

**Status and ecology of leopard (*Panthera pardus*) in  
relation to prey abundance, land use patterns and  
conflicts with human in Garhwal Himalayas**

**THESIS**  
**SUBMITTED TO THE**  
**FOREST RESEARCH INSTITUTE UNIVERSITY**  
**DEHRA DUN**  
**UTTARAKHAND**  
**For**  
**THE AWARD OF THE DEGREE OF**  
**DOCTOR OF PHILOSOPHY IN FORESTRY**  
**(Forest Ecology and Environment)**



**By**  
**DEVENDRA SINGH**  
**Wildlife Institute of India**  
**Dehra Dun**

**2007**

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**Dehra Dun**

**2007**

## DECLARATION

I hereby declare that the thesis entitled "Status and ecology of leopard (*Panthera pardus*) in relation to prey abundance, land use patterns and conflicts with human in Garhwal Himalayas" submitted for the award of Doctor of Philosophy in Forestry (Forest Ecology & Environment) to Forest Research Institute University, Dehra Dun is a record of original research work done by me under the supervision of Dr. S. P. Goyal, Professor, Wildlife Institute of India, Dehra Dun, and it has not formed the basis for the award of any other degree or diploma. I also declare that the thesis embodies the result of my own work and observations and in that respect the investigation appears to advance knowledge in the subject.

Date: 27 February, 2007

Place: Dehra Dun

*Devendra Singh*  
(DEVENDRA SINGH)  
Candidate

Countersigned:



(Dr. S. P. GOYAL)  
Supervisor

## CERTIFICATE

This is to certify that the thesis entitled “**Status and ecology of leopard (*Panthera pardus*) in relation to prey abundance, land use patterns and conflicts with human in Garhwal Himalayas**” submitted for the award of Doctor of Philosophy in Forestry (Forest Ecology & Environment) to Forest Research Institute University, Dehra Dun is a record of original research work done by **DEVENDRA SINGH** at Wildlife Institute of India, Dehra Dun under my guidance and supervision. I further certify that this research work has not previously formed the basis for the award of any other degree or diploma and it fulfils all the requirements laid down in the Ordinance governing award of Ph.D. degree of Forest Research Institute (Deemed University).



Date: 27 February, 2007  
Place: Dehradun

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(Supervisor)  
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FOREST RESEARCH INSTITUTE  
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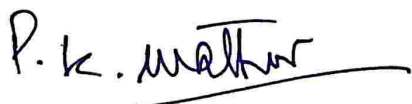
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(S.D. ARORA)

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F.R.I., Deemed University

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2. The Nodal Officer, Wildlife Institute of India, P.B. No. 18, Chandrabani, Dehra Dun - 248 001.
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Registrar

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## CONTENTS

### ACKNOWLEDGEMENTS

### LIST OF FIGURES

### LIST OF TABLES

### SUMMARY

I-IV

V-VI

VII-XIII

<b>CHAPTER 1</b>	<b>Introduction</b>	<b>1-21</b>
1.1.	General	1
1.2.	Study species: <i>Panthera pardus</i>	3
1.2.1.	Taxonomy	3
1.2.2.	Distribution	5
1.2.3.	Morphology	7
1.2.4.	Biology	9
1.2.5.	Ecology and behavior	10
1.2.6.	Principal threats	12
1.2.7.	Conservation efforts	14
1.3.	Review of literature	15
1.4.	Overview of leopard-human conflicts	17
1.5.	Justification, objectives and hypothesis of the study	19
1.6.	Organization of the thesis	20
<b>CHAPTER 2</b>	<b>Study area</b>	<b>22-26</b>
2.1.	Extent and geography	22
2.2.	Climate	22
2.3.	Biodiversity	23
2.4.	Administrative setup	24
2.5.	Socio economic profile of people and demography	25
<b>CHAPTER 3</b>	<b>Distributions and current status of leopard in Pauri Garhwal</b>	<b>27-77</b>
3.1.	Introduction	27
3.2.	Methods	31
3.2.1.	Distribution of leopard in Pauri Garhwal	31
3.2.2.	Relative habitat use by leopards	33
3.2.2.1.	Major habitat assessment and land use/land cover mapping	33
3.2.2.2.	The habitat availability utilization	34
3.2.3.	Status of leopard	34
3.2.3.1.	Selection of Intensive Study Area	34
3.2.3.2.	Based on sign (scat and track) indices	36
3.2.3.3.	Based on camera trapping	38

3.3.	Results	42
3.3.1.	Distribution of leopard in Pauri Garhwal	42
3.3.2.	Relative habitat use by leopard	47
	3.3.2.1. Land use patterns of study area	47
	3.3.2.2. The habitat availability-utilization	53
3.3.3.	Status of leopards in intensive study area of three conflict categories	60
	3.3.3.1. Encounter rate of leopard scats	60
	3.3.3.2. Track index estimation	63
3.3.4.	Camera trapping	66
	3.3.4.1. Capture frequency of leopards in ISA of three conflict categories	70
	3.3.4.2. The problem with use of camera trapping	73
3.4.	Discussion	74
3.4.1.	Distribution and habitat use	74
3.4.2.	Current status	76
3.5.	Summary	77

**CHAPTER 4                    Extent and severity of leopards-human conflict problems in relation to its ecological requirements, land use patterns and human life style                    78-108**

4.1.	Introduction	78
4.2.	Methods	81
4.2.1.	Extent and severity of leopard-human conflict	81
4.2.2.	Quantification the circumstances of conflict	82
4.2.3.	Opinion of local people on leopard- human conflict problems	82
4.3.	Results	83
4.3.1.	Extent and severity of leopard-human conflict	83
	4.3.1.1. Intensity of leopard attacks on human	83
	4.3.1.2. Intensity of leopard predation on livestock	85
	4.3.1.3. General distribution of leopard-human conflicts	87
	4.3.1.4. Conflicts in relation to land use patterns	89
	4.3.1.5. Intensity of leopard deaths in Pauri Garhwal	91
4.3.2.	Quantification of the circumstances of conflicts	96
	4.3.2.1. Age and sex of leopard victims	96
	4.3.2.2. Seasonal patterns of human mortality	97
	4.3.2.3. Leopard attacks with respect to the time of the day and general activities of people	97
	4.3.2.4. Leopard attacks in relation to other factors	100
4.3.3.	Opinion of local people on leopard-human conflict problems	104
4.4.	Discussion	105
4.4.1.	Extent and severity of leopard-human conflict	105
4.4.2.	Quantification the circumstances of conflict	106
4.4.3.	Opinion of local people on leopard-human conflict problems	107
4.5.	Summary	108

<b>CHAPTER 5</b>	<b>Food habits in relation to prey abundance (wild and domestic)</b>	<b>109-153</b>
5.1.	Introduction	109
5.2.	Methods	112
5.2.1.	Relative abundance of prey species	112
5.2.1.1.	Wild prey species	112
5.2.1.2.	Domestic prey species	114
5.2.2.	Food habits	116
5.2.2.1.	Collection and identification of leopard scats	116
5.2.2.2.	Collection of references hair sample and examination of hair characteristics	116
5.2.2.3.	Species identification from scats	117
5.3.	Results	121
5.3.1.	Relative abundance of wild prey species in ISA of three human-leopard conflict categories	121
5.3.2.	Relative abundance of domestic prey species	128
5.3.3.	Food habits	130
5.3.3.1.	Variation in size and weight of leopard scats	130
5.3.3.2.	Minimum sample size determination	132
5.3.3.3.	Number of prey species	133
5.3.3.4.	Prey selection	134
5.3.3.5.	Temporal and spatial variation in leopard diet	135
5.3.3.6.	Prey use across conflict categories	139
5.4.	Discussion	147
5.4.1.	Prey abundance	147
5.4.2.	Food habits	150
5.5.	Summary	153
<b>CHAPTER 6</b>	<b>Factors responsible for leopard-human conflict</b>	<b>154-161</b>
6.1.	Introduction	154
6.2.	Major factors leading leopard-human conflicts	155
6.3.	Circumstances which provoking leopard attacks on human	158
6.4.	Mitigatory measures to minimize leopard-human conflicts	159
<b>LITERATURE CITED</b>		<b>162-171</b>
<b>ANNEXURE</b>		<b>172-174</b>

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## LIST OF FIGURES

Figure No.	Title	Page No.
Figure 1.1.	Geographic distribution of leopard	6
Figure 2.1.	Pauri Garhwal district along with administrative blocks	26
Figure 3.1.	Surveyed grids in Pauri Garhwal district for determining distribution of leopard	32
Figure 3.2.	Selection of Intensive Study Areas (ISA) in different conflict category in Pauri Garhwal	35
Figure 3.3.	Track plot on a forest trail	38
Figure 3.4.	Camera trap system and iron housing used for placement	41
Figure 3.5.	Identification of same leopard based on spot patterns	41
Figure 3.6.	Different parameters used to ascertain leopard presence	42
Figure 3.7.	Distribution of scats recorded while during survey	43
Figure 3.8.	Reported livestock deaths from the study area	44
Figure 3.9.	Reported human deaths from the study area	45
Figure 3.10.	Map showing overall leopard distribution in the study area	46
Figure 3.11.	Map showing land use patterns in Pauri Garhwal district	48
Figure 3.12.	Areas dominated with scrubs	49
Figure 3.13.	Areas dominated with forest	50
Figure 3.14.	Observed human settlements in study areas	51
Figure 3.15.	Proportion of different land use patterns in term of land cover in 15 administrative blocks of Pauri Garhwal district	52
Figure 3.16.	Relationship between number of livestock killed by leopards and observed scrub cover in administrative blocks of Pauri Garhwal.	53
Figure 3.17.	Use of scrub cover by leopards based on availability-utilization approach	56

