Euclidean distance between the focal cell (presence location) and the closest cell belonging to a given category. The presence database was collected in the form of direct or indirect sighting (faecal matter) of the animals during line transects or trail walk.

4.2.13 Habitat Suitability Index

Habitat suitability maps are calculated by the median algorithm based on the first factors obtained by the ENFA. The number of factors included results from a comparison of factors' eigen values based on a MacArthur's broken-stick distribution (Hirzel *et al*., 2002). On one factor axis, calculation is based on a count of all cells of the species distribution that lay at least as far apart from the median as the focal cell. This procedure is repeated for each factor included in the habitat suitability calculation. Overall habitat suitability for each cell is calculated by combining the score of each factor. Habitat suitability varies from 0 (worst habitat) to 100 (best habitat) and indicates how the environmental combination of a single cell suits the requirements of the focal species.

4.2.14 Model validation /evaluation

The habitat suitability map was evaluated for predictive accuracy by a cross validation procedure (Boyce *et al.,* 2002). The species locations were randomly partitioned into k mutually exclusive but identically sized sets. Each k minus one partition was used to compute a habitat suitability model and a left out partition was used to validate it on independent data. The process was repeated k times, each time by leaving out a different partition. The process resulted in k different habitat suitability maps and the comparison of these maps and how they fluctuated, provided an assessment of predictive power. The number of partition used was four. Each map was reclassified into *i* bins, where each bin *i* covered some proportion of total study area (*Ai*) and contained some proportion of validation points (*Ni*).

4.3 Results

The distribution pattern and abundance of leopard population based on the forest trail walks, direct sightings in the vicinity of den sites or outside and estimating density indices from indirect evidences such as scat abundance has been mapped in the Mandi district and presented.

4.3.1 Distribution of leopard

Through intensive surveys and transect study in Mandi district, leopard den sites were located and identified as active sites and temporary ones. Besides collecting den sites information along the forest trails, villagers were contacted to find location of den sites in their areas during the field work. Den or crevices in hills was considered as one den site. Distinct tunnels in a hill slopes were considered as separate den sites. Local name of each den site and its nature (actively or temporarily used) was recorded.

Besides location of direct sightings, scat collection, indirect evidences and also leopard attacks on humans and livestock were also marked to know the distribution of leopards in the districts. Across the intensive study areas of Mandi district, altogether 98 leopard den sites were identified **(Table 1).** Among these 85 den sites were found to be actively used by leopards and rest 11 were used occasionally. It was observed that in Mandi district, most of the den sites were located in the forest areas on hilly slopes, and very few dens were found in the low lying hill slopes.

Related to the number of active and temporary dens, distribution of leopards has been determined. **Plate 1** shows the active den site of leopard on a hill slope which provides shelter and safety to leopard. Leopards occupied almost 73% area in Mandi districts. The distribution of leopards based on occurrence of active and temporary dens has been shown village wise in the intensive study sites of these two districts. Since the Mandi district encompassed 3950 km^2 areas, the leopard population could be projected as very high.

4.3.2. Leopard abundance based on direct sightings

Along the 31 forest trails covering various habitat types and landuse categories, the leopard population abundance has been calculated in the Mandi district. Although all the transects were walked three times over a period of one year in different seasons, but the data was not indicative because of only a few sightings for estimating leopard population. Along transects in 372 walks, only 4 leopards (2 males, 1 female and 1 cub) were seen in 3 sightings in the study area. Average leopard encounter rate during each walk was very low i.e. 0.01. In the fragmented and disturbed habitat conditions, leopards were rarely active during the day time and so there was remote possibility of their sightings. So leopard abundance was estimated in terms of leopard indirect evidences i.e. abundance of scats and claw marks per hectare.

4.3.3. Leopard abundance based on indirect evidences

Scats recorded on trails during 2003 to 2008 were used to understand the relative abundance of leopard in the study area. A total of 389 scats were collected out of which 131 collected in winter, 140 in summer and 118 in monsoon. Based on availability of scats, the mean encounter rate of leopard in Mandi district was found to be 1.04±0.39 (SD). During summer, monsoon and winter season, the mean encounter rate of leopard is 1.12±0.47, 0.95±0.43 and 1.05±0.54 respectively. Single factor ANOVA test reveals that the relative abundance of leopard is not significantly different **(F = 1.04, df=2, P=0.35)** across the different seasons. This represents a high abundance of the leopard in the study area.

4.3.4. Landuse categories

The landuse categories of the Mandi district identified on the basis of tone, texture and pattern in the satellite imageries showed that each landuse category was distinct with the specific characteristics **(Map 1)**. Altogether 16 landuse categories were initially identified. To make it more meaningful and convenient, these were finally reduced to 10 categories. The landcover and landuse pattern in Mandi district were studied through generation of maps with vegetation, habitation and agriculture, water distribution, road network, elevation, aspect and biotic pressure layers. Based on the vegetation and habitat features classification in the study area, 10 major habitat classes, namely, Pine forest, Mixed deciduous forest, Agricultural land, Deodar dominated forest, Oak dominated forest, Scrub, Grassland, Snow, Water bodies and Bare surface were recorded. The area under different landuse and landcover classes of the Mandi district is given in **Table 2**. **Plate 2 to 10** show different habitat types in the study area.

The forest cover was calculated to 2283.9 km^2 out of total **3950** km^2 area **(Table 2, Map 1)**. Among all the landuse categories, Bare surface covered the maximum area (1101.8 km^2, 27.9%), followed by the Pine forest (822.2 km^2, 20.8%), Scrub land (569.4 km^2, 14.4%), Mixed deciduous forest (428.4 km^2, 10.8%), Deodar dominated forest (368.1 km^2, 9.3%), Agricultural land (302.0 km^2, 7.7%), Grassland (236.4 km^2, 6.0%), Oak dominated forest (95.8 km^2, 2.4%), and the least area under Snow (1.4 km^2, 0.1%). Though water bodies covered 24.5 km^2 (0.6%) area, they were more or less evenly distributed in the whole area. All these landcover and landuse categories fell into 500 to 4042 m range and flat to undulation terrain facing different directions.

4.3.5. Habitat suitability Index

In Mandi district, habitat use by leopard was assessed based on its direct sighting, indirect evidences and conflict sites. Various habitat types including the Pine forest, Mixed deciduous forest, Agricultural land, Deodar dominated forest, Oak dominated forest, Scrub, Grassland, Snow, Water bodies and Bare surface areas were found to be differentially used by leopard.

Ecological niche factor analysis (ENFA) by putting all sixteen (16) uncorrelated eco-geographical or environmental variables (**Table 3**) has resulted in the habitat suitability (HS) map. The proportion of explainable information in model 1 is 96% (i.e. 100% of the marginality and 96% of the specialization). An overall marginality value (*M*) of 1.01 indicates that the niche occupied by leopard is slightly different from the average within the study area. Specialization was calculated at 3.59 (**Table 4**) indicating that leopard is somewhat restricted in the habitats they utilize in the Mandi district. Environmental variables sorted by decreasing absolute value of marginality (**Table 5**) indicate frequency of occurrence of scrub as major contributor of the model. Positive and negative signs marginality mean that leopard prefers higher or lower average than the global mean in each particular environmental variables. Marginality and specialization can explain the ecological habitat preferences of leopard. Both the topographic and landcover variables contributed almost equally to predict leopard distribution. The second factor (23% of the *specialization*) accounted for more specialization, in particular proportion of altitude. Though NDVI used as surrogate of vegetation cover has poor contribution to the distribution of leopard but the selection of Landsat image from the month of April when most of the vegetation class has lower representation, could have affected the its performance.

The habitat suitability map resulted from ENFA which successfully identified areas of high habitat suitability are given in **Map 9**. Only 17.15% of total geographic area of Mandi district was identified as highly suitable. Smaller suitable patch where leopard presence was occasionally recorded was identified as moderate suitable area which was around 39.98% of total geographic area, 31.01% of RNP was area identified as a least suitable while around 11.86% is unsuitable (**Figure 1**). A close examination of satellite image reveals that unsuitable habitat is mostly associated with high altitude (>3000m). We evaluated the distribution of suitability values of cells from the validation set. As shown in **Figure 1**. These cells differ drastically from the global distribution. And the two distributions obviously differ, as the global one is mostly confined to low values (suitability, 1-5%), while the validation set concentrates on high-suitability values (27-79%).

4.4 Discussion

Besides location of direct sightings, scat collection, indirect evidences and also leopard attacks on humans and livestock were also marked to know the distribution of leopards in the districts. Across the intensive study areas of Mandi district, altogether 98 leopard den sites were identified. Among these 85 den sites were found to be actively used by leopards and rest 11 were used occasionally. It was observed that in Mandi district, most of the den sites were located in the forest areas on hilly slopes, and very few dens were found in the low lying hill slopes.

Based on the number and location of active and temporary dens, distribution of leopards has been determined. Leopards seem to be distributed throughout the study area; almost 73% area is occupied in Mandi district. Like other carnivores, leopard presence in an area is determined by ecological factors such as prey abundance and habitat requirements (Bailey, 1993). Landscape patterns also affect animal distribution in an area (Ferguson *et al.*, 1998).

Leopards are territorial and with the assumptions that leopards did not change their den sites frequently and the population of each den represented the number of leopards in other similar den sites as well. The distribution of leopards based on occurrence of active and temporary dens has been correlated village wise in the intensive study sites of these two districts. Since the Mandi district has 3950 km^2 area, the leopard population could be projected as very high. According to the census of the wildlife department conducted in 2004, the highest concentration of leopards has been placed at 222 in Mandi district (Source: The Himachal Times, Tribune, 21 July, 2004).

In Mandi district, the forest cover was found to be fragmented and interspersed with human settlement and agricultural areas. Out of total 3950 km^2 land area, forest cover was only 2283.9 km^2. We found mosaic of land cover and landuse pattern throughout the study area. There were 10 major classes, namely, Pine forest, Mixed deciduous forest, Agricultural land, Deodar dominated forest, Oak dominated forest, Scrub, Grassland, Snow, Water bodies and Bare surface of landuse categories. These categories included the Bare surface area (27.9%), Pine forest (20.8%), Scrub land (14.4%), Mixed deciduous forest (10.8%), Deodar dominated forest (9.3%), Agricultural land (7.7%), Grassland (6.0%), Oak dominated forest (2.4%), and the least area under Snow (0.1%). Bare surface of landuse area occupied the maximum areas. Scattered distribution of Pine forest patches revealed that this area had abundant Pine or Mix forests, but due to tremendous biotic pressure and forest fragmentation, vegetation pattern of the area has been changed over the period of time. The remote sensing data revealed very large open area in Mandi district.

The habitat evaluation of any wildlife depends on the knowledge about the species behaviour, food habits, mating season, taxonomy and its position in the trophic niche (Porwal *et al*., 1996). The social behaviour of animal is shaped largely by the distribution and abundance of its food, competitors, and predators. In present study, it has been attempted to develop an approach for habitat suitability mapping using spatial landscape patterns, specific habitat requirements and disturbance from human beings. Leopard distribution, movement pattern and habitat use have been shown to be related to the food availability and also the availability of protective or escape cover within the leopard.

In the Mandi district, the forests are highly disturbed, fragmented and interspersed with human habitation and agricultural areas. Due to continuous encroachment on forest land and increasing biotic interference for collection fuelwood and non-timber forest produce, livestock grazing and land mining, leopard population seems to be ecologically dislocated. All these factors together might have adversely impacted the habitat use pattern of leopard in these areas. The proportional habitat availability to leopard in Mandi area was highest in Bare surface covered the maximum area, followed by the Pine forest, Scrub land, Mixed deciduous forest, Deodar dominated forest, Agricultural land, Grassland, Oak dominated forest, and the water bodies.

Although leopard are well distributed all over the forest ranges of central India, but due to increasing habitat loss and fragmentation by rapidly increasing human population in and around the protected areas, leopard population is drastically declining in its ranges. In Mandi district, habitat available for leopard is fragmented, degraded and interspersed with villages with high human and cattle populations and agricultural fields. The habitat suitability index map showed probability of occurrence of leopard in highly patchy and fragmented habitats interspersed with denning areas and human habitations. Most of the leopard dens are located close to the human habitation and agricultural fields.

Habitat fragmentations affect species distribution and abundance (Crooks, 2002). Fragmentation of habitat was one of the major causes of predator extinction across their ranges. Most of predators are sensitive to habitat fragmentation and their numbers are reducing as potential habitat get smaller and isolated (Crooks, 2002). Few species are tolerant of habitat fragmentation due to their ecological flexibility and ability to adapt to vastly differing challenges both environment and anthropogenic (Crooks, 2002 and Marker and Dickman, 2005). Studies have indicated that the distribution of species is positively correlated with habitat fragmentation (Vijayan and Pati, 2002 and Singh, 2005). Data on distribution and habitat use by leopards in Mandi district revealed that the species is quite flexible in its occupancy as reported by others (Seidensticker *et at*., 1990 and Marker and Dickman, 2005). Unlike other large cats, leopards appear to be tolerant of habitat fragmentation, with little effect of landscape variables on their distribution and abundance (Seidensticker *et at*., 1990; Egaonkar and Chellam, 1998; Crooks, 2002 and Vijayan and Pati, 2002). Previous studies suggested the adaptability of leopards in terms of diet and behavior and probably that have attributed their survival in unprotected areas (Hamilton, 1976; Seidensticker *et al*., 1990 and Bothma and Coertze, 2004). Their dietary flexibility means that they have a propensity to eating domestic animals where their natural prey has been depleted (Marker and Dickman, 2005). Previous studies have also reported that the leopards are subsisting largely upon domestic prey where wild prey species are dwindling (Hamilton, 1976; Sediensticker *et al*., 1990; Edgaokkar and Chellam, 1998 and Mann and Chaudhry, 2000).

In the present study, leopards have been found to greatly prefer human habitation areas. Their preference to human habitation may perhapsy be due to their dependency on domestic animals. Previous studies have found shown that leopards specially females configure their home range around important resources, such as patches of prey, rich habitat and cover (Bailey, 1993; Mizutani and Jewell, 1998 and Marker and Dickman, 2005). Utilization of habitat types by carnivores is another important variable for their survival (Bailey, 1993). Habitat types were also found to influence predation rates as the density of vegetation could affect the delectability of both predator and prey (Bailey, 1993). In the present study, leopards significantly preferred scrub cover throughout the study area. Leopard scat encounter rate was highest in scrub habitat with comparison of other habitats. A significant positive correlation was also noted between livestock killed by leopards and scrub cover. It corroborates with the findings of the previous studies that leopard preferred to hunt relatively in dense cover areas. Bailey (1993) noted that most of the kills made by leopard during day time in Kruger national park attributed to the effective dense cover. In northern Bengal of India, there were high incidences of tea workers being mauled by leopard during the day time, because leopard increasingly used this cover and sometimes found to raise their litters in the deep drains under the tea bushes (P.C. Dass in litt 1987 D.K. Lahiri Choudhery in litt. 1987). Leopards have also been reported to use sugarcane crop as permanent habitat and even breed in cultivated fields (Vijayan and Pati, 2002 and Singh, 2005). Data on the livestock kills in this study has also indicated that leopard used scrub cover more and more to approach prey. These patches are perhaps providing ideal habitat for their litters.

The statistical assessment of landscape conditions based on the ENFA model provided the basis for identifying potential leopard habitats in Mandi district. The high marginality (1.01) and low tolerance (0.27) suggested the selective nature of leopard. It is not distributed throughout Mandi district. Leopard was found to prefer the habitat with high vegetation cover which is mainly associated with scrubland, mixed deciduous forest and pine forest. In Scrub vegetation, tree growth is sparse and is represented by occasionally chir or some broad leaved tree species. The dominated shrubs found in Scrub and Mix deciduous forest are *Adhatoda zeylanica*, *Aechmenthera gossypina*, *Caesalpinia decapetala*, *Carrisa opaca*, *Cassia* spp., *Murraya koeinghii*, *Randia tetrasperma*, *Reinwardtia indica*, *Rubus ellipticus*, *Themeda anathera*, *Ziziphus oxyphylla* and *Zanthoxylum armatum*. *Euphorbia royleana* occurs in degraded and overgrazed areas while mixed deciduous forest is dominated by *Albizia chinensis*, *Bauhinia variegate*, *Bombax cieba*, *Cassia fistula*, *Dalbergia sissoo*, *Emblica officinalis* and *Grewia optiva* etc.

Besides the habitat preferences, there were other optimal environmental factors which contributed for the presence of leopard in these contrasting habitats. The terrain features (ruggedness and proportion of plain area) and distance from stream have major contribution to the habitat use by leopard in Mandi district. However leopard presence had a negative association with the variables, distance from village, ruggedness of terrain (avoiding highly undulating terrain) and proportion of plain area which indicates that it prefers less heterogeneous terrain with gentle slopes. Leopard seems to be avoiding sparse vegetation but negative relationship with distance from human habitation cannot be directly interpreted in its strict sense because of the fact that due to poor distribution of natural prey in forest (Chapter 6), it frequently visits village surroundings for easy prey like livestock and dogs. Study by Edgaonkar (2008) in Bori wildlife sanctuary also showed that leopard presence had a negative association with the distance to villages. Unlike tigers, which are shy and prone to move away from disturbance, leopards are known to be bold and not uncommonly found in proximity to human habitats, where they prey upon livestock (Odden and Wegge, 2005). In Thailand leopard activity has been shown to be negatively correlated with distance from villages (Ngoprasert *et al*., 2007). On the contradictory Chauhan (2009) study shows that leopards are widely preferred human habitation areas. Their preference to human habitation may be probably due to their dependency on domestic animals. Negative relationship with altitude shows that leopard avoids high altitude which is closely related with deodar dominated forest that has also poor contribution to the habitat use of the animal. Leopard presence was negatively correlated with elevation and slope was also reported by Edgaonkar (2008). The negative eigen value of variables, ruggedness of terrain and proportion of plain area indicates the preference of low values from the global mean i.e. proximity of leopard towards gentle slopes. Cougar (*Puma concolor*) abundance has also been shown to be affected by terrain ruggedness and forest cover at the landscape scale (Riley and Malecki, 2001).

Leopard avoids the areas with high steep slopes and open areas. In the Mandi district, least suitable habitats for leopard are likely to be very less. Leopard requires relatively large tracts of contiguous habitat (Marker and Dickman, 2005), they probably move through and spend time in habitats that are not highly preferred, but are still inhabitable (Edgaonkar, 2008). Leopards have been found occupying a great variety of habitats ranging from prime forest to degraded areas (Pocock, 1939; Prater, 1971 and Daniel, 1996). Leopard is known to occupy all kinds of niches from Thar Desert (Robert, 1977) to hilly tracts in Himalayan regions (Green, 1987 and Johnsingh *et al*., 1991). Leopard's ability to feed on a broad spectrum of prey makes them most successful predator among big cats, its size gives it the ability to feed on a variety of prey species ranging in size from a young buffalo to smallest rodent (Daniel, 1996). Changed behaviour of leopard has been noticed due to habitat degradation along with decline in wild prey species.

In the present study it was found that optimal area used by leopard in Mandi district is around 60% of the total area available. The habitat model was used to estimate the area occupied by various habitat categories in the study area. Ecological niche factor analysis (ENFA) model seems to work better at larger spatial areas for a long ranging species like leopard. ENFA is a purely descriptive method and cannot extract causality relations.

Nonetheless, it provides (at worst) important cues about preferential conditions, and remains a powerful tool to draw potential habitat maps.

Though enumeration of cat numbers have always been controversial in India, the State Forest Department census data indicates an increase in leopard population between 18 and 70 percent in the states of Bihar, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh between 1984 and 1989. Green (1987) has also opined the same view.

Table 1. Permanent and temporary den sites of leopard in Mandi district.

S. No.	Locality Name	Tehsil Name	Den type
1	Chauntra	Jogindar Nagar	Permanent
2	Maswahan	Padhar	Permanent
3	Barot	Jogindar Nagar	Permanent
4	Aihju	Jogindar Nagar	Temporary
5	Kot	Padhar	Permanent
6	Tehri	Padhar	Permanent
7	Matkehr	Jogindar Nagar	Permanent
8	Urla	Padhar	Permanent
9	Darubbal	Jogindar Nagar	Permanent
10	Chhatri	Jogindar Nagar	Permanent
11	Cheli	Padhar	Permanent
12	Chimnu	Jogindar Nagar	Permanent
13	Banaun	Jogindar Nagar	Permanent
14	Utpur	Ladbharol	Permanent
15	Kothi	Ladbharol	Permanent
16	Gehra	Sandhol	Permanent
17	Kot	Sarkaghat	Permanent
18	Kot	Kotli	Permanent
19	Ropa	Padhar	Permanent
20	Kataula	Mandi	Permanent
21	Chaswal	Dharmpur	Permanent
22	Hukkal	Sarkaghat	Permanent
23	Pali	Padhar	Permanent
24	Gandheru	Mandi	Temporary
25	Parashar Dhar	Mandi	Permanent
26	Nagwain	Aut	Permanent
27	Chori	Sarkaghat	Permanent

28	Rissa	Sarkaghat	Permanent
29	D.p.f.khair	Dharmpur	Permanent
30	Janitri	Kotli	Permanent
31	Sarki Dhar	Mandi	Permanent
32	Lagdhar	Kotli	Permanent
33	Aradha	Mandi	Temporary
34	Bagalu	Mandi	Permanent
35	Chandrakri	Sarkaghat	Permanent
36	Bhatoh Phakrehr	Sarkaghat	Permanent
37	Chhatrot	Mandi	Permanent
38	Tawa	Mandi	Permanent
39	Riur	Mandi	Permanent
40	Daran Gahar	Bali Chowki	Permanent
41	Gahra	Sarkaghat	Permanent
42	Majhdhar	Bali Chowki	Permanent
43	Tarapur	Mandi	Temporary
44	Arthi	Mandi	Permanent
45	Bagi Banwar	Bali Chowki	Permanent
46	Gandharb	Mandi	Permanent
47	Birni Samlohi	Bali Chowki	Permanent
48	Bheklidhar	Bali Chowki	Permanent
49	Dhuadevi	Mandi	Permanent
50	Binglao	Bali Chowki	Permanent
51	Chandes	Sarkaghat	Permanent
52	Sakroha	Mandi	Permanent
53	Sadhyani	Mandi	Permanent
54	Chauk	Sundarnagar	Permanent
55	Kharsi	Chachyot	Permanent
56	Shikawari	Thunag	Temporary
57	Chet	Thunag	Permanent

58	Kot	Mandi	Permanent
59	Chantyani	Baldwara	Permanent
60	Kandha	Thunag	Temporary
61	Kapahi	Sundarnagar	Permanent
62	Chhamiar	Mandi	Permanent
63	Babag	Chachyot	Permanent
64	Sidhkot	Baldwara	Permanent
65	Ahun	Thunag	Permanent
66	Bagra	Bali Chowki	Permanent
67	Nihri	Thunag	Permanent
68	Chawari	Sundarnagar	Temporary
69	Janjehli	Thunag	Permanent
70	Bunga Dhar	Thunag	Permanent
71	Maloh	Sundarnagar	Permanent
72	Chanol	Sundarnagar	Permanent
73	Kuthahin	Sundarnagar	Permanent
74	Chuhar	Nihri	Temporary
75	Kango	Sundarnagar	Permanent
76	Darudeo	Chachyot	Permanent
77	Gada Galu	Thunag	Permanent
78	Kamrunag	Chachyot	Permanent
79	Kamand	Nihri	Permanent
80	Rohanda	Nihri	Permanent
81	Jachh(a)	Karsog	Permanent
82	Bandli Dhar	Nihri	Temporary
83	Shiv Shankar	Nihri	Permanent
84	Bajhu Jhungi	Karsog	Permanent
85	Charkhari	Nihri	Permanent
86	Katanda	Karsog	Permanent
87	Mamel	Karsog	Temporary

88	Bunga	Nihri	Permanent
89	Kot	Karsog	Permanent
90	Kelo Dhar	Karsog	Permanent
91	Gadahach	Nihri	Permanent
92	Nihri	Nihri	Permanent
93	Nagaltha	Karsog	Permanent
94	Kinder	Nihri	Permanent
95	Mehndi	Karsog	Permanent
96	Kandha	Karsog	Temporary
97	Bagshad	Karsog	Permanent
98	Tatta Pani	Karsog	Permanent

Table 2. Extent of different habitat classes in Mandi district.

Class	**Area (km²)**	**% area**
Pine forest	822.2	20.8
Mixed deciduous forest	428.4	10.8
Agriculture land	302.0	7.7
Deodar dominated forest	368.1	9.3
Oak dominated forest	95.8	2.4
Grassland	236.4	6.0
Scrub	569.4	14.4
Snow	1.4	0.1
Water body	24.5	0.6
Bare/rocky land	1101.8	27.9
Total	**3950.0**	**100.0**

Table 3. Environmental variables used in ecological niche factor analysis.

S. No.	Descriptor	Eco-geographical variable	Data source
1.	Topographical variables	Altitude Topographic ruggedness index Proportion of plain area Proportion of gentle slope Proportion of steep slope Distance from narrow valley Distance from open valley	Aster global digital elevation model
2.	Ecological variables	Vegetation cover proportion of pine forest proportion of mixed broad leaved forest Proportion of deodar dominated forest Proportion of agricultural land Proportion of grassland Proportion of scrubland	Landsat thematic mapper (TM)
3.	Hydrological variables	Distance to water bodies	Topographic map of Survey of India
4.	Anthropogenic variables	Distance from road Distance from village	Topographic map of Survey of India

Table 4. Predictions of marginality and specialization for ENFA models.

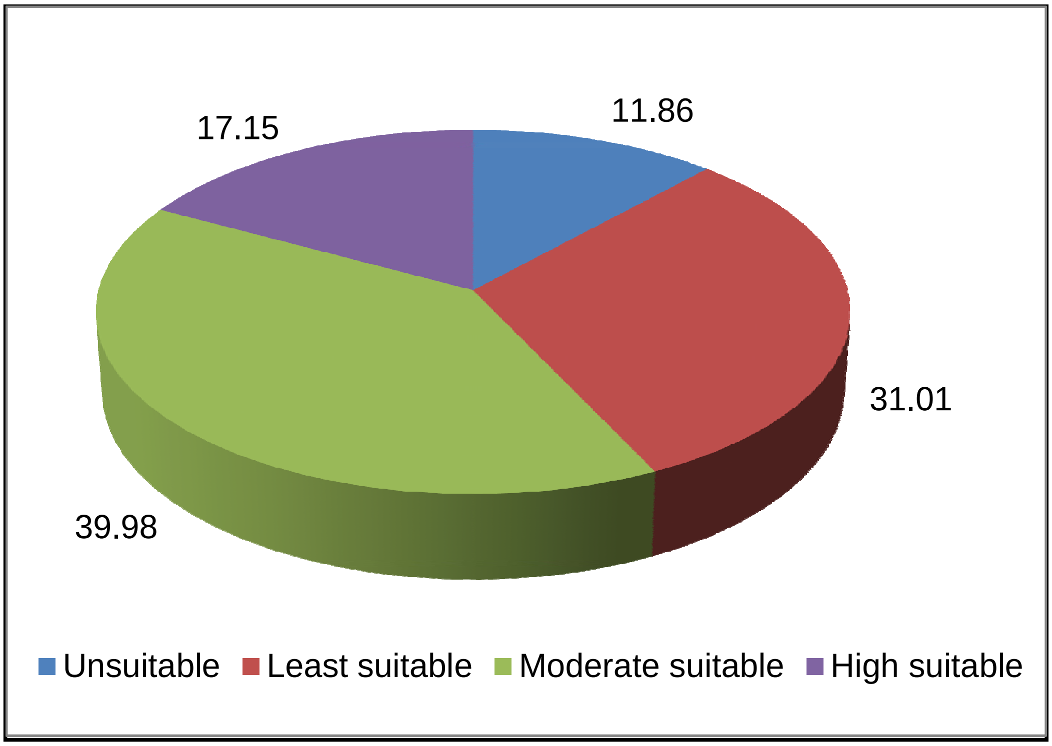
Marginality	1.01
Specialization	3.59
Tolerance (1/S)	0.27
Number of factors explained information	3
Explained information	0.89
Explained specialization	0.79

Table 5. Coefficient value of 16 uncorrelated environmental variables.

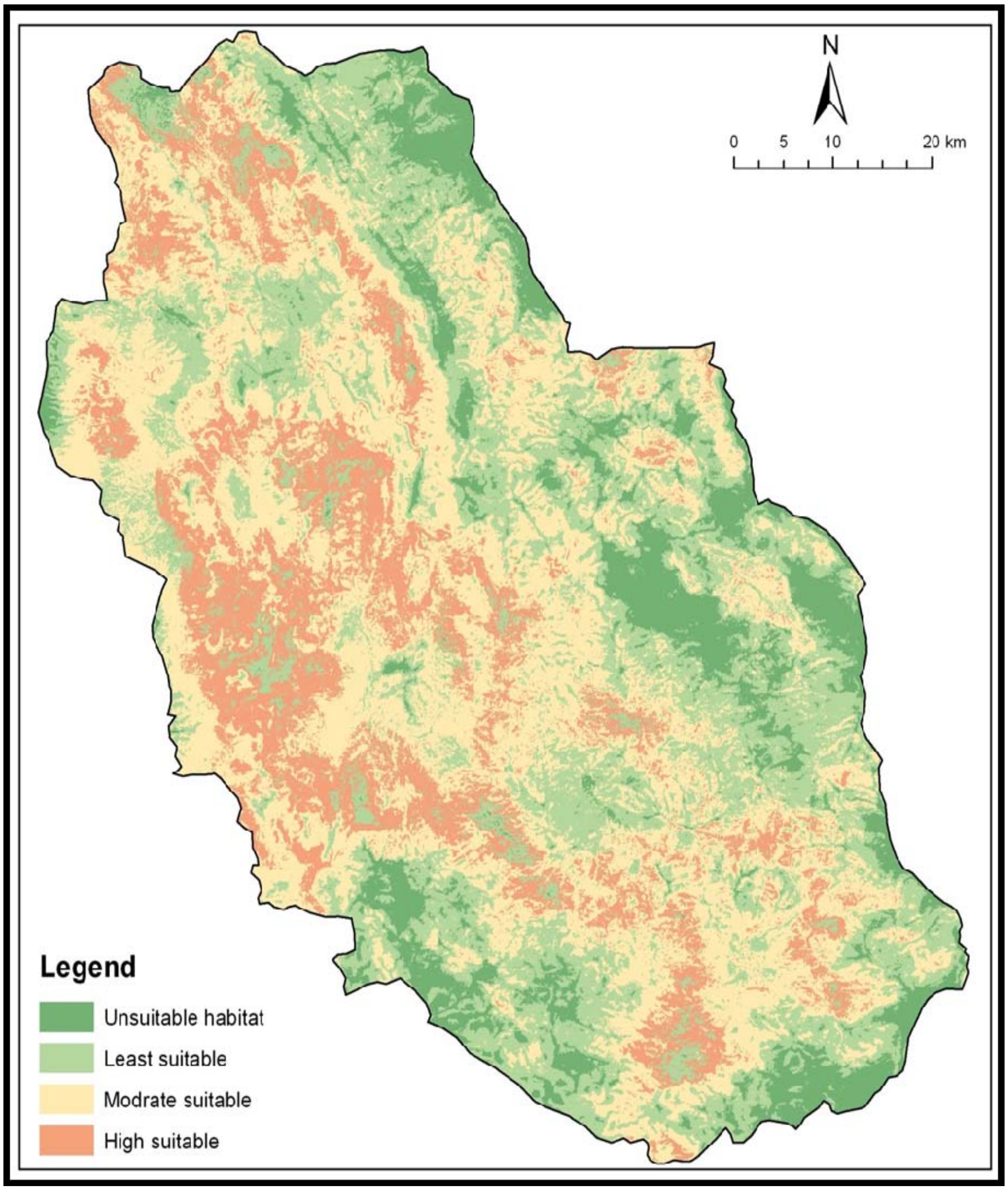
Eco-Geographical variable	Marginality (50%)	Factor 2 (23%)	Factor 3 (7%)	Factor 4 (6%)
Frequency of scrub land (FOS)	FOS (0.46)	ALT (-0.67)	DFV (-0.70)	FPL (0.65)
Frequency of mixed deciduous forest (FOM)	FOM (0.41)	DFV (0.51)	ALT (-0.38)	FST (0.53)
Frequency of pine forest (FOP)	FOP (0.39)	FST (-0.34)	FOO (0.35)	FOO (-0.30)
Distance from village (DFV)	DFV (-0.34)	FOD (0.19)	FST (0.32)	FOP (0.23)
Frequency of agriculture land (FOA)	FOA (0.31)	ROT (-0.17)	FOM (-0.26)	DFS (0.18)
Ruggedness of terrain (ROT)	ROT (-0.24)	FOO (0.16)	FOD (0.17)	ROT (-0.17)
Distance from stream (DFS)	DFS (0.22)	FPL (0.14)	FOS (-0.11)	FOA (0.16)
Frequency of plain area (FPL)	FPL (-0.20)	FGL (0.14)	FPL (0.10)	FGL (0.15)
Frequency of grassland (FOG)	FOG (0.19)	FOG (0.12)	FOA (-0.07)	ALT (-0.14)
NDVI	NDVI (0.15)	FOP (0.11)	ROT (0.07)	FOS (0.11)
Frequency of steep slopes (FST)	FST (-0.14)	FOS (-0.10)	FOP (-0.06)	DFV (0.11)
Altitude (ALT)	ALT (-0.11)	DFS (0.07)	NDVI (-0.05)	FOM (-0.05)
Distance from road (DFR)	DFR (-0.10)	FOM (0.05)	DFS (0.04)	NDVI (-0.05)
Frequency of gentle slope (FGL)	FGL (-0.10)	FOA (-0.04)	FGL (-0.02)	FOD (-0.04)
Frequency of Deodar forest (FOD)	FOD (0.05)	DFR (-0.03)	FOG (-0.02)	DFR (0.04)
Proportion of open valley (FOO)	FOO (-0.01)	NDVI (0.00)	DFR (0.02)	FOG (-0.01)

Note: The marginality of each environmental variable is sorted in decreasing order by the absolute value.

Figure 1. Proportion of habitat suitability classes for leopard in Mandi district.



Map 9. Map showing different habitats available for leopards in Mandi district.



Chapter 5

To study nature and extent of human-leopard conflict in relation to land use pattern.

5.1 Introduction

Carnivores exert a profound influence on biological communities via predation and interspecific competition. Carnivores often regulate or limit the numbers of their prey, thereby altering the structure and function of entire ecosystems (Schaller, 1972; Estes *et al*., 1998; Berger *et al*., 2001 and Terborgh *et al*., 2002). As a result, carnivore management is of central concern to conservation biologists. The Hominids and large carnivore's co-existence produced risk and opportunity for human ancestors. The risk to hominids stems from predation and has long been acknowledged, even if its magnitude is uncertain (Traves and Traves, 1999). Human-carnivore conflict is considered to be a major conservation and rural livelihood issue because many carnivore species have been heavily persecuted due to elevated conflict levels with communities (Dar *et al*., 2009). One of the main contributors to human-wildlife conflict in Bhutan is predation of livestock by wild mammalian carnivores (Sangay and Vernes, 2008).

This is a worldwide problem, exemplified by carnivores preying on cattle and goats in Africa; and tigers (*Panthera tigris*) and leopards (*Panthera pardus*) killing livestock in Asia (Nowell and Jackson, 1996; Kaczensky, 1999 and Karanth and Madhusudan, 2002); pumas (*Puma concolor*) and jaguars

(*Panthera onca*) taking cattle in South America and wolves (*Canis lupus*) and bears (*Ursus* spp.) killing sheep in North America and Europe. Under some conditions, individual carnivores attack humans, with tragic consequences for all (Brain, 1981; McDougal, 1987; Treves and Naughton-Treves, 1999; Rajpurohit and Krausman, 2000 and Karanth and Madhusudan, 2002). This competition over food and space is not restricted to big, fierce predators. Smaller carnivore species have long been involved in competition with humans over game species, crops, apiaries, fish stocks, and poultry (Gipson, 1975; Jorgensen *et al*., 1978 and Reynolds and Tappen, 1996).

Human carnivore conflict arises for several reasons. Carnivore's protein rich diet and large home ranges draw them into recurrent competition with humans, who have somewhat similar needs. Indeed many carnivore species are specialized for ungulate predation; therefore some individuals readily kill domesticated ungulates when opportunities arise (Meriggi and Lovari, 1996; Karanth *et al*., 1999; Polisar, 2000 and Treves and Karanth, 2003).

Conflict between livestock owners and predators dates back 9000 years to the time when animals were first domesticated by humans; it is not a recent phenomenon caused by the establishment of nature preserves or wildlife protection laws as commonly believed. While predation rarely affects the local economy, it can lead to very negative attitudes to wildlife conservation among herders (Oli *et al*., 1994 and Jackson, 1998). In Namibia, the majority of large predators, such as lions (*Panthera leo*) and spotted hyaenas (*Crocuta crocuta*) have been extirpated from the farm lands to reduce livestock depredation, leaving leopards and cheetahs (*Acinonyx jubatus*) as the top predators.

All the large cats viz. lion, tiger, leopard and snow leopard are involved in conflicts with humans in India (Chakrabarti, 1992; Chellem and Johnsingh, 1993; Sabarwal *et al*, 1994; Daniel, 1996; Mishra, 1997; Jhala and Sharma, 1997; Jackson, 1999; Rangarajan, 2001; Linnell *et al.*, 2002; Mishra *et al.*, 2003; Atherya *et al.*, 2004; Chauhan, 2005, 2006 and Yadav, 2011). When large cats live in proximity to humans, some level of conflict between them is inevitable (Sawarkar, 1986). In India, leopard has reported as the most common problematic carnivore among human-carnivore conflicts (Saberwal *et al.*, 1994; Rajpurohit and Chauhan, 1996; Negi, 1996; Daniel, 1996; Chauhan and Goyal, 2000; Chauhan *et al.*, 2002, Athreya *et al.*, 2004, Singh *et al*. 2008; Rahalkar, 2008 and Yadav, 2011). But the conflicts due to these carnivores have been mostly restricted in and around their ranges and their impacts were not as widespread as that of leopard. The problem of human-leopard conflict has been recently increased in the Indian Himalayan region due to change in land use patterns (Johnsingh *et al.* 1991, Negi 1996, Mohan, 1997; Chauhan *et al.*, 2002 and Singh *et al*., 2008).The leopard interface with human in this region is not new (Corbett, 1944, 1948, 1957).

Leopards are the most widely distributed wild cat in India. But due to expansion of human influence and ever-increasing pressure on natural resources, the issue of human-leopard conflict has been greatly intensified in a wide variety of situations. Human-wildlife conflict has been defined as ‘When the needs and behaviour of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact the needs of wildlife’ (Recommendation 5.20, 2003 World Parks Congress) and now it has become a very common global phenomenon. Carnivore-human conflict is a worldwide problem for the wildlife management (Rajpurohit and Chauhan, 1996; Linnell *et al.,* 1996; Mizuatani, 1999; Butler, 2000; Bauer and Kari, 2001; Stahl *et al.,* 2001; Karanth and Madhusudan, 2002, Chauhan *et al.*, 2002, Treves and Karanth, 2003 and Hoogesteijn *et al*., 1993). Carnivores are involved in a wide range of conflicts including predation on human and livestock and carnivore mortality by people (Chakrabarti, 1992; Chellum and Johnsingh, 1993; Daniel, 1996; Woodroffe, 2000 and Ginsberg, 2001.

Due to urbanization in India, several wild species have declined across their range. Habitat degradation has negative impact on ungulate species, but leopards still widely distributed due to their ability to adapt to different challenges, both environmental and anthropogenic (Daniel, 1996). These adaptations include variation habitat selection and prey selection. Previous studies have indicated leopard using significantly fragmented habitats (Vijayan and Pati, 2002; P.C. Dass in litt 1987 D.K. Lahiri, Choudhery in litt 1987). Leopard has been reported to change their food habits in the absence of potential wild prey and subsisting on livestock and dog (Chellam and Johnsingh, 1993 and Edgaonkar and Chellam, 1998).

Leopard is well known for it use of habitat edges and its ability to live close to human habitation where livestock are available (Sediensticker *et al*., 1990; Santialillai and Ramono, 1992 and Chellam and Johhsingh, 1993). Livestick can be important prey for carnivores in areas where wild ungulates are not abundant (Hamilton, 1986; Sediensticker *et al*., 1990 and Santialpillai and Ramono, 1992). In certain areas of Java island of Indonesia, leopards are largely subsisting upon cattle, village dogs and chickens (Santiapillai and Ramono, 1992). Hamilton (1986) reported that leopard population subsisting mainly upon livestock in western Kenya. Variation in the diet of leopards in different areas was most likely due to its opportunistic behavior, resulting in a diet that closely link prey use with availability (Bailey, 1993). In fragmented and disturbed areas, they are increasingly preying upon domestic stock, a behaviour that brings them into direct conflict with humans.

In many areas, significant population of leopard is outside the protected areas where they area are sharing their living space with domestic animals and do occasionally frequently kill livestock (Chellam and Johnsingh, 1993.). Retaliation killing from livestock owner is one of the major threats to the leopards living outside the protected areas (Woodroffe, 2000). Due to lack of effective conservation strategies for areas outside the protected Areas, leopard often come into conflict with human.

The frequency and economic cost of conflicts between humans and carnivores appears to be on the increase in many areas (Halfpenny *et al*., 1991; Mech, 1998; Karanth, 2002; Rajpurohit and Krausman, 2000 and

Treves *et al*., 2002). Conflicts between humans and wildlife increase with the expansion and growth of human populations, farming frontiers, and housing (Thouless and Sakwa, 1995; Torres *et al*., 1996; Woodroffe, 2000 and Naughton-Treves *et al*., 2003). Under a variety of demographic, economic, and social pressures, human alteration of carnivore habitat or exploitation of carnivores has led to escalated conflicts (Mladenoff *et al*., 1997; Liu *et al*., 2001 and Naughton-Treves *et al*., 2003). Humans have also allowed the recovery of carnivores, which has promoted conflicts in some areas. For example, changing land-use practices exemplified by the re-growth of forests in many regions of the United States are providing room for potential re-colonization by previously extirpated carnivores (Mladenoff *et al*., 1997). Also, successful recovery programs for extirpated carnivores have raised concerns about conflict (Bangs *et al*., 1998 and Breitenmoser, 1998). Conservationists must now resolve human-carnivore conflicts in a setting of rapid social and ecological changes across the landscape.

Human carnivore conflict arises for several reasons. Carnivore's protein rich diet and large home ranges draw them into recurrent competition with humans, who have somewhat similar needs. Indeed many carnivore species are specialized for ungulate predation; therefore some individuals readily kill domesticated ungulates when opportunities arise (Meriggi and Lovari, 1996; Karanth *et al*., 1999; Polisar, 2000 and Treves and Karanth, 2003). Various reasons have been put forward to explain about the increase in human-leopard conflict in different places. The main reasons were found to be depletion of the natural prey base and degradation or fragmentation of leopard habitat. The man-made changes of the landscape led to creation of suitable habitats for the leopard (e.g. sugarcane fields, tea plantation areas), which resulted in increase of local leopard populations (Seidensticker, 1986; Johnsingh *et al.,* 1991; Karanth, 1991; Rabinowitz, 1991; Bailey, 1993, Daniel, 1996 and Rahalkar, 2008).

Changes in leopard behaviour to become extremely bold have been noticed due to habitat disturbance and degradation and loss of forests to plantation of monoculture timber species and rubber, coffee and tea plantation. With the result, there has been an increase in man-wildlife conflict on the forest edges and in this process, irate farmers killed a number of animals by using poison, snare or shot dead (Cobb, 1981; Green, 1987; Seidensticker *et al*., 1990 and Bailey, 1993). In India, while collection of minor forest produce or working on the edge of forest, people have been mauled or killed by leopard. During 1982 to 1989, 170 people were reported to be killed by leopard in India, of which 111 cases were reported from Uttar Pradesh only (Johnsingh *et al*., 1991). From 1991 to 2003, 239 human casualties were reported from Himachal Pradesh (Chauhan, 2003). In most of the time, cases may go unreported. Negi (1996) reported that sixty one human beings were killed and injured by man-eating leopards, whereas 50 leopards were killed in Garhwal district of Uttar Pradesh between 1986 and 1996.

Large carnivore populations have declined worldwide in the last centuary (Nowell and Jackson, 1996) primarily as a result of conflict with humans (Gittleman *et al.*, 2001). Human animal conflict might affect species conservation in an area (Saberwal *et al.*, 1994). Studies on human-animal conflict suggest that peoples attitude toward the conflict causing species from positive acceptance to negative acceptance has created problems in many areas (Saberwal *et al.*, 1994 and Jackson, 1999).

In the new socio-political context, the strategies for managing carnivores may need to be re-evaluated. Preventing and mitigating human-carnivore conflict must be based on an improved understanding of carnivore behavioral ecology and public acceptance of wildlife management, and it must draw upon accumulated empirical knowledge and local experiences. To suggest some directions for the future, we examined past management of carnivores in the light of modern research into human-carnivore conflicts.

Leopard is regarded as nuisance in hills of Himachal Pradesh. They are common in the forests across the state, and their food comprises of wild prey species such as goral, barking deer, wild boar, monkey, langur and jungle fowl. Due to severe human pressure mainly from hunting, cattle grazing, fire wood collection, forest fire, deforestation and habitat alteration, most of these prey species are either locally extinct or their numbers are too low to sustain the existing number of leopards. Increase in frequency of confrontation between leopard and man during last decade may be due to accelerating trend in habitat fragmentation, decline in potential habitat for dispersing young ones, scarcity of wild prey base, predominantly feeding on domestic prey and to some extent may be due to increase of local leopard population. Leopard predation on human and livestock is on the increase in

Garhwal and Kumaun region (Chauhan *et al*., 2002). Incidents of tea workers being mauled has also been reported in North Bengal, because leopards use the cover as shelter and to raise their litters in the deep drains under the tea bushes (P.C. Dass, in litt, 1987; D.K. Lahiri Choudhery, in litt. 1987). Cobb (1981) reviewed the conservation of leopard and reported that a disproportionate number of nuisance leopards are adult males. Lack of quantitative information on ecology and behaviour preclude the management of leopard population in many states. Although the research conducted so far in India includes few ecological parameters, but the studies are not management oriented.

It is intriguing that the leopard predation on human and livestock is also on the increase in Mandi and Hamirpur districts alone while a large number of cases of man-eating have been reported from other adjoining districts of Himachal Pradesh. There is no information available on man-leopard conflict, ecology of leopard and human dimension in Himachal Pradesh. Therefore the study envisages a comparative study on the nature and extent of man-leopard conflict and ecology and behaviour of leopard in the village interface man-altered fragmented areas of Mandi and Hamirpur districts. This will provide a basis for developing an action plan for conservation of leopard in the state and mitigation strategies for man-leopard conflict, which will be effective and can be used on a long-term basis.

In Mandi district, human-leopard conflict has been a serious problem. In all five forest divisions of Mandi district, leopards are causing lot of nuisance. Incidences of human casualties and livestock predation are frequent. Occurrence of leopard inside the villages and villagers in the patchy, degraded and fragmented forests, leopard habitat, has resulted in serious problem of human-leopard conflicts; human mauling and livestock killing by leopard are on the increase, which in turn, are posing threats to the future conservation of leopard.

In this chapter, we have documented about the enormity of the problem, problem areas and human casualties and livestock depredation with respect to places of occurrence, season, time and circumstances of attack. It would help plan mitigation of leopard problem, besides conservation and future scientific management of the species.

5.2 Methods

This study aimed to investigate the nature and extent of human injuries and deaths and livestock killing by leopard and also leopard deaths by human beings, spatial and temporal patterns of conflict between humans and the leopard, economic losses caused by leopard and local perceptions and tolerance towards the leopard and its conservation.

To study the human-leopard conflict, a reconnaissance survey was done in the Mandi district. We examined predation activity of leopard on humans and a variety of livestock for the period 1988 to 2007. Field data were collected using a combination of qualitative methods (unstructured interviews, participatory observation and focus group discussions) and quantitative methods (structured interviews). Information on the human casualties, livestock killing and circumstances was collected in specially designed questionnaire formats from the forest department and by interviewing the affected villages **(Appendix 1)**. Information on the number of injured and killed persons; time of incidence, age and sex of the victims, place of attack, activity of the victims, mode of attack and nature of injuries etc was collected from all the affected villages and survey sites in pre-designed questionnaire formats. This method is used by other researchers also (Traves and Traves, 1999 and Sangay and Vernes, 2008).

Verification of the payment of compensation for the treatment or human death was also done. For this, the victims or his or her relatives were questioned directly. Information so collected through questionnaire formats was compared with the recorded information in the forest department.

Similarly the information on the livestock killing by the leopard, time and place of incidence and age class was collected. A zone map showing man-leopard conflict in relation to distribution and abundance of domestic livestock has also been developed.

5.3 Results

Human casualties and livestock killings by leopard occurred to varying extent in five forest divisions of Mandi district during 1988-2007. In these forest divisions, forests are interspersed with human habitation, agricultural areas where people coexist with leopards **(Plate 1 and 2)**.

5.3.1 Human casualties

Based on information collected from the forest department and by interviewing local people, a total of 162 human casualties were reported in different villages situated in Mandi, Sundernagar, Jogindernagar, Karsog and Nachan forest divisions from 1988 to 2007 **(Table 1)**. Out of these cases, maximum incidences (n=71) occurred in Sundernagar forest division, followed by Mandi division with 37 attacks, Jogindernagar division with 34 attacks and Karsog and Nachan divisions with 10 attacks in each during this period. In Mandi division, there were two human killings and 35 injury cases. In Sundernagar division, there were two human killing cases and 69 injury cases. There were 26 injury cases and eight killings in Jogindernagar division. And there were ten and nine injury cases in Karsog and Nachan divisions respectively. **Plate 3** shows a victim who is hospitalised due to injuries caused by leopard near BSL colony, Slapper, Kangoo range. **Plate 4** shows a victim with injuries caused by leopard. One human killing incidence occurred in Nachan. In total, there were 13 human killings (8%) and 149 injury cases (92%). **Plate 5** shows a victim of leopard whose body is partially eaten.

In Mandi district, human casualties by leopard occurred every year from 1988 to 2007 **(Table 2)**. Number of human casualties varied from 1 to 22 cases in these years. Maximum incidences (n=22) occurred in the year 2002, followed by 13 cases in 1998; 12 cases each in 1993, 2001 and 2005; 11 cases in 1992; 10 cases each in 2003, 2003 and 2006; 9 cases in 2000; 8 cases in 2007 and 1 to 6 cases in rest of the years. A trend line was drawn to know the variation in human casualties across the years. Polynomial regression showed a significant variation with increasing pattern from 1988 onwards to 2002 and then decreasing gradually over the years till 2007 **(Figure 1)**. Out of the total of 162 cases, 13 people were reported to be killed and remaining 149 people were injured. Number of male casualties (n=99) was more than the female casualties (n=63). Among 13 killings, there were six cases of males and seven cases of females. Out of 149 human injury cases, there were 93 males and 56 females. There was a significant variation between male and female casualties **(χ2=8.45, df=1, p<0.004)**. Male human killings occurred in 1991, 1992, 1994 and 2005; whereas female killings occurred in 1992, 1993, 1995, 2002, 2003, 2004 and 2007. Male and female human injury cases occurred almost every year except in 1991 when no male was injured and 1990 when no female was injured.

5.3.2 Seasonal variation

Leopard attacks on human showed some variation across the seasons **(Figure 2)**. The frequency occurrence of human casualties was found to 38.9%, 30.2% and 30.9% during winter, monsoon and summer seasons respectively. However the seasonal variation in human casualties was not significant **($\chi 2=1.46$, df=2, $p<0.48$)**. Similarly there was no monthly variation in human casualties by leopard during 1988-2007 **($\chi 2=16.6$, df=11, $p<0.12$)**. Out of total 162 casualties, maximum number of casualties occurred in the month of November (n=21) **(Figure 3)**. In January, there were 18 human casualties, and during February, March, May, June, July and October, there were 14, 13, 14, 13, 15 and 16 cases respectively.

5.3.3 Age group of victims

In Mandi district, victims of leopard were found to be from different age groups **(Figure 4)**. Among the victims, middle age group people suffered the most. Out of total 162 human casualties, highest number of human casualties (n=28, 17.2%) occurred in the age group of 25-30 years, followed by 23 (14.2%) casualties in the age group of 40-48 years. Number of human casualties was 20 (12.3%), 17 (10.5%), 16 (9.9%) and 11 (6.8%) in the age group of 31-36, 37-42, 13-18, and 60 or > years respectively. There were 10 human casualties (6.2%) in the age group of 7-12, 55-60 years and 9 casualties (5.5%) in the age group of 0-6, 19-24, 49-54 years each.

5.3.4 Time and place of casualties

The time of occurrence of human casualties by leopard i.e. morning, daytime, evening and night has also been recorded **(Figure 5)**. There was significant variation in the diurnal pattern of occurrence of human mauling and killing **(χ2=91.8, df=3, p<0.00)**. Highest number of casualties (n=91, 56.2%) occurred in the evening time during 1601-2200 hours. There were 37 (22.8%), 22 (13.6%) and 12 (7.4%) human casualties occurred during morning (0401-1000h), daytime (1001-1601h) and night time (2201-0400h) respectively. **Figure 6** shows the place of occurrence of human casualties by leopard in the study area. Highest number of human casualties (35.8%) occurred in villages, followed by crop field (18.5%), grassland (14.2%) and other places like nallah/ravine, school playground etc. (12.3%). Out of total cases, 10.5% human casualties occurred in forest areas and only 8.6% casualties occurred in cowshed.

5.3.5 Activity of victims

The victims were found engaged in different activities like farming, household activities, livestock rearing, walking, defecation and NTFP/fodder collection at the time when they were attacked by leopard **(Figure 7)**. There was significant variation among the victims engaged in the different activities **(χ2=45.4, df=5, p<0.00)**. Incidences of human casualties were very high when the victims were engaged in walking through forest or crop field (39.4%), followed by NTFP/fodder collection (19.7%), livestock rearing (15.3%), farming (11.9%), household activities (10.2%) and least in defecation (4.4%).

5.3.6 Compensation

Human casualties

Compensation or ex-gratia amount was paid by the forest department to all the victims of leopard attacks or their relatives in Mandi district **(Table 3)**. Out of 162 human casualties, compensation was paid for 13 killing cases and 149 injury cases. A total amount of Rs. 13,40,230 was paid as compensation for human casualties in the study area during 1988-2007. A sum of Rs. 6,30,000 was paid as compensation for the killing cases and Rs. 7, 10,230 was paid as compensation to the injury cases. Maximum compensation of Rs. 2,63,875 was paid in the year 2002, which included Rs. 1,00,000 for one killing case and Rs. 1,63,875 for 21 injury cases. In the year 2005, an amount of Rs. 1,00,000 was paid as compensation for one killing case and Rs. 1,45,125 for 11 injury cases. A lowest amount of Rs. 1500 was paid as compensation for the human casualties, which included only 2 injury cases in the year 1989.

Time interval of payment of compensation for human casualties by leopard varied from within three months to more than a year (**Table 4)**. The time interval of payment of compensation was recorded for all 162 human casualties occurred during 1988-2007. Out of total cases, compensation was paid to maximum number of cases (n=111) within three months of occurrence of incidences. Compensation was disbursed for forty four human casualties between three to six months period after the occurrence of incidences. During the time interval of 6.1 to 9 months, 9.1 to 12 months and 12.1 to 15 months, only 4, 2 and 1 human casualty cases respectively received compensation.

5.3.7 Livestock depredation

In Himachal Pradesh, livestock are being attacked, killed and eaten mainly by leopard (*Panthera pardus*), Asiatic black bear (*Selenarctos thibetanus*) and Himalyan brown bear (*Ursus arctos*) in these areas. There might be large number of cattle-lifting cases in the state, which perhaps could not be reported timely to the forest department. Amongst livestock, sheep, goat, cow, bull, horse, mule and dogs were predated upon by leopard, black bear and brown bear.

In total, there were 4967 incidences of leopard attacks, in which 8905 livestock were killed by leopard in five forest divisions of Mandi district during 1987-2007 **(Table 5.)**. Highest number of attacks (n=2222) with 3710 livestock killings by leopard was reported in Sundernagar forest division, followed by Jogindernagar forest division with 1702 attacks and 2545 livestock killings. In Mandi forest division, leopard attacked livestock 569 times and there were 1236 killings. There were only 224 and 250 leopard attacks in Karsog and Nachan forest divisions, in which 683 and 731 livestock respectively were killed.

Leopard was responsible for killing goat, sheep, cow, bull, horse, mule and dogs in these areas. Number of incidences of livestock killings varied in different years. There was an increasing trend of livestock killings from 1987 onwards and showed highest number of killings (n=958) in the year 1991 (**Table 6)**. Following this, there were 841 livestock killings in 1992. Thereafter number of incidences declined and there were only 46 attacks by leopard with 107 livestock killings in the year 2007. Lowest number of livestock killings (n=32) occurred in the year 1987. Polynomial regression showed a significant variation in the number of livestock killings with increasing trend from the year 1987 onwards to 1991 and then decreasing gradually over the years **(Figure 8).**

Sheep, goat and cow suffered maximum, there were 3043, 2598 and 1677 killings respectively, followed by ox and buffalo with 855 and 328 killings. During this period, leopard killed 182 calves, 165 horses and mule and 57 donkeys and mare **(Figure 9)**. There were significant variation in different types of livestock killings by leopard **(χ2=27.9, df=4, p<0.00)**. **Plate 6 and 7** show a goat and a bull (calf) killed by leopard in Tundal village, Karsog range, and Jogindernagar range respectively. **Plate 8** shows the carcass of buffalo calf killed and eaten by leopard in Tikkar village, Karsog range.

In Mandi district, incidences of attacks on livestock by leopard showed marked variation in different months during 1987-2007 **(Figure 10)**. There was significant difference in the number of attacks in different months **(χ2= 93.70, df=11, p<0.00)**. Although the number of attacks on livestock was high throughout the year, but it was highest during the month of May (n=527), followed by 519 attacks in October, 434 in June, 431 in September and 430 attacks were in the month of August. During the month of January, February, March, April, July, November and December, number of attacks on livestock by leopard was 343, 342, 397, 379, 383, 403 and 379 respectively. Livestock killings occurred in different seasons as such showed no variation **(χ2=0.6, df=2, p<0.72)**. But there was significant differences in the monthly occurrence of livestock killings **(χ2= 93.70, df=11, p<0.00)**.

Leopards were responsible for killing livestock of different age groups in the study area. There was marked variation in the age group of livestock killed by leopard during 1987-2007. Out of the total 8905 cases, adults were killed maximum (n=8723) and only 182 calves were killed. Various livestock killings took place in different places viz. forest, crop fields, grassland, cow-sheds and other places **(Figure 11)**. **Map 2** shows the place of occurrence of livestock killings in the study area. Out of the total 4967 cases, highest number of livestock killings (82.8%) occurred in the cowsheds, followed by forest area (5.2%), villages (4.1%), grassland (3.6%) and crop fields (2.5%). Only few livestock killings (1.9%) occurred in other categories including nallahs and ravines. **Plate 9 and 10** show a horse and mule killed by leopard in Karsog range and in Siraj range, Janjehli respectively. Owner of the horse sitting by the side carcass that has been partially eaten by leopard (**Plate 11).** A photograph of donkey killed by leopard in village Nalani, Sundernagar range (**Plate 12)**.

The time period of occurrence of livestock killings by leopard showed some specific pattern **(Figure 12).** Highest number of killings (74.5%) occurred during night time between 2201-0400 hours, followed by 15% killings in evening time between 1601-2200 hours. Livestock killings were found to be 7.6% and 3% during day time (1001-1601 h) and morning time (0401-1000 h).

Occurrence of livestock killings at different time of the day showed significant variation **(χ2= 133.5, df=3, p<0.00)**.

5.3.8 Compensation

Livestock killings

In Mandi district, out of total 4967 cases of livestock killings by leopards, compensation was paid to 4907 cases and the amount of compensation paid each year from 1987 to 2007 is shown in **Table 7**. Sixty cases were rejected by the forest department. An amount of Rs. 52 44269 was paid as compensation for livestock killings by leopards during 1987-2007. Maximum compensation of Rs. 5,14,459 was paid in the year 1994, followed by Rs. 4,76760 in the year 1993. A lowest amount of Rs. 1700 was paid as compensation for the livestock killings In the year 1987.

The time interval of payment of compensation for livestock killings by leopard was categorized as 0.0-3.0, 3.1-6.0, 6.1-9.0, 9.1-12.0 and 12.1- > months **(Table 8)**. The time interval of payment of compensation was recorded for all 4967 livestock killing cases occurred during 1987-2007. Out of total cases, highest number of cases (n=2149) received compensation within 3 months of occurrence of incidences. During time interval of 3-6, 6-9, 9-12 and 12-15 months, 1253, 541, 438 and 526 cases respectively received compensation. Sixty cases were rejected for the compensation because of the different reasons like delay in reporting to forest department or incomplete of documents etc.

5.4 Discussion

Predators have been a long-standing and traditional focus of basic ecological research. The lack of consistency is surprising, given the long history of human-predator conflicts. In the past, little attention was paid to ecological considerations because the primary goal of wildlife management was to fulfill social and economic requirements (Reynolds and Tapper, 1996). Only recently, there has been a requirement to examine the ecological context of human-predator conflicts.

Human–carnivore conflict is considered to be a major conservation and rural livelihood issue because many carnivore species have been heavily persecuted due to elevated conflict levels with communities. Human-carnivore conflict arises for several reasons. Carnivore's protein-rich diet and large home ranges draw them into recurrent competition with humans, who have somewhat similar needs. Indeed, many larger carnivore species are specialized for ungulate predation; therefore, some individuals readily kill domesticated ungulates when opportunities arise (Meriggi and Lovari, 1996 and Karanth, 1991).

5.4.1 Human casualties

Human-leopard conflict in form of human casualties and predation on livestock has been reported from all five forest divisions of Mandi distirict. Sundernagar, Mandi and Jogindernagar forest divisions are more affected as compared to Karsog and Nachan forest divisions. A total of 162 human casualties were reported in villages situated in Mandi, Sundernagar, Jogindernagar, Karsog and Nachan forest divisions from 1988 to 2007.

The reasons for attacks on human are believed to be due to the fact that the leopards crippled with injuries, old age, disease, which made them handicap to take wild prey (Corbett, 1944). Lack of habitat and food, obstruction of escape route, straying away from the natural habitats, driven by hunger, displacement by tigers and green cover in the crop fields could be the some main causes of increased predation on human by the leopards (Shah *et al*., 2004). Another potential explanation for the increased number of attacks on humans is that leopards moving through unfamiliar human-dominated landscapes are more likely to encounter people. Furthermore, a leopard may not obtain prey efficiently in an unfamiliar landscape, and this could lead to predatory attacks on humans (Hamilton, 1981). In Junnar, Maharashtra, the translocated leopard were found to move more frequently than resident animals, presumably in an attempt to return to their original territory or to establish a new territory, also increased the probability of human-leopard conflict, especially in a densely populated landscape (Athreya *et al*., 2011).

In Mandi district, human casualties by leopard occurred every year and number of human casualties varied from 1 to 22 cases from 1988 to 2007. Highest number of casualties occurred in the year 2002. In and around Machiara national park, Pakistan, number of human injuries and deaths from leopard was reported to be substantial from January 2004 to May 2007 (Dar *et al*., 2009). In Nepal, a total of 441 humans were attacked by leopard in Nepal during 1994 to June 2004 (Shah *et al*., 2004). Leopard killed 270 individuals and injured 171 individuals. The number of human attacks per year ranged from 20 to 72 individuals with an average of 40 individuals. In the Satbariya range post of Dang district, Nepal, there were few injury cases. Among the injury cases, 85.7% were due to sloth bear, 9.5% due to crocodile and 4.8% due to leopard (Pokhrel and Shah, 2008). In Uganda four large carnivores were jointly responsible for 636 human casualties during 1923-1994 (Traves and Traves, 1999). Lions caused 275 and leopards caused 114 casualties. Out of 114 casualties by leopard 32.5% were fatal while 67.5% were injury cases.

In India, similar studies conducted on human-leopard conflict showed varying number of attacks by leopard on human which resulted in their death or serious injuries. In Pauri Garhwal, 191 humans were killed and 364 were injured by leopards during 1998 to 2005 (Chauhan, 2009). Leopard predation on human is on the increase in Garhwal and Kumaun region (Chauhan *et al*., 2002). A total of 328 human casualties by leopard were reported in during 1988-2001. Negi (1996) reported 61 human deaths and 76 human injury cases during the years 1986 to 1996. In Gir national park, there were 12 (7%) confirmed deaths, 132 (81%) cases of normal injuries (with fang marks on hand, back, head etc.), and 20 (12%) cases of serious injuries from 1990 and 1997 (Srivastav, 1999). In Jammu and Kashmir, 60 victims of leopard were examined, and out of which 75% of the victims died and others were injured during 2005, 2006 and 2007 (Singh *et al*., 2008). In the past five years i.e.

from 2001 to 2005, more than fifty people got killed and many more were mauled by leopards in and around Sanjay Gandhi National Park (Grylls, 2006).