Figure 3.18.	Use of human habitation by leopards based on availability-utilization approach	57
Figure 3.19.	Use of forest cover by leopards based on availability-utilization approach	58
Figure 3.20.	Mean Encounter rate of leopard scats (no./km) in relation to three different habitats	59
Figure 3.21.	Variation in Mean Encounter Rate of leopard scats across the seasons among conflict categories	62
Figure 3.22.	Variation in track index across the seasons among conflict categories	65
Figure 3.23.	Relationship of individual leopards captured with increasing photographs	66
Figure 3.24.	Identified individual leopards during camera trapping efforts (2003-2005) in ISA of low conflict category	67
Figure 3.25.	Identified individual leopards during camera trapping efforts in ISA of medium conflict category	68
Figure 3.26.	Identified individual leopards during camera trapping efforts in ISA of high conflict category	69
Figure 4.1.	No. of human killed/injured in Pauri Garhwal district	83
Figure 4.2.	Percent human mortality across the administrative blocks in Pauri Garhwal	84
Figure 4.3.	Percent livestock mortality across different administrative blocks in Pauri Garhwal	85
Figure 4.4.	Relationship between human and livestock deaths in 15 administrative blocks of Pauri Garhwal	86
Figure 4.5.	General distribution of leopard-human conflict based on cases reported of human and livestock predation	88
Figure 4.6.	Extent of area under conflict category across the administrative blocks	89
Figure 4.7.	Proportion of different land use patterns in three conflict categories	90
Figure 4.8.	Correlation between percent scrub cover and conflict cases in 15 administrative blocks	90

Figure 4.9.	Correlation between percent human habitation and conflict cases in 15 administrative blocks	91
Figure 4.10.	Patterns of leopard deaths in Pauri Garhwal	92
Figure 4.11.	Number of leopard deaths over the years in Pauri Garhwal district	93
Figure 4.12.	Proportion of leopard death across the administrative blocks	93
Fig 4.13.	Sex of leopards killed as declared man-eaters	94
Figure 4.14.	Relationship between leopard and human deaths in two highly affected administrative blocks in Pauri Garhwal	95
Figure 4.15.	Age and sex of human killed by leopards	96
Figure 4.16.	Seasonal patterns of human mortality	97
Figure 4.17.	Leopard attacks in relation to the time of the day	98
Figure 4.18.	Leopard attacks in relation to location of house	100
Figure 4.19.	Destiny of shrub within 500 m at human killing sites	101
Figure 4.20.	Surrounding vegetation of houses where human were killed by leopards	102
Figure 4.21.	Leopard attacks on human in relation to presence of electricity	103
Figure 4.22.	Leopard attacks on children in relation to presence of adult male	103
Figure 5.1.	Medullary patterns of wild and domestic prey species	119
Figure 5.2.	Cuticular characteristic of wild and domestic prey species	120
Figure 5.3.	Mean encounter rate of domestic species observed during 2003-2004	128
Figure 5.4.	Variation in diameter of leopard scats in Pauri Garhwal	130
Figure 5.5.	Frequency of occurrence and normal distribution of diameter of leopard scats across the various conflict categories	131
Figure 5.6.	Variation in weight (oven dried) of leopard scats collected from Pauri Garhwal	132

Figure 5.7.	The relationship between the number of scats and the percent frequency occurrence of three major prey species (dog, cattle and goat)	133
Figure 5.8.	Number of prey species in leopard scats across the 3 conflict categories	134
Figure 5.9.	Proportion of different prey species in leopard diet determined from scats	135
Figure 5.10.	Leopard predation on cattle in terms of frequency occurrence in leopard diet across the seasons	136
Figure 5.11.	Spatial distribution of scats having remains of two major prey species	138
Figure 5.12.	Proportion of different prey species in terms of frequency of occurrence across the three conflict categories	140
Figure 5.13.	A comparison of prey species abundance and their proportion in terms of frequency of occurrence in leopard diet in low conflict category	143
Figure 5.14.	A comparison of prey species abundance and their proportion in terms of frequency of occurrence in leopard diet in medium conflict category	144
Figure 5.15.	A comparison of prey species abundance and their proportion in terms of frequency of occurrence in leopard diet in high conflict category	145
Figure 5.16.	Percent proportion of prey species in scats in relation to prey abundance	146

## LIST OF TABLES

Table No.	Title	Page No.
Table 3.1.	Details of trails monitored in ISA of three conflict categories	37
Table 3.2.	Camera trapping schedules in ISA of three conflict categories	40
Table 3.3.	Types and characteristics of forest and non forest classes	47
Table 3.4.	Use of scrub by leopards based on availability- utilization approach.	54
Table 3.5.	Utilization of human habitation by leopards based on availability- utilization approach	55
Table 3.6.	Utilization of forest cover by leopards based on availability- utilization approach	55
Table 3.7.	Average encounter rate of scats observed in ISA of three conflict categories.	61
Table 3.8.	Track index of leopard observed in ISA of three conflict categories	64
Table 3.9.	Number of leopard deaths reported from surrounding of three intensive study areas of three conflict categories	65
Table 3.10.	Capture frequency of leopard in three conflict categories	71
Table 3.11.	Capture frequency in relation to leopard deaths in ISA of three conflict categories.	71
Table 3.12.	Leopard movement patterns and human deaths in various conflict categories	72
Table 4.1.	General activities of hill peoples	99
Table 5.1.	Summary of forest trails monitored during 2002 to 2005 in conflict categories for estimating relative abundance of wild prey species	115
Table 5.2.	Summary of road side transects monitored 2003-2004 in conflict categories for estimating domestic prey species	115
Table 5.3.	A comparison of different methods used for estimating relative abundance	121

Table 5.4.	Average Encounter Rate of barking deer in ISA of three conflict categories observed during 2002 to 2005	123
Table 5.5.	Track index of wild pig observed in ISA of three conflict categories	125
Table 5.6.	Track index of porcupine observed in ISA of three conflict categories	126
Table 5.7.	Track index of pheasants observed in ISA of three conflict categories	127
Table 5.8.	The average encounter rate of domestic species in ISA of three conflict categories	129
Table 5.9.	Seasonal variation in the proportion of different prey species remains in terms of frequency of occurrence in leopard diet observed during 2001 to 2005	137
Table 5.10.	Proportion of different prey species in terms of frequency of occurrence remain in leopard diet over the sampling periods in ISA of low, medium and high conflict categories	142
Table 5.11.	Comparison of density estimates of major prey species of leopard in different study sites	149
Table 5.12.	Percent frequency occurrence of major prey species in leopard scats reported from different study sites	152

## SUMMARY

The leopard *Panthera pardus* is most widely distributed of all the world's large cats. In India, leopards are found through out the country with the exception of desert areas and Sundarbans mangroves. The leopard appears tolerant of habitat modification and successfully adapted to live in the vicinity of human settlement areas. Leopard's ability to feed on a broad spectrum of prey makes them most successful predator among big cats. In Asia, the leopard is also advantaged over the tiger by its ability to exist with human. Changes in behavior of leopard have been noticed due to habitat degradation along with decline in wild prey. With the result, there has been an increased human-leopard conflicts outside the protected areas and in this process irate human killed a number of animals. No such study has been undertaken to study such changes in behaviour of leopard due to habitat modification in South Asia except a few studies undertaken in Africa.

The problem of human-leopard conflict has recently been increased in the Indian Himalayan region due to change in land-use patterns. Leopard-human conflict as predation on human and livestock has been quite frequent in 16 districts of Uttarakhand state and Pauri Garhwal district is worst affected. Recent increase in such incidences has been reported from this region. The main goal of this research was to provide a base line information on status of leopard-human conflicts in Pauri Garhwal district and response of leopard in relation to prey abundance, land use patterns and human dimension in human dominated landscape.

Present Ph. D. work was undertaken in Pauri Garhwal district of Uttarakhand to (i) determine distribution and current status of leopard in Pauri Garhwal (ii) to determine extent and severity of leopard-human conflict problems in relation to its ecological

requirements, land use patterns and human life style. (iii) to study food habits in relation to prey abundance (wild and domestic) and habitat characteristics and (iv) to determine factor responsible for leopard-man conflict.

A survey was carried from February 2000 to October 2001 in 15 administrative blocks of Pauri Garhwal district. Information was collected on distribution and extent and severity of leopard-human conflict. Village survey was found to be the best way and cost effective. Study area (5444 km<sup>2</sup>) was divided into 2x2 grids and survey was done at least for 50% villages in each grid. Structured questionnaire was designed to obtain information on all aspects related to leopard distribution and conflict with human. Leopard scats encountered during survey were collected along with GPS location. Existing information with forest department was also noted. Data of leopard victims was analysed with respect to sex and age, seasons and time of the day. Data were also collected on gender of leopards killed as alleged man-eaters. Leopard distribution map was prepared based on different parameters such as presence of leopard scat and livestock and human killed by leopards in each surveyed grid. Land use/land cover map of study area was prepared and major land use patterns identified. Leopard distribution was correlated with respect to different land use patterns. In order to determine uses of different habitats by leopards, Neu *et al.*, (1974) method was adopted. Number of livestock and human deaths caused by leopards were the criteria for determining the severity of conflict in each surveyed grid. Entire study area was stratified into three category of conflict viz. low, medium and high according to the severity of leopard-human conflict in each grid. Intensive study areas (ISA) of 40 km<sup>2</sup>, representative of each conflict category, was selected for detailed study to determine abundance of leopard and

it's prey species (wild and domestic) by using sign indices and camera trap methods. Being typical hilly terrain, it was not possible to use straight line transects for this purpose, therefore forest trails were considered for collecting information on abundance of leopard and it's prey species. Scats were collected from these intensive study sites to understand the food habits of leopards. A total of 428 scats were analysed. Prey species in scats were identified based on microscopic analyzing remains through hair characteristics whereas portion of other parts present in the scats were noted. All places where leopard attacked on human during field work were visited and circumstances of attacks were quantified.

Leopards are distributed through out the study area. The major land use patterns of the study area are forest, scrub and human habitation. Among these, scrub is dominating with more than 50 percent of total land cover whereas percentage of forest and human habitation is more or less equally distributed with 25 percent. Leopard distribution was positively correlated with scrub. Habitat-Utilization data suggest that scrub cover is widely used in terms of area. The grids in which scrub occupy 40-60% of total area were significantly preferred by leopards. Similarly leopards have shown a significant preference to the grids where human habitations occupy 40-50% of total area. Forest cover was used by leopards in proportion to its availability. Average encounter rate of leopard scat was significantly ( $\chi^2=34.4$ ;  $P<0.01$ ) higher in high conflict category than other and ranged from 0 to 0.55/km during sampled periods. Track index has not shown any statistically difference across the conflict categories. Estimated track index of leopard was highest in medium conflict category and ranged from 0 to 0.64 during sampling periods. Estimated capture frequency of leopard was highest in medium conflict

category and ranged from 0.2 to 3.9/100 camera trap nights during sampling efforts. A declining trend was observed in track index and capture frequency from 2002 to 2005. This may be due to as a result of leopard deaths in surrounding of three intensive study sites during sampled periods. However scat data has not shown such trend. Camera trap data was not used for density estimation by using program CAPTURE as frequent leopard deaths were reported from all intensive study sites during trapping efforts. Individual leopards identified based on camera trap data were observed moving shorter distances.

Frequency of leopard-human conflict has increased during last decade. Conflict have been reported from entire area but intensity varied across the administrative blocks. Pabau, Kalgikhal, Dugadda, Jaiharikhal, Dwarikhal and Rikhinikhal blocks are severely affected in terms of leopard attack on human. While block such as Thalissain and Khirshu were worst affected in terms of leopard predation on livestock. Low leopard predation on human was found in blocks where predation on livestock is relatively high. Leopard attack on livestock and human were positively correlated with scrub cover. Proportion of livestock and human death was relatively high in those blocks where large proportion of area is under scrub cover. Similarly leopard attacks on human and livestock were positively correlated with human habitation but statistically it was not significant. This is probably due to their dependency on livestock. There has been decreasing trends in leopard predation on human in the blocks where large numbers of leopards have been killed. Limited data (n=27) about sex of leopards killed as alleged man-eaters indicates that female leopards were more likely to cause conflict. After analyzing the events of conflict, it appears leopards are targeting soft preys such as children and 69% victims

were children below 15 years. Leopard attacks on human were varied across the seasons and majority of attacks were during rainy (45.8%) and winter (42.7%) seasons. Due to dense vegetation cover, leopards probably come more close to human settlement areas during these seasons where they seek opportunities to kill livestock and in this process some time human fall prey of them. Leopard attacks were varying across the time of day, as 68 % human were killed between 1600-2100 hours and 16.4% in early morning between 0400 to 0800 hours. This is coincided with their timing of toilet as in hills most of the families do not have toilet facilities and they often use open space for this purpose. Majority of women fell victim during their daily routine work which they often perform alone. Adult males were killed while returning from working places. Based on observation during field work, it was observed that leopard attacks on human might be affected by factors such as no electricity and distance of house from main village. Frequencies of attacks on children may be affected by presence of adult males.

Methods were standardized to understand the relative abundance of different prey species existing in study area. Track index was found quick and effective means to estimate relative abundance of recorded species such as wild pig *Sus scrofa*, porcupine *Hystrix indica* and pheasants. While direct sighting method was suitable for estimating abundance of barking deer *Muntiacus muntjak* in this study. Among wild prey species, barking deer, wild pig, porcupine and pheasant were recorded in all conflict categories and their relative abundance was very low in comparison to reported studies in literature. Barking deer encounter rate (no./km walk) was significantly high ( $\chi^2= 13.09$ ;  $P<0.01$ ) in low conflict category and ranged from 0 to 0.20/km. Track index of wild pig, porcupine and pheasant was not statistically varied across the conflict categories. Among the

domestic species, cattle, dog, goat, sheep and buffalo were sighted on roadside transects in all conflict category. Among observed species, the average encounter rate of cattle was highest than other domestic animals in all conflict categories. Most of the observed species have not shown any significant variation across the conflict categories. Scat analysis data indicates that leopards are subsisting mainly upon domestic prey species in all conflict categories. Leopard mainly preyed on domestic animal such as dog, cattle, goat and sheep which made up 93% of total diet while wild species including barking deer, wild pig and pheasants contributed <3% of total diet. Among domestic species, dog is contributing 45 % of total diet and is followed by cattle which contributes around 42% of total diet. Rodents were also part of leopard diet and contributed upto 4.9 % of total diet. No temporal and spatial differences in prey selection were observed for most of the prey species. Leopard predation on cattle is relatively high during winter and rainy season but statistically it was not significant. Cattle and dog were frequently taken prey in all conflict categories and making a bulk (>70%) of leopard diet during sampling periods. Percent contribution of two or more than two prey species in leopard diet was relatively higher in high to medium conflict categories. All prey species were preyed more than expected on the basis of their relative abundance. Leopard consumes domestic animals only less than 10% in areas of high wild prey abundance in protected areas.

The results of this study indicate that the two major factors leading leopard-human conflict in this region. The first factor is habitat degradation followed by depletion of prey species. Conflict is prominent in those areas where degraded forest is being replaced by shrubs. Shrub cover is providing ideal stalking and breeding cover for leopards. The abundance of wild prey is such a low that leopards are now mainly

dependent on cattle and dogs. While other factor may probably be due to increase in local leopard population or change in ranging behaviour to some extent. Mitigatory measures are discussed to minimize leopard-human conflicts in this area based on the study

There is a need of understanding ranging behaviour and systematic population estimation of leopards specially in high to medium conflict categories in order to achieve the reasons for such changed behaviour of species and to plan a proper strategy to reduce such conflicts.

## CHAPTER 1 INTRODUCTION

### 1.1. GENERAL

Large carnivores have an important role to play in the structuring of communities and ultimately of ecosystems. Thus, the preservation of carnivores becomes an important consideration in the discipline of conservation biology (Eisenberg 1986; Ginsberg 2001; Gittleman *et al.* 2001).

Leopard *Panthera pardus* is the most common and widely distributed species (Johnsingh *et al.* 1991; Daniel 1996) among large carnivores protected by law in India. Leopard populations have been greatly reduced throughout their former vast range in India due to several reasons and population is confined to smaller insularized areas or forest patches (Rodgers and Panwar 1988; Johnsingh *et al.* 1991; Daniel 1996).

In recent past, attrition of leopard range in India has been an accelerating trend due to changes in land use patterns, encroachment and continuous mounting pressure in these habitats due to high human population. (Johnsingh *et al.* 1991; Daniel 1996). In spite of this leopard has been able to survive and is considered the most successful and perfect predator. The leopard has survived due to its ability to adapt a variety of environmental situations (Guggisberg 1975; Seidensticker *et al.* 1990; Bailey 1993; Daniel 1996). The leopard appears tolerant to habitat modifications and has successfully adapted to live in the vicinity of human settlements (Seidensticker *et al.* 1990). Leopard's ability to adapt and remain elusive and unseen in the most adverse of habitats and flexibility of behavior with respect to boldness and its ability to feed on a broad spectrum of prey makes it the most successful predator among large cats (Mitchell *et al.*

1965; Schaller 1972; Muckenhirn and Eisenberg 1973; Hamilton 1976; Seidensticker *et al.* 1990; Henschel *et al.* 2005).

Leopard as a species is classified by International Union for the Conservation of Nature (IUCN) (1978) as vulnerable because of threats it is facing: (i) the leopard is killed for its valuable skin. (ii) animal is killed because its conflict with human and domestic animals. (iii) it is threatened by ever diminishing available wild habitat. Most of these threats are increasing continuously. Other conservation threats to leopards are fragmentation of habitat into smaller pockets and loss of wild prey population (Myres 1976; Daniel 1996; Woodroffe 2000). The species continues to be killed for socioeconomic purposes.

Unlike other large cats in India, a large population of leopard resides outside protected areas. These areas are too small or lack enough wild prey to maintain viable population of leopards. Thus these leopards need to move into the agricultural landscape where they have to co-exist with humans. When living near people, this species is regarded as a nuisance due to their predation on livestock and threats to human (Johnsingh *et al.* 1991; Chellam and Johnsingh 1993; Daniel 1996). Leopards are often prosecuted when they turn to livestock as prey and sometime killed because of actual perceived threats to human life (Johnsingh *et al.* 1991; Daniel 1996; WWF-report 1996).

In India leopard behaviour has changed and has become bold at several places due to habitat degradation and depletion of wild prey (Johnsingh *et al.* 1991; Chellam and Johnsingh 1993; Daniel 1996). Intense human-leopard conflicts have forced the decline of leopard populations in many areas due to frequent killing of alleged man-eaters (Johnsingh *et al.* 1991; Daniel 1996; WWF report 1996).

Frequent leopard-human conflict have been reported from the Garhwal region of Uttarakhand state (Johnsingh *et al.* 1991; Negi 1996; Mohan 1997). Although leopard attacks on human are not new in Garhwal but the frequency has increased surprisingly during the last decade (Negi 1996). Leopards are not uncommon in this region as their food consisting of a number of wild prey species have been historically common (Corbett 1957). But due to severe human pressure on habitat (mainly hunting, cattle grazing, fire wood collection, forest fires, 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. All these factors have put the leopards survival under pressure.

Most of the studies on leopard have been undertaken in Protected Areas where as there is a need to understand responses of animal to changes in habitat attributes specially 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.

## **1.2. STUDY SPECIES: *Panthera pardus***

### **1.2.1. Taxonomy**

The Felidae are a monophyletic family of 37 species and 21 genera (Bekoff *et al.* 1984). Felids are found in all continents except Australia (Bekoff *et al.* 1984). 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*) (Wozencraft 1993). Leopards are put in the genus *Panthera* on the basis of several characteristics. Fossile evidences suggest that leopards were there 1.5 to 2.0 million years ago (Hemmer 1976; Bailey 1993).

Classification (Linnaeus 1758) of leopard is as follows:

Kingdom	Animalia
Phylum:	Chordata
Class:	Mammalia
Order:	Carnivora
Family:	Felidae
Subfamily:	Felinae
Genus:	Panthera
Species:	pardus

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; 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 leopards: (1) African, (2) Central Asian (3) Indian, (4) Sri Lankan, (5), Javan and (6) East Asian. Thus, Miththapala *et al.* (1996) recommended that leopard taxonomy should be revised to comprise eight sub species: (1) *P. p. pardus* (Africa), (2) *P.p. saxicolor* (Central Asia), (3). *P. p. fusca* (Indian subcontinent), (4) *P. p. kotiya* (Sri Lanka), (5) *P.p. melas* (Java), (6) *P.p. orientalis* (Amur), (7) *P.p. japonensis* (Northern China) and (8) *P.p. delacouri* (Southern China).

### 1.2.2. Distribution

The leopard is the most widely distributed (Fig. 1.1) of all the world's large cats (Bailey 1993). Leopards were once more widely distributed than today. During the Pleistocene, leopards inhabited Africa, Asia and Europe (Bailey 1993). Leopards were once ranged from northern region and south of Sahara in Africa, Sinai Peninsula north to West Caspian through Arabia, across Turkey, Iran and Afghanistan in the 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; Bailey 1993).