In Mandi district, out of the total of 162 cases, 13 people were killed and 149 people were injured. Number of male casualties was more than the females among killed and injured persons in all forest divisions. This might be due to fact that men were mostly active and increasingly involved in agricultural work, livestock grazing, fuel wood collection, fodder collection, and collection of NTFP from forests, labour work and moving to markets or other villages crossing forests or den sites for their day to day activities. So there were chances of more encounters with leopards, and the predators, mostly in their self defence, attack people.

Leopard attacks resulted in human deaths when victims succumbed to serious injuries. In Mandi district, middle age groups suffered the most. Out of total 162 human casualties, highest number of 28 casualties occurred in the age group of 25-30 years, followed by 23 casualties in the age group of 40-48 years. On the contrary in Uganda, out of the 114 human casualties caused by leopard, women and children were 70% while men suffered 8% casualties only (Traves and Traves, 1999). Likewise in Pauri and Garhwal, female casualties and children below 15 years were found to be relatively high (68.6%) in comparison to males (Chauhan, 2009). In Jammu and Kashmir also, leopards attacked more females and children below 15 years (Singh *et al*., 2008).

From April 1988 to December 2007, there was not much seasonal variation in the human casualties in our study area in Mandi, but monthly variation was found to be significant. The frequency occurrence of human casualties was found to be 38.9%, 30.2% and 30.9% during winter, monsoon and summer seasons respectively. So highest number of the cases occurred in the winter season, followed by monsoon and summer time. Although the incidences of human killings and mauling occurred in different months but they were highest in November. In a study conducted in Jammu and Kashmir, leopard's attacks varied seasonally, and there were more casualties during winter as in our study area (Singh *et al*., 2008). In Pauri and Garhwal, majority of attacks were reported during rainy (45.8%) and winter season (45.2%) (Chauhan, 2009). In Nepal, leopard's attacks on human were found to be relatively higher in winter and rainy seasons (Shah *et al*., 2004). Grylls (2006) also reported the monsoon season as worst for attacks on human by leopards.

In Mandi district, highest number of 91 casualties occurred in the evening time during 1601-2200 hours. There were 37, 22 and 12 human casualties in the morning (0401-1000h), daytime (1001-1601h) and night time (2201-0400h) respectively. This is the time when children returned from their school, women were coming back to villages after fodder and fuel wood collection etc. In the morning hours, most of the people were out for toilet or taking bath or bringing drinking water, milking cattle and engaged in labour work etc. During the day time, they were also found moving in to forests for collection of fodder or grazing their livestock and because of which, there were encounters with leopard that resulted in human casualties. Similar findings were reported from Pauri Garhwal, where frequency of attacks was relatively high during the evening time, as 68.3% attacks were between 1600-2100 hours, followed by 16.4% incidents in the morning time between 0300-0800 hours and 7.7% cases were between 1300 -1500 hours (Chauhan, 2009). In Jammu and Kashmir, most of the leopard attacks were in the evening time (Singh *et al*., 2008).

In our study area, highest number of human casualties (35.8%) occurred in villages, followed by crop field (18.5%), grassland (14.2%) and other places like nallah/ravine, school playground etc. (12.3%). Out of total cases, 10.5% human casualties occurred in forest areas. Likewise Chauhan (2009) also found that leopard predation on human and livestock were positively correlated with human habitation areas in Pauri Garhwal. Grylls (2006) reported that most of the attacks occurred outside the park boundaries and in the city municipal area.

For giving some relief to victims or their families, although the forest department started the compensation scheme from 1987 onwards and compensated all the reported 162 casualty cases in Mandi district, but even then all the cases were not reported due to cumbersome procedure of payment of compensation. Out of total cases, compensation was paid to maximum number of cases (n=111) within three months of occurrence of incidences. Compensation was disbursed for 44 human casualties between three to six months period after the occurrence of incidences. Such compensation schemes for human deaths or injuries were always found to improve the local tolerance towards wild animals (Dar *et al*., 2009), but this was not always the case especially if payments were considered to be inadequate or delayed (Madhusan, 2003 and Naughton-Treves *et al*., 2003).

5.4.2 Livestock killings

Livestock form the second most important component of traditional subsistence economy in Himachal Pradesh. Domestication of animals is supposed to be one of the important components of agriculture and domestic sector. Almost every household has a pair of bullocks and own cows. Sheep and goats are mainly domesticated in remote villages purposely for wool production and distress selling. The average number of livestock per household differs significantly and varies from 10 to 100. Most of the cattle and livestock are stall-fed with crop by-product supplemented with fodder from grazing in the forests and pastures. These livestock are found to be killed mainly by leopard, Asiatic black bear (*Selenarctos thibetanus*) and brown bear (*Ursus arctos)* in these areas. There may be large number of cattle-lifting cases in Himachal Pradesh, which perhaps are not reported timely. Amongst livestock, sheep, goat, cow, bull, horse, mule and dogs are predated upon by leopard, black bear and brown bear.

In the five forest divisions of Mandi district, there were 4967 attacks by leopard and 8905 livestock were killed during 1987-2007. Highest number of attacks i.e. 2222 with 3710 livestock killings by leopard was in Sundernagar forest division, followed by Jogindernagar forest division with 1702 attacks and 2545 livestock killings. Lowest number of attacks i.e. 224 with 683 livestock killings by leopard was made in Karsog forest division. Reasons for livestock predation could be several like leopards might be injured or suffering from some disease or had old age, and which could have made him a handicap to take wild prey (Corbett, 1944). Among other reasons, there could be a mother with cubs, and large number of goats or sheep in poorly constructed pens, unattended herds of sheep and other livestock, and loss of natural prey (Shah, 2006). Inadequate day time guarding and grazing in the forests were associated with livestock depredation. Varying number of livestock killings in different forest divisions could be related to overall population of leopards, number and distribution of livestock and all the above factors. Mizuatani (1993) found only one leopard out of nine individuals habitually consumed livestock in an area where wild ungulate prey was available. So in this case, livestock were not the principal prey for leopard. But the leopard living close to human settlements were commonly found to prey on domestic animals, goats, sheep, ponies, donkeys and calves and quite commonly dogs, because of lack of natural preys.

In Mandi district, number of incidences of livestock killings varied in different years. There was an increasing trend of livestock killings from 1987 onwards and showed highest number of killings (n=958) in the year 1991. Year-wise variation in human casualties might be due to simply encounter rate, human activity pattern, leopard population and prey availability etc. Similarly the annual variation in occurrence of livestock killings could be mainly due to availability of livestock and extent of guarding of these livestock in different forest divisions from 1987-2007. Leopards were responsible for killing 3043 sheep, 2598 goats and 1677 cows, followed by killing of 855 bulls and 328 buffalos in the study area. During this period, leopard killed 182 calves, 165 horses and mules and 57 donkeys and mare in the study area. In other similar studies, leopards were found to be responsible for killing large number of livestock. In Pauri Garhwal and Kumaun region, a total of 463 livestock killings by leopard were reported during 1996-2001 (Chauhan *et al*., 2002). Livestock killing showed significant variation over the years, it showed increasing pattern from 1996 onwards and reached to a maximum in the year 1999 and then declined to lowest level in year 2001. Likewise in Jammu and Kashmir also, leopards have been responsible for heavy livestock losses and, more importantly and regardless, was perceived by the pastoralists to be a major threat to their livelihood (Termizi and Rafique, 2001). In Sariska tiger reserve, goats, sheep and calves comprised of 88% livestock kills of leopard (Sekhar, 1998). The mean wild and domestic prey body mass in Indian tropical forests was 23 kg (Karanth and Sunquist, 1995), while a synthesis of several leopard diet studies found that leopard preferentially preyed upon smaller species (Hayward *et al*., 2006).

In and around Machiara national park, Pakistan, leopard killed 208 goats, 101 sheep, 15 cows, four donkeys, one horse and 34 dogs from January 2004 to May 2007 and in retaliation, two leopards were killed by people (Dar *et al*., 2009). In Gallies forest division, Abbotabad district, Pakistan, leopard killed 182 livestock including 175 goats, 5 buffaloes and only two cows from January to July 2008 (Khalil, 2008). In another study in Pakistan, the frequency of goats and sheep killing by leopard was greater than their availability (Sangay and Vernes, 2008). A study in Bhutan revealed that leopard killed more sheep and horses than would be expected, although goats were not kept by the pastoralists in this area. In Nepal, predation on livestock was found to be common. Surplus killing of sheep, goats and poultry by leopard was quite frequent, but cattle were also killed in different parts (Shah *et al*., 2004). In Satbariya range of Dang district, Nepal, highest depredated livestock and poultry were goat (33.8%) and chicken (33.8%), followed by cattle (19.6%), pigs (8.7%), buffaloes (2.7%) and sheep (1.4%). Chicken were most vulnerable to predation by jackal and jungle cat while goat and cattle were vulnerable to predation by leopard (Pokhrel and Shah, 2008). In Kunjo of Mustang district, Nepal, leopard reportedly killed 21 cows, 5 oxen, 10 sheep, 14 goats, 3 horses, 7 mules, 4 dogs and wounded one dog in the year 2002 (Ghimirey, 2006). A lower availability of wild prey in Africa, which was often found associated with rainfall patterns and seasonal movements of these prey, has been found to increase the risk of livestock attacks by carnivores (Patterson *et al*., 2004 and Kolowski and Holekamp, 2006).

In Sangamner, Ahmednagar, 232 goat mortality and 43 dog mortality was attributed to leopards in last two years i.e. 2006 and 2007 (Rahalkar, 2008). During the years 2003-2005, 1375 livestock killings were reported by large carnivores in Bhutan, of which 70% livestock were killed by leopards (Sangay and Vernes, 2008). Leopards killed fewer cattle and yak than expected, and more horses and sheep than expected. In Jigme Singye

Wangchuck national park, Bhutan respondents reported a total of 76 domestic animals killed by predators in one year (Wang and Macdonald, 2006). Farmers attributed 40 kills to leopards, 20 to tigers, 10 to dholes and 6 to bears.

In Mandi district, monthly incidences of livestock killing by leopard showed marked variation in during 1987-2007. Number of attacks on livestock was high throughout the year, but it was highest during the month of May (n=527), followed by 519 attacks in October, 434 in June, 431 in September and 430 attacks were in the month of August. But the livestock killings occurred in different seasons as such showed no variation. There were substantial numbers of killings during the rainy and winter seasons. During rainy season, vegetation grew profusely, and shrub species turned bushy and thick. This provided shelter and hiding cover to leopard near the villages. During summer, leopards were forced to move towards the villages or rivers or streams for water and easy cattle prey. Similarly in Jammu and Kashmir, goats and sheep were the livestock most vulnerable to attacks, especially during the warmer months (Termizi and Rafique, 2001). In Machiara national park, Pakistan, the natural prey of leopard became more abundant during the winter months, as heavy snowfall at higher elevations forced the prey to descend (Dar *et al*., 2009). In the summer months, when wild prey became less abundant, pastoralists were also found to graze their livestock away from their villages in meadows near the forest edge and often leave them unattended, thereby increasing their vulnerability to leopard attack.

Livestock of different age groups were found to be killed by leopard in our study area in Mandi. There was marked variation in the age group of livestock killed by leopard during 1987-2007. Out of the total 8905 cases, adults were killed maximum and only 182 calves were killed. Livestock of adult age group were mainly left outside in crop fields or forests for grazing, while the sub-adults were kept in houses or cow-sheds, and thus exposed less compared to adult ones. This could be the main reason of killings of adult livestock.

In Mandi district, livestock killings took place in different places viz. forest, crop fields, grassland, cow-sheds and other places. Out of the total 4967 cases, 83% cases were occurred in the cowshed, followed by forest, village and grassland, and crop field and other (nallah/ravine etc.). On the contrary, the leopards reportedly killed large number of animals grazing in the forests as well as fenced enclosure at night (Shah *et al*., 2004). Mostly livestock depredation occurred in the community forests during the grazing period. Depredation inside the animal shed rarely occurred (Pokhrel and Shah, 2008). In Kunjo of Mustang district, Nepal, cows were attacked mostly in the forests, followed by pastureland and villages (Ghimirey, 2006).

In our study area, the time period of occurrence of livestock casualties by leopard showed some specific pattern. Highest number of killings (74.5%) occurred during night time between 2201-0400 hours, followed by 15% killings in evening time between 1601-2200 hours. Leopards were found to be a solitary and nocturnal hunter, relying on stealth and camouflage to stalk up close to their prey (Rabinowitz, 1989). In and around Machiara national park, Pakistan, livestock in villages were particularly vulnerable at night, as they were often left unattended and in poorly constructed pens. Furthermore, villages without electricity supplies were more vulnerable to leopard attacks, presumably because the leopard had a greater chance of successfully approaching livestock undetected. Leopard attacks exhibited a peak during the late afternoon (1600-1700 h), coinciding with livestock being left to graze unattended in fields nearby the village. While dogs might have alerted pastoralists to the presence of an approaching predator, dogs were found to be ineffective in reducing leopard kills both inside and outside of villages. In Kenya also, dogs were ineffective in deterring leopard attacks, as well as those by hyena (Kolowski and Holekamp, 2006). Outside villages, the risk of predator attack by day was greatest for larger herds (e.g. in Africa; Woodroffe *et al*., 2007), while attentive herding could lower predator attacks on livestock during the day (Ogada *et al*., 2003).

5.4.3 Compensation

In Mandi district, out of total 4967 cases of livestock killings by leopards, compensation was paid to 4907 cases. An amount of Rs. 52 44269 was paid as compensation for livestock killings by leopards during 1987-2007. The time interval of payment of compensation was recorded for all 4967 livestock killing cases. Out of total cases, highest number of cases (n=2149) received compensation within 3 months of occurrence of incidences. During time interval of 3-6, 6-9, 9-12 and 12-15 months, 1253, 541, 438 and 526 cases respectively received compensation. Sixty cases were rejected for the compensation because of the different reasons like delay in reporting to forest department or incomplete of documents etc. Such compensation schemes for livestock losses to wild carnivores, which has been found not existing in Pakistan today (Bagchi and Mishra, 2006), could also improve local tolerance towards wildlife (Dar *et al*., 2009). But this has not always been the case (Naughton-Treves *et al*., 2003), especially if payments were considered to be inadequate or delayed (Madhusan, 2003).

Table 1. Human casualties by leopard in different forest divisions of Mandi district during 1988-2007. (n=162)

Forest division	Human killed	Human injured
Mandi	2	35
Sundernagar	2	69
Jogindernagar	8	26
Karsog	0	10
Nachan (Gohar)	1	9
Total	**13 (8%)**	**149 (92%)**

Table 2. Human casualties by leopard in different years Mandi district during 1988-2007. (n=162)

Year	Male		Female		Total
	killed	Injured	Killed	Injured	
1988	-	3	-	-	3
1989	-	1		1	2
1990	-	1	-	-	1
1991	1	-	-	2	3
1992	3	4	1	3	11
1993	-	7	1	4	12
1994	1	2	-	1	4
1995	-	3	1	1	5
1996	-	4	-	2	6
1997	-	2	-	2	4
1998	-	8	-	5	13
1999	-	3	-	2	5
2000	-	6	-	3	9
2001	-	8	-	4	12
2002	-	12	1	9	22
2003	-	4	1	5	10
2004	-	5	1	4	10
2005	1	7	-	4	12
2006	-	9	-	1	10
2007	-	4	1	3	8
Total	**6**	**93**	**7**	**56**	**162**

Figure 1. Trendline in human casualties developed by using polynomial regression in Mandi district during 1987-2007.

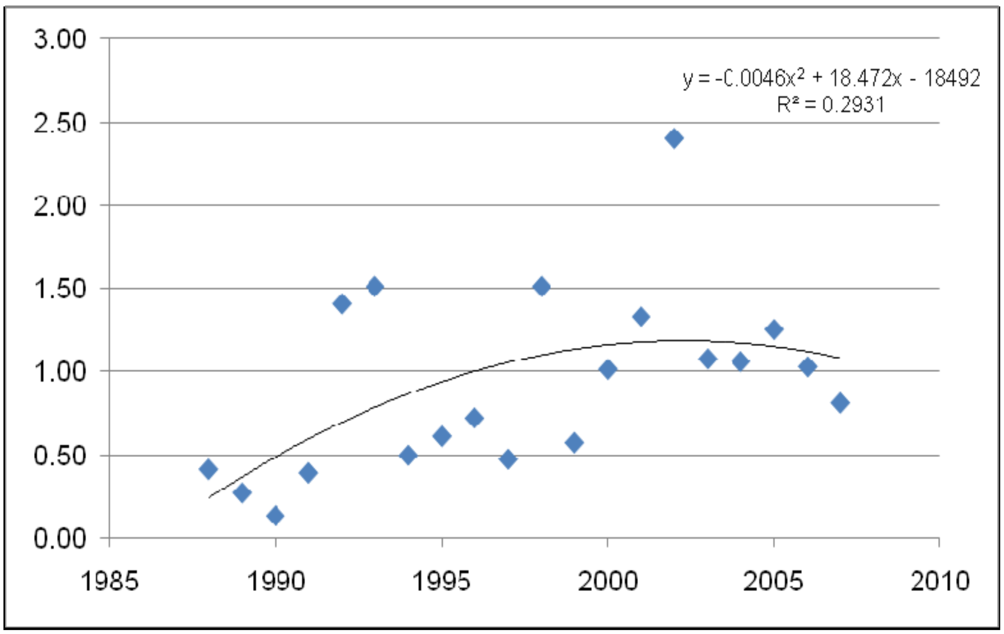


Figure 2. Seasonal variation in human casualties by leopard in Mandi district during 1988-2007. (n=162)

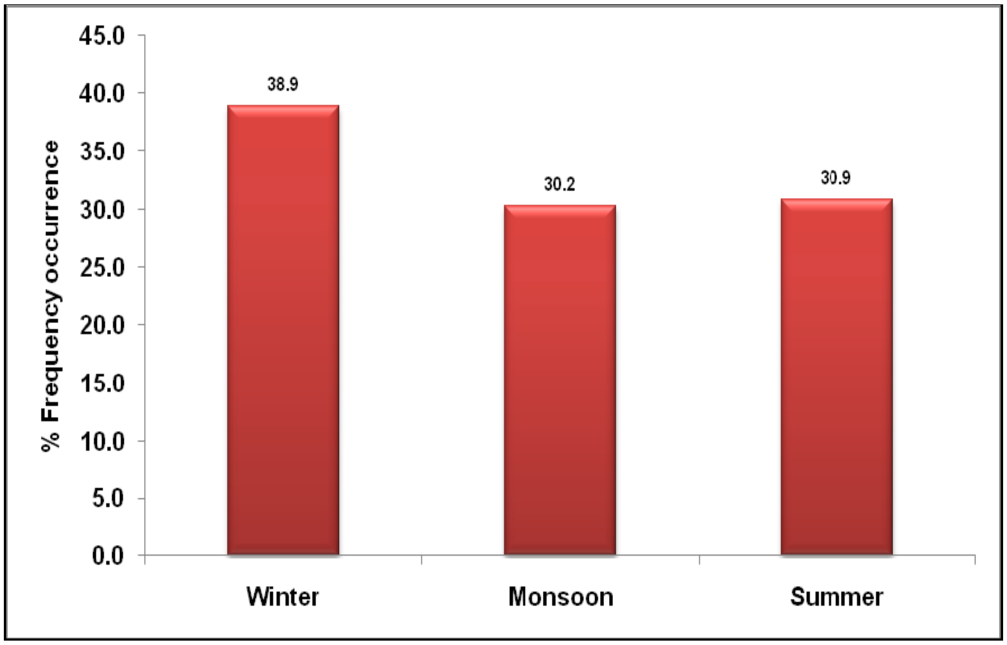


Figure 3. Monthly variation in human casualties by leopard in Mandi district during 1988-2007. (n=162)

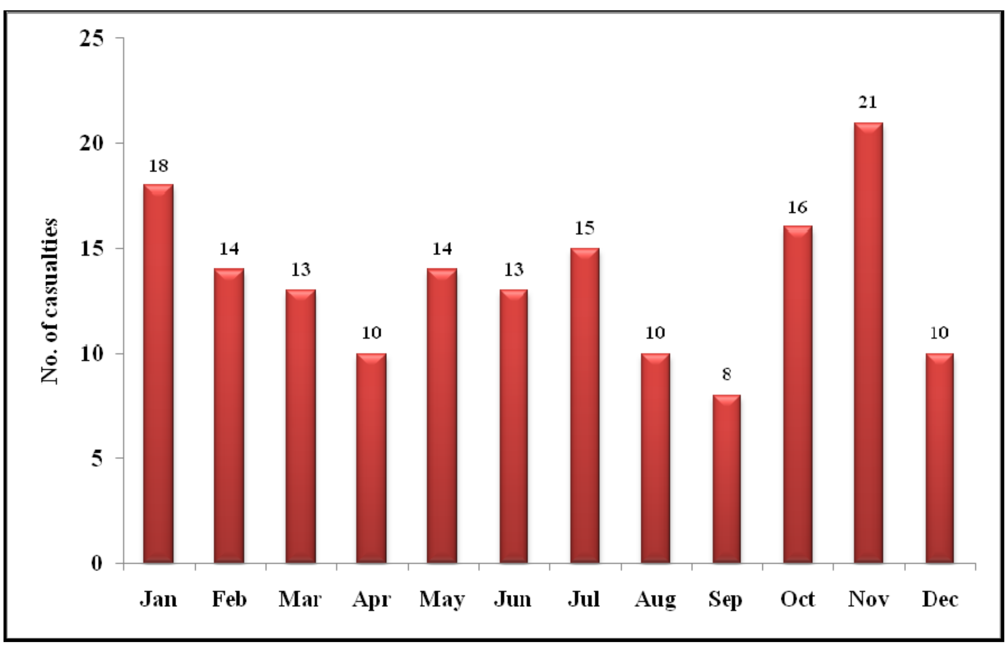


Figure 4. Age group of human casualties by leopard in Mandi district during 1997-2001 (n=162).

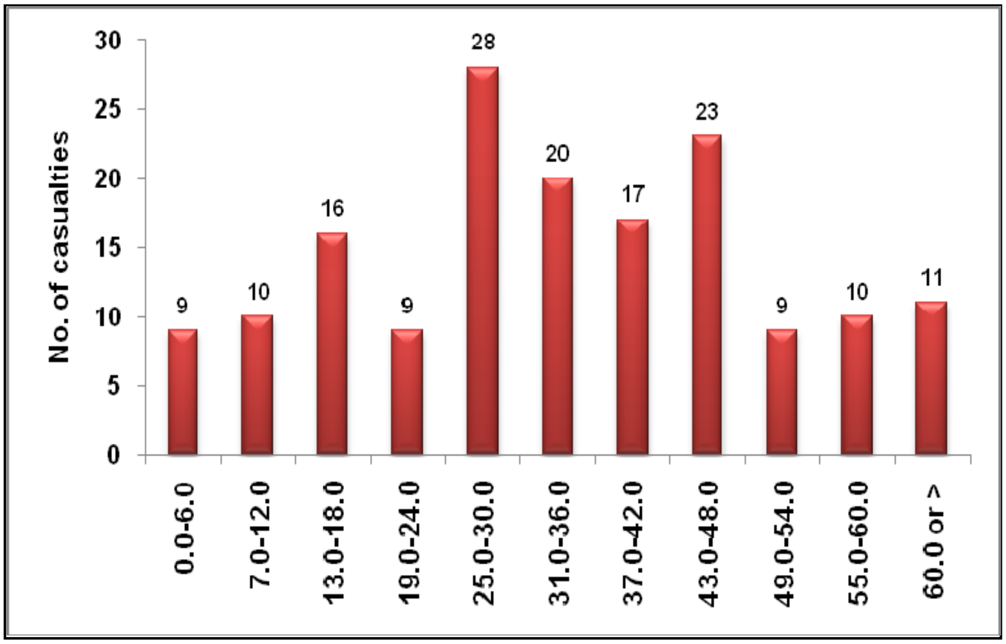


Figure 5. Time of human casualties in Mandi district during 1988-2007. (n=162)

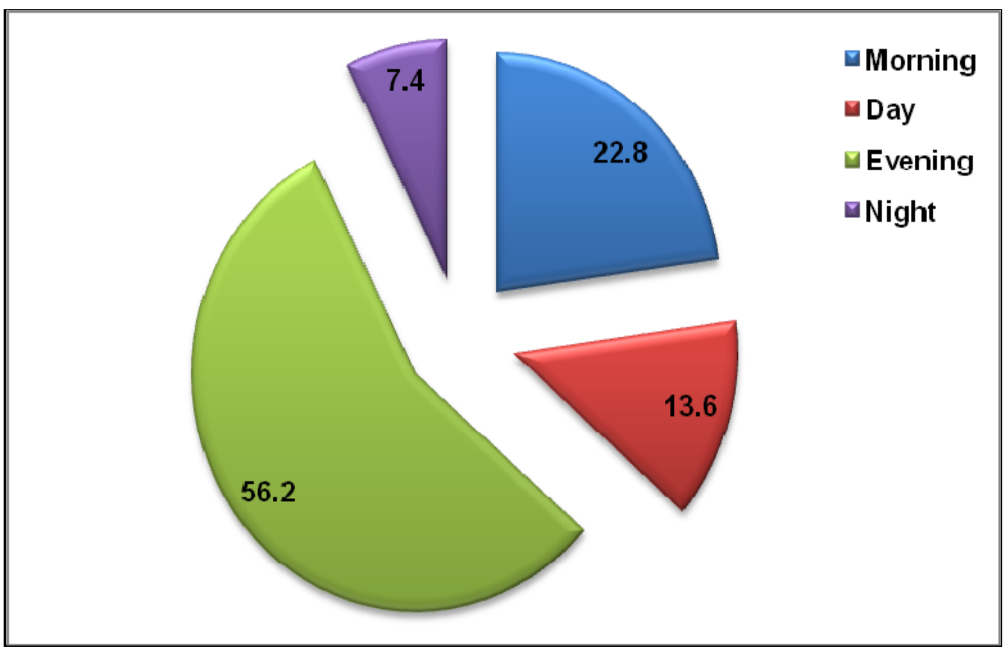


Figure 6. Place of human casualties by leopard in Mandi district during 1988-2007. (n=162)

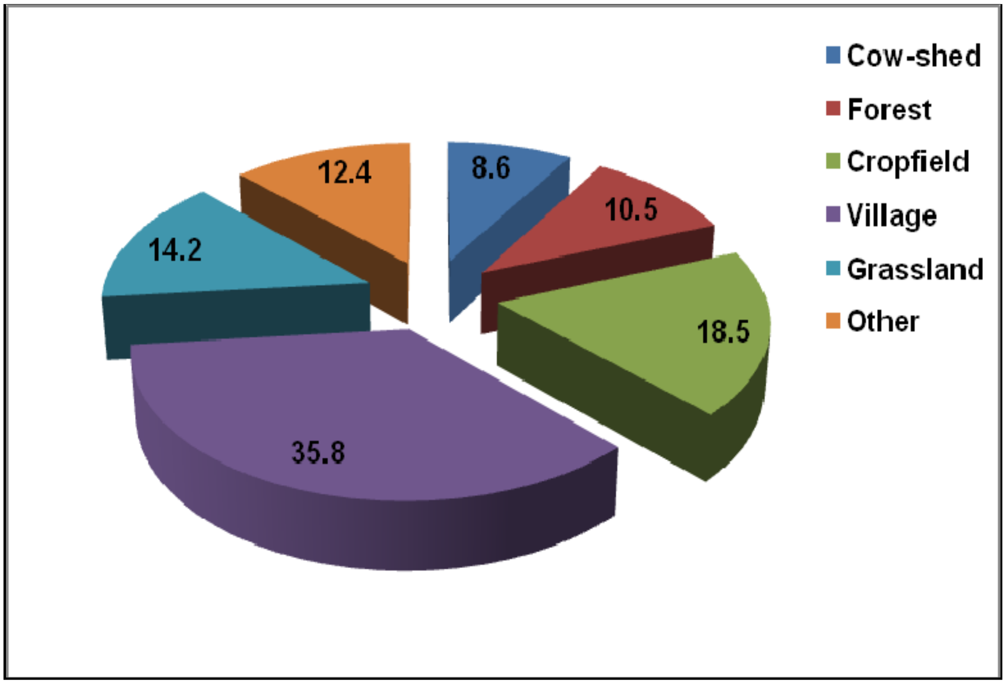


Figure 7. Activity of victims of leopard attacks in Mandi district during 1988-2007. (n=137)

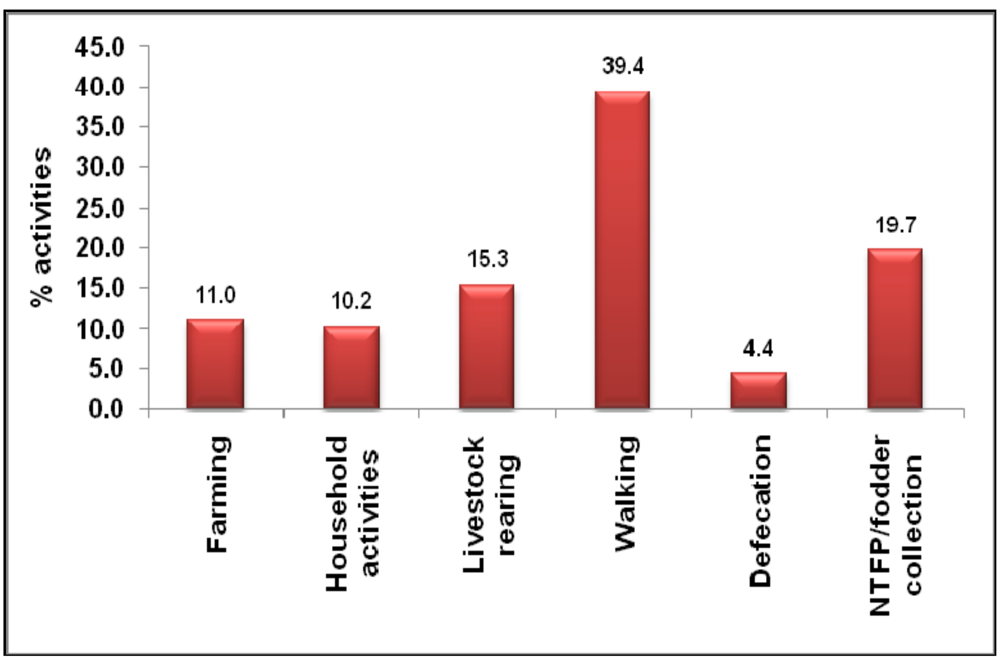


Table 3. Human casualties by leopard and compensation paid in Mandi district during 1988-2007. (n=162)

year	Killed	Compensation (Rupees)	Injured	Compensation (Rupees)	Total (Rupees)
1988	-	-	3	3000	3000
1989	-	-	2	1500	1500
1990	-	-	1	1000	1000
1991	1	15000	2	3000	18000
1992	4	60000	7	10000	70000
1993	1	15000	11	12500	27500
1994	1	15000	3	2500	17500
1995	1	25000	4	5000	30000
1996	-	-	6	9000	9000
1997	-	-	4	5375	5375
1998	-	-	13	22250	22250
1999	-	-	5	8775	8775
2000	-	-	9	16250	16250
2001	-	-	12	53425	53425
2002	1	100000	21	163875	263875
2003	1	100000	9	47000	147000
2004	1	100000	9	16850	116850
2005	1	100000	11	145125	245125
2006	-	-	10	96625	96625
2007	1	100000	7	87180	187180
Total	**13**	**630000**	**149**	**710230**	**1340230**

Table 4. Number of human casualty cases received compensation and time interval of payment in Mandi district during 1988-2007.

Time interval (Months)	No. of cases received compensation
0.0-3.0	111
3.1-6.0	44
6.1-9.0	4
9.1-12.0	2
12.1-15.0 or >	1
Total	**162**

Table 5. Number of attacks and livestock killing by leopard in different forest divisions of Mandi district during 1987-2007.

Forest division	No. of attacks	No. of livestock
Karsog	224	683
Nachan	250	731
Sundernagar	2222	3710
Jogindernagar	1702	2545
Mandi	569	1236
Total	**4967**	**8905**

Table 6. Livestock killing by leopard in Mandi district during 1987-2007.

Year	No. of attacks	No. of livestock
1987	21	32
1988	320	478
1989	310	477
1990	449	724
1991	472	958
1992	483	841
1993	346	634
1994	438	809
1995	312	502
1996	371	637
1997	293	543
1998	247	450
1999	221	387
2000	141	277
2001	99	260
2002	110	194
2003	88	155
2004	73	134
2005	64	150
2006	63	156
2007	46	107
Total	**4967**	**8905**

Figure 8. Trend line in livestock killings developed using polynomial regression in Mandi district during 1987-2007.