Current distribution of the species includes the Africa, (south of the Sahara in the north to the 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 neighboring 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; 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; Daniel 1996). Among eight subspecies declared endangered by IUCN, Amur leopard (*P. p. orientalis*) is critically endangered and the population is estimated at approximately 50 mature individuals (Miquelle *et al.* 2003).

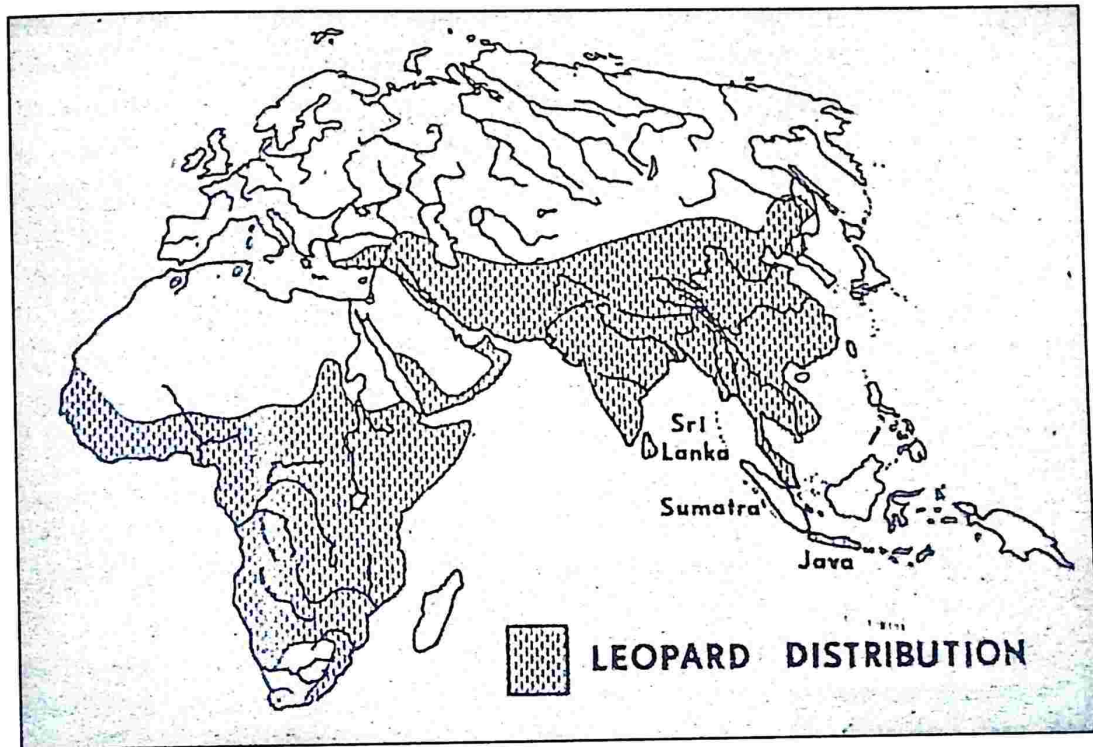


Figure 1.1. Geographic distribution of leopard (Source: Bailey 1993)

There is a 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; Ilany 1986; Khan 1986; Green 1987; 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 costal forests. But situation over the years has changed and leopards are now confined to one isolated habitat block (Khan 1986). The numbers of leopards have been greatly 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). The Amur leopards of Russia are threatened by the small size of their

population (Korkishko and Pikunov 1994). Species is extinct in most part of Arabia and in Israel, it is threatened by the small size of their population (Ilany 1990).

In India, leopards are found throughout the country with the exception of desert areas and Sundarbans mangroves areas (Khan 1986; Johnsingh *et al.* 1991). In India leopard is listed as endangered. It is also listed as vulnerable in the Red List of IUCN. The exact number of leopards present in India is not known. However the species is still widespread (Daniel 1996). All India Tiger Census Data indicates that leopard population is stable or has increased in the states of Assam, Arunachal Pradesh, Bihar, Gujarat, Himachal Pradesh, Madhya Pradesh, Mizoram, Maharashtra, Orissa, Karnataka, Rajasthan, Tripura, Tamilnadu, Uttarakhand and Uttar Pradesh between 1984 and 1993. It is difficult to conclude whether leopard population has increased during last three decade after implementation of Wildlife (Protection) Act-1972.

### 1.2.3. Morphology

The leopard's coat color varies from pale yellow to deep gold and is with black rosettes (Turnbull-Kemp 1967; Prater 1971; Bailey 1993). 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). Coat color and rosettes pattern 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; Khorozyan 2003).

In humid forest habitats specially in India and South East Asia melanism is frequent in leopard populations (Kingdon 1977). The melannistic leopards are referred as "Black Panthers". Black leopard are merely colour variation, and not a subspecies

(Miththapala *et al.* 1996). Leopards in Iran and Central Asia have a lighter color and a long-haired winter coat (Bailey 1993).

The leopard is well known for its versatility and shows a number of morphological adaptations (Turnbull-Kemp 1967; Prater 1971; Guggisberg 1975). Leopard body size varies across its range. Size of leopard varies according to the geographic region (Stuart 1986; Norton *et al.* 1986; Bailey 1993). The larger subspecies of leopards are found in Iran and West Africa and the smaller subspecies occur in Somalia and Java (Bailey 1993). In length, the leopard averages between 5 and 8 feet (Bailey 1993). Average leopard weight reported is 58 kg for male and 37.5 for female (Jenny 1996; Bailey 1993). Exceptionally large males weighing over 91 kg have been reported from South Africa in Kruger National Park (Turnbull-Kemp 1967). The smallest male weighing 30-31 kg has been reported from South Africa's Cape Province and Judean Desert (Ilany 1986; Norton *et al.* 1986; 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 climb trees (Hopwood 1947 *in litt*). Leopard's 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 darkness (Skinner and Smithers 1990). Despite its relatively small body size, the leopard is still capable of

taking large prey (Kingdon 1977; Rabionwitz 1989; Karanth and Sunquist 1995; Sediensicker *et al.* 1990; Bailey 1993; Henschel *et al.* 2005).

#### 1.2.4. Biology

Leopards breed throughout the year across their range except in the tropics (Prater 1971). In Africa most courtships (49%) among leopard was observed between January to March (Bailey 1993). Amur leopards (*P. p. orientalis*) have reported to breed in June-July (Shibnev in litt 1989). In Sri Lanka, breeding was reported during dry season (May-July) (Santiapillai *et al.* 1982). In the Himalayan region of India, mating calls are heard more often during winter (Johnsingh in litt 1993). Estrous cycles of about 26 days were reported from captive females (Bailey 1993).

In female leopards, gestation lasts for about 90-110 days (Bailey 1993). The mean litter size varies between 2-3 (Turnbull-Kemp 1967; Santiapillai *et al.* 1982; Sediensicker *et al.* 1990; Bailey 1993). Leopards may give birth to litter of 1-6 cubs (Turnbull-Kemp 1967). Cubs are born in a den or under bushes (Bothma and Le Riche 1984; Seidensticker *et al.* 1990; Bailey 1993).

The cubs remain with their mother for 12 to 18 months. Then they become independent and establish territories of their own. (Eisenberg and Lockhart 1972; Muckenhirn and Eisenberg 1973; Bailey 1993). Mortality among cubs is frequently observed (Schaller 1972; Sediensicker *et al.* 1990; Bailey 1993). High mortality among juveniles was observed by Sediensicker *et al.* (1990) while working in Chitwan National Park, Nepal. Male cubs have higher mortality rate than females (Bailey 1993).

The cubs are weaned at the age of three months when they begin to accompany their mother on hunts. (Bothma and Le Riche 1984; Bailey 1993). The males become sexually mature at 2-3 years, where the female becomes sexually mature at about 3 years (Bailey 1993). Female leopards appear to grow more rapidly than males (Bailey 1993).

Reported interbirth interval is of 20-21 months (Seidensticker *et al.* 1990; Bailey 1993). Females in captivity have produced offspring as old as 19 years, but the average age of last reproduction is 8.5 years (Bothma Le Riche 1984; Bailey 1993). The maximum life expectancy for wild leopard is 12 years where in leopards have lived up to 20 years (Bailey 1993). Females in captivity have produced offspring as old as 19 years, but the average age of last reproduction is 8.5 years (Bailey 1993).

#### **1.2.5. Ecology and Behavior**

Wide distribution of the leopard reflects the diverse adaptability of the species (Turnbull-Kemp 1967; Guggisberg 1975; Bailey 1993; Daniel 1996). The species show great variation in appearance and behaviour. Leopard is adapted to live well in savannah, rain forest, mountain elevation, dense vegetation, low scrub and thickets and even quite close to human habitation (Seidensticker *et al.* 1990; Bailey 1993).

The species is known to occupy all kinds of niches and occupy a broad variety of habitats (Ilany 1986; Khan and Beg 1986; Bailey 1993). In Himalaya the leopard presence has been reported up to 3400 m except in Trans-Himalayan regions (Green 1987). Exceptionally leopards range up to 5700 mt 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 successful at adapting to human modified landscapes (Hamilton 1986; Seidensticker *et al.* 1990;

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; Seidensticker *et al.* 1990). Leopards not only adapt well to drier areas with low cover (Seidensticker *et al.* 1990) but they have also been shown to be independent of free water sources, using it when it is available (Hamilton 1976; 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).

Leopard's ability to feed on a broad spectrum of prey makes them most successful predator among big cats. Because of its hunting technique, the silent and solitary leopard is able to live of a much broader spectrum of prey than other large carnivores (Mitchell *et al.* 1965; Muckenhirn and Eisenberg 1973). The species is known to be an ecological generalist rather than specialist and can survive by feeding on a variety of prey species ranging in size from the smallest rodent to a young buffalo (Bothma and Le Riche 1986; Norton and Henley 1987; Bailey 1993; Bothama and Coertze 2004; Henschel *et al.* 2005). The known prey of leopards ranges from dung beetles to adult male eland (Kingdon 1977). Bailey (1993) observed 92 prey species in leopards' diet in sub-Saharan Africa. Leopards generally focus their hunting activity on locally abundant medium-sized ungulate species while opportunistically taking other prey (Seidensticker *et al.* 1990; Johnsingh 1992; Bailey 1993; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002; Bothama and Coertze 2004; Henschel *et al.* 2005).

The leopard's ability to scale trees allows it to overcome its carnivorous competitors, often taking its preys far out of reach from them (Bailey 1993; Stander 1998). Leopards usually kill prey during night hours (Hamilton 1976; Santiapillai *et al.*

1982; Bailey 1993). Bothma and Le Riche (1984) observed that male leopards killed every three days on average and females with cubs every 1.5 days.

Studies revealed that leopards of same sex and age had distinct home range (Hamilton 1976; Bertram 1982; Santiapillai *et al.* 1982; Rabinowitz 1989). Home range is the area over which an animal normally travels in pursuit of its routine activities (Jewell 1966). In Serengeti national park, the home range estimated for 2 female leopards were 40 and 60 km<sup>2</sup>. Hamilton (1976) in Tsavo National Park estimated that a male had an average minimum home range size of 36.3 km<sup>2</sup> with a range from 17.9 to 63.4 km<sup>2</sup> where as females had home ranges of about 14.4 km<sup>2</sup>. Minimum home range size of 5.6 km<sup>2</sup> of a radio-collared leopard was recorded in Ruhuna National Park, Sri Lanka (Santiapillai *et al.* 1982). In Royal Chitwan National Park, Nepal minimum area occupied by three females were 6 km<sup>2</sup> (Seidensticker *et al.* 1990).

#### **1.2.6. Principal threats**

As with many endangered animals, increasing human population, loss of habitats and hunting have reduced the number of leopards. They are endangered through much of their range (Roberts 1977; Santiapillai *et al.* 1982; Ilany 1986; Green 1987; Khan 1986; Bailey 1993; Daniel 1996), though the species is not yet threatened with extinction except in certain areas (Myers 1976). The leopard appears to be very successful at adapting to altered natural habitat and settled environments in the absence of intense persecution (Turnbull-Kemp 1967; Guggisberg 1975; Martin and De Meulenaer 1988; 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; Bailey 1993). The wide geographic distribution of leopards is

also attributed to their ability to co-exist with other larger carnivores (Hamilton 1976; Sediensicker *et al.* 1990). In South Asia, leopard has an advantage over tiger due to its ability to survive outside protected area (Sediensicker *et al.* 1990).

Leopards continue to get killed for socio-economic reasons, as demand for bones, skin (Hamilton 1981; Bailey 1993; WWF Report 1996). 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. (Bailey 1993). Hamilton (1981) reported that poaching for the fur trade has substantially reduced the leopard population in Kenya. In Africa at many places leopard population are increasingly threatened due to prosecution by local people to protect livestock (Myers 1986). People travel long distances to kill leopard in their vicinity (Hamilton 1981). Due to excessive hunting for their skins and depletion of prey species, leopards have become rare in the Savanna and West African rainforest zones (Myres 1976; Norton *et al.* 1986; Martin and De Meulenaer 1988). Human pressure has reduced leopard populations 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 threats to the species in Java come from the increasing use of poison.

In Middle East, many population have become quite small and are increasingly vulnerable due to disruption of healthy population dynamics (Ilany 1986). In Russia the species is threatened by small size of the population (Korkishko and Pikunov 1994). The Russian range of Amur leopard decreased dramatically between 1970 and 1983 due poaching and depletion of wild prey (Korkishko and Pikunov 1994).

Leopards are threatened by a depleted wild prey base in many areas (Hamilton 1976; Johnsingh *et al.* 1991; Chellam and Johnsingh 1993; Korkishko and Pikunov 1994; Negi 1996). Leopards are persecuted when they turn to livestock (Hamilton 1986; Korkishko and Pikunov 1994; Daniel 1996). In several areas leopard are facing threats from its carnivorous competitors (Schaller 1972; Bailey 1993).

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 immediate extinction (WWF Report 1996). In the hill region of North India, leopards are being killed due to their confrontation with human (Negi 1996; WWF Report 1996).

#### **1.2.7. Conservation efforts**

The leopard is placed in Appendix 1 in the Convention on International Trade in Endangered Species (CITES) which prohibits trade of leopard or it's body parts in those countries who are members. In India, under the CITES treaty the leopard or their pelts or body part for commercial purposes has banned. But in absence of effective public relation campaign leopard killing for commercial purposes has not been checked (WWF-report 1996).

Alarmed at the rate at which leopards are being killed for socioeconomic purposes, the IUCN (International Union for the Conservation of Nature) listed eight sub species endangered or critically endangered. In India leopard is declared Schedule-I species and it's hunting is banned since 1972 after implementation of Wildlife (Protection) Act-1972. Leopard is conserved along with co-existing carnivores with in Protected Areas (PAs). But there is no clear cut management strategies for leopard

conservation residing outside of protected areas as have been seen in protected areas. Thus, there is a strong need to have management plan for conserving species especially in human dominated landscape.

### 1.3. Review of literature

Up to 1970s, leopards remain essentially unstudied in wild (Bailey 1993). Leopards are extensively studied in African continent during last two decades (Schaller 1972; Hamilton 1976; Bailey 1993; Bothma and Le Riche 1984; Mizutani and Jewell 1998; Spong *et al.* 2000). Information on leopard's ecology and biology was first given by Schaller (1972) while studying lions in Serengeti National Park. Hamilton (1976) intensively studied the movement patterns of radio-collared leopards in Tsavo National Park. Bailey (1993) monitored leopards for a long time in Kruger National Park and provided valuable information on different aspects of leopard ecology, biology, behaviour and population composition. Leopard abundance and ranging patterns were studied by monitoring radio-collared leopards in Lolldaiga Hill of Kenya (Mizutani and Jewell 1998). In Namibia, data on leopard ecology was collected by monitoring of radio collared animals for three years (Stander 1998). Population structure and history of Tanzanian leopard have been studied by using molecular tools (Spong *et al.* 2000). Diet of leopard was studied by analyzing scat contents and observed leopard kill in Ituri Forest, Zaire (Hart *et al.* 1996), Matopos National Park in Zimbabwe (Grobler and Wilson 1972) and Lope National Park of Gabon Africa (Henschel *et al.* 2005). Among other intensive studies, Bothma and Le Riche (1984, 1986), Norton and Lawson (1985), Norton *et al.* (1986) and Norton and Henley (1987) collected information on behavioral ecology, biology and food habits in Africa.

Little is known about population composition and behavioral ecology of leopard in Asia. Among a few detailed studies undertaken on leopard in Asia, the species has been studied by direct observation or by monitoring radio collared animals. Rabinowitz (1989), studied leopards in Huai Kha Khaeng wildlife sanctuary, Thailand and determine the home range for leopard along with it's food habit assessment by observing kills. Home range and activity pattern in relation to breeding biology of the species were studied by Eisenberg and Lockhart (1972) in Wilpattu National Park, Ceylon. Leopards were studied intensively at the edge of Royal Chitwan National Park, Nepal by Seidensticker *et al.* (1990). Radio-collared leopards were monitored for a long time and their home range and food habits were examined in relation to composition and distribution of preys. Social structure and food habits of the leopards were studied by monitoring radio-collared animals in Ruhuna National Park, Sri Lanka (Santiapillai *et al.* 1982). In China, food habits of leopard was studied over 7 years in Wolong Reserve, Sichuan by analyzing faces (Johnson *et al.* 1993).

In India, the leopard has mostly been studied while studying other animals sharing the same habitat. Johnsingh (1992) studied leopard food habits along with its coexisting carnivore species like tiger (*Panthera tigris*) and dhole (*Cuon alpinus*) by observing their kills in Bandipur Tiger Reserve. Prey selection by leopard in relation to prey availability was assessed along with tiger and dhole in Nalkeri reserve forest area of Nagrahole National Park (Karanth and Sunquist 1995). In Nagrahole National Park, Karanth and Sunquist (2000) studied the behavioral factors contributing to their coexistence by monitoring radio-collared leopard and tigers. Study raveled that both coexisting carnivores selectively killed different prey in term of species, size and age- sex classes. In

Rajaji National Park, leopard status along with tiger was assessed based on information collected through survey (Johnsingh and Negi 2003). Diet of leopards was studied by means of scat contents in Sanjaya Gandhi National park, India (Edgaonkar and Chellam 1998). Various information on leopard has been summarized by Daniel (1996).

#### 1.4. Overview of leopard-human conflict

Human-wildlife conflicts pose urgent challenges in wildlife conservation (Woodroffe 2000). Carnivores are involved in a wide range of conflicts including predation on human and livestock (Chakrabarti 1992; Chellam and Johnsingh 1993; Daniel 1996; Woodroffe 2000; Ginsberg 2001). Large carnivore populations have declined worldwide in the last century (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 problem in many areas (Saberwal *et al.* 1994; Jackson 1999).

All large cats viz. lion, tiger, snow leopard and leopard are involved in conflict with human in India (Chakrabarti 1992; Chellam and Johnsingh 1993; Daniel 1996; Mishra 1997; Jackson 1999; Mishra *et al.* 2003; Athreya *et al.* 2004). Most of the conflicts caused by tigers, lions and snow leopards are reported from the edges of the Protected Areas (Chakrabarti 1992; Chellam and Johnsingh 1993; Mishra 1997). Extent of leopard-human conflict is greater than other large cats as a large population of leopard is outside the protected areas (Daniel 1996; WWF-report-1996).

Leopard-human conflict cases have been reported from various parts of India (Saberwal *et al.* 1994; Negi 1996; Daniel 1996). There have been human deaths caused by

leopards in Maharashtra, Gujrat, Himachal Pradesh and West Bengal Karnataka, Orissa and Uttarakhand state of India (Das, in litt; 1887; Choudhary, in litt., 1987; Negi 1996 Athreya, *et al.* 2004).

Surprisingly, the problem of leopard-human conflict has recently increased during the last decade in the hill state of Uttarakhand in northern India (Negi 1996; Mohan 1997). During 1982 to 1989, 170 people reported to be killed by leopards in India in which 111 cases were from the hills of Uttarakhand (Johnsingh *et al.* 1991).

Such incidences are being reported much less from rest of the country. Incidents of tea workers being mauled has been reported from Northern Bengal (Das, in litt; 1887; Choudhary, in litt. 1987). Recently some incidents of man-eating have been reported from the adjoining human colony of Borivali National Park, Maharashtra (Athreya, *et al.* 2004).

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 1900's nearly a thousand people were killed by leopards and a dozen of leopards were killed as man-eaters (Corbett 1957). Among popular man-eaters, leopard of Rudyaprayag killed more than 115 people over an eight-year period (Corbett 1948).