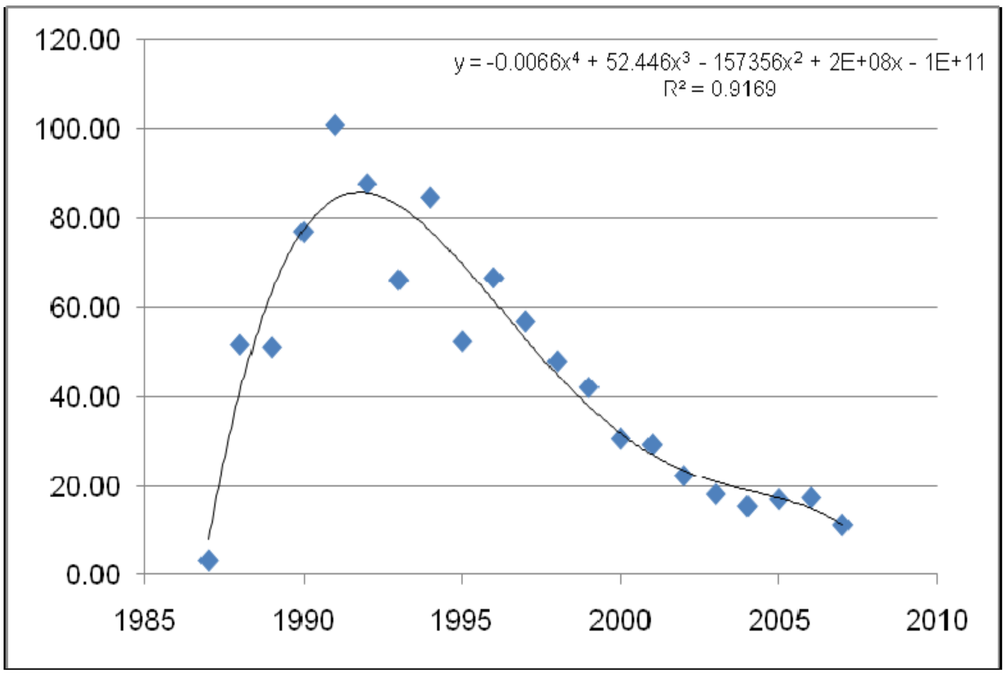


Figure 9. Livestock killing by leopard in Mandi district during 1987-2007. (n=8905)

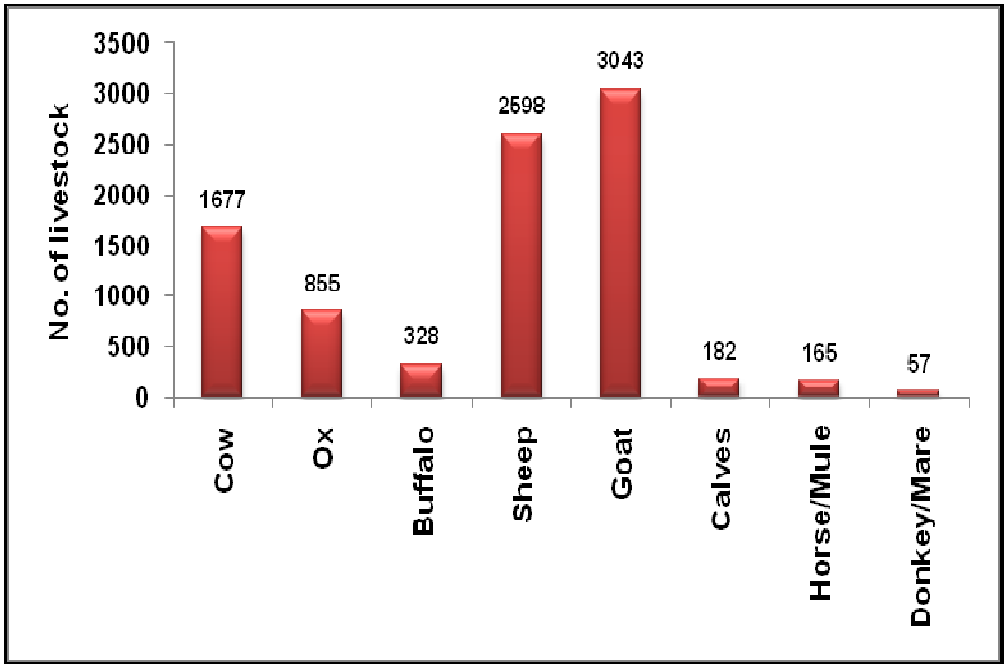


Figure 10. Monthly variation in attacks on livestock by leopard in Mandi district during 1987-2007. (n=4967)

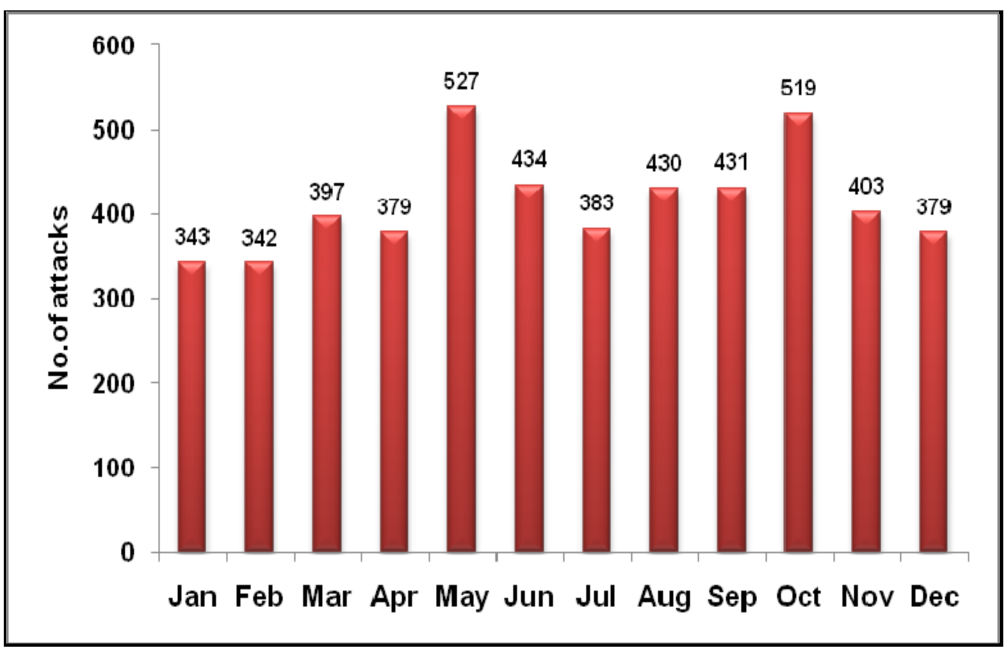


Figure 11. Places of livestock killing by leopard in Mandi district during 1987-2007. (n=4967)

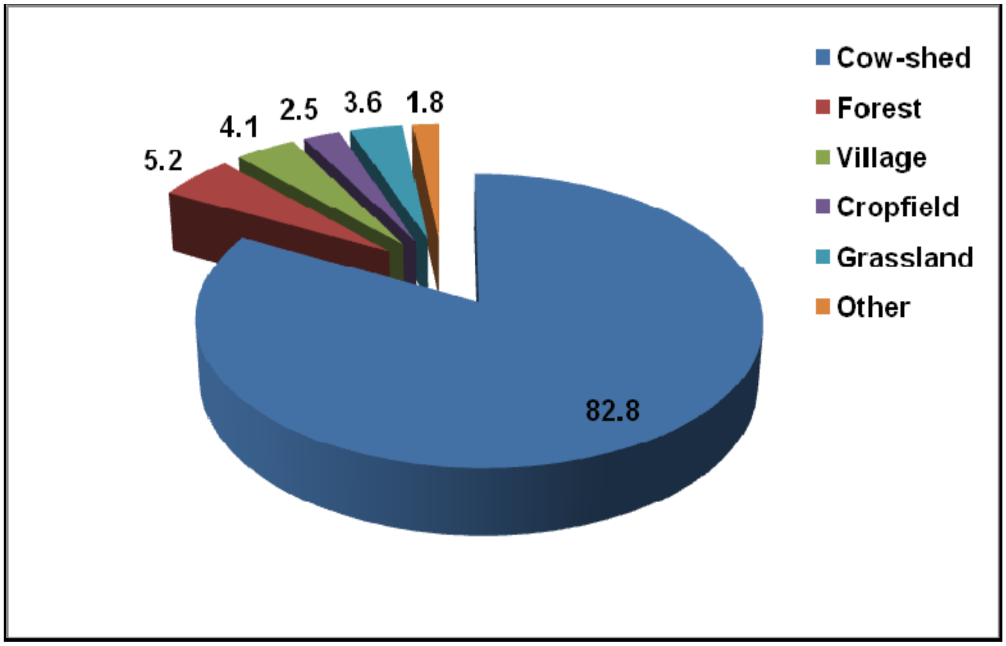


Figure 12. Time of livestock killing in Mandi district during 1987-2007. (n=4967)

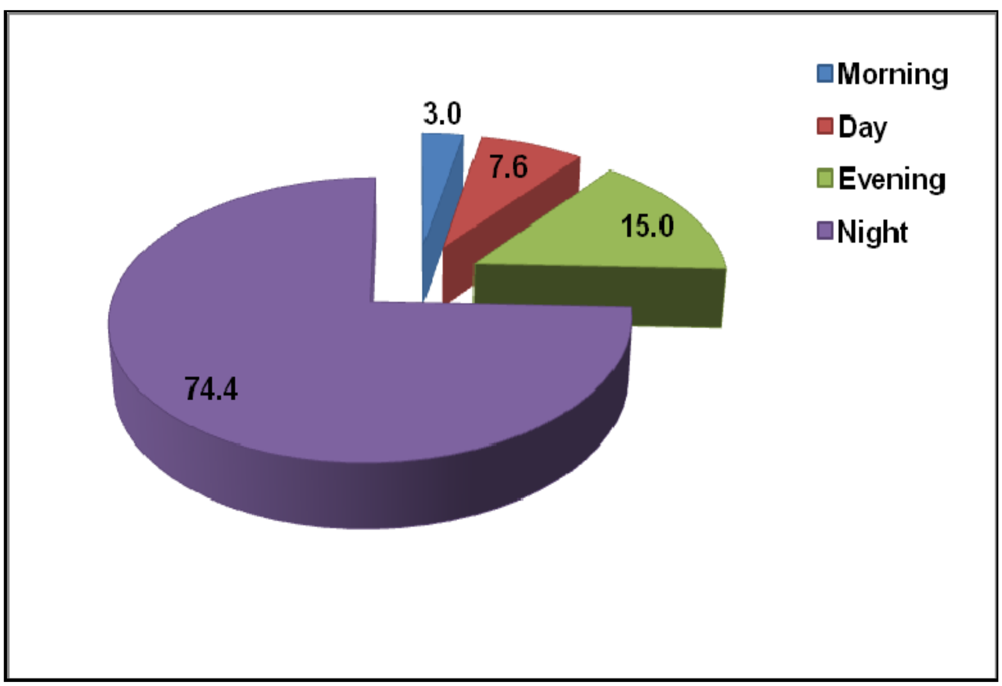


Table 7. Compensation paid for livestock killings in Mandi district during 1988-2007.

Year	Compensation (Rs.)	No. of rejected cases
1987	1700	2
1988	111120	-
1989	270850	-
1990	161700	-
1991	353066	5
1992	399290	11
1993	476760	5
1994	514459	22
1995	303675	14
1996	427120	-
1997	367422	1
1998	325949	-
1999	280942	-
2000	238888	-
2001	147443	-
2002	208375	-
2003	159475	-
2004	111026	-
2005	99875	-
2006	108925	-
2007	161584	-
2008	14625	-
Total	**5244269**	**60**

Table 8. Number of livestock killing cases received compensation and time interval of payment in Mandi district during 1988-2007.

Time interval (Months)	No. of cases received compensation	No. of rejected cases
0.0-3.0	2149	23
3.1-6.0	1253	11
6.1-9.0	541	6
9.1-12.0	438	6
12.1-15.0 or >	526	14
Total	**4907**	**60**

Plate 1. A view of study area - forests interspersed with villages.

Plate 2. A problematic leopard trapped in Jogindernagar range.

Plate 3. A victim of leopard attack in BSL colony, Kangoo range.

Plate 4. A victim with injuries caused by leopard.

Plate 5. Body of victim killed and partially eaten by leopard.

Plate 6. Goats killed by leopard in village Tundal, Karsog Range.

Plate 7. A bull (calf) killed by leopard in Jogindernagar range.

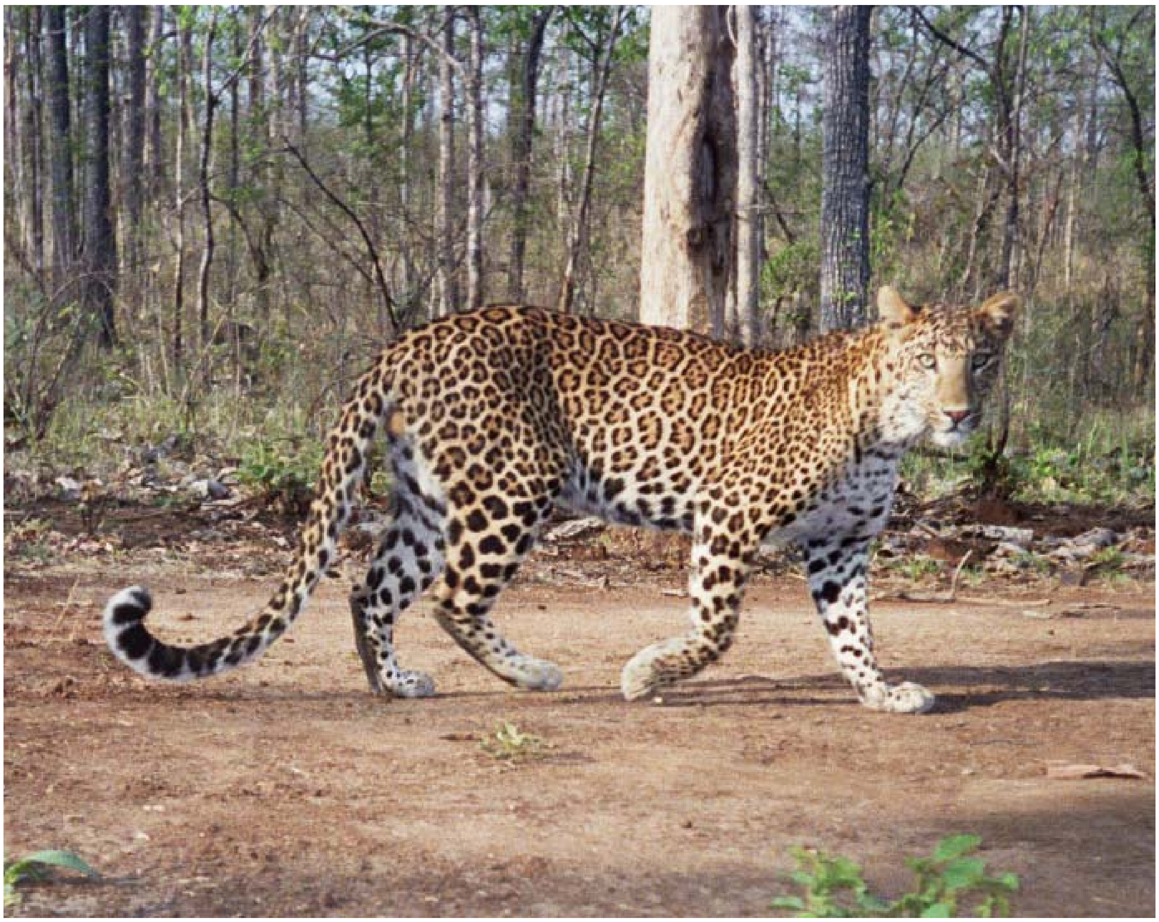
Plate 8. A carcass of buffalo calf killed and eaten by leopard in Tikkar village, Karsog range.

Plate 9. A horse killed by leopard in Karsog range.

Plate 10. A mule killed by leopard in Siraj range, Janjehli.

Plate 11. Owner sitting with the body of a donkey killed and partially eaten by leopard in Siraj (Janjehli) range.

Plate 12. A mare killed by leopard in village Nalani, Sundernagar range.



Chapter 6

Food habits of leopard in relation to prey species availability.

6.1 Introduction

Leopards are considered as ecological generalist rather than specialist and can survive by feeding on large or small prey. They can be efficient scavengers. Leopard hunt by stalking, taking their prey opportunistically and mostly at night, especially where people have persecuted it (Nowell and Jackson, 1996). They prey on a wide range of animals, including birds, fish, reptiles, small mammals and large herbivores of more than twice of their body weight, as well as carrion (Turnbull-Kemp, 1967; Bertram, 1982; Bothma and LeRiche, 1984, 1986; Bailey, 1993; Grobler and Wilson, 1972; Hamilton, 1976; Smithers, 1983; Mitchell *et al*., 1965; Muckenhim and Eisenberg, 1973; Kruuk and Turner, 1967; Mills, 1984; Schaller, 1972, 1977; Seidensticker, 1976; Seidensticker *et al*., 1990; Johnsingh, 1992 and Smith, 1978; Daniel, 1996; Stander *et al*., 1997). This flexibility, combined with their secretive habits, has enabled leopards to survive over a wide geographic range in Africa and Asia.

Food habits comprise one of the major determinants of various life history strategies in carnivores including pattern movement and habitat selection, social structure and geographical distribution (Krebs, 1978; Bekoff, *et al*., 1984; Sunquist and Sunquist, 1989 and Miquelle *et al*., 1996). The dietary information of predators is also important in predicting its impact on the dynamics of prey populations (Harihar, 2005). So the study on food habits is one of the major aspects of leopard ecology that has been studied worldwide (Emmons, 1987; Wemmer and Sunquist, 1988; Rabinowitz, 1989; Stander *et al.,* 1997; Mizutani, 1999 and Ray and Sunquist, 2001). The food habits of leopard are influenced by distribution and abundance of preferred prey species and cover. They have an exceptional ability to adapt to change in prey availability and small preys are taken where large ungulates were less common (Norton *et al*., 1986).

Prey population is a major factor responsible for the current decline of large cats worldwide (Seidensticker, 1986 and Rabinowitz, 1993). Predator density in an area is ultimately controlled by availability of food resources (Martin and de Meulenaer, 1988; Karanth and Sunquist, 1995 and Carbone and Gittleman, 2002). The availability and abundance of prey is one of the major factors that affect the community of large cats (Sunquist and sunquist, 1989; Bailey, 1993; Karanth and Sunquist, 1995 and Khan, 2004). Overall prey selection by predators depends on availability of prey species in an area (Bailey, 1993; Bothma and Coertze, 2004 and Khan, 2004). In prey rich habitats, leopards can afford to select their prey in terms of those species, age and sex classes that are most abundant or easiest to kill (Karanth and sunquist, 1995 and Bothma and Coertze, 2004). Carnivores resort to secondary prey when primary prey is less available or vulnerable (Hamilton, 1981; Seidenstikcer *et al*., 1990; Santiapillai and Ramono, 1992 and Bailey, 2003). Domestic animals may constitute secondary prey, and may be killed at higher frequency where wild prey is less available (Seidensticker *et al*., 1990). Adequate wild prey abundance may reduce livestock predation by large carnivores (Hamilton, 1981).

The prey of predators varies in different geographical areas and also in disturbed and fragmented habitats compared to undisturbed landscapes. In the Indian subcontinent, the studies conducted on food habits of leopards indicated that medium sized ungulates were the principal prey species (Seidensticker *et al*., 1990; Johnsingh, 1992; Ramakrishnan *et al*., 1999 and Sankar and Johnsingh, 2002). In the Royal Chitwan national park, prey includes wild pig, sambar, spotted deer, hog deer, barking deer and domestic cattle (Seidensticker *et al*., 1990). In another study on the food habits of common leopard in Dhorpatan hunting reserve, Nepal, 18% of the diet was constituted by barking deer (*Muntiacus muntjak*) and 6% by blue sheep (*Pseudois nayaur*) (Aryal and Kreigenhofer, 2009). A study conducted on food habits of leopard in Dachigam national park revealed the presence of nine prey species in the diet (Shah *et al*., 2009). The major prey items were dog, langur, hangul and rodents with frequency occurrence of 21%, 21%, 18.4% and 15.7% respectively. Aryal and Kreigenhofer (2009) studied the dietary pattern of common leopard in Dhorpatan Hunting reserve, Nepal and found 18% barking deer (*Muntiacus muntjak*) and 6% blue sheep (*Pseudois nayaur*). In the Wilpattu national park, Sri Lanka, leopards were found to predate mainly on spotted deer *(Axis axis)* and wild pig (*Sus scrofa*), while they were also feeding on sambar (*Cervus unicolor*), common langur (*Semnopithecus entellus*), black-naped hare (*Lepus nigricollis*), Indian porcupine (*Hystrix indica*) and calves of domestic buffalo (Muckenhirm and Eisenberg, 1973). Sixty percent of the 511 observed preys were spotted deer.

In India, Schaller (1967), Johnsingh (1983), Karanth and Sunquist (1995, 2000) and Venkatraman *et al.* (1995) studied the food habits of leopard; the major prey reported were spotted deer, sambar, barking deer (*Muntiacus muntjak*), goral (*Nemorhaedus goral*) and livestock. In Bandipur national park, 65% of kills of leopards were ungulates, mainly chital (Johnsingh, 1983). According to Edgaonkar and Chellam (1998), the major prey of leopard was found to be domestic dog, domestic buffalos and rodents in Sanjay Gandhi national park, Maharashtra. In the Mundanthurai plateau of Tamil Nadu, leopards were found to prey mainly on sambar, black-naped hare, chital and livestock (Sathyakumar, 1992). Chellam (1993) found that in Gir, 40% of leopard scats were containing chital and 25% common langur. In the tropical forest of Nagarhole, southern India, chital constituted the major prey base of leopards (Karanth and Sunquist, 1995). A study conducted on food habits of leopard in Dachigam national park revealed the presence of nine prey species (Shah *et al*., 2009). The major prey items were dog, langur, hangul and rodents.

Leopards hunt by stalking, taking their prey opportunistically and mostly at night, especially in human dominated landscapes (Nowell and Jackson, 1996). Studies on leopards in other countries also showed that they preferred mainly medium sized prey. In Kruger national park, South Africa, leopards were found to mainly prey on medium-size species such as impala (*Aepyceros melampus*), though a wide variety of small animals including hyrax, civet and mongoose also formed part of their diet (Bailey, 1993). In Tai national park, Ivory Coast, leopards were found to prey on about 30 species of animals (Hoppe-Dominik, 1984). Small prey also constituted a significant proportion of leopard diet in Tsavo national park, Kenya (Hamilton, 1976). Bothma and LeRiche (1984) found that in the Kalahari desert, leopard fed on small prey like bat-eared fox (*Otoeyon megalotis*), jackal (*Canis* spp.), genet (*Genetta* spp.), hare (*Lepus* spp.), duiker (*Cephalopus* spp.) and porcupine (*Hystrix* spp.). In the Serengeti, Tanzania, 30 species were found in 150 leopard kills (Bertram, 1978). Leopards require between 1.6 to 4.9 kg of meat per day to maintain body mass (Bothma and Le Riche, 1986 and Bailey, 1993). A leopard weighing 45 kg requires 1.5 to 2.5 kg of food daily (Emmons, 1987; Wemmer and Sunquist, 1988 and Mizutani, 1999). Average prey weight ranges between 5-70 kg (Rabinowitz, 1989; Stander *et al.*, 1997 and Ray and Sunquist, 2001).

Studies conducted in south Asia showed that leopard had more diverse diet ranging from lower size classes of animals to medium size wild species usually weighing less than 50 kg (Eisenberg and Lockhart, 1972; Santiapillai *et al*., 1982; Rabinowitz, 1989; Seidensticker *et al*., 1990 and Johnsingh, 1992). To fulfill food requirement, leopard kill around 40-60 kills in a year (Le Roux and Skinner, 1989). However female with cubs appeared to hunt more frequently than those without cubs (Bothma and Coetze, 2004). Generally leopards hunt on prey items less than 50 kg (Muckenhirm and Eisenberg, 1973; Seidensticker *et al*., 1990; Johnsingh, 1992; Bailey, 1993; Ramakrishnan *et al*., 1999 and Sankar and johnsingh, 2002). Whereas the average weight of prey species killed by leopard in Nagarahole national park was 37.6 kg (Karanth and Sunquist, 1995, 2000). However males with larger body weight were reported to invest more energy in capturing larger prey than females (Bothma and Le Riche, 1984). Bothma and LeRiche (1984) found that the prey species killed by African leopard weighed less than 20 kg in areas where large ungulates were unavailable. Mean prey weight of leopard in forests in Zaire was found to be 25 kg with ungulates and primates being the most common prey items (Hart *et al.,* 1996). Prey species killed by leopard in Chitwan national park were in the range of 25-50 kg with the average of 28 kg (Seidensticker, 1976 and Seidensticker and Lumpkin, 1991).

Leopards are well known for the use of habitat edges and its ability to live close to human habitation where livestock are available (Sediensticker *et al*., 1990., Santialillai and Ramono, 1992 and Chellam and Johhsingh, 1993; Nowell and Jackson, 1996 and Edgaonkar and Chellam, 2002). In fragmented and disturbed areas, they were increasingly preying upon domestic stock, a behaviour that brought them into direct conflict with humans. Livestock can be important prey for carnivores in areas where wild ungulates are not abundant (Hamilton, 1986; Sediensticker *et al*., 1990 and Santialpillai and Ramono, 1992). Hamilton (1986) reported that leopard population subsisting mainly upon livestock in western Kenya. In some areas of Java island of Indonesia, leopards were found to be largely subsisting upon cattle, village dogs and chickens (Santiapillai and Ramono, 1992). Variation in diet of the leopards between areas was most likely due to its opportunistic behavior, resulting in a diet that that closely link prey consumption with availability (Bailey, 1993).

Among various studies undertaken on ecological, biological and behavioural aspects for carnivores, study on food habits has always been crucial for planning better conservation of species. Understanding food habits of leopard in disturbed and fragmented habitats will enable us to recognize the plasticity in the ability of predators to use the resources in various human-altered landscapes. In this chapter, the results of the study on food habits of leopard conducted in disturbed and fragmented habitats of Mandi district, where the prey abundance seems to be lower than other places, are presented. The study includes the seasonal variation in dietary composition, frequency occurrence of food items and relative biomass of food items consumed. The study on food habits of leopard is useful for conservation and management of the species and also for mitigation of human-leopard conflict.

Bothma and LeRiche (1994) studied the food habits and defecation in northern Cape leopards in Augrabies Falls national park and found that dassie (*Procavia capensis*) remains were present in nine scats, springhare (*Pedetes capensis*) and gemsbok (*Oryx gazelle*) remains in two scats each, and silver fox (*Vulpes chama*) remains in one scat. Of the 40 leopard scats from the Kalahari, porcupine (*Hystrix africaeaustralis*) remain were found in 12 scats (30%), duiker (*Sylvicapra grimmia*) and gemsbok remains in 10 scats (25%) each, springhare and black-beched jackal (*Canis mesomelas*) remains in 6 scats (15%) each, plant material, including the gemsbok cucumber (*Acanthosycios naudianus*) in 4 scats (10%), steenbok (*Raphicerus campestris*) and springbok (*Antidorcas marsupialis*) in 2 scats each. No evidences of small rodents were found in any scat from the Augrabies Falls or the Kalahari Gemsbok national parks. Hart *et al*. (1996) studied leopard and African golden cat in Ituri forest of Ziare and found that felids consumed predominantly mammalian prey. Ungulates comprised 53.3% and primates 25.4% of prey items identified in leopard scats; mean prey weight estimated from scats was 24.6 kg. Hoppe-Dominik (1984) has analyzed 215 scats of leopard in Le Pare National de Tai in the Ivory Coast. More than 30 different prey species were found in the diet, which included duikers, monkeys, rodents and other carnivores. Some degree of dietary separation between pumas and jaguars has been noted, with jaguars tending to take slightly larger prey and more peccaries (Emmons, 1987).

Mahar *et al*. (1990) studied the diet of Florida Panthers (*Felis concolor coryi*) in southwest Florida during 1977-1989. Seven vertebrate species were identified as kills, and fourteen species were identified in scats. The frequency of occurrence in scats indicated that wild hog (Sus scrofa) was the most common prey, followed by white-tailed deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), and 9-banded armadillo (*Dasypus novemcinctus*) and there was no seasonal variation in the diet. Schaller *et al*. (1985) found that diet of leopards was constituted mostly (85.1%) of tufted deer (*Elaphodus cephalophus*) in Wolong reserve, Sichuan, China. Although leopards occasionally consumed young giant pandas, they were a small component (0.6%) of the diet. Later the study conducted by Johnson *et al*. (1993) in Wolong reserve showed 15 species of large and medium-sized mammals constituting the diet of Asiatic leopards. There was dominance of pheasants, livestock, grasses in the diet of leopards, and soil being eaten occasionally.

In Royal Chitwan National Park, prey includes wild pig, sambar, chital, hog deer, muntjac and domestic cattle (Seidensticker, 1976). In Wilpattu National Park in Sri Lanka, 60% of the 51 observed preys were axis deer (Muckerhirm and Eisenberg, 1973). Most of the rest of the diet comprised wild pigs, but other prey included buffalo, calves, sambar, muntjac, langur, porcupine, squirrel, hare and birds. In Wilpattu leopards took chital, wild pig (*Sus scrofa*), sambar, langur, hare, porcupine and domestic buffalo calves (Muckenhirn & Eisenberg, 1973). In Nepal, wild pig, sambar, chital, hog deer (*Axis porcinus*), muntjac and domestic cattle were part of their diet (Seidensticker *et al*., 1990). In the Pakistan Himalayas, leopards took mainly wild goats (*Capra aegagrus*) but also preyed on livestock, hare and porcupine (Schaller, 1977). Alan Robinowitz (1989) studied the behaviour of large cats including leopard in dry tropical forest mosaic in Huai Kha Khaeng wildlife sanctuary, Thailand during 1987- 1989. The major prey of the leopards was barking deer, although wild pigs, sambar, porcupine and hog badger were important secondary prey items. In another study on food habits of Indochinese leopards (*Panthera pardus delacouri*) in Kaeng Krachan national park, Petchaburi Province, Thailand, scat analysis revealed that feces were dominated by hog badger, *Arctonyx collaris* (44%), barking deer, *Muntiacus muntjak* (19.5%) and wild pig, *Sus scrofa* (7.3%) (Grassman, 1999).

In India too, dietary studies have found that leopards take a wide range of prey. Some food habit studies have been conducted on single species (Bagchi *et al*., 2003; Biswas and Sankar, 2002; Edgaonkar and Chellam, 2002 and Reddy *et al*. 2004), and there is information on diet selection and overlap between multiple species including tigers, leopards and dholes from southern India (Johnsingh, 1983 and Karanth and Sunquist, 1995), and on leopards and tigers (Sankar and Johnsingh, 2002) and lions and leopards (Chellam, 1993) in western India. Johnsingh (1992) found that out of 58 kills by leopard, 66% were of chital and 5% samber in Bandipur tiger reserve. Besides, cattle and village dogs were also killed by leopard. Sixty nine percent of leopard kills were found to weigh less than 50 kg. In Sariska tiger reserve leopard scats contained rodents (Sankar and Johnsingh, 2002). The leopards on the Mundanthurai plateau in Kalakad-Mundanthurai tiger reserve have been preying mainly on sambar (Sathyakumar, 1992). Black-naped hare (*Lepus nigricollis nigricollis*) and chital remains in scats accounted for 16.2% and 9.3% respectively. Although five of the nine leopard kills were of livestock, only 6.9% of scats contained livestock remains. Vegetation (grasses) was present in 4.6% of the scats. Whereas in Bandipur, the leopard kills were mainly chital (Andheria *et al*., 2007 and Johnsingh, 1983).

In Gir, 40 percent of leopard scats contained chital remains while langur remains were found in 25% of the scats (Chellam 1993). In subsequent study in Gir, an analysis of leopard scats showed that chital formed the major prey (27.74%), followed by monkey (14.25%), porcupine (7.24%), peafowl (6.37%), sambar (5.87%), hare (4.59%), civet (4.60%), feral dogs (4.59%), livestock (12.50%) and others (12.06%) (Srivastava, 1999). Singh *et al*. (1999) also analysed 102 scats of leopard in the Gir proteced area and reported that 28% of the scats contained chital hairs and 14.7% contained the remains of monkey, about 10% of the scats contained feathers, presumably of peafowl, and nearly 8% contained the remains of civet cat and sambar. Leopard living near urban areas of Munbai were found mainly dependent on domestic dogs and rodents (Edgaonkar and Chellam 1998).