Leopards are not man-eater by nature. It is believed that leopards turn to man-eater due to problems pertaining to physical fitness, which makes them 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 behavior in which it is becoming extremely bold has been noticed in several regions (Johnsingh *et al.* 1991;

Daniel 1996; Negi 1996). It is intriguing that leopard predation on human and livestock is on the increase in hilly regions due to degradation of habitat and depletion of wild prey species.

## **1.5 Justification, objectives and hypothesis of the study**

### **1.5.1. Justification**

Most of the studies on leopards have been confined to Protected Areas. Large population of the species has been reported outside the Protected Areas as well as in human dominated landscape and reported to have large number of conflict than the leopard of Protected Areas. Among various parts of Himalayan regions, though leopard-human conflicts have been reported from all over the hills but most incidents have been reported from Pauri Garhwal district and it has become an intolerable nuisance to the people in this areas. It needs to be defined why the chances of their coming into contact with human have increased and why there is conflict between them in this area. It requires understanding the status of conflict in relation to distribution and food habit of leopards. Problems need to be tackled scientifically by understanding response of species in modified habitat in human dominated landscapes and to plan a proper strategy to reduce such conflict.

### **1.5.2. Aims and objectives**

The objectives of the study on leopard in Pauri Garhwal Himalaya are:

1. To determine the distribution and current status of leopard in Pauri Garhwal,
2. To determine the extent and severity of leopard-man conflict problems in relation to its ecological requirements, land use patterns and human life style,
3. To study food habits in relation to prey abundance (wild and domestic) and habitat characteristics and
4. To determine factors responsible for leopard-human conflict.

### **1.5.3. Hypothesis**

My hypotheses were as follows:

There is increased frequency of leopard-human conflict during the last decade in the hills of Uttarakhand due to accelerating trends in habitat fragmentation, decline in potential habitats, scarcity of wild prey and predominantly feeding on domestic species. These factors are probably reasons that made leopards come more closely to human and to some extent due to increase of local leopard population.

### **1.6. Organization of the thesis**

The entire work for the thesis and its outcome have been synthesized into six chapters viz. 1) Introduction, 2) Study area, 3) Distributions and current status of leopard in Pauri Garhwal 4) Extent and severity of leopards-human conflict problem in relation to its ecological requirements, land use patterns and human life style, 5) Food habit in relation to prey abundance (wild and domestic) and 6) Factors responsible for leopard-human conflict. Literature cited has been placed after all chapters and thesis has two Annexure.

Chapter 1 discuss the biological, ecological, behavioural and conservation attributes of the leopard distribution and it's survival in protected as well unprotected

areas. Major conservational threats to species are also discussed in this chapter. It also provides background to the research, highlighting the aspects of leopard-human conflict. Chapter 2 describes the study area (Pauri Garhwal district) in terms of geography, climate, biodiversity and administrative set up. Socioeconomic profile of people is also discussed in this chapter. Chapters 3-5 maintain independent identities in form of introduction followed by detailed Methods, Result, Discussion and Summary. Chapter 3 discusses the distribution of leopard in relation to habitat characteristics. In addition the relative abundance of leopard in different human-leopard conflict categories are presented in this chapter. Chapter 4 provides the information on status and severity of leopard-human conflict in study area. Intensity of conflict in relation to habitat characteristics and human life dimension in addition with circumstances of conflict are also discussed in this chapter. Chapters 5 discuss the food habits of leopard in terms of prey abundance (wild and domestic) and their percent occurrence in scats.

Chapter 6 describes the factors leading leopard-human conflict in study area based on finding discussed in chapters 3-5. The mitigatory measures to minimize leopard-human conflict in study area are also discussed in this chapter.

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## CHAPTER 2 STUDY AREA

### 2.1. Extent and geography

Pauri Garhwal (PG) district of Uttarakhand is selected for the present study as frequent leopard-human conflicts have been reported from this area. Pauri Garhwal district lying between (29° 20' N-30° 15' N and 78°10' E -79°20' E) is of the size 5444 km<sup>2</sup> and ranges between lower to middle Himalayan ranges and elevation reaches up to 3200 m. The Pauri Garhwal is surrounded by the districts of Chamoli, Rudraprayag & Tehri Garhwal in North, Bijnor & Udham Singh Nagar in South, Almora & Nainital in East and Dehradun & Haridwar in West (Fig 2.1).

The Pauri Garhwal district is entirely of mountainous terrain except for the pasture of Panai on the banks of Alaknanda, the valley of Srinagar and the narrow strip of Bhabar Physiographically, it may be divided into three main parts, the mountains and ridges, the valleys and the sub mountainous region (Aggarwal and Agarwal 1995).

The main rivers flowing through the district are Ganga, Alaknanda, Nayar, Huinl, Malin, Ramganga and Mandal. Of the fifteen administrative blocks in the district seven lies in the Nayar catchment area.

### 2.2. Climate

Climatically the area is divided into three distinct seasons viz. rainy, winter and summer. The rainy seasons generally commences from mid June and extends till the end of September. Early October to the middle of November constitutes the post -monsoon season, and after which winter starts which lasts till March. This is followed by the summer. Rainfall in the district has large variations due to its topography and 90% of the

rainfall is received during monsoon. The winter precipitation (December to February) accounts for nearly 10% of the rainfall (Aggarwal and Agarwal 1995). Average annual rainfall in the district is 218 cm. Temperature varies considerably from place to place depending upon the elevation. Mean daily maximum temperature at elevations less than 1000 m is around 36<sup>0</sup> C in the month of May. This is around 26<sup>0</sup> C at elevation of 2000 m (Aggarwal and Agarwal 1995). The maximum temperature recorded is 45°C in the month of June at Kotdwar. The mean daily maximum and minimum temperature in the valleys at elevations of less than 1000 m in winter are around 19<sup>0</sup> C and 6<sup>0</sup> C respectively. At the elevations of around 2000 m temperature descends to a minimum of 1.3°C in January. Relative humidity varies between 54 and 63 percent (Aggarwal and Agarwal 1995). The higher reaches receive some snowfall in winter when temperature falls below freezing point

### 2.3. Biodiversity

There is great variation in soil, precipitation, rocks, topography, climate and corresponding vegetation features. Gaur and Bartwal (1993) classified forests of a Pauri Garhwal in to Sub-Montane (Tropical and Subtropical), Montane (Temperate) broad leaves, and Gymnospermous. Each forest was further sub divided into five to twelve sub-forest types.

In present study vegetation in Pauri Garhwal district has been broadly classified into five types based on dominating plant species viz. (i) Oak forest mainly dominated by *Quercus leucotrichophora* and *Quercus incana* (ii) Pine forest mainly dominated by *Pinus roxburghii* and *Pinus wallichiana* (iii) Sal forest mainly dominated by *Shorea*

*robusta* and (iv) Scrub dominating by shrub/woody shrub, like *Lantana*, *Eupatorium* and *Xanthium* etc.

Pauri Garhwal had been the home of a large variety of wild fauna including mammals, reptiles, primates and birds. The district is adjacent to two national parks, with Corbett National Park (CNP) is lying on south eastern border and Rajaji National Park (RNP) lying in the south western region. Among large mammals, leopard (*Panthera pardus*) is common and is found throughout the district. The tiger (*Panthera tigris*) and hyaena (*Hyaena pinnacus*) were reported from lower hills and Bhabar (south eastern and south western) area. Goral (*Nemorhaedus goral*), barking deer (*Muntiacus muntjak*) and sambar (*Cervus unicolor*) are common, medium to large sized wild herbivores and troops of rhesus macaques and common langur are also reported from this area (Aggarwal and Agarwal 1995). Habitat also supports a fairly large population of domestic livestock such as cow, buffalo, goat, sheep and dog.

#### **2.4. Administrative setup**

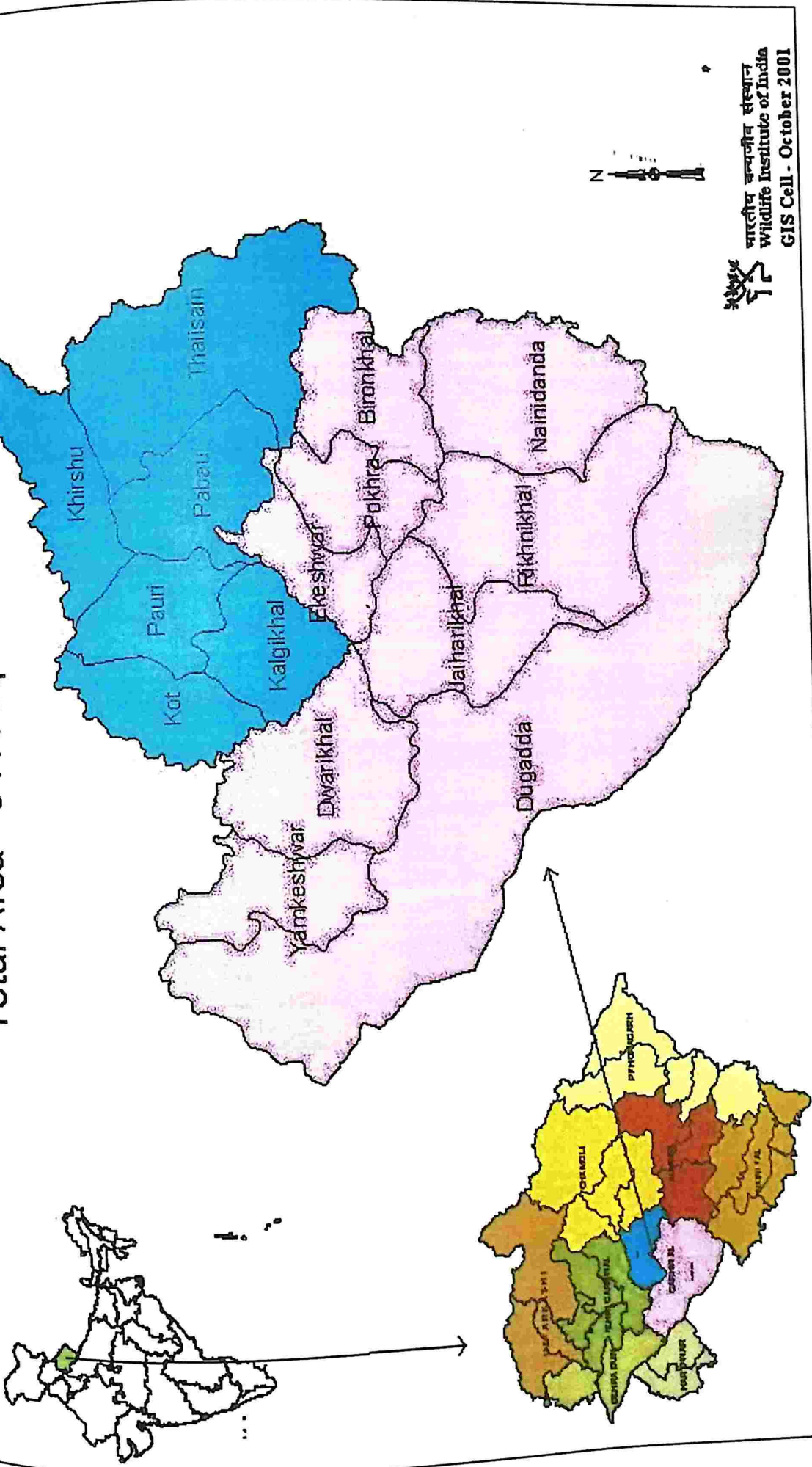
District comprises of two divisions viz. Pauri and Lansdowne. Politically it has been divided into six tehsils which consists of 15 administrative blocks (Fig 2.1). Among 15 administrative blocks, Dugadda is the largest block where as Ekeshwar is the smallest in terms of area (Fig. 2.1). Most of the part of these administrative blocks are approachable by road from its district headquarter.


## 2.5. Socioeconomic profile of people and demography

As per 1991 census, total population of the district is 6,71,541 with a male population of 3,26,380 and a female population of 3,45,160. There is an increase of 8.34% in the population in comparison to the 1981 census figures. (Census report-1991). The population was reported to be 5,53, 028 in 1971 and 6,37,877 in 1981. The population density (no. per sq. km) was 102 and 117 in 1971 and 1981 respectively and has now increased to 126 in 1991. Majority of the population lives in villages. Due to migration of males for employment elsewhere, the sex ratio in the district is 1119 females per 1000 males (Census Report 1991).

The economy of the region is predominantly agrarian. Other important occupations include horticulture, forestry, sheep rearing and livestock farming and household or cottage industries. Livestock plays a key role in the agricultural economy. Livestock subsists mainly on forest vegetation. In this area, over 90% of the cattle owned by local people graze in these forests (Aggarwal and Agarwal 1995). They derive their fuel wood for cooking and heating, small wood for agricultural equipment and timber for building and furniture from these forests. Forest cover has declined in Pauri Garhwal during the last two decade (Rao and Nandy 2001).

**Study Site - Pauri Garhwal District**  
**Total Area - 5444 sq. km.**




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**Figure 2.1.** Pauri Garhwal district along with administrative blocks.

## CHAPTER 3                      DISTRIBUTION AND CURRENT STATUS OF LEOPARD IN PAURI GARHWAL

### 3.1. INTRODUCTION

In several countries leopard populations are increasingly threatened by habitat fragmentation and degradation, depletion of wild prey, as well as prosecution of local people to protect livestock (Myers 1986; Nowell and Jackson 1996; Woodroffe 2000). In spite of these threats, leopard is still most successful among all cats in terms of distribution (Bailey 1993). Its ecological and behavioural plasticity are probably the main reasons for the leopard's continued persistence in areas where changes in land use, prey base and habitat structure have caused the extinction of other large cats or less adaptive carnivores (Marker and Dickman 2005).

The most basic information about a species status is its distribution (Linnell *et al.* 2000). Understanding factors that influences 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 population (Rushton *et al.* 2004).

Habitat requirements are most important factors which influence the distribution and abundance of species, therefore habitat evaluation is a vital step in the formulation of carnivore management in an area (Mladenoff *et al.* 1995; Cleverger *et al.* 1997). 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 and changes in distribution of 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 survey or statistical model. Therefore, using Geographic Information System (GIS) has become an evitable 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.

Estimating population abundance of large carnivores has always been controversial and finding comparable and reliable data on carnivore populations is even today questionable (Smallwood 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 status and population trend of large carnivores are lacking due to high cost of sampling across large geographical areas (Smallwood and Fitzhugh 1995).

In previous studies, different methods have been used for carnivore survey. These methods include track and signs indices (Smallwood and Fitzhugh 1995), density based on habitat qualities (Fuller and Sievert 2001; Carbone and Gittleman 2002) and more recently use of camera trapping in a mark-recapture framework (Karanth 1995; Karanth and Nicholas 1998; Carbone *et al.* 2001; Kawanishi 2002; Wegge *et al.* 2004).

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 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 (Kutilek *et al.* 1983; Fox *et al.* 1991; Smallwood and Fitzhugh 1995). Track surveys are efficient and usually involve low cost, but depend on suitable field conditions and trained personnel (Smallwood & Fitzhugh 1995; Silveira *et al.* 2003).

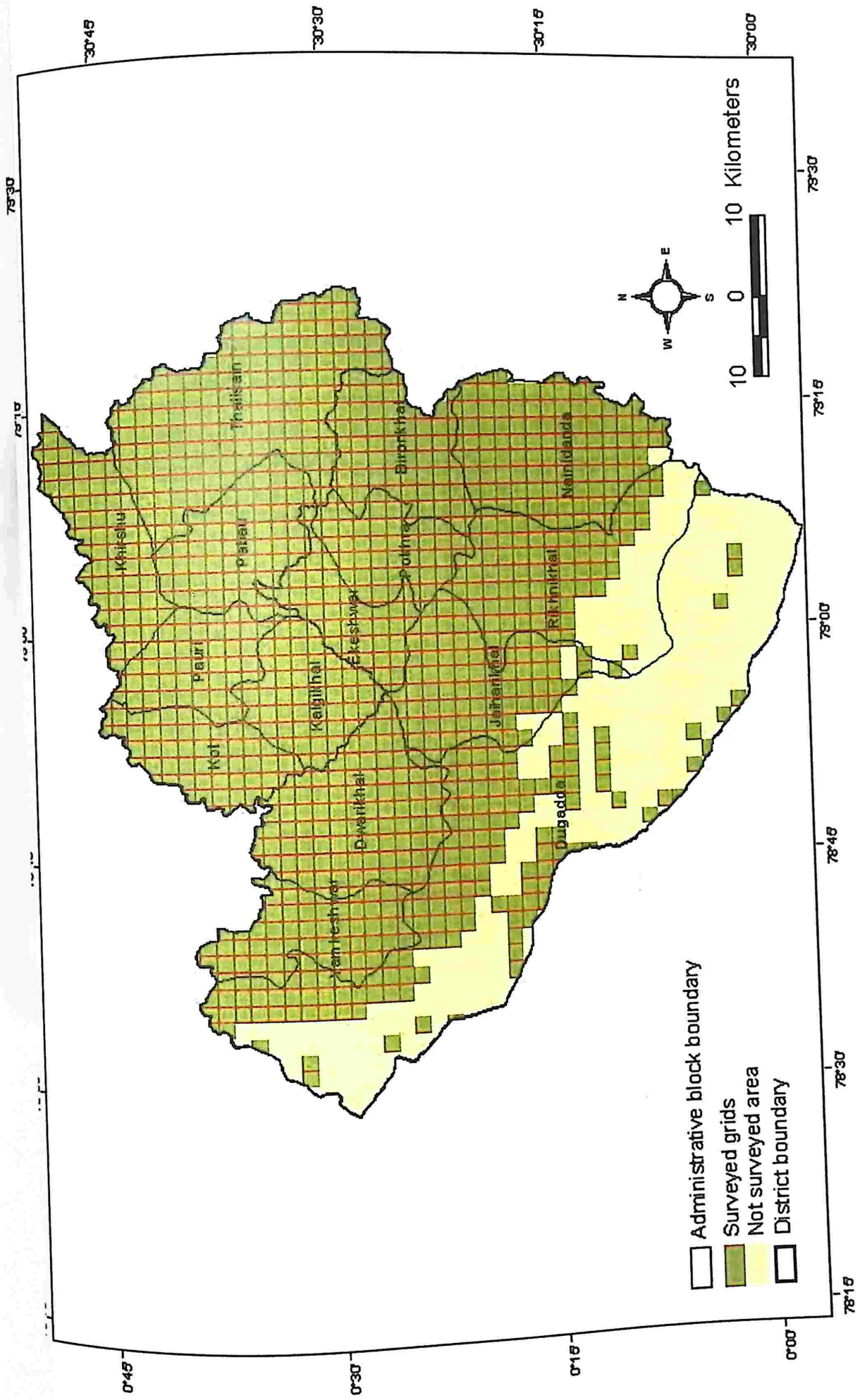
The use of Relative Abundance Indices (RAI) and their correlation (if any) with the real population is appears to be the most promising and cost effective techniques since it allow potentially to estimate the density from scat counts, track counts, and similar procedure without disturbing the target 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; Silveira *et al.* 2003). As carnivores mostly use the available habitat in a non-random fashion and favour certain routes, the probability of detecting carnivore can be increased by placing transects in area where they are most likely to pass (Smallwood and Fitzhugh 1995; Beier and Cunningham 1996). Studies suggested that the correlation between density and RAI does exist in carnivores (Fox *et al.* 1991; Smallwood Fitzhugh, 1995; Beier and Cunningham 1996; 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 Sievert 2001; Carbone and Gittleman 2002), but such a relationship is possible only in prey-rich and low human abundance where anthropogenic pressure do not affect the predator abundance (Carbone and Gittleman 2002; Khorozyan 2003).

In the present study a base line information is generated on distribution and relative abundance of leopard in Pauri Garhwal district.

The general objective in this Chapter is to "*determine the distribution and current status of leopard in Pauri Garhwal*". The specific research questions are:

1. What is the distribution of leopard in Pauri Garhwal District?
2. Is distribution of leopard is affected by habitat characteristics?
3. What is the relative abundance of leopards in various human-leopard conflict categories?