In a study conducted in the Shiwalik hills of Rajaji national park, diet of leopards was comprised of chital (65%), langur (15%), barking deer (11%) and rodents (11%), and proportion of goral, nilgai and wild pigs was negligible (Johnsingh *et al*. 1993). In the Himalayas, Schaller (1977) found that leopards fed mainly on wild goats, but livestock and porcupine were also important dietary components. Mukherjee and Mishra (2000) studied the food habits of leopard in Majhatal Harsang wildlife sanctuary and reported that cattle remains were found in 33% of the scats (n=47), followed by langur (30%), goral (30%) dog (23%). Remains of buffalo, rodents, goat and hare occurred in less than 15% of the scats. Fifty percent of the scats contained the remains of a single prey species, 33% contained 2 prey species and 17% contained 3 prey species.

Edgaonkar and Chellum (2002) studied the food habits of leopard by analyzing scats in Sanjay Gandhi national park, a small, isolated, prey-poor protected area abutting Mumbai city and concluded that the leopard were adapted to its prey impoverished habitat by feeding largely on domestic animals. The frequency occurrence of domestic dog was 63.7%, followed by domestic buffalo (14.8%), rodents (26.1%), primates (11.4%), cervids (9.1%) and others (5.7%). The relative biomass consumed by leopard was also highest for domestic dog (0.58) followed by domestic buffalo (0.14), rodents

(0.05), primates (0.10) and cervids (0.11). K. Sankar and A. J. T. Johnsingh (2002) analysed 125 leopard scats and found 61% scats contained single prey species, 33% contained two prey species, 5% contained three prey species and 1% contained four prey species. Remains of rodents (largely Indian gerbillle *Tatera indica*) and insectivore (grey musk shrew *Suncus murinus*) were found in 45.6% of the leopard scats, and chital, sambar and nilgai were found in 20.8%, 20%, and 7.2% of the leopards scats respectively. Sambar contributed the maximum (34.55%) biomass to the diet of leopard, followed by rodents and insectivores (23.19%), chital (19.32%) and nilgai (15.41%). Arivazhagan *et al*. (2007) studied the food habits of leopard (*Panthera pardus fusca*) in Singur and Thalamalai reserve forests of Tamilnadu and found that chital (*Axis axis*) was the major prey of leopard in both areas. Chital was found in 40% leopard scats in highly disturbed area and 65% in the less disturbed area. Other important prey species were sambar (*Cervus unicolor*), blackbuck (*Antilope cervicapra*), black napped hare (*Lepus nigricolis*), Indian wild boar (*Sus scrofa*), Indian porqupine (*Hystrix indica*), common langur (*Semnopithecus entellus*), and Indian pea fowl (*Pavo cristatus*). A study conducted on food habits of leopard in Dachigam national park revealed the presence of nine prey species in the diet (Shah *et al*., 2009). The major prey items were dog, langur, hangul and rodents with frequency occurrence of 21%, 21%, 18.4% and 15.7% respectively. In this chapter, the food habits of leopard in human altered landscapes in Mandi district have been presented.

6.2 Methods

6.2.1 Relative abundance of prey species

The Mandi district, the study area, has a very low density of wild ungulates. So it was not possible to obtain absolute density estimates for the prey of the leopard. The relative estimate (abundance) of wild and domestic prey species was based on their direct sightings and indirect evidences along the forest trails or transects in the study area. The encounter rates were calculated on the basis of diurnal sightings of wild and domestic prey species.

Faecal matter or pellets were found to persist on the forest floor for a long time, enabling detection of prey species. Dung or pellet groups were found to reflect both nocturnal and diurnal relative abundance of prey species. The indirect evidences such as diggings of wild pig, pellets of hare and quills and digging signs of porcupine were recorded. Similarly the indirect signs of the presence of buffalo, cattle and horse/mule were in the form of dung, and goat and sheep were pellets and dog were the faecal matter. So the relative abundance was obtained by counting pellet groups of faeces of potential prey species along the forest trails.

6.2.2 Food habits

To determine the food habitat of a carnivore, availability of prey species is an important factor (Leopold and Krausman, 1986). Scats are commonly used to determine the food habit, as it is non-destructive technique (Bailey, 1993 and Mukherjee *et al.*, 1994). However the nocturnal food habits of leopard primarily do not permit collection of adequate information based on direct observations on their feeding behavior. So the data on composition and seasonal variation in leopard diet were based on scat analysis.

6.2.3 Collection of scats

A total of 390 scats were collected opportunistically as well as systematically from different habitats including den sites all over the study area as and when encountered during the field work or walking on forest trails (transects) or during village survey work during 2004 to 2008. These scats were differentiated from other co-existing carnivore species based on their shape, size and associated signs like scraps and tracks (Norton *et al*., 1986; Rabinowitz, 1989 and Chauhan, 2009). Leopard was the only big cat found in most part the study area so in the absence of tiger and lion; it was easy to identify its scat from other small predators without any confusion. There was a possibility of confusing leopard scats with the faeces of dogs in the study area. Scats were considered to be leopard scats if they had pointed ends and many lobes in relation to their size or if they were associated with the pug marks or scraps (Edgaonkar and Chellum, 2002). Scats that did not meet the shape, size or sign criteria were discarded.

For each scat, information on date and time of its collection, GPS location, habitat (vegetation type), size (diameter), number of segment and its dry weight was recorded. Diameter of thickest, medium and thinnest part of scat was measured by digital vernier caliper. Scats collected in polythene bags were sun dried and stored in air tight bags for further analysis in the laboratory.

6.2.4 Sample size adequacy

Firstly, we calculated the minimum number of scats required for the analysis, which could provide significant results. On the basis of number of prey items and scats, items/species area curve was plotted to find minimum numbers of scats required. Out of the total 390 scats, 132 scats of winter season, 118 scats of monsoon season and 140 scats of summer season.

To check for the stability of percent frequency of occurrence in the diet, all scats were randomized and the percent frequency of occurrence of each prey item in the diet was plotted cumulatively with the help of software EstimateS 8.2.0. The number of scats required to reach an asymptote was considered sufficient to quantify that prey item in the diet reliably (Edgasonkar, 2008). At least 40 scats were collected every season.

6.2.5 Scat analysis

Based on preliminary examination of leopard scats, broadly the occurrence of prey items were determined. These scats were processed for analysis. These scats were subsequently washed in flowing water through a fine (<1mm) sieve (Cunningham *et al*., 1999; Anndheria *et al*., 2007 and Chauhan, 2009). The sieved prey remains, grass and soil were sun dried and oven dried (60°) in thin paper bags for 2-3 days to avoid fungal growth. The dried scat samples were then labeled and stored in airtight bags.

The hairs of prey species, which passed out undigested through the gut of predators was primary source of information for identifying the prey consumed (Sunquist, 1981; Mukharjee *et al*., 1994a, b; Karanth and Sunquist, 1995 and Anndheria *et al.,* 2007; Edgaonkar, 2008 and Chauhan, 2009). At least fifteen hairs, sufficient to document the presence of multiple prey species in scats, were taken from each scat. So the undigested remains of hairs were mounted on a slide to study the medullary and cuticular pattern. The identification was based on the general appearance of hair, colour, relative length, relative width, texture, basal configuration, cortex pigmentation, medullary width and pattern as described by earlier workers (Moore *et al.*, 1974; Putman, 1984; Karanth and Sunquist, 1995; Mukherjee *et al*., 1994; Sujai, 2004; Edgaonkar, 2008 and Chauhan, 2009). Prey species were identified based on the microscopic hair analysis and compared under a microscope with a reference collection of hairs of different prey species as per the standard protocol developed at the Wildlife Institute of India.

Reference hair samples were collected from all domestic livestock species representing the study area. Hairs were collected tufts from different body parts, which include a representative of all hairs types. References hair sample of wild ungulate species were collected from laboratory of Wild life

Institute of India. Hair was cleaned in an ether- alcohol mixture and dried on blotting paper. The hair sample of each species was than studied with respect to medullary and cuticular patterns (Brunner and Coman, 1974; Oli, 1993 and Mukherjee *et al*., 1994)

(a) Medullary patterns

Cleaned hair sample was placed on microscope slide. Individual hair was well separated from each other to avoid an untidy jumble of hair on the slide. Long hairs were cut into 2 or more pieces before they were placed on the glass slide. DPX was used as temporary mounting medium and slide was covered by cover slip for further study under microscope. Medullarly pattern of different wild and domestic prey species have shown in **Plate 1 to 3.**

(b) Cuticular characteristics

Gelation solution was prepared by mixing gelatin powder in boiling water and a few grains of methylene blue were added it. A thin layer of gelatin solution was applied to one side of microscope slide. Cleaned dry hair were placed on the slide and then allowed to dry. Hairs were than removed by using forceps and scale pattern were studied under microscope at standard magnification (400X) by using Leica DMLB microscope with digital micro photographic attachment. Cuticular characteristics of different wild and domestic prey species have been shown in **Plate 4 to 7**.

6.2.6 Species identification from scats

Scats were soaked, macerated in water and washed with tap water in a fine mesh sieve (1.58mm).Washed samples were oven dried at a temperature of 65C. Components of sample including hair, bones, teeth, feathers, scales, claws, and hooves remains were than separated and stored in individual plastic bag. To create permanent slides for species, five slides were made per scat sample. Fifteen hairs were taken from each scat as Mukherjee *et al*. (1994) reported that fifteen hairs are sufficient to document the presence of multiple prey species in scats. Whole mount (medulla) and scale pattern (cuticular) were prepared according to the methods described above. Hairs were identified by comparison with the reference slide of wild and domestic species. Prey species were also identified based on hard parts (bones, teeth, feathers, scales, claws, and hooves) present in the scats.

Prey species were also identified based on presence of bone fragments, teeth, nails, feathers, scales, claws and other hard parts as described by Grobler and Wilson (1972) and Mukherjee *et al*. (1994). Bird and rodent taxa were not identified to species level.

6.2.7 Frequency of occurrence, relative biomass and relative number of prey species consumed

The frequency of occurrence (proportion of total scats in which an item was found) and percent occurrence (number of times a specific item was found as a percentage of all items found) were calculated. Programme SIMSTAT was used to compute the 95% confidence intervals for the percent occurrence generated from 1000 bootstrap simulations (Tibshirani, 1993).

It is found to be biased towards smaller sized prey, since relatively more scats are produced for smaller prey than larger prey. If the body sizes of different prey items are highly variable, frequency of occurrence can be a misleading metric because of the surface and volume ratio problem as indicated before by Floyd *et al*. (1978) and Ackerman *et al*. (1984). Because of relatively greater surface area in relation to volume in smaller prey types, their consumption result in production of relatively more predator's scats compared with larger prey types. This leads to an over estimation of the proportion of small prey and underestimation of large prey in predator diet profiles when the frequency of occurrence is used as a measure.

To overcome this problem, Floyd *et al*. (1978) and Ackerman *et al*. (1984) developed regression equations by conducting feeding trials on wolves (*Canis lupus*) and cougers (*Puma concolor*) respectively in captivity using known prey of different sizes. Later Karanth and Sunquist (1995) also adopted these regressions in their dietary studies of tigers, leopard and dhole in Nagarhole. However giving the logistic in conducting the species-specific trials, they adopted the regressions developed for cougars for tigers and leopards and those of wolves for dholes. This approach for correcting diet frequency data was also successfully used by Biswas and Sankar (2002) for tigers and Sujai (2004) for tigers, leopard and dholes.

These regression equations relate the independent variable, the average weight of a prey animal consumed (X) to the dependent variable, the number of field collectable scats for the weight of consumed prey biomass (Y). The dependent variable can be converted into the relative biomass of prey consumed by multiplying it by the relative frequency of each prey species found in the scats. The relative number of each species consumed is obtained by dividing relative biomass by the average weight of the prey species.

$Y = 1.980 + 0.035X$ (For tigers and leopard)

$Y = 0.035 + 0.02X$ (For dhole)

The term Y is used as a correction factor and multiplied to the observed frequency of occurrence data, to correct the over-representation of smaller prey. Using the correction factor Y, the relative biomass and the relative number of a prey species consumed were estimated as given below:

$D = (A \times Y)/\Sigma(A \times Y) \times 100$

$E = (D/X)/\Sigma(D/X) \times 100$

The weights of various prey species killed by leopard analysed in this study were based on Karanth and Sunquist (1995). The prey species were categorized into three size classes, with cattle and buffalo being classified as large prey (>50 kg), sheep, goat and pig as medium sized prey (between 20 and 50 kg) and dog, langur, hare and porcupine being classified as small prey (between 5 and 30 kg). Prey species like mongoose and rodents having < 5 kg body weight were also a part of the analyses.

Accordingly, we also followed these regression equations to calculate the relative biomass consumed and relative number of species consumed. The relative number of each species consumed was obtained by dividing relative biomass by the average weight of the prey species. The frequency of occurrence of different species was calculated along with their bootstrap confidence intervals. The 95% confidence intervals for these frequency occurrences were generated from 1000 bootstrap simulation following the method of Tibshirani (1993) and Edgaonkar (2008). Prey composition was estimated in terms of frequency occurrence of food items in the scats and % dry weight of each item was calculated. Variation in dietary composition in different seasons, summer (March-June), monsoon (July-October) and winter (November-February) was estimated. Kruskal-Wallis test was used to determine the seasonal variation in the overall dietary composition. Post Hoc test was used to determine any seasonal variation in the livestock consumption.

6.3 Results

The relative abundance of wild and domestic prey species was based on their direct sightings and indirect evidences or a sign along the forest trails or transects in the study area. The indirect evidences such as diggings of wild pig, pellets of hare and quills and digging signs of porcupine were recorded. Similarly the indirect signs of the presence of buffalo, cattle and horse/mule were in the form of dung, and goat and sheep were pellets and dog were the faecal matter.

6.3.1 Relative abundance of wild prey

Among the wild prey species, monkey, langur, wild pig, hare, monitor lizard, mongoose, porcupine and birds were sighted on walking trails (n=31) during the field work. The mean encounter rates i.e. number of individuals per km (mean±S.D.) of different wild prey species based on direct sighting and indirect evidences are presented in **Figure 1**. These encounter rates of the wild prey species were tested with one-way ANOVA test to check whether these values had any significant variation across seasons or not.

The observed mean encounter rate of monkey was highest (3.81±3.28) as compared to other prey species. The mean encounter rates of monkey did not show significant variation (f=0.72, df=2, p=.489) across seasons; it was 4.42 in winter, 3.24 in monsoon and 3.76 in summer. The mean encounter rate of langur was 0.14±0.56. The encounter rate did not show significant variation (f=0.11, df=2, p=.892) in different seasons; it was 0.17 in winter, 0.16 in monsoon and 0.10 in summer. The encounter rate of wild pig based on the direct sighting was 0.06±0.19. The encounter rate did not show significant variation (f=0.49, df=2, p=.608) across different seasons; it was 0.03 in winter, 0.10 in monsoon and 0.04 in summer. On the basis of indirect signs, the mean encounter rate of wild pig was 0.30±0.34, and it did not vary significantly (f=0.98, df=2, p=.377) across different seasons; it was 0.25 in winter, 0.39 in monsoon and 0.28 in summer.

The mean encounter rate of hare on the basis of direct sighting was 0.29±0.18. The mean encounter rate did not vary significantly (f=0.52, df=2, p=.596) across different seasons; it was 0.33 in winter, 0.30 in monsoon and 0.26 in summer. But on the basis of pellet group count, the encounter rate of hare was 0.68±0.32, and it varied significantly (f=5.75, df=2, p=.004) across different seasons; it was 0.74 in winter, 0.48 in monsoon and 0.83 in summer. Based on the direct sighting, the encounter rate of monitor lizard was 0.06±0.09. The encounter rate did not vary significantly (f=0.09, df=2, p=.907) across different seasons; it was 0.06 in winter, 0.05 in monsoon and 0.07 in summer. Likewise the encounter rate of mongoose on the basis of direct sighting was 0.14±0.12. The encounter rate of mongoose did not show significant variation (f=1.95, df=2, p=.147) across different seasons; it was 0.09 in winter, 0.12 in monsoon and 0.20 in summer. There was no direct sighting of porcupine while walking the trails. But on the basis of indirect signs like digging and presence of quills (spines), the mean encounter rate of porcupine was 0.14±0.13. The encounter rate did not vary significantly (f=1.79, df=2, p=.172) across different seasons; it was 0.11 in winter, 0.18 in monsoon and 0.12 in summer. On the basis of direct sighting, the mean encounter rate of birds was 2.18±1.23. The encounter rate varied significantly (f=5.88, df=2, p=.004) across different seasons; it was 2.10 in winter, 1.59 in monsoon and 2.85 in summer.

6.3.2 Relative abundance of domestic prey

Among the domestic prey species, goat, sheep, cattle, buffalo and dog were sighted on walking trails during the field work. The mean encounter rates (i.e. number of individuals per km) of different livestock are presented in **Figure 2**. These encounter rates of the domestic species were tested with one-way ANOVA test to check whether these values had any significant variation across seasons or not.

The observed encounter rate of sheep was relatively high, followed by goat, cattle, buffalo, horse/mule and dog. On the basis on direct sighting, the observed mean encounter rate of sheep was 5.04±5.59. The encounter rate of sheep varied significantly (f=5.07, df=2, p=.008) in different seasons; it was 9.38 in winter, 2.14 in monsoon and 3.61 in summer. On the basis of pellet group count, the mean encounter rate of sheep was 4.78±2.60. The encounter rate of sheep was 7.00 in winter, 2.81 in monsoon and 4.52 in summer; it showed significant variation (f=9.8, df=2, p=.000) across different seasons. Similarly the mean encounter rate of goat based on direct sighting was 4.89±6.33 and it varied significantly (f=3.80, df=2, p=.025) across seasons; it was 9.13 in winter, 1.99 in monsoon and 3.55 in summer. Based on pellet group count, the mean encounter rate of goat was 4.7±2.46 and varied significantly (f=9.84, df=2, p=.000) in different seasons; it was 6.70 in winter, 2.77 in monsoon and 4.80 in summer. The mean encounter rate of cattle sighted was (1.70±0.77) and it also varied significantly (f=9.83, df=2, p=.000) across seasons. The encounter rate of cattle was 2.11 in winter, 1.16 in monsoon and 1.84 in summer. The mean encounter rate of cattle on the basis dung count was 1.90±0.73. The dung encounter rate also varied significantly (f=7.38, df=2, p=.001) in different seasons; it was 2.25 in winter, 1.44 in monsoon and 2.01 in summer. Likewise the mean encounter rate of buffalo based on direct sighting was 1.19±0.87 and varied significantly (f=3.39, df=2, p=.037) across seasons. The sighting rate of buffalo was 1.30 in winter, 0.80 in monsoon and 1.46 in summer. Based on the dung count, the mean encounter rate of buffalo was 1.36±0.97 and it was marginally significant (f=3.11, df=2, p=.049) across different seasons; it was 1.51 in winter, 0.95 in monsoon and 1.63 in summer.

Whereas the mean encounter rate of horse and mule based on direct sighting was 0.78±0.85 and it showed no significant variation (f=0.71, df=2, p=.490) across seasons; it was 0.95 in winter, 0.66 in monsoon and 0.74 in summer. Based on dung count, the mean encounter rate of horse/mule was 1.00±0.97 and it did not vary significantly (f=1.34, df=2, p=.266) across different seasons; it was 1.25 in winter, 0.81 in monsoon and 0.94 in summer. The mean encounter rate of dog based on direct sighting was 0.18±0.20 and there was no significant variation (f=0.71, df=2, p=.063) across seasons; it was 0.31 in winter, 0.12 in monsoon and 0.11 in summer. Based on the count of faecal matter of dog, the mean encounter rate was 0.36±0.35 and it did not show significant variation (f=1.01, df=2, p=.367) across seasons; it was 0.41 in winter, 0.27 in monsoon and 0.39 in summer.

So the results of one-way ANOVA test showed that the encounter rates of horse, mule and dog did not vary significantly across seasons.

6.3.3 Food habits

One of the important aspects in studying the food habits of carnivores is to find the number of scats required to get the accurate picture of the diet of the leopard (Mukherjee *et al*., 1994 and Edgaonkar and Chellam, 1998). These studies revealed that minimum of 55-80 scats were needed to determine the diet of leopard. For this purpose, observation area curves in terms of frequency of occurrence of species and number of scats collected were developed to find minimum number of scats required annually and during different seasons i.e. summer, monsoon and winter seasons.

A total of 390 scats were collected in different seasons from the study area. On the basis of food item/species area curve, minimum of 115 out of 132 scats in winter, 113 out of 118 scats in monsoon and 126 scats out of total 140 scats in summer were required to know the dietary composition of leopard **(Figure 3)**. Analysis of these 390 scats showed that all the food items were represented in as minimum as 295 scats. So all the scats collected during summer, winter and monsoon seasons were analysed, and the proportion of food items and seasonal variation in dietary pattern was found out.

Different prey species including wild and domestic were found out through identification of the food remains and hairs present in the scats. A comparison of the hair medullary and cuticular characteristics were compared with reference slides showed presence of both wild and domestic prey species in the diet of leopard **(Plate 1 to 7)**. **Annexure 1 and 2** show the hair medullary and cuticular patterns of different prey species. Portions of other hard parts present in the scats were also identified. Based on scat analysis, the dietary composition of leopards and seasonal variation in their food habits were found.

6.3.4 Dietary composition

An analysis of total 390 scats, comprising of 132 scats of winter season, 118 scats of monsoon season and 140 scats of summer season, showed 13 different prey species in the diet of leopard in Mandi district. Out of which, 11 were mammals, one was reptile and others were birds. Birds were considered as one prey item in the leopard diet. All these prey species constituted parts of its diet throughout the year. But the rodents, sheep, goat, cattle and birds were frequently eaten by leopard, followed by langur, hare, buffalo, wild pig, reptile, dog, porcupine and mongoose. While attempting to kill and eat a civet, leopard fell in the well. When all the scats were analysed, leopard was found to prey upon on single prey species 332 times (85.1 %) and two species 56 times (14.4%). Only two times (0.5%), leopard preyed on three different species. But rodents and sheep were found maximum times in scats (n=14), followed by goat and rodents (n=8), goat and birds (n=7), rodents and reptiles (n=4), rodents and birds (n=3), and goat and langur and sheep and cow (n=2 each), and rest prey items were preyed in combination of two species 14 times.

Among wild prey species, the frequency occurrence of rodents was 28.9% in the diet, followed by birds (7.1 %), langur (*Semnopithecus schistaceus*) and hare (*Lepus nigricolis*) (2.7% each), wild pig (*Sus scrofa*) and reptile (1.8% each), porcupine (*Hystrix indica*) (1.3%) and mongoose (*Herpestes* sp.) (0.2%) **(Figure 4)**. **Plate 8 and 9** show the bones and teeth of rodents respectively in the scat of leopard. Whereas among domestic prey, the frequency occurrence of sheep (*Ovis aries*) was highest (22.9%), followed by goat (*Capra hircus*) (14.9%) and cattle (*Bos taurus*) (9.1%). Buffalo (*Bubalus bubalis*) and dog (*Canis familiaris*) were also preyed upon and the frequency occurrence was found to be only 2.7% and 1.6% respectively in the diet **(Figure 4)**. Leopard were found to prey mainly on rodents and sheep and goats because there was scarcity of other wild prey species like sambar (*Cervus unicolor*), chital (*Axis axis*), barking deer (*Muntiacus muntjak*) and nilgai (*Boselaphus tragocamelus*) in the study area. The scat analysis also revealed occurrence of plant matter (2.2%) and soil (0.2%) in diet of leopard. **Plate 10** shows hairs of goat in the scat of leopard. **Plate 11** shows the carcass of a cattle killed and eaten by leopard in Mandi district. **Plate 12** shows a leopard in a well alongwith a palm civet.

6.3.5 Percent composition

The total samples of 390 scats were subjected to re-sampling to get the confidence limits on the mean percent frequency occurrence of prey species in scats as followed by Reynolds and Aebischer (1991), Edgaonkar and Chellam (1998) and Sujishnu *et al*. (2006). This was done by using bootstrapping method (SIMSTAT computer programme) and using 500 sub-sampling with 390 observations bias corrected at 95% confidence limit.

The diet of leopard was found to have higher proportion of domestic prey species (59%) than wild prey (53.7%) **(Figure 5 and 6)**. Among wild prey species, the mean percent occurrence of rodents was 33.3% in the diet, followed by birds (8.2%), langur and hare (3.1 % each), wild pig and reptile (2.1 % each), porcupine (1.5%) and mongoose (0.3%) **(Figure 5**). Whereas among domestic prey species, the mean percent occurrence of sheep was highest (26.4%), followed by goat (17.2%) and cattle (10.5%). Buffalo and dog were also preyed upon and the frequency occurrence was found to be only 3.1% and 1.8% respectively in the diet **(Figure 6)**. In addition to prey species, plant matter and soil were also found present in diet of leopard and their mean percent occurrence was 2.6% and 0.3% respectively.

6.3.6 Seasonal dietary pattern

Seasonal variation in the dietary composition was found out; the summer season was from March to June, monsoon season was from July to October and winter season was from November to February. An analysis of 140 scats of summer, 118 scats of monsoon and 132 scats of winter season showed some variation in the dietary pattern of leopard in different seasons. The wild prey species found were rodents, birds, langur, hare, wild pig, reptile, porcupine and mongoose, and the domestic prey species were sheep, goat and cattle, buffalo and dog. During summer season, leopard preyed on single species 116 times, on two species 22 times and on three species 2 times. During winter season, leopard preyed on single species 107 times and on two species 24 times. Whereas, leopard preyed on single species 108 times and on two species 10 times during monsoon season.

Although the prey species found were the same in different seasons, but the frequency occurrence of these items showed differences in summer, monsoon and winter seasons **(Figure 7)**. The frequency of occurrence of wild prey items was 40.3%, 54% and 47% and domestic prey species was 59.7%, 46% and 53% during summer, monsoon and winter respectively. In the seasonal diet of leopard, the frequency occurrence of rodents was highest in monsoon (35.16%), followed winter (28.39%) and summer (24.7%), and among the wild prey species, and sheep and goat constituted the highest frequency occurrence in higher in summer (51.8%), winter (36.12%) and monsoon (21.87%) among the domestic prey species **(Table 1, Figure 8 and**

9). Thus the frequency occurrence of rodents was highest in all seasons, and sheep and goat also contributed the major part of the diet of leopard in all seasons in the study area.

Kruskal-Wallis was used to determine any seasonal variation in the dietary composition. Kruskal-Wallis test revealed that there was significant difference of overall prey number per scat sample (p=0.044) **(Figure 10)**. To check this seasonal difference further, we made three categories of leopard prey item viz. wild prey items, livestock and dog, and used different test to determine the seasonal variation in the dietary composition in each category.

Kruskal Wallis test revealed that there was no significant difference of wild prey item number per scat sample across the seasons (p=0.522) **(Figure 11)**. Livestock number per scat sample was found significantly different across seasons **(Figure 12)**. Post Hoc test revealed that maximum significant difference of livestock number per scat sample was between monsoon versus summer (p=0.000). There was marginal difference of livestock number per scat sample between winter versus summer (p=0.023) and there was no significant difference of livestock number per scat sample between winter and monsoon (p=0.162). Similarly Kruskal Wallis test reveals that there is no significant difference of dog number per scat sample across the seasons (p=0.867).

6.3.7 Biomass consumption

Estimation of the relative biomass contribution of different prey species to leopard diet using the equation developed by Ackerman et- al. (1984) gave a better assessment of the prey use than results obtained in terms of frequency occurrence. The relative biomass and relative number of individuals of prey species consumed by leopard are given in **Table 2, Figure 13 and 14**. When the measures of prey intake i.e. viz. frequency of occurrence, relative biomass consumption and relative numbers of different prey species killed were compared, the relative importance of different prey species varied considerably.

Domestic prey species contributed more biomass (66.3%) to the diet of leopard as compared to the consumption of wild prey biomass (33.7%). The large size prey species (cattle, buffalo) contributed 26.4% of the prey biomass to the diet of leopard, medium size prey (sheep, goat, dog, wild pig and langur) contributed 44.0% of prey biomass and small prey (hare, rodents, porcupine, mongoose, reptiles and birds) provided 29.6% of biomass consumed. Sheep contributed the maximum biomass (23.4%) to the diet of leopard, followed by rodents (20.1%), cattle (19.7%), goat (15.0%), and buffalo (6.7%) **(Figure 13)**. Large wild prey species were not present in the diet of leopard and medium wild preys were not contributing significantly to the consumed biomass of leopard. In terms of relative number of individuals consumed, rodents were the dominant prey (90.7%) compared to rest of the wild and domestic prey species **(Figure 14)**. The relative number of wild and domestic individuals consumed by leopard, except dominant rodents varied from 0.1 % to 3.2%.

6.4 Discussion

Availability of prey is an important factor to determine the food habit of a carnivore (Leopold and Krausman, 1986). In the study area, Mandi district, there was very low density of wild ungulates. Among the wild prey species, monkey, langur, wild pig, hare, monitor lizard, mongoose, porcupine and birds were occasionally sighted. The domestic prey species on which the predators were dependent for their food were goat, sheep, cattle, buffalo and dog. Mosaic of forest areas, agricultural land and human habitation provided a mix of habitats to leopard. Availability of wild prey in these habitats varied from area to area, whereas the domestic prey species were found every where. Large number of sheep and goat were brought to forest areas and pastures for grazing.

6.4.1 Prey abundance

The direct sighting of prey species and indirect signs such as dung or pellet group count were quite useful in establishing the presence and estimating relative abundance of prey species. Previous studies have shown that despite of the variety of field techniques for mammalian survey, all the methods can not be effectively applied in different ecosystems and for all species (Smallwood and Fitzhugh, 1995 and Silveira *et al.*, 2003). Pellet or faecal matter count method was likely to be applicable for recording species like wild pig, langur and porcupine. While direct sighting method was found suitable and effective for estimating relative abundance of barking deer.

In this study, one of the important objectives was to estimate the abundance of wild and domestic prey species. As stated before, the study area was found to hold a low wild prey density. However monkey was found to be the most abundant prey species, followed by common langur, wild pig, sheep, goat cow, buffalo, horse, mule and dog. The mean encounter rate of monkey was highest as compared to other prey species like langur, wild pigs based on direct sighting and indirect signs. The encounter rates of monkey did not show significant variation during winter, monsoon and summer. It was quite evident that monkey population was high and monkey troops were found distributed in all parts of the district. The monkey troops could be sighted in forests and human habitation interface including agricultural areas throughout the year. So they were the easy prey of leopard in all the seasons. The encounter rate of langur was less compared to monkeys and there was no significant variation in different seasons. Likewise wild pigs were found scattered and occasionally seen mainly in lower elevations. Based on direct sighting and indirect evidences, the encounter rate of wild pig was also very less and there was no significant variation in different seasons. Barking deer and nilgai were not found as dietary component; it could be due to their low numbers and sparse distribution in these areas.

The dietary habits of leopard were found correlated with availability of prey species in the study area. But prey species constituted significant part of the diet of the predator. In human dominated hilly landscapes of lower Himalayas, sambar, monkey, barking deer, wild pigs, porcupine, rodents, cattle, goat and sheep were found to be the prey species and their abundance determined the dietary pattern of leopard. Whereas in protected areas, sambar, spotted deer, barking deer, nilgai, wild pig, rodents were identified as major prey species of leopard. The studies carried out in different protected areas across the country also showed that the dietary habits of leopard was correlated with availability and density of different prey species (Johnsingh 1983; Ramakrishnan *et al.*, 1999 and Sankar and Johnsingh, 2002). In all these studies, the frequency of the prey species consumed by leopards was related to their abundance.

As compared to the abundance of the prey species found in this study, the animal density or abundance was very high in protected areas. In Sariska national park, density of chital, sambar, nilgai and wild pig was very high (Sankar, 1994; Khan *et al.* 1996; Karanth and Nichols, 1998; Chundawat *et al.*, 1999; Biswas and Sankar, 2002; Bagchi *et al.*, 2003, 2004; Singh *et al.*, 2005 and Mondal, 2006). The presence of water bodies, salt licks, availability of the preferred grass species, and fallen *Zizyphus mauritiana* fruits and fallen leaves of *Anogeissus pendula* might be contributing to the high density of wild ungulates in Sariska. Nilgai and sambar densities were always found very high (Sankar, 1994 and Avinandan *et al.*, 2008). A high density of sambar in Sariska was attributed to hilly terrain, varied habitats and availability of food plants in diverse habitats in the valley. In Mandi district, low abundance of the prey species might be due to disturbed habitat conditions, high biotic pressure and poaching factor.

Among domestic preys, the encounter rate of sheep and goat based on direct sighting and pellet group count was relatively high in the study area, followed by cattle, buffalo, horse/mule and dog. High encounter rate of sheep and goat in the study area was due the presence of local livestock population as well as livestock brought in large numbers to the forest areas and pastures for grazing. The encounter rate of cattle and buffalo was 1.70 and 1.19 respectively based on direct sighting, and it was 1.90 and 1.36 respectively based on dung count. As compared to these prey species, the encounter rate of horse and mule was less than half. The encounter rate of dog based on direct sighting and faecal matter was the least. Cow, bull, buffalo and dog showed sparse and scattered distribution and perhaps because of this reason, the encounter rates of domestic animals were less in the study area.

There was no significant seasonal variation in the encounter rate or abundance of wild prey species of leopard. But cattle, sheep and goat showed significant variation between different seasons. The observed encounter rate for sheep and goat in winter season was quite high. As mentioned above, Nomadic graziers were seasonally migrating to different parts of the state for grazing their sheep and goat. The agro-pastoral Gaddi community, numbering over 100,000 people, were found to migrate with their goats and sheep semi-annually between the alpine meadows of the Himalaya in summer and scrub forests of the Siwaliks, the Himalayan foothills, in winter (Saberwal, 1996). The Gaddis were found to spend the summer in the alpine meadows of Bara Banghal, a part of Kangra district of Himachal Pradesh, and the winter in various parts of the Siwalik mountain range including Mandi district. The intensity of grazing in Sarkaghat tehsil of Mandi district was almost ten times more as compared to some other areas of Siwalik mountain areas. Perhaps this could be the reason for significant variation in the number of sheep and goat during winter, monsoon and summer. The encounter rate of cattle and buffalo also varied significantly across seasons. Villages were found to restrict movement of livestock from going outside in forests during rainy and winter seasons. Dogs were found throughout the year in the vicinity of villages. Thus there was no significant variation in the encounter rate of dogs between different seasons.

6.4.2 Frequency

Analysis of total 390 scats showed 13 different prey species in the diet of leopard in Mandi district. Out of which, 11 were mammals, one was reptile and others were birds. All these prey species constituted parts of the diet of leopard throughout the year. But the rodents, sheep, goat, cattle and birds were frequently eaten by leopard, followed by langur, hare, buffalo, wild pig, reptile, dog, porcupine and mongoose. So the predator was mainly dependant on domestic species in the study area.

The prey species of leopards varied in different geographical areas. Several studies conducted in the past on prey selection and feeding habits showed that leopards fed on variety of prey species in their range of occurrence (Mills, 1984; Reddy *et al.*, 2004; Arivazhagan *et al.*, 2007 and Ramesh *et al.*, 2008). Previous studies revealed that leopards were found to select prey smaller than themselves (Johnsingh, 1983; Hes, 1991; Karanth and Sunquist, 1995; Rabinowitz, 1991; Schaller, 1972 and Sunquist, 1981). In Kruger national park, South Africa, leopards were found to kill mainly medium-sized prey such as impala (*Aepyceros melampus*), though a wide variety of small animals including hyraxes, civets and mongooses also constituted part of their diet (Bailey, 1993). In Tai national park, Ivory Coast, leopards were found to prey upon about 30 species of animals (Hoppe-Dominik, 1984). Small prey also constituted a significant proportion of leopard diet in Tsavo, Kenya (Hamilton, 1976). Bothma and Riche (1984) found that in the Kalahari desert, leopards fed on small prey like bat-eared fox (*Otoeyon megalotis*), jackal (*Canis* spp.), genets (*Genetta* spp.), hare (*Lepus* spp.), duiker (*Cephalopus* spp.) and porcupine (*Hystrix* spp.). In the Serengeti, Tanzania, 30 species in a sample of 150 leopard kills were found Bertram (1978). Muckenhirn and Eisenberg (1973) reported that in Sri Lanka, leopards preyed mainly on chital and wild pigs, while they also preyed upon sambar, common langur, black-naped hare (*Lepus nigricollis*), Indian porcupine (*Hystrix indica*) and calves of domestic buffalo. In Wolong reserve, Sichuan, China, 15 species of large and medium-sized mammals constituted the diet of Asiatic leopards (Johnson *et al.*, 1993). There was dominance of pheasants, livestock and grasses in the diet of leopards, and soil was eaten occasionally. Sunquist and Sunquist (1989) proposed that large felids, especially leopards, foraged optimally with differences in food habits reflecting differences in availability and vulnerability of various prey species. In the Kalahari desert where large preys were relatively scarce, leopards selected more small prey, which perhaps facilitated coexistence of leopard with lions (Bothma and LeRiche, 1986). In Kaeng Krachan national park, Thailand, leopards utilized at least nine prey species, and hog badger (*Arctonyx collaris*) occurred in 41% of total feaces, while other important prey species included barking deer and wild pig (Grassman, 1999). Emmons (1987) working in a Neotropical rainforest with a diverse prey base reported that felids were found to hunt by opportunistic encounter of any readily captured prey and that most mammalian prey were consumed in about the ratios of their occurrence.

In India, leopards were reported to prefer and kill medium-sized wild and domestic prey species weighing between 10 and 70 kg (Schaller, 1972; Johnsingh, 1983; Santiapillai *et al.*, 1982 and Bailey, 1993). In most of the previous studies, chital was preferred among wild prey species (Johnsingh, 1983; Ramakrishnan *et al.*, 1999 and Sankar and Johnsingh, 2002). Leopard preference for this species could probably resulted from the ideal size and grouping tendency of chital (Bailey, 1993). Among other ungulates species, sambar was also significantly preferred. Schaller (1967), Johnsingh (1983), Karanth and Sunquist (1995, 2000) and Venkatraman *et al.* (1995) studied the food habits of leopard in selected protected areas and the major prey reported were chital, sambar, barking deer (*Muntiacus muntjak*), goral (*Nemorhaedus spp*.) and livestock. In the Mundanthurai plateau of Tamil Nadu, Sathyakumar (1992) reported that leopards preyed mainly on sambar, black-naped hare, chital and livestock. In Bandipur tiger reserve, Johnsingh (1983) found that 66% of leopard kills were chital. In another study in Bandipur, tiger, leopard and dholes were found to predate on 11 to 15 prey species; the relatively abundant ungulate species provided 88 to 97% of biomass consumed by these predators (Andheria *et al.*, 2007). Chellam (1993) found that in Gir, 40% of leopard scats were having remains of chital and 25% common langur. In another study in Gir, 28% of leopard scats contained hairs of chital, 14.7% scats contained hairs of monkeys, 10% feathers and 8% contained remains of civet cat and sambar (Singh *et al.*, 1999). In the tropical forest of Nagarhole, southern India, Karanth and Sunquist (1995) found that chital constituted the major prey base of leopards. Wild pig and barking deer were other ungulate species consumed by leopard. But a few studies suggested that wild pigs were too aggressive and dangerous to become prey of leopard (Eisenberg and Lockhart, 1972 and Ramakrishnan *et al.*, 1999). Other three studies indicated no significance of wild pig and barking deer in the diet of leopard (Johnsingh, 1983; Ramakrishnan *et al.*, 1999 and Sankar and Johnsingh, 2002). In Sanjay Gandhi national park, Maharashtra, the major prey species of leopard were found to be the domestic dog, buffalos and rodents (Edgaonkar and Chellam, 1998).

In Mandi area, leopards were found to prey upon on single prey species 332 times and two species 56 times. Only two times, leopard preyed on three different species. But rodents and sheep were found maximum times in scats, followed by goat and rodents, goat and birds, rodents and reptiles, rodents and birds, and goat and langur and sheep and cow. Rest of the prey items were preyed in combination of two species 14 times. The frequency occurrence of single prey species in scats was higher. This might be due to killing of single prey species most of the times by leopard in the study area. Bothma and Coertze (2004) also observed that leopard regularly killing a prey species maximum time in southern Kalahari region of Africa where population of this prey species had declined. In Gir national park, there was not much difference between scats containing single prey and scats containing two preys; and 6 scats showed three prey items (Maheshwari and Khan, 2006). There were in total 12 prey items recorded in the leopard scats. In our study also, killing of high frequency of small prey by leopard might be one of the survival strategies in the prey poor areas.

In the present study, the diet of leopard was found to have higher proportion of domestic prey species (59%) than wild prey (53.7%). Among wild prey species, the frequency occurrence of rodents was highest i.e. 28.89% in the diet, followed by birds (7.11 %), langur and hare (2.67% each), wild pig and reptile (1.78% each), porcupine (1.33%) and mongoose (0.22%). Similarly, the mean percent occurrence of rodents was highest i.e. 33.3% in the diet, followed by birds (8.2%), langur and hare (3.1 % each), wild pig and reptile (2.1 % each), porcupine (1.5%) and mongoose (0.3%). Rodents were most frequently eaten prey species. Among domestic prey, the frequency occurrence of sheep was highest (22.89%), followed by goat (14.89%) and cattle (9.11%). Though there was a sizeable population of buffalo and dog, they were preyed upon to only some extent by leopard. This might be due to sparse and scattered distribution of these prey species as mentioned before. Similarly the mean percent occurrence of sheep was highest (26.4%), followed by goat (17.2%) and cattle (10.5%). Buffalo and dog were also preyed upon and the mean percent occurrence was found to be only 3.1% and 1.8% respectively in the diet. Higher proportion of domestic prey species than wild prey in the diet of leopard could be due to higher encounter rate of domestic species and more predation on them in the study area. In addition to availability of domestic species in high proportion, their body size might also be ideal for predation by leopard. So the leopards were found to be mainly dependent on rodents and sheep and goats because there was scarcity of other natural wild prey species like sambar, chital, barking deer and nilgai in the study area.

In other studies also, leopards in absence or low density of wild prey were found to be adapted to live on domestic prey species. Perhaps this carnivore might have not taken livestock if wild ungulates prey would have been abundant as opined by Biswas and Sankar (2002) and Reddy *et al.* (2004). Such ability was undoubtedly a reason why leopards were found to survive close to human settlements (Sediensticker *et al.*, 1990). Livestock were recorded as a major component of the diet of leopards at the edge of Royal Chitwan national park where the densities of domestic ungulates in the peripheries were far more than those of wild ungulates inside the park (Seidensticker *et al.* 1990). Muckenhirn and Eisenberg (1973) reported predation on domestic buffalo calves by leopard in Sri Lanka. In Africa, the intensity of leopard predation on cattle and dog was high because these prey species were encountered more frequently than scarce prey (Bailey, 1993). Hamilton (1986) reported that leopard population was subsisted mainly upon livestock in western Kenya. In certain areas of Java island of Indonesia, leopards were largely subsisting upon cattle, village dogs and chickens (Santiapillai and Ramono, 1992). Seidensticker (1986) found that an abundant and diverse prey base in Chitwan national park resulted in the leopard taking macaque and langur only occasionally; while Schaller (1967) found leopard to be killing langur frequently in Kanha tiger reserve. Sediensticker *et al.* (1990) concluded that availability of domestic livestock allowed leopard to live at a higher density than could be supported by wild prey.

Likewise several studies conducted on the diet of these predators in the Indian subcontinent over the years (Schaller, 1967; Johnsingh, 1992; Chundawat, Gogate and Johnsingh, 1999; Mukherjee and Mishra, 2000; Reddy *et al.***,** 2004 and Dharaiya and Soni, 2010**)** revealed differential prey preferences and these were correlated with prey body size and their availability. In Sariska tiger reserve, chital, sambar and common langur constituted 47.2% of the diet of leopard (Sankar and Johnsingh, 2002). The higher percentage of rodent remains in leopard scats in Sariska tiger reserve could be attributed to high rodent and insectivore availability. Nocturnal grey musk shrew and Indian gerbille were common in the tiger reserve. Grobler and Wilson (1972) also reported a very high percentage of rodent remains in leopard scats in South Africa and the reasons attributed for this were the nocturnal habits and abundance of rodents. In Dachigam national park, the principal prey items were dog, langur, hangul and rodents with a percentage occurrence of 21.0, 21.0, 18.4 and 15.7 respectively (Shah *et al.*, 2009). Henschel *et al.* (2005) reported that leopards preyed mainly on ungulates, primates and rodents. Whereas Karanth and Sunquist (1995) reported that leopard fed on different prey species like langur, chital, chevrotain, porcupine etc. Rice (1986) observed that the diet of leopard in Eravikulum national park, Kerala consisted mainly of sambar (*Rusa unicolor*) and nilgiri tahr (*Nilgiritragus hylocrius*). Wild pigs were not found to be the important component of the diet of leopard in Gir national park (Mukherjee *et al.*, 1994), in Sariska national park (Sankar and Johnsingh, 2002) and in Bandipur (Johnsingh, 1992) or Nagarhole (Karanth and Sunquist, 1995). According to Edgaonkar and Chellam (1998), the major prey of leopard was found to be the domestic dog, domestic buffalos and rodents in Sanjay Gandhi national park, Maharashtra. Satyakumar (1992) found sambar to be the most preferred prey of leopard in the Mundanthurai plateau, and which was attributed to the fact that leopard and sambar were nocturnal animals and leopard, as a stalker, could easily stalk and kill sambar.

The scat analysis also revealed occurrence of plant matter and soil in diet of leopard in Mandi district, and their mean percent occurrence was 2.6% and 0.3% respectively. Vegetable matter, mainly grasses, was also found in scats of tiger and leopard in Sariska tiger reserve (Sankar and Johnsingh, 2002). Fox *et al*. (1991) suggested that consumption of vegetable matter by carnivores could be a means to compensate the lack of minerals in their diet. Consumption of grasses by carnivores was also reported to keep the digestive system functional during starvation (Bothma, 1965, 1966) or it might be serving to bind bone fragments in the formation of faeces (Grobler and Wilson, 1972) or it might act as a scour (Murie, 1994).

6.4.3 Seasonal dietary pattern

An analysis of 140 scats of summer, 118 scats of monsoon and 132 scats of winter season showed some variation in the dietary pattern of leopard in different seasons. Among wild prey species: rodents, birds, langur, hare, wild pig, reptile, porcupine and mongoose, and domestic prey species: sheep, goat and cattle, buffalo and dog, leopard preyed on single species 116 times, on two species 22 times and on three species 2 times during summer season. During winter season, leopard preyed on single species 107 times and on two species 24 times, and monsoon season, the predator preyed on single species 108 times and on two species 10 times. Although the prey items consumed were the same in different seasons, but the frequency occurrence of these items showed differences in summer, monsoon and winter seasons. The frequency of occurrence of wild prey was 40.3%, 54% and 47% and domestic prey species was 59.7%, 46% and 53% during summer, monsoon and winter respectively. The variation in frequency occurrence of wild and domestic prey species could be due to proportion of their availability in different seasons. The availability of domestic prey species was highest during summer and winter seasons in the study area. In the seasonal diet of leopard, the frequency occurrence of rodents was highest in summer, followed by monsoon and winter among the wild prey species. This variation in the frequency occurrence of rodents could be correlated to their availability in different seasons. Among the domestic prey species Sheep and goat constituted the highest frequency occurrence in summer, followed by monsoon and winter season. So the rodents and sheep and goat contributed to the diet of leopard in all seasons but these prey species contributed maximum in the summer season. In Africa, there was no significant variation in selection of prey species by leopard across the seasons and landscape (Bailey, 1993).

In similar studies conducted in the past, occurrence of prey species in the scats showed varied types of results in different seasons. In Dachigam national park, the percent occurrence of cattle, sheep and goat put together was significant (18.3%) in the diet of leopard during summer and autumn months, (Shah *et al.*, 2009). It was related to the presence of heavy cattle stock in the protected area during these months and that were easily accessible prey for the leopard. Johnson *et al.* (1993) reported that large-and medium-sized mammals composed the majority of the leopard diet, with livestock, pheasants, grasses and soil eaten occasionally. These dietary shifts could reflect opportunistic encounters leading to changes in leopard hunting behaviour, prey availability or prey vulnerability. Karanth and Sunquist (2000) related activity of predator to that of the prey species. During winter and early spring the scats were mostly found to contain hangul and langur hairs. This might be due to the fact during winter because of heavy snow cover hangul dear and langur remained concentrated in a small belt of lower Dachigam and could become easy targets of leopard. Some prey species were found tend to congregate in small areas in deeper snow as forage becomes unavailable elsewhere (Fuller and Sievert, 2001) and encounter rates were also found to increase (Huggard, 1993).

6.4.4 Biomass

Domestic prey species contributed more biomass (66.3%) to the diet of leopard as compared to the consumption of wild prey biomass (33.7%). Cattle and buffalo contributed 26.4% of the prey biomass to the diet of leopard; sheep, goat, dog, wild pig and langur contributed 44.0% of prey biomass and small prey (hare, rodents, porcupine, mongoose, reptiles and birds) provided 29.6% of biomass consumed. Sheep contributed the maximum biomass (23.4%) to the diet of leopard, followed by rodents (20.1%), cattle (19.7%), goat (15.0%), and buffalo (6.7%). Large wild prey species were not present in the diet of leopard and medium wild prey species were not contributing significantly to the consumed biomass of leopard. In terms of relative number of individuals consumed, rodents were the dominant prey (90.7%) compared to rest of the wild and domestic prey species. The relative number of wild and domestic individuals consumed by leopard, except dominant rodents varied from 0.1 % to 3.2%. Consumption of high proportion of biomass of domestic prey species could be attributed to higher encounter rate i.e. availability of domestic species in the study area. Sheep and goats were found to be accompanied by graziers annually in summer months and they were staying in higher reaches for many days. Thus there was high chance of predation by leopard on them.

Rodents were preyed upon in large numbers by leopard and this, suggested that they were taken as and when encountered, but they were unlikely to contribute a significant biomass to the diet because of their low weight. Because of the scattered distribution of dogs in the study area in

Mandi district and the paucity of wild ungulates, leopards were found to be largely surviving on small prey species. More than sixty percent of the biomass taken was contributed by domestic animals. The preference of leopard for dogs as prey in villages and near human habitation has been well documented (Daniel, 1996). But in this study, leopard did not show much preference for dogs. Most studies on food habits in Africa however showed ungulates to be the main prey species of the leopard (Bailey, 1993). Schaller (1972) found that the leopard was mostly taking prey in the 20-70 kg body weight class in the Serengeti national park. Biomass consumption of wild pig and hare by leopard was very low. Both the species occurred at low densities in the study area, which could possibly explain their low occurrence in the scats. Chellam and Johnsingh (1993) did not find any hare in leopard scats in Gir, while Karanth and Sunquist (1995) estimated that only about 5% of the leopard's prey in Nagarhole was comprised of hare. Common langur, porcupine and mongoose contributed low proportion of biomass to the diet of leopard. In Sariska tiger reserve, the overall prey species density recorded was one of the highest in the Indian sub-continent, so the estimated overall biomass of the prey species was also found to be high as compared to Kanha tiger reserve (Schaller, 1967), Bandipur tiger reserve (Johnsingh, 1983), Nagarahole (Karanth and Sunquist, 1995) and Pench tiger reserve (Biswas and Sankar, 2002). In Bandipur tiger reserve, tiger, leopard and dholes were found to predate on 11 to 15 prey species; relatively abundant ungulate species provided 88 to 97% of biomass consumed by them (Andheria *et al.*, 2007). The medium-sized chital and wild pig formed 65% of the biomass intake of leopards. In terms of the relative numbers of prey animals killed by the leopard, chital were the most abundant prey species and thus dominated the diet.

Figure 1. The mean encounter rate of wild prey species in Mandi district.

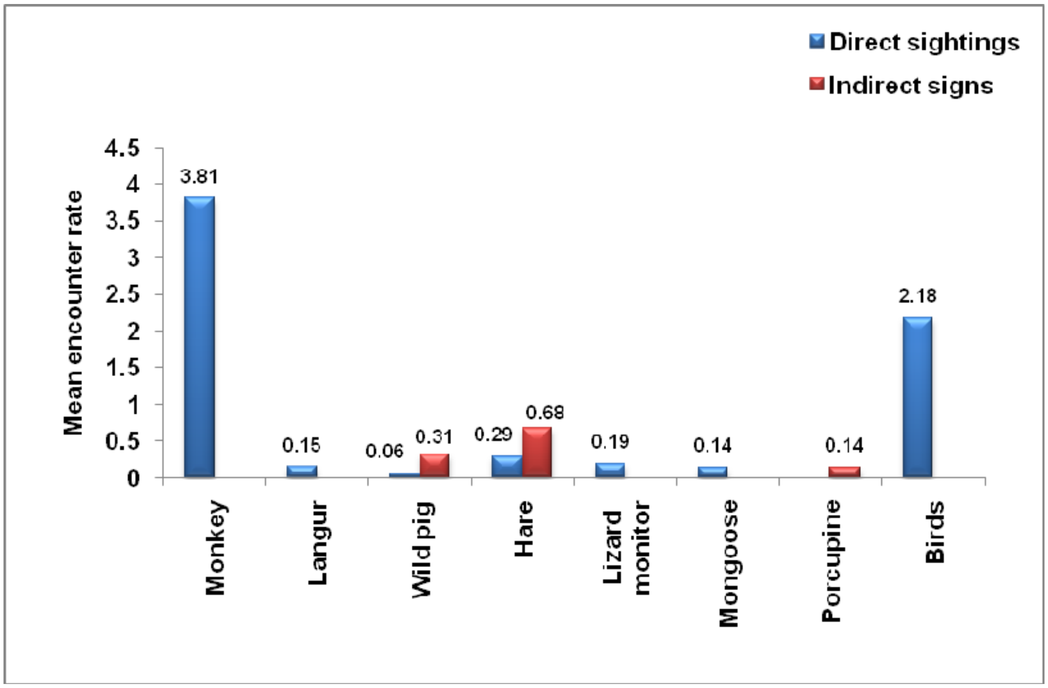


Figure 2. The mean encounter rate of domestic prey species in Mandi district.

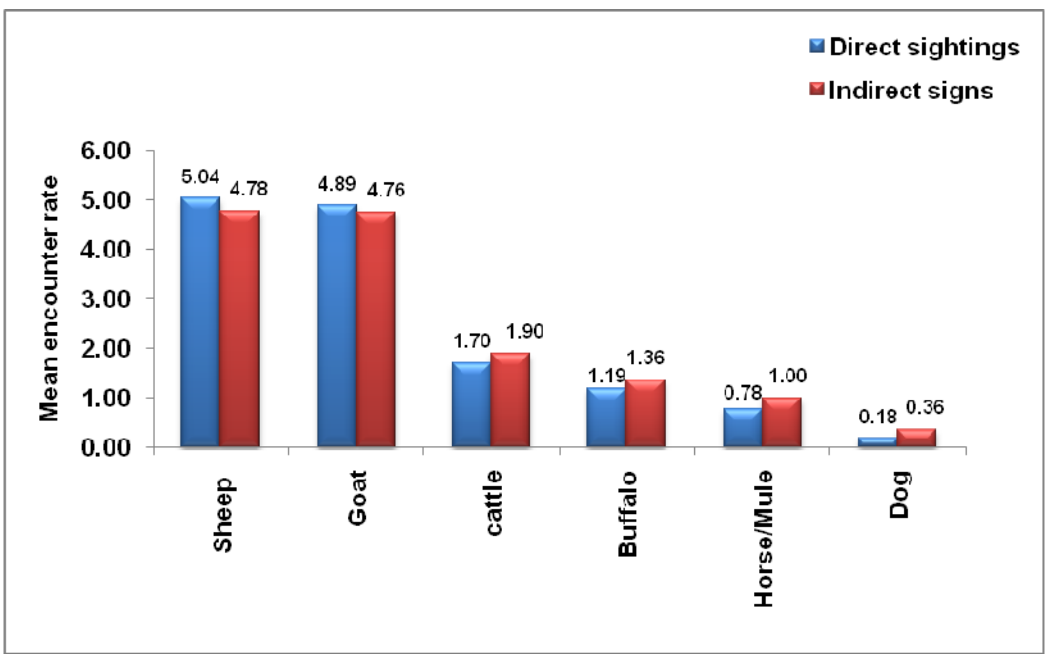
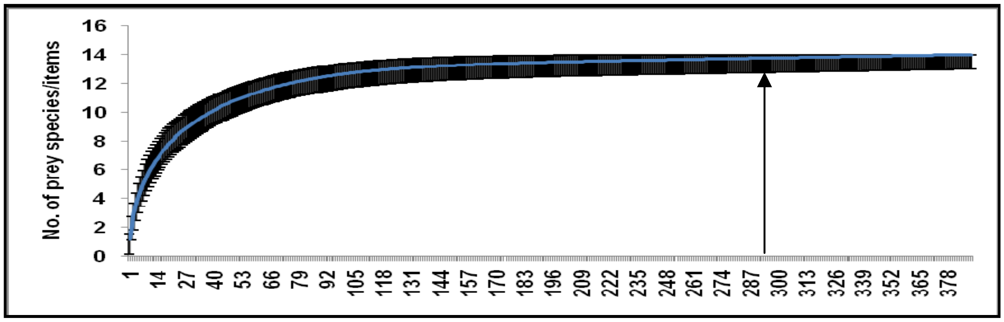
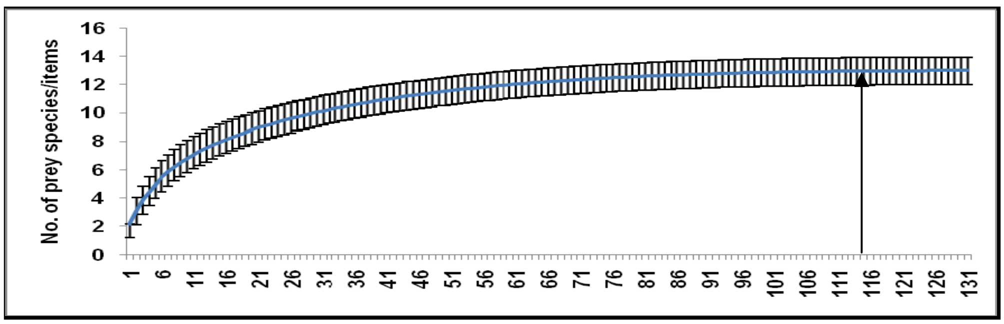


Figure 3. Food species/items area curve to find minimum number of scats (marked by arrow) required to study dietary composition.

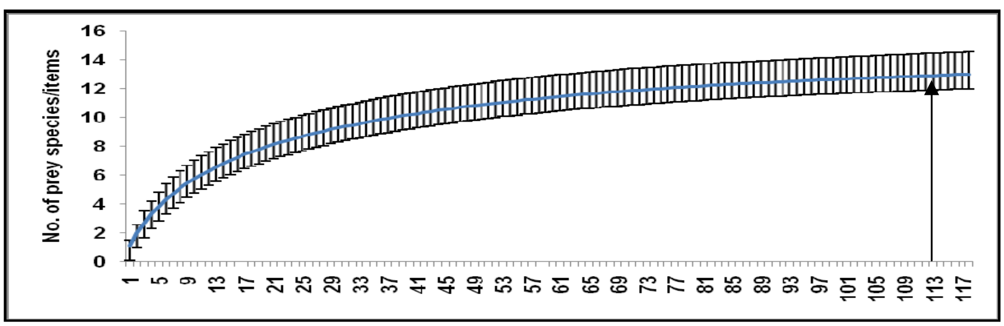
Annual



Winter



Monsoon



Summer

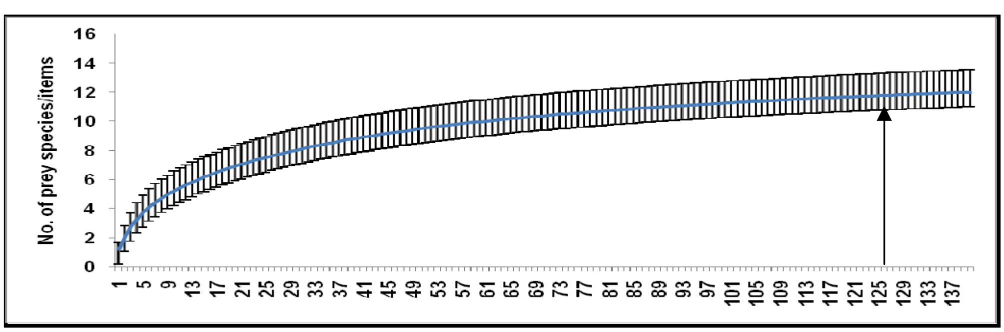


Figure 4. Frequency of occurrence of food items in the scats of leopard in Mandi district (n=390).

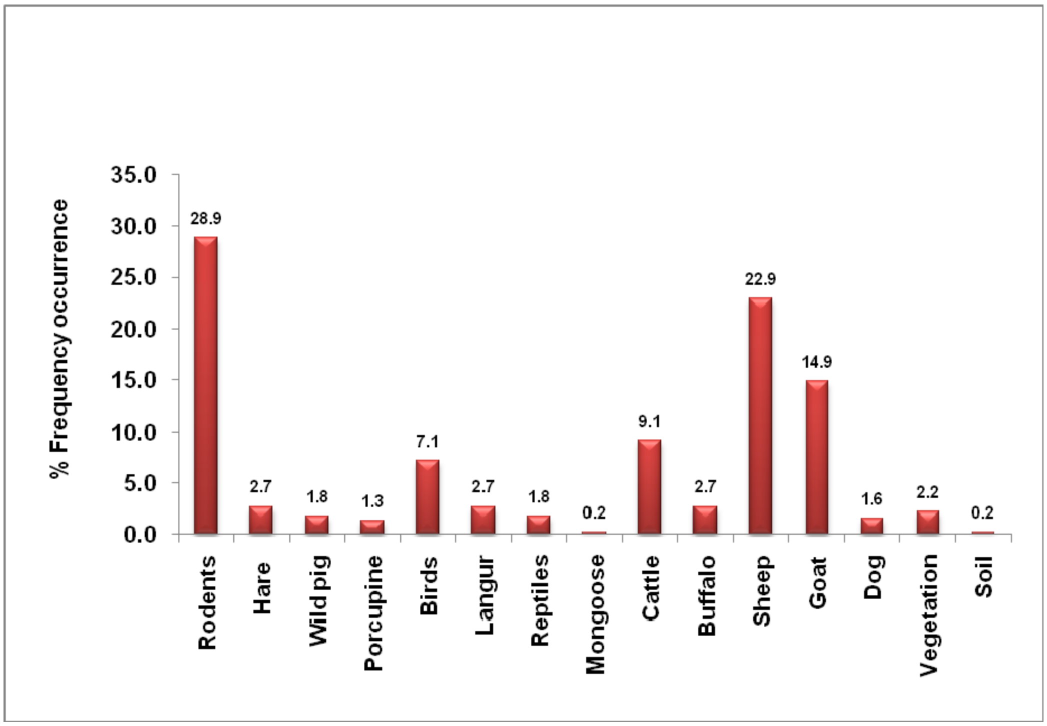


Figure 5. Percent proportion occurrence of wild prey species in scats of leopard in Mandi district. Error bars showing 95% bootstrap confidence intervals.

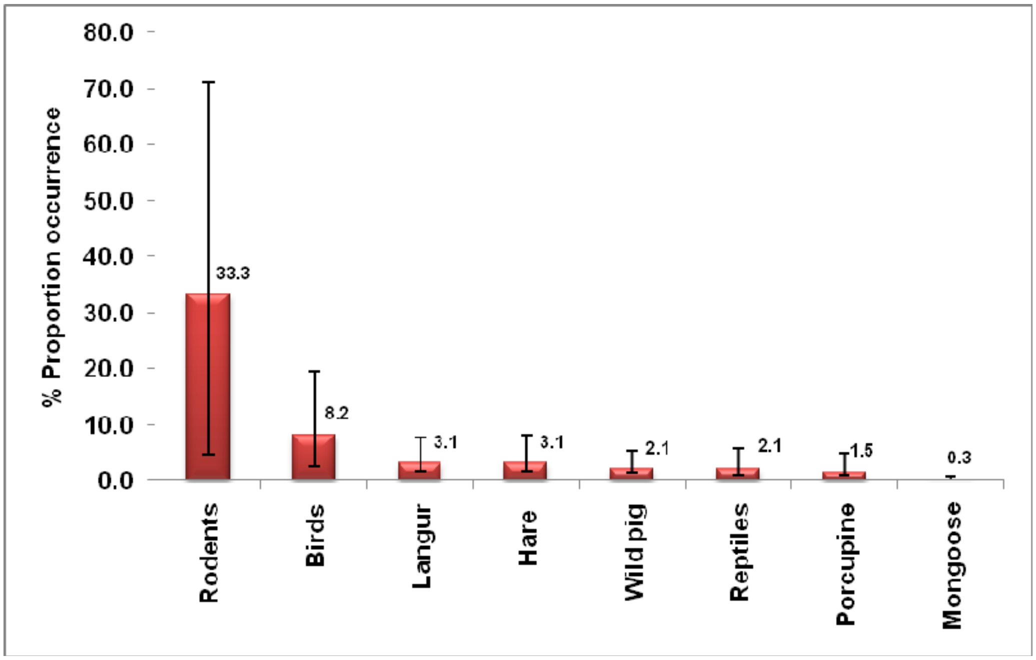


Figure 6. Percent proportion occurrence of domestic prey species in scats of leopard in Mandi district. Error bars showing 95% bootstrap confidence intervals.

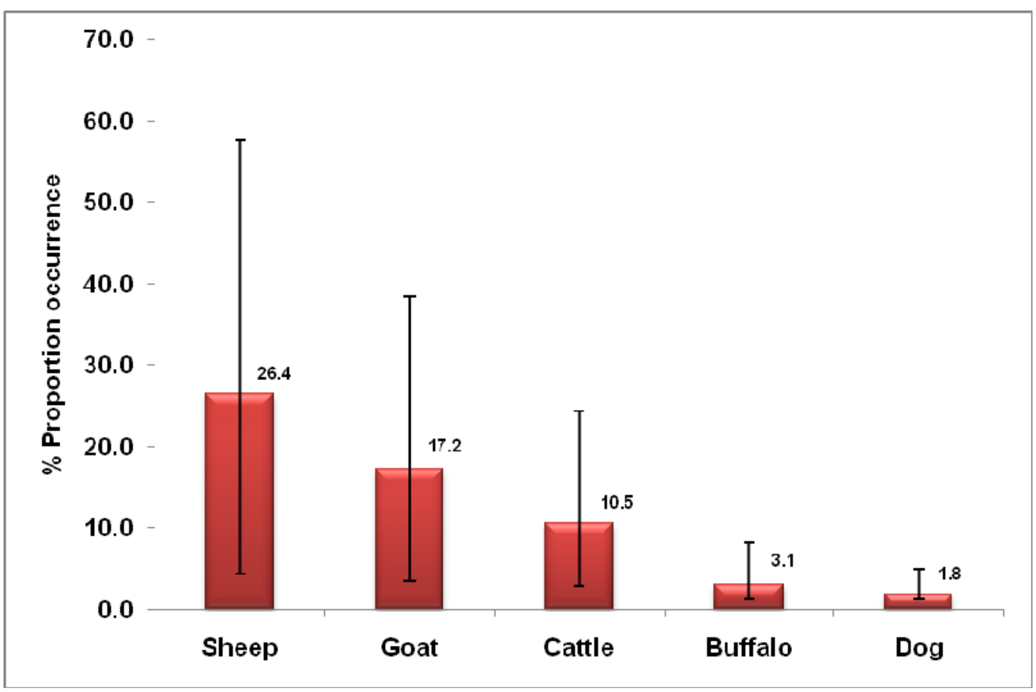


Table 1. Percent frequency occurrence of prey species/items in the diet of leopard in different seasons.

Prey species	Winter	Monsoon	Summer
Rodents	28.39	35.16	24.70
Hare	3.23	2.34	2.41
Wild pig	3.23	1.56	0.60
Porcupine	1.94	0.78	1.20
Birds	6.45	8.59	6.63
Langur	2.58	0.78	4.22
Reptiles	1.29	4.69	0.00
Mongoose	0.00	0.00	0.60
Cattle	9.03	15.63	4.22
Buffalo	2.58	3.13	2.41
Sheep	19.35	13.28	33.73
Goat	16.77	8.59	18.07
Dog	1.29	2.34	1.20
Vegetation	3.87	3.13	0.00

Figure 7. Percent frequency occurrence of wild and domestic prey in the diet of leopard in different seasons.

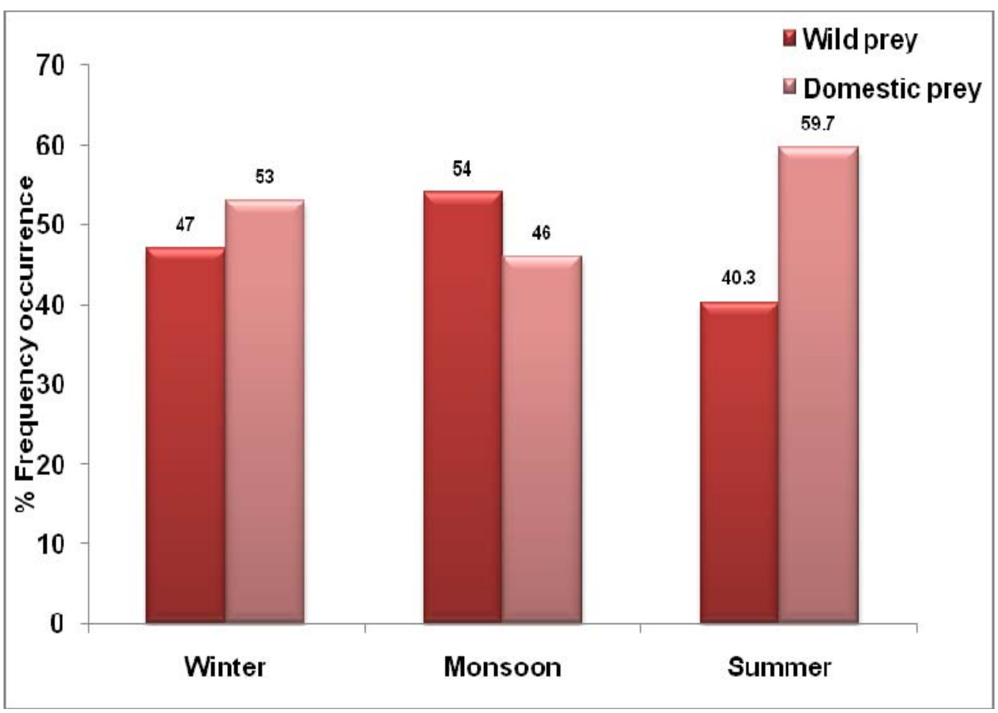


Figure 8. Seasonal percent frequency occurrence of natural prey items in the diet of leopard in Mandi district.

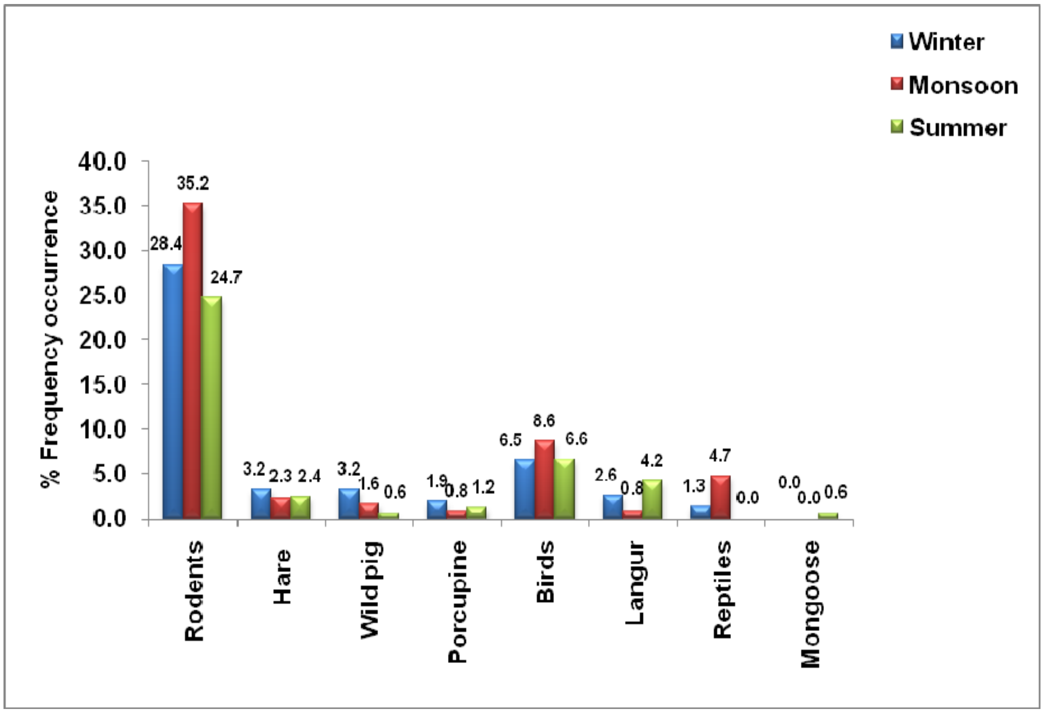


Figure 9. Seasonal percent frequency occurrence of domestic prey items in the diet of leopard in Mandi district.

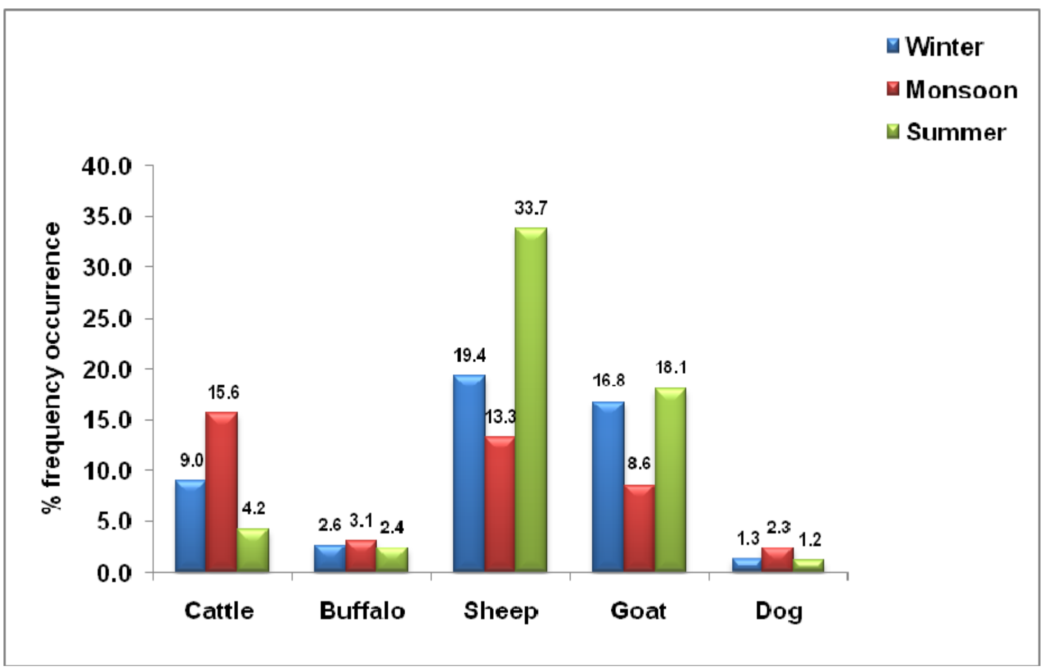


Table 2. Frequency occurrence of prey species/items, relative biomass consumed and relative number of prey individuals consumed by leopard in Mandi district (n=390), after bootstrapping simulation with 95% Confidence limits.

Prey species/ items	No. of scats	Av. body weight (x)	Frequency of occurrence	Percent occurrenc e	Mean-UCL	Mean-LCL	No. of collectabl e scats per kill (y)	Relative biomass consumed (kg)	Relative number consumed (%)
Rodents	130	0.25	28.9	33.3	37.9	28.7	2.0	20.1	90.7
Hare	12	3	2.7	3.1	5.1	1.5	2.1	1.9	0.7
Wild pig	8	37	1.8	2.1	3.3	0.5	3.3	2.0	0.1
Porcupine	6	8	1.3	1.5	3.3	0.5	2.3	1.1	0.1
Birds	32	1.8	7.1	8.2	11.3	5.6	2.0	5.1	3.2
Langur	12	8	2.7	3.1	4.6	1.5	2.3	2.1	0.3
Reptiles	8	0.5	1.8	2.1	3.8	1	2.0	1.2	2.8
Mongoose	1	1.4	0.2	0.3	0.5	0	2.0	0.2	0.1
Cattle	41	120	9.1	10.5	13.8	7.7	6.2	19.7	0.2
Buffalo	12	150	2.7	3.1	5.1	1.8	7.2	6.7	0.1
Sheep	103	27.11	22.9	26.4	31.3	22.1	2.9	23.4	1.0
Goat	67	26.08	14.9	17.2	21.3	13.8	2.9	15.0	0.7
Dog	7	20	1.6	1.8	3.1	0.5	2.7	1.5	0.1
Vegetation	10	-	2.2	2.6	4.1	1	-	-	-
Soil	1	-	0.2	0.3	0	1.3	-	-	-

X = Average body weight of an individual prey type in kg.

Y = Kg of prey consumed per field collectible scat (Y=1.980 + 0.035 X).

Figure 10. Difference of overall prey numbers across seasons.

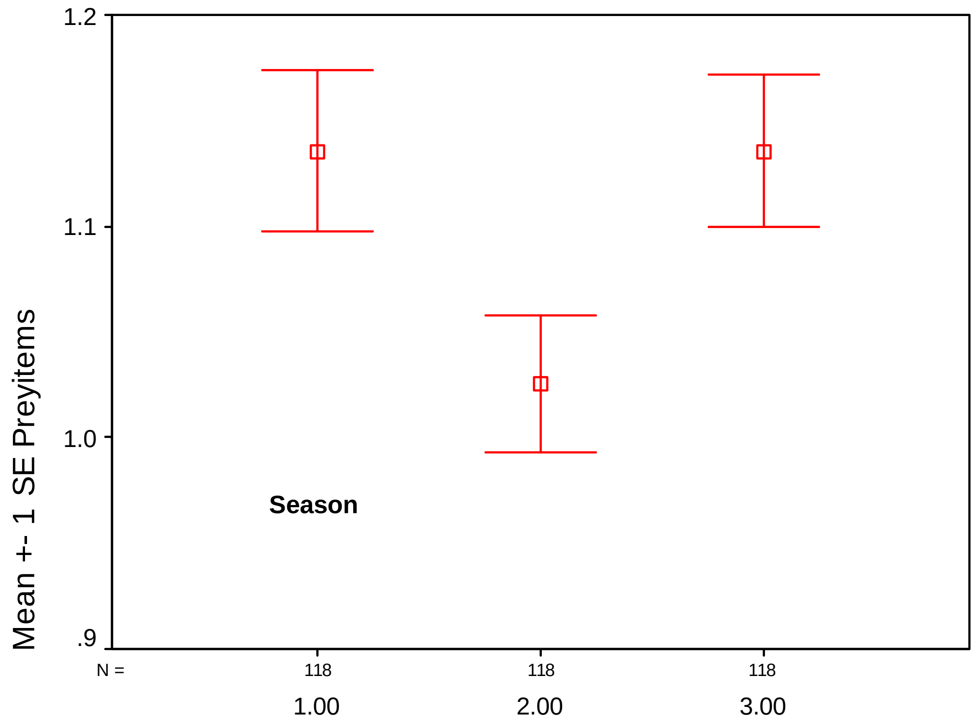


Figure 11. Difference of wild prey numbers across seasons.

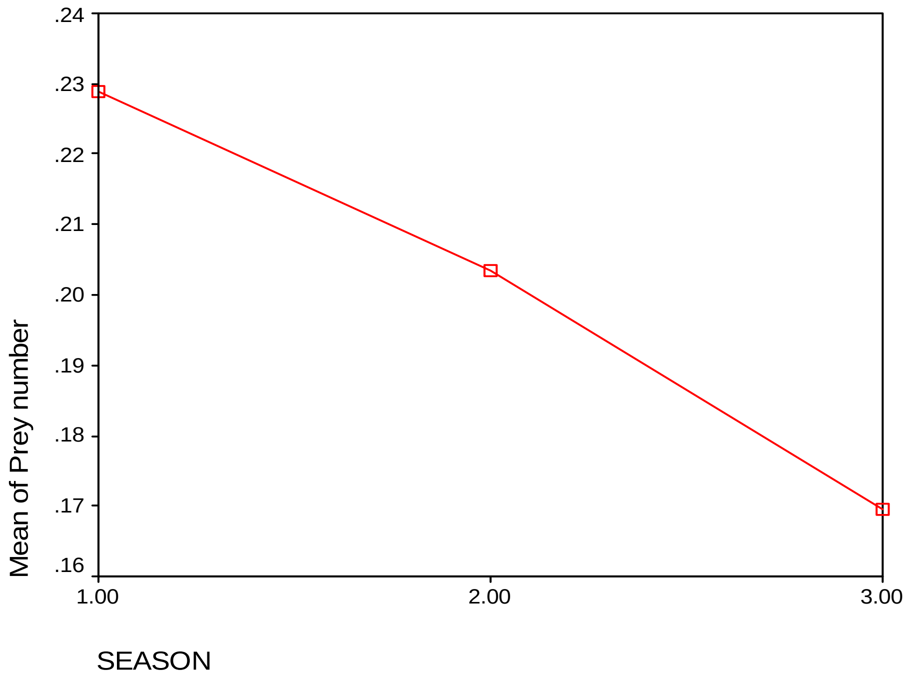


Figure 12. Difference of overall livestock numbers across seasons.

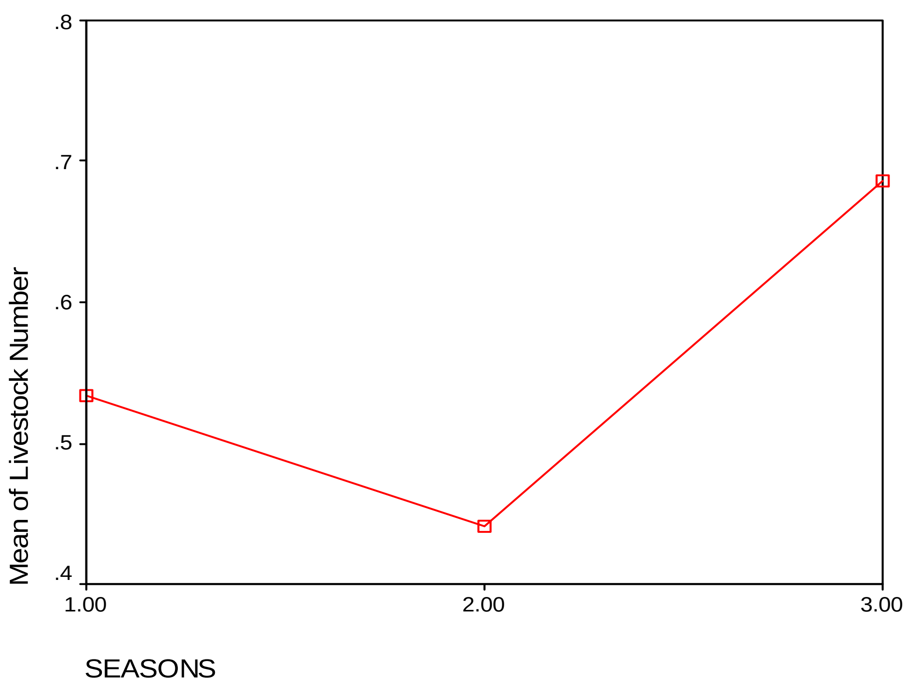


Figure 13. Relative biomass consumed (kg) by leopard in Mandi district.

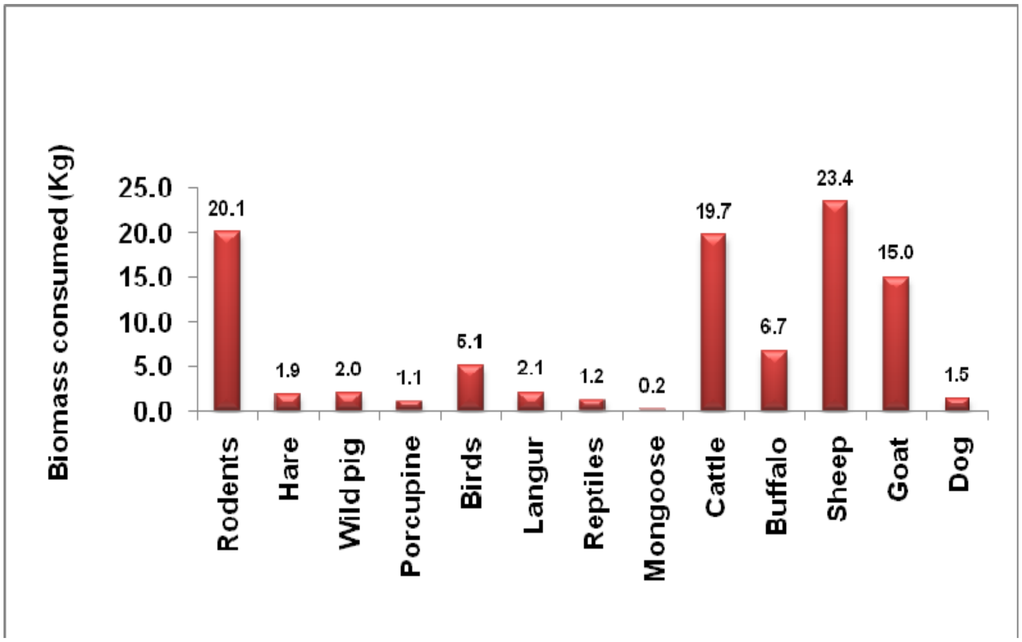
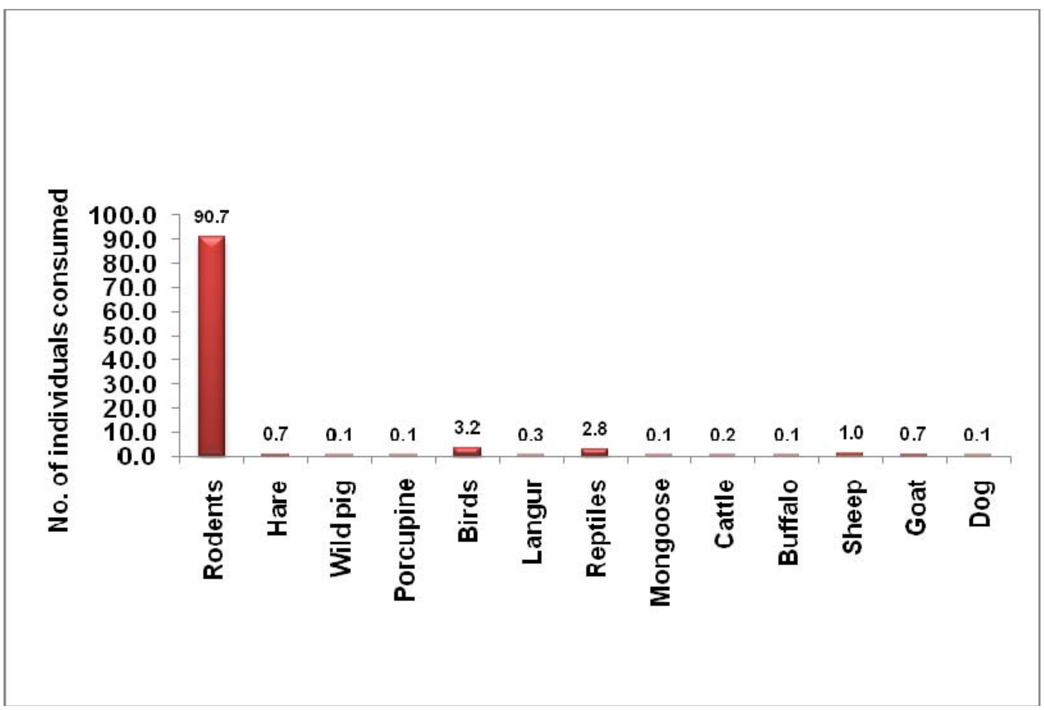


Figure 14. Relative number of individuals consumed by leopard in Mandi district, Himachal Pradesh.



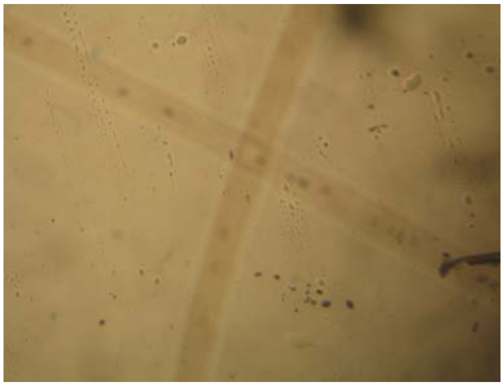
Annexure 1. Hair cuticular pattern of different prey species found in Mandi district.

Species	**Scale margin**	**Scale distance**	**Scale pattern**
Cattle	Crenate	Near	Irregular wave
Buffalo	Crenate	Near	Irregular wave
Sheep	Smooth	Distant	Broad petal
Goat	Crenate	Near	Irregular wave
	Rippled	Near	Irregular wave
Mule	Smooth	Near	Regular wave
	Crenate	Near	Irregular wave
Horse	Crenate	Near	Irregular wave
Dog	Crenate	Near	Irregular wave
Langur	Smooth	Near	Regular wave
Hare	Smooth	Near	Double chevron
	Smooth	Near	Regular wave
Rodent	Smooth	Near	Regular wave
	Crenate	Near	Irregular wave
Monkey	Smooth	Near	Regular wave
Mongoose	Smooth	Near	Regular wave
	Rippled	Near	Irregular wave
Wild pig	Rippled	Near	Irregular wave

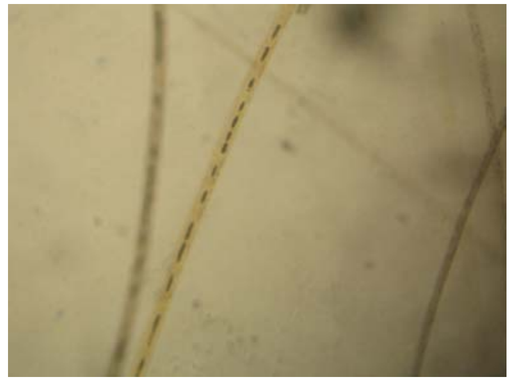
Annexure 2. Hair medullary pattern of different prey species found in Mandi district.

Species	Type
Cattle	Wide and simple medulla
Buffalo	Simple medulla
Sheep	Wide medulla lattice
Goat	Multi-serial ladder
Dog	Simple medulla
Horse	Fragmental medulla
Langur	Fragmental medulla
Wild pig	Fragmental medulla
Hare	Multi-serial ladder, Dumb bell shaped
Rodent	Uni-serial ladder
Bird	Uni-serial ladder or Fragmental medulla

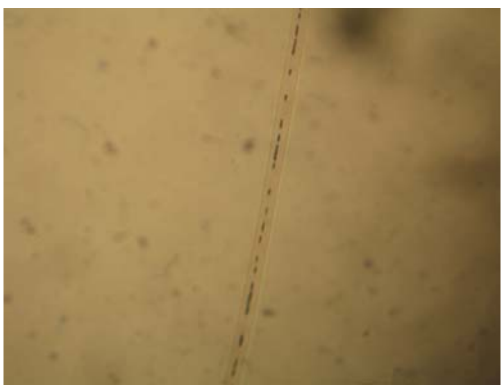
Plate 1. Hair medullary pattern of prey species found in scats.



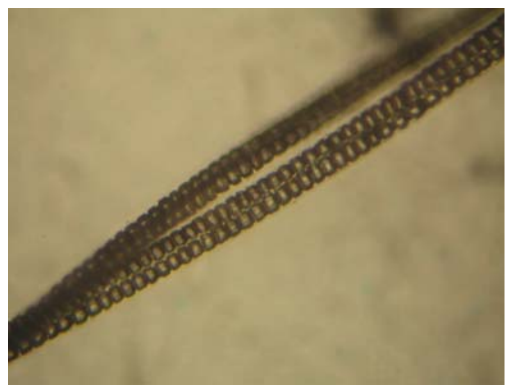
Langur (Fragmental medulla)



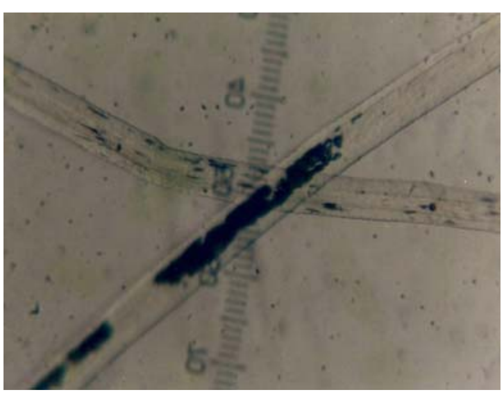
Langur (Fragmental medulla)



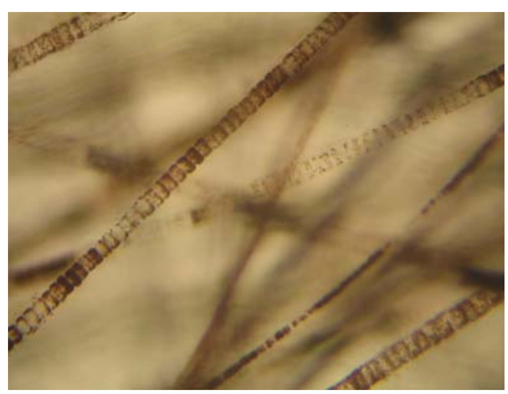
Hare (Multi-serial ladder)



Hare (Dumb bell shaped)

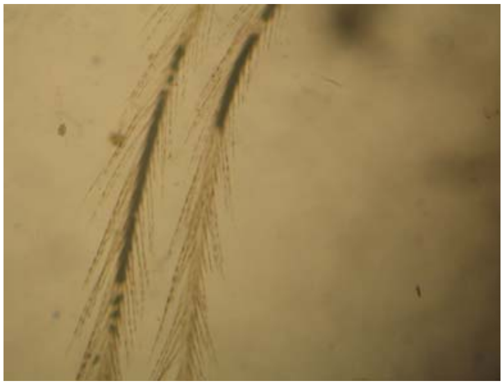


Wild pig

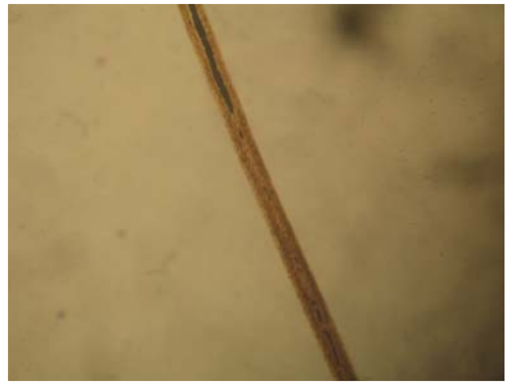


Rodent (Uni-serial ladder)

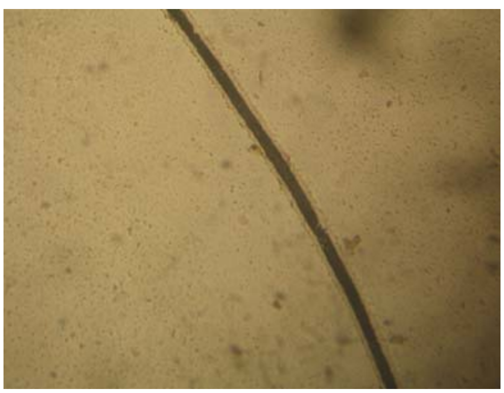
Plate 2. Hair medullary pattern of prey species found in scats.



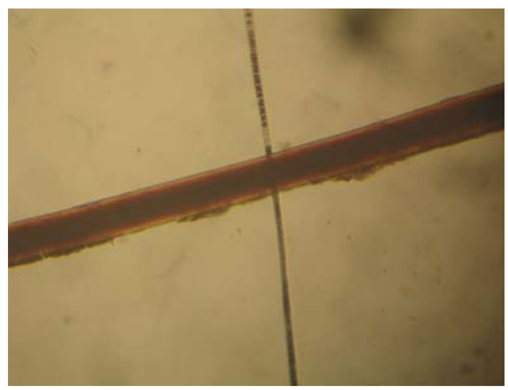
Birds (Fragmented medulla)



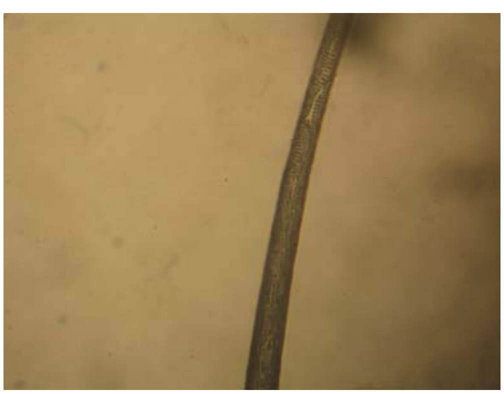
Bird (Uni-serial ladder medulla)



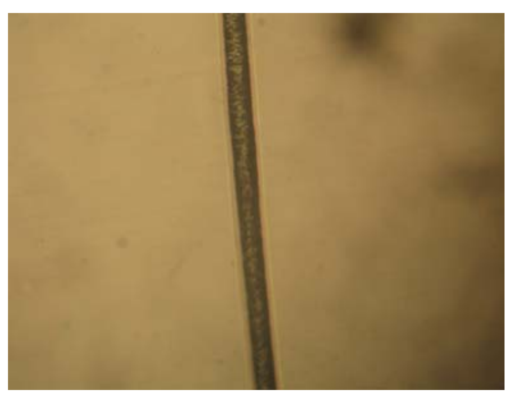
Sheep (Wide medulla lattice)



Sheep (Wide medulla lattice)

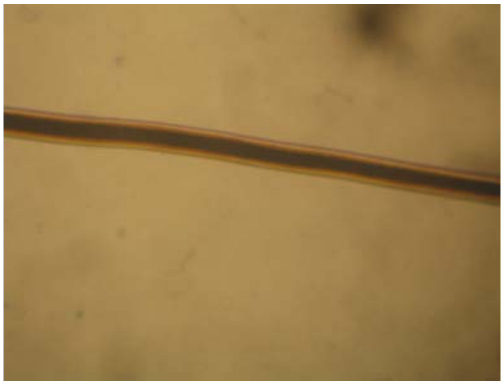


Goat (Multi-serial ladder)

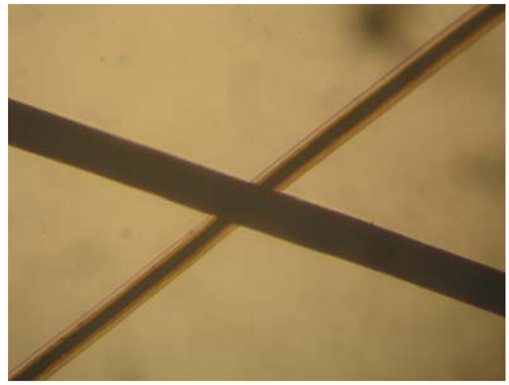


Goat (Multi-serial ladder)

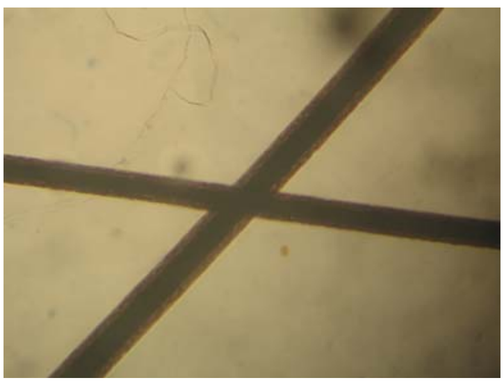
Plate 3. Hair medullary pattern of prey species found in scats.



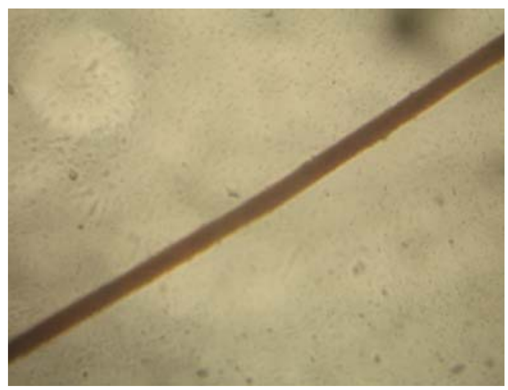
Dog (Simple medulla)



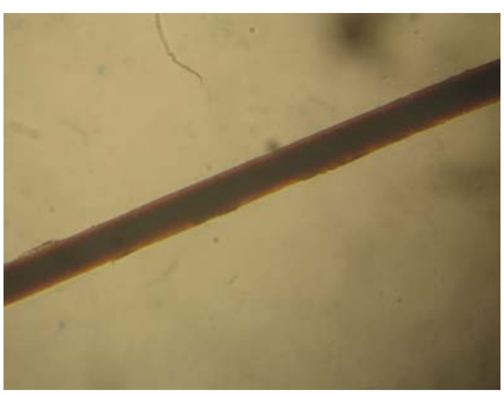
Dog (Simple medulla)



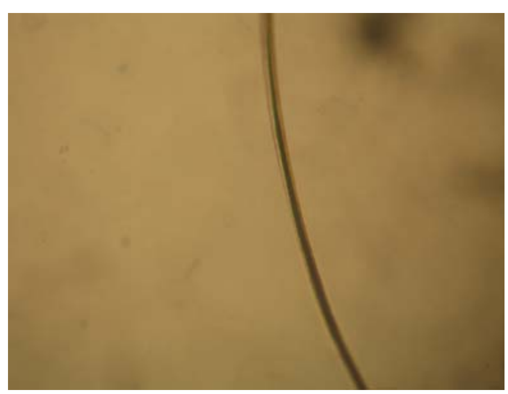
Buffalo (Simple medulla)



Buffalo (Simple medulla)

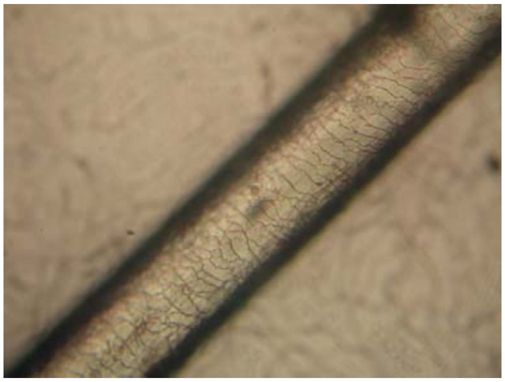


Cow (Wide and simple medulla)

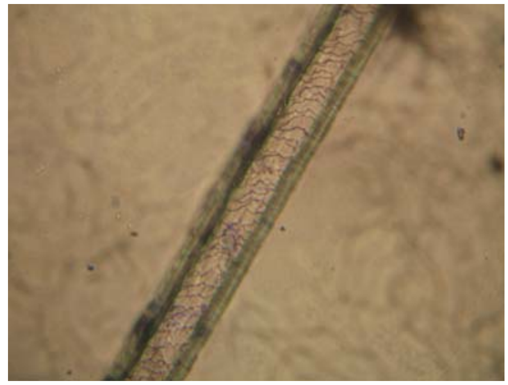


Cow (Wide and simple medulla)

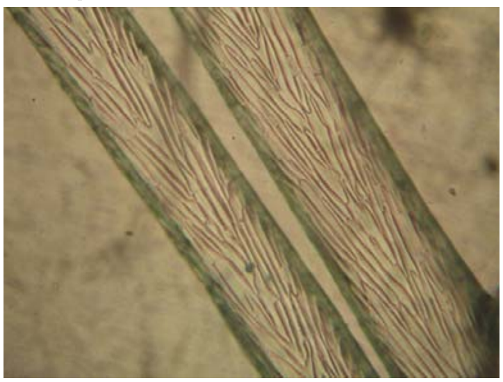
Plate 4. Hair cuticular pattern of prey species found in scats.



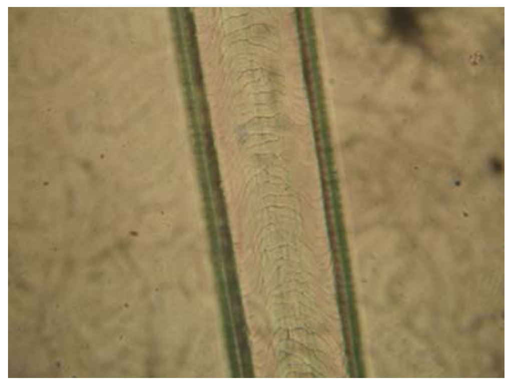
Langur (Smooth, near, regular wave)



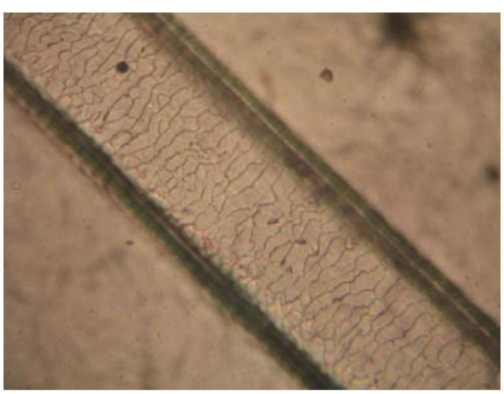
Langur (Smooth, near regular wave)



Hare (Smooth, near, double chevron)



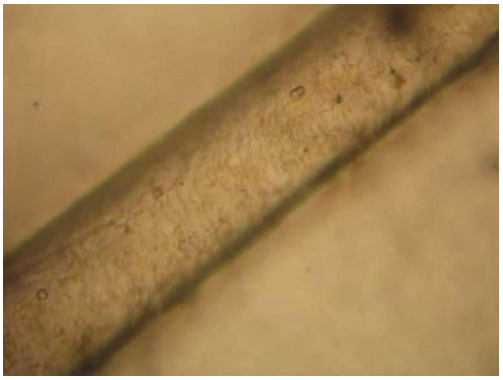
Hare (Smooth, near, regular wave)



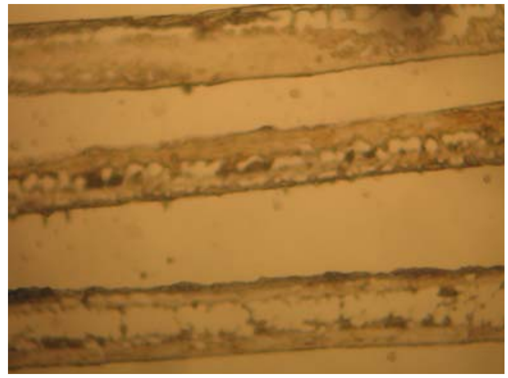
Rodent (Smooth, near, regular wave)

Rodent (Crenate, irregular wave)

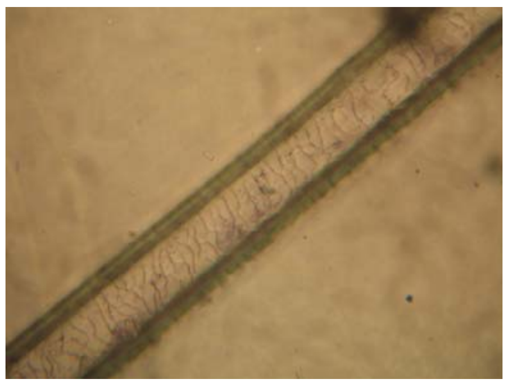
Plate 5 Hair cuticular pattern of prey species found in scats.



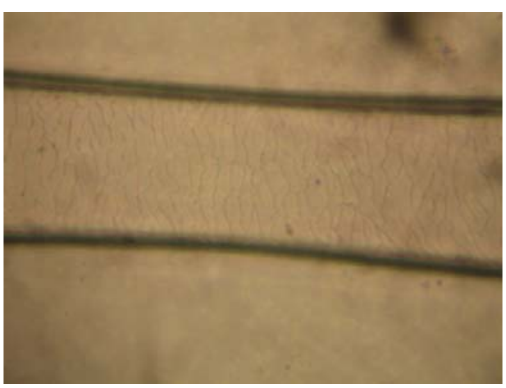
Wild pig (Rippled, irregular wave)



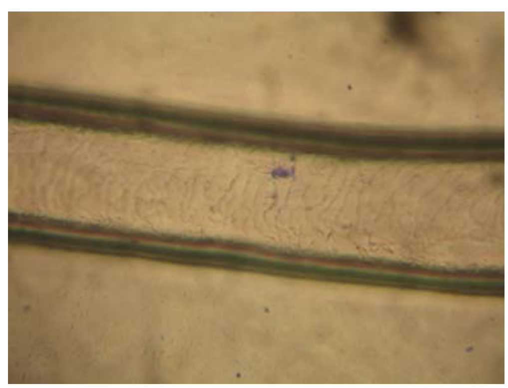
Wild pig (Rippled, irregular wave)



Monkey (Smooth, near, regular wave)

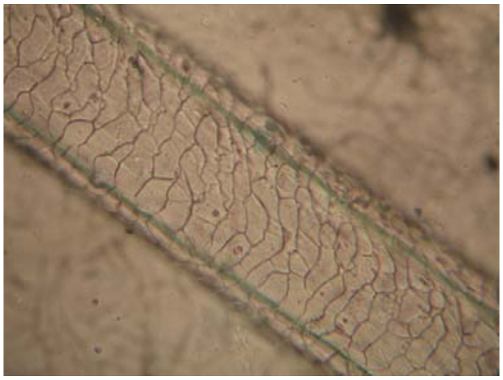


Mongoose (Smooth, regular wave)

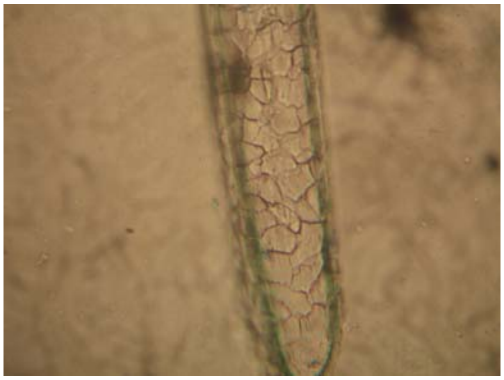


Mongoose (Rippled, irregular wave)

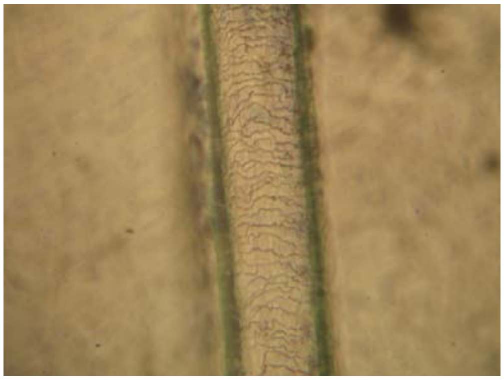
Plate 6 Hair cuticular pattern of prey species found in scats.



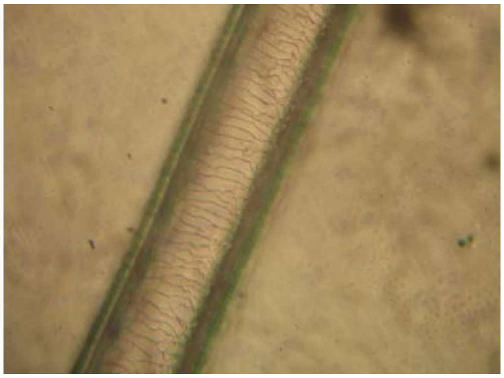
Sheep (Smooth, distant, broad petal)



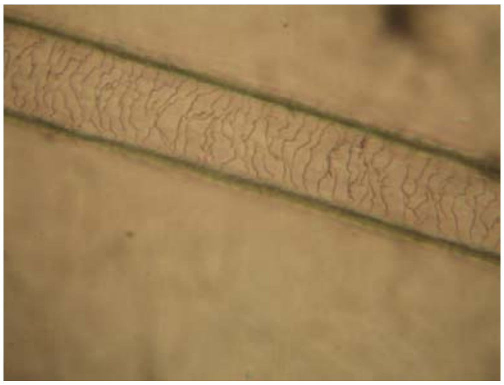
Sheep – Tip portion



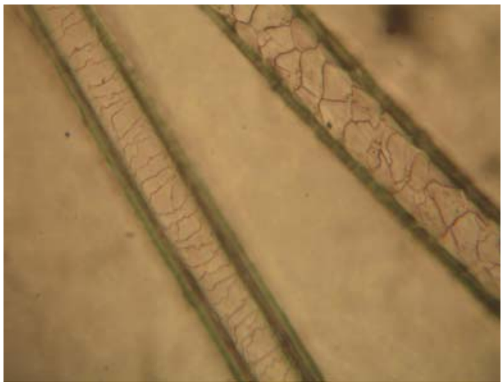
Goat (Crenate, near, irregular wave)



Goat (Rippled, near, irregular wave)

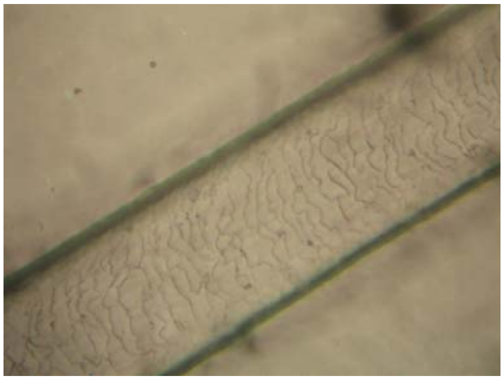


Dog (Crenate, near, irregular wave)

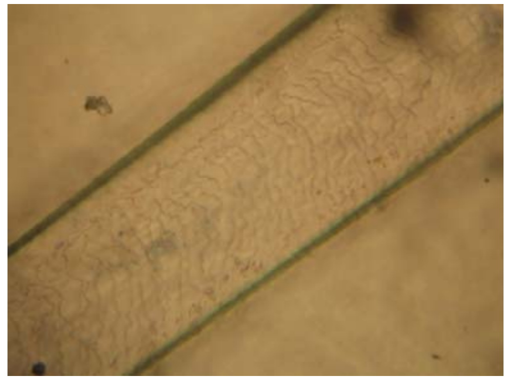


Dog – Tip portion

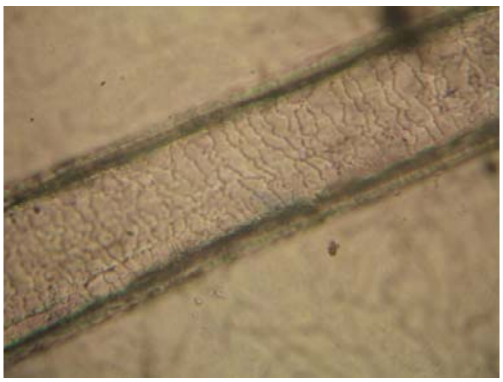
Plate 7. Hair cuticular pattern of prey species found in scats.



Horse (Crenate, irregular wave)

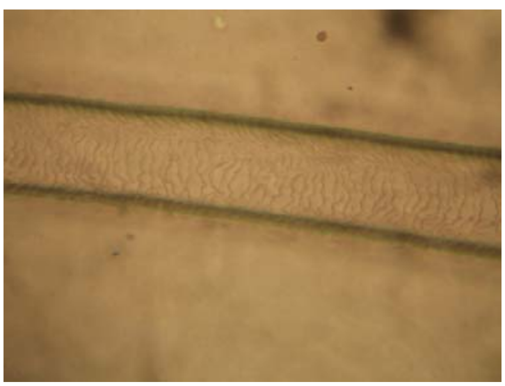


Buffalo (Crenate, irregular wave)

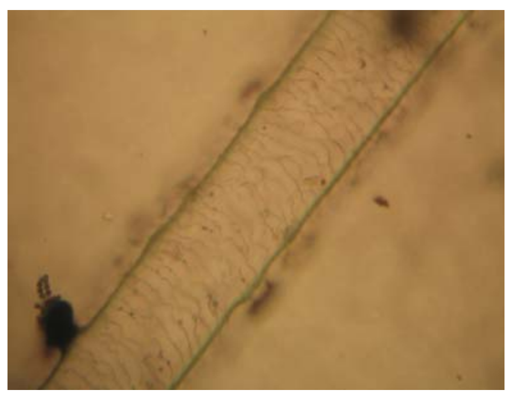


Mule (Crenate, near, irregular wave)

Mule – Tip portion



Cattle (Crenate, near, irregular wave)



Cow (Crenate, near, irregular wave)

Plate 8. Teeth of rodents found in the scat of leopard.

Plate 9. Teeth and bones of dog in scat of leopard.

Plate 10. Leopard scat with hairs of goat.

Plate 11. Carcass of cattle abandoned by leopard.

Plate 12. Leopard attempt to kill a civet.

Plate 13. Carcass of cattle abandoned by leopard.

Plate 14. Carcass of cattle abandoned by leopard.

Chapter 7

To suggest measures to minimize human-leopard conflict in Mandi district.

Management Recommendations

Based on the records of the forest department, survey of affected areas and interview with the local people in Mandi district, the following general recommendations are made to minimize human-leopard conflict.

Short Term

1. For mitigation of human-leopard conflict under given socio-economic and political framework, one of the ways is to minimize the ill effects of socio economic constraints and socio-ecological constraints in these areas. Human casualties and livestock killings are the socio-ecological constraint identified. To minimize their ill effects on people, education and awareness programmes related to ecology and behaviour of leopard, genesis of leopard menace, possible mitigation strategies need to be conducted for the villagers in these areas.

2. In Mandi district, forests were patchy and fragmented, and shrubs like *Lantana camera, Parthenium hystenophorus, Rubus biflorus, Eupatorium edinoforum* and *Colebrookia oppositifolia* were growing in abundance. These shrub species were found to provide hiding places and ambush cover for leopard.

3. In Mandi distrcit also, the forests were patchy and fragmented, and different shrub species were growing in abundance near around villages. Leopard increasingly used the shrub cover for hiding and attacking on people. Furthermore villages were scattered but most of them were located in the close vicinity of forests.

4. In Mandi, leopard attacks were significantly less as compared to other leopard menace areas. This might be due to strategic locations of villages and movement of people in hilly terrain. The villages were scattered all over in the hills but quite isolated and distantly located from forest areas. The forests were patchy but dense in some pockets. Near around villages, occurrence of shrub species which were found to provide hiding ground and ambush cover for leopard were absent or in scanty.

5. There is also opinion that the natural prey base in the forests around seems to be inadequate to support existing population of leopard in Mandi. On the contrary, there is also a view point that leopard population is apparently on the increase and livestock population is adequate in Mandi. Because of these reasons, human casualties are also frequent.

Medium Term

6. We recommend a detailed study on population ecology including habitat use, movement and activity pattern and dietary pattern of

leopard, and human-leopard conflict and mitigation for developing conservation and management plan for leopard.

Long term

7. Leopard attacks on young boys and girls can be contained if they move in groups or accompanied by some elderly people. Most of the casualties have occurred when children were alone or not accompanied by elders. A few cases of human injury were reported when leopard attacked on 2-3 young people moving together.

8. Vulnerability of leopard attacks on adult and sub adult people can be reduced if they move in groups and children going to their school can be accompanied by some elders. They should always move on regular paths, passing through open areas without bushes and shrubs.

9. Also when women go in forest area for collection of fodder or fuel wood, they should always move in a group. They should prefer moving to forest area avoiding peak activity time of leopard and return early in the evening.

10. Till people are awake in the late evening or night hours, they must light their houses. The though dogs are the delicacy of leopard, villagers must keep dogs in their houses. In the late evening and night time, dogs can be kept inside rooms or safe pet house. This will greatly help in keeping leopard away and attacks can be minimised.

11. In villages, people often go outside in open areas or near bushes or margins of forests for toilet in the late evening or morning time. This time coincides with the peak activity time of leopard. Such people become more vulnerable to leopard attacks. It is suggested that people should have some toilet facility in any form in their village houses or they should move out in a group of 2 to 3 people and use open areas away from bushes and forests.

12. The villagers must regularly remove all bushes or shrubs from the vicinity of houses and village area in a cooperative manner. Such vegetation clearance will increase visibility and keep the nuisance leopard away from their houses.

13. The villagers should be very vigilant and alert in early morning and late evenings when leopards are active. They should complete outside activities such as social visit, fetching water from streams or river, grazing cattle, collection of household items etc. during day time only.

14. When the livestock are taken in and around forests or pastures or near around crop fields in hilly areas, they should attended by graziers. Any type of bell or sound producing device should be put around the neck of the cattle. When the cattle realize the danger or presence of leopard, it will try to escape or run and produce alarm sound for not only other cattle but also indicate to the graziers. This way, incidences of cattle killing by leopard can be contained.

15. The cattle shed in village houses should be constructed leopard-proof using wooden material and/or concrete structure, and should be lighted. The pet dogs kept in houses can also alarm the presence of predator in the vicinity of houses.

16. The land use patterns in the hilly areas are changing constantly. Under such circumstances, some ameliorative action is required. Problem mitigation efforts should be made by way of protection and improvement of natural habitat of wild animals. In the fragmented and degraded forest areas, habitat improvement through protection and reduction of biotic pressures need to be carried out to sustain wild animal populations. Local people should help and cooperate in protection of forests and wild animals therein, which will help increase in prey base in the wild for leopard. They should also protect forests from fire, and any outbreak of forest fire should be immediately informed to the forest department.

Policy Recommendations

17. The scheme for payment of compensation for human casualties and livestock killings by leopard exists. The payment of compensation for menace is sometimes delayed due to completion of procedural requirement or untimely action. The payment cases need to be considered on priority and settled promptly by simplifying the verification procedure.

18. To avoid attacks on human beings by leopard in the hilly region, problematic nuisance leopard are captured by setting traps with live bait or killed when they become serious threat to the human life.

19. For conducting systematic research study on leopard menace, we should take into account people's feelings, perceptions and attitudes towards the menace, and involve them. It would help in confidence building and creation of awareness among the rural community.

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Annexure 1

QUESTIONAIRE : SOCIO-ECONOMIC IMPACTS

(Family Interview – Based on severity of problem)

S. No. ……….. Date: ……………….

Name of Village: ……… ……….. Post: …………….. Time: ………………

No. of families in the village: …….. ……… ………… …………. .. ….. …………….

A. Demography of village:

1. Family details:

i. Name of Respondent: ………………………………………………….. ………

ii. Address: ………………………. ……………….. …………………… ………………..

iii. Caste. ………………….

v. Family size: Male (s) …………………. Female (s) ……………………….. ……..

vi. Age class: Adult …… Yrs …… Yrs …… Yrs …… Yrs …… Yrs

Children: …… Yrs …… Yrs …… Yrs …… Yrs …… Yrs

2. Details of property:

i. Landless / Marginal / Small / Large

ii. Type of House: Area ……. Concrete …… Kutcha …… Wooden ……., Door ………

iii. Area of crop fields (Bigha) Cultivated ………, Uncultivated ……… Barren ……... ...

Cost of land (Bigha = ……… .) Rs. ……… …………………

iv. Household items: Car/Scooter/Bicycle/TV/Refrigerator/Tape Recorder/ … ……….

3. Educational Status:

Father ………. ……. Mother ………. ……. ….

Son	1.	2.	3.	4.	5.
Daughter	1.	2.	3.	4.	5.

Others …………….. ……………… ……………. ……………. ……………. …..

Illiterate - IL, Primary - P, Jun. High School - JH, High School - HS, Intermediate - INT, Graduate - G, Above - A

4. Occupational Pattern:

i. No. of earning members: ………… ………….. .

ii. Members involved in agriculture ……….. Male (s) ………. Female(s) ……. ……. .

iii. Private ………… Rs ……… Yearly; Government …… Rs.. .. ………… Month

iv. No. of dependents: ………………………

B. Livestock

i. No. of livestock: …………………………

ii.

Category	Adult	Young ones
Buffalo	[ ]	[ ]
Cow	[ ]	[ ]
Bull	[ ]	[ ]
Goat	[ ]	[ ]
Sheep	[ ]	[ ]
Horse/Mule	[ ]	[ ]
Poultry	[ ]	[ ]

iii. Are your livestock Stall-fed: Yes/No

iv. Are Livestock taken in forests for grazing? Yes/No No. of livestock ……………

v. Members accompanying livestock in forests:

	Adult	Sub-adult
Male(s)	………..	……………
Female(s)	………..	……………

vi. Which period: Time period: a.m. p.m.

Month(s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec

vii. No. of milching animals …………… No. of non-milching animals …………… ……...

viii. Used in Agriculture:

He buffalo	[ ]
Bull	[ ]
Horse/Mule	[ ]

ix. How livestock are kept in village houses?

Livestock sheds: Concrete Kutcha Wooden Door Outside

C. Agricultural practices:

i. Crops grown: Rabi - Wheat, Mustard, Gram, Rai, Tarmira, Lentils, ……. ….. …… .
   Kharif - Rice, Sugarcane, Jowar, Bajra, Maize, Groundnut, Til, Moong, Moth .. .

ii. Extent of area under different crops:
   Wheat Mustard Gram Rice Sugarcane Groundnut …. Til
   Jowar Bajra Maize Any other ……………

iii. Farming facilities (Tick mark): Tractor, tubewell, plough, . ……. ….. ………………

iv. Crop damage: Wild animals …….. Pests ……. Disease Water scarcity ……...

v. Crop pattern:

Crops	Sowing time (Mo)	Seeds sown per bigha	Cost of seeds (Rs)	Harvesting time (Mo)	Crop yield (Kg)
Wheat					
Maize					
Mustard					
Rice					
Sugarcane					
Jowar					
Bajra					
Moong					
Arhar					
Moth					
Rai					
Tarmira					
Groundnut					
Any other					

vi. Crop damage by different wild animals. Tick mark (+ or --).

Crops	Nilgai	Bear	Wild boar	Monkey			Total damage **(%)**
Wheat							
Maize							
Mustard							
Rice							
Sugarcane							
Jowar							
Bajra							
Moong							
Arhar							
Moth							
Rai							
Taramira							
Any other							

vii. Crop damage month-wise: Tick mark yes (   ) or no (x).

Crop	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Wheat												
Maize												
Mustard												
Rice												
Sugarcane												
Jowar												
Bajra												
Moong												
Arhar												
Moth												

Rai												
Tarmira												
Groundnut												
Any other												

viii. Damage pattern & protection time.

Crops	Growth stage	Parts eaten	Month(s)
Wheat			
Maize			
Mustard			
Rice			
Sugarcane			
Jowar			
Bajra			
Moong			
Arhar			
Moth			
Rai			
Tarmira			
Any other			

ix. Damage to orchard (s)

Orchard	Problem species	Total damage (%)
Apple		
Plum		
Cherry		

D. Crop protection

a. Protection & vigil - No. of members involved in crop protection . …………… ……….

b. Traditional methods used:

Method	(y/x)	Specify animals
Haka	[ ]	[ ]
Drum beating	[ ]	[ ]
Crackers	[ ]	[ ]
Gun shots	[ ]	[ ]
Driving away	[ ]	[ ]
Brush-wood fence	[ ]	[ ]
Animal Proof-trench	[ ]	[ ]
Barbed wire fencing	[ ]	[ ]
Rubble wall	[ ]	[ ]
Any other	[ ]	[ ]

c. Protection provided by Forest Department.

Method	(√ or x)	Cost/km	Animal(s)
Trench	[ ]	[ ]	[ ]
Barbed wire fence	[ ]	[ ]	[ ]
Electric fence	[ ]	[ ]	[ ]
Rubble wall	[ ]	[ ]	[ ]
Any other	[ ]	[ ]	[ ]

E. NTFP collection:

Name	Species	Quantity (kg)	Month(s)	Time (h)
Medicinal plants				
Fodder				
Fuel wood				
Timber				
Grass				
Mushroom				
Fruits				
Honey				
Gum				
Others.				

Use & distance of water resource(s) from village: For bathing, washing clothes, livestock

River ……….m, Pond ………..m, Nallah ………m, Well ……… m, …… … m …… …m

Water collection: Frequency ……………………. Time ………. ……………

F. Income generating activities:

i. Family income Rs. ………….. /Month Rs. …………… .. /Annum
Various sources Agriculture/Horticulture/Livestock/Fibre craft/Apiculture/Handicraft/ Mushroom/ ………….. ……………

ii. What fuels are used? Biogas / LPG / Kerosene / Solar energy / Dung cake / Agricul. residue

iii. Are these fuels available on subsidized rates? Yes No

iv. Do you sell milk or products? If yes Kg ……… Kg ………Kg ……. ….. Month
Rs. ……… Rs. ……… Rs. ……… Month

v. Purchase of cattle feed: ……….. …. ……… …. ……… …..………. ………

Rs. ……… Rs. ……… Rs. ……… Rs. ……… daily.

vi. Do you sell livestock? Adult/Sub-adult/Male/Female Rs. ……………………..

vii. Do you sell dung cakes, fuel wood etc? Kg. …………….Rs. ……………….. .

viii. Do you sell agriculture/horticultural crops?

Crop	**Quantity (Kg)**	**Rupees**
Wheat		
Maize		
Mustard		
Rice		
Sugarcane		
Jowar		
Bajra		
Gram		
Moong		
Arhar		
Moth		
Rai		
Tarmira		
Apple		
Plum		
Any other		

ix. Do you sell NTFP? Items . …………….. …….. …….. ……………… …………

Rs. ……………… .. . ………….. ……………….. .. ………..

x. Labour work? Yes ( ) No ( ) Rs. …… daily Rs. ……… Yearly

G. People's attitude:

i. Do you wish to have/protect forests? Yes / No

ii. Attitude towards leopard and other animals: …………………………………..

iii. Any time leopard shot or captured in your area:…………………………………………

iv. Peoples problems: Employment/Land/Education/Roads/Buses/Electricity/Dairy/ Fuelwood/ Timber / Fodder / Drinking water for people / Drinking water for livestock / Medical facilities / Irrigation / Veterinary services/Crop protection/Others

H. Remarks