**Figure 3.1.** Surveyed grids in Pauri Garhwal district for determining distribution of leopard.

### **3.2.2. Relative habitat use by leopards**

#### **3.2.2.1. Major habitat assessment and land use/ land cover mapping**

To prepare the landuse/landcover map for the study area, the remote sensing technique was effectively utilized as a tool for mapping of forests and other landuse patterns. The Indian Remote Sensing Satellite LISS-III digital data of November 1998 was considered worth with spatial resolution of 23.5x23.5 m. District boundary, divisional boundary, human settlements, extracted from Survey of India top-sheets at 1:50000 scale and a base map of study area were prepared. The polygenic projection system was used to project all the spatial layers and Digital Imageries. A False Color Composite (FCC) was generated and georectification of FCC was done to get more visual information. These imageries were taken to the study area for ground truthing. Ground truthing was done on 200 point by covering all habitat types and latitude-longitudes were noted by GPS. Survey of India topo maps (1:50000 scale) have also been used for accuracy while ground truthing.

Interpretation of imageries was done as per the objectives of the work by using different GIS package (ERDAS Imagine ARCVIEW and ARC/INFO). Individual imagery was classified by using digital classification process techniques. Final interpreted imageries were once again taken into the field for ground checking and misclassified features were corrected. Classification improvement was taken place during the entire classification process. Normalized Difference Vegetation Index (NDVI) was also considered to get accurate landuse/landcover map. All imageries were classified using hybrid classification method comprising unsupervised, supervised and rule based classification scheme. Finally land use/ land cover map was prepared.

### 3.2.2.2. The habitat–availability utilization

In order to see uses of different habitats by leopards, Neu *et al.* (1974) method was adopted. This program examines the significant difference between available and used habitat categories. As larger information of leopard distribution in this study is based on leopard predation on livestock, therefore the habitat utilization by leopards was determined based on livestock kills recorded in each surveyed grid. The scat data were also subjected to different habitat types.

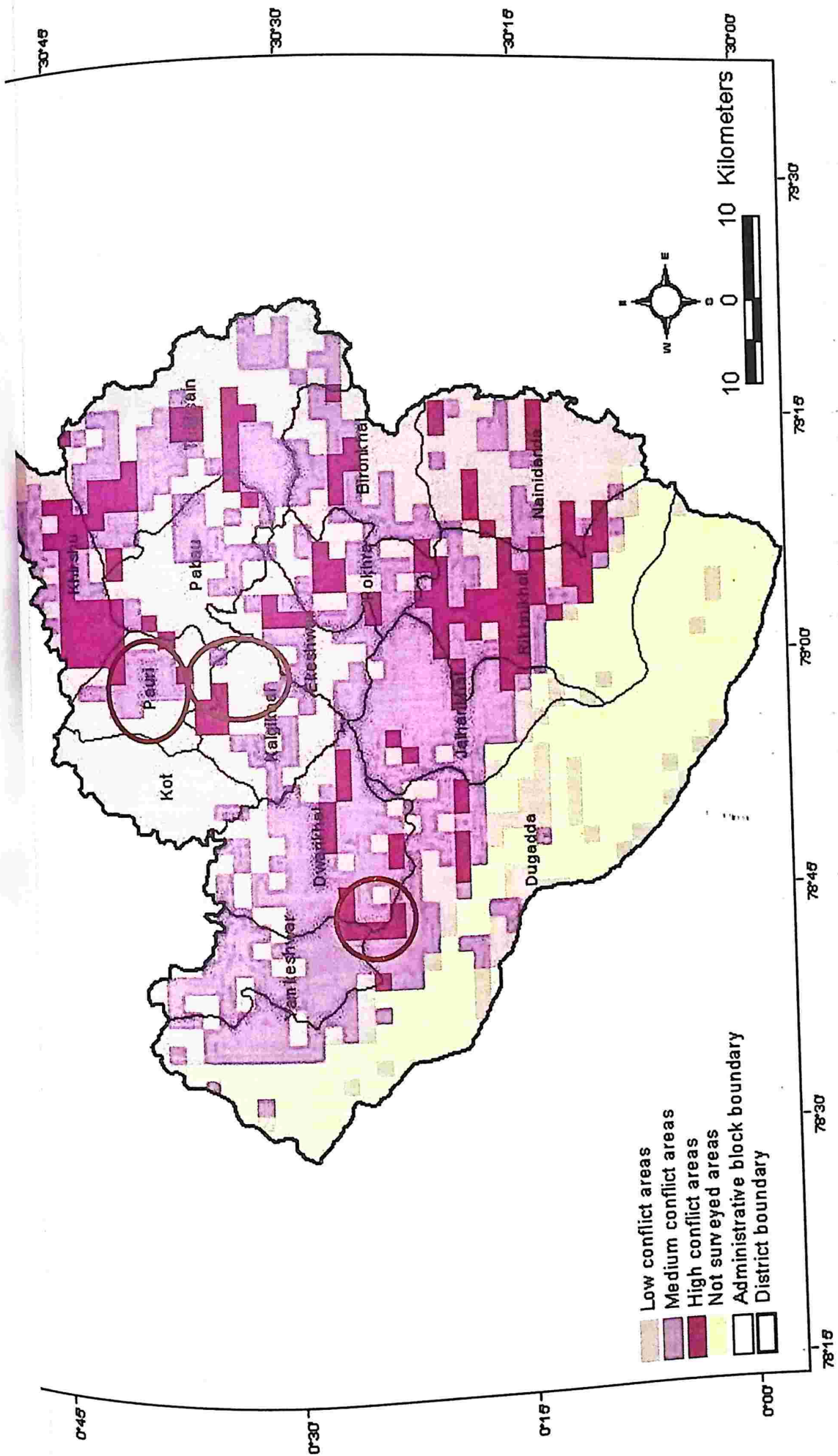
### 3.2.3. Status of leopard

#### 3.2.3.1. Selection of Intensive Study Area

Based on intensity of livestock and human mortality caused by leopards in each surveyed grid, Pauri Garhwal district was stratified into three categories of conflict viz low, medium and high. The each grid was classified into high, medium and low conflict categories based on following parameters:

Conflict category	No. of livestock killed	No. of human killed
Low	1-2	1-2
Medium	2-5	2-3
High	5<	3<

It was planned to understand the current status of leopards in these conflict categories. Therefore, Intensive Study Area (ISA) of 40 km<sup>2</sup> was selected in each conflict category (low, medium and high). Fig. 3.2 indicates the general distribution of leopard-human conflict along with selected ISA.



**Figure 3.2.** Selection of Intensive Study Areas (ISA) in different conflict category in Pauri Garhwal.

### 3.2.3.2. Based on sign (scat and track) indices

Trails ranging from 2 to 3.5 km were identified and monitored throughout the year in selected Intensive Study Areas (ISA) within these three conflict categories. Details of trail monitored in ISA of three conflict categories have been summarized in Table 3.1. Leopard signs such as scats and tracks were collected systematically on these trails between 2002 to 2005. A total of 291 days were walked in ISA of low conflict category for monitoring 5-12 trails covering a distance of 662 km distance during 2002-2005. Similarly in ISA of medium conflict category, 370 days were walked for monitoring 7-18 trails and a total of 953.5 km distance was covered during sampling periods. In ISA of high conflict category, 348 days were walked to monitor 5-16 trails covering 713.5 km distance during sampling periods (2002-2005). Encounter rate of scats recorded in ISA of each conflict category was estimated as follows:

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

**Mean Encounter Rate (MER)** =  $\sum ER_{(1,2...X)} / X$

where X= no. of monitored trails in each conflict zone

Track plots were prepared at each 250mt on selected trails and leopard tracks on these plots were recorded systematically (Fig. 3.3). A total of 655 plots were monitored on 5-12 trails in ISA of low conflict category during 2002 to 2005. In ISA of medium conflict category, 814 plots were monitored on 7-18 trails while 778 plots were monitored on 7-16 trails in ISA of high conflict category. Leopard tracks on plots were converted into index of abundance as follows:

**Track Index** = # of plots having sign/ total # of plots monitored

**Table 3.1.** Details of trails monitored in ISA of three conflict categories.

Year	LOW						MEDIUM						HIGH					
	# of trail	No. of days	Total distance covered, km	No. of track plots monitored	# of trails	No. of days	Total distance covered, km	No. of track plots monitored	# of trails	No. of days	Total distance covered, km	No. of track plots monitored	# of trails	No. of days	Total distance covered, km	No. of track plots monitored		
2002	5	16	37	39	10	67	164.5	164	5	11	30	20						
2003	12	112	260.5	223	18	153	400	350	16	90	180	204.						
2004	12	142	321.5	347	18	81	217	161	16	195	395	435						
2005	5	21	43	46	7	69	172	139	6	52	108.5	119						



**Figure 3.3.** Track plot on a forest trail

### **3.2.3.3. Based on camera trapping**

Leopards were also monitored by using camera trap method in ISA of three human-leopard conflict categories. Trails were monitored to understand the movement of leopards and find out suitable place to set camera traps. Camera trapping was carried during 2003-2005 in ISA of three conflict categories. Camera trapping schedules in the ISA of three conflict categories have been summarized in Table 3.2. Camera traps were placed at 4-6 sampling stations in each conflict category. Camera traps were placed on similar point during trapping session over the years. It was planned to sample all stations with equal trap nights. But realized theft and damage threats from local people to some station were major constraint in using camera traps. Inconsistent whether has also been

one of the constraints during trapping efforts. Camera traps were kept active during night hours only (1900–0600 hours) due to threat of theft from surrounding villages. In ISA of low conflict category camera traps were distributed within 7 km<sup>2</sup> area. In ISA of medium and high conflict category, camera traps were distributed within 13 and 6 km<sup>2</sup> areas respectively.

For the present study, a single modified motion sensor (Passive infra red of Radioshack, USA) with camera kit (Goodson and Associates, Lenexa, Kansas, USA) was used at each trapping station (Fig. 3.4a). Single side camera was used only in the present study. The camera and sensor were placed within iron housings (Fig. 3.4b) so as to protect the units from weather and animal damage.

All film rolls used during camera trapping were given a unique identity enabling us to correctly note the date, time and location of the photographs resulting from each capture event. Leopards were identified based on their coat patterns (Fig. 3.5). Only good photographs obtained through camera traps enabled to identify individuals based on rosette patterns were only used for individual identification. The photographs of leopard individuals walking in same direction were used for further analysis. The movement of individual leopards recaptured during trapping efforts was observed by measuring maximum distance covered by them across trapping stations.

**Table 3.2.** Camera trapping schedules in ISA of three conflict categories.

**(a) Low**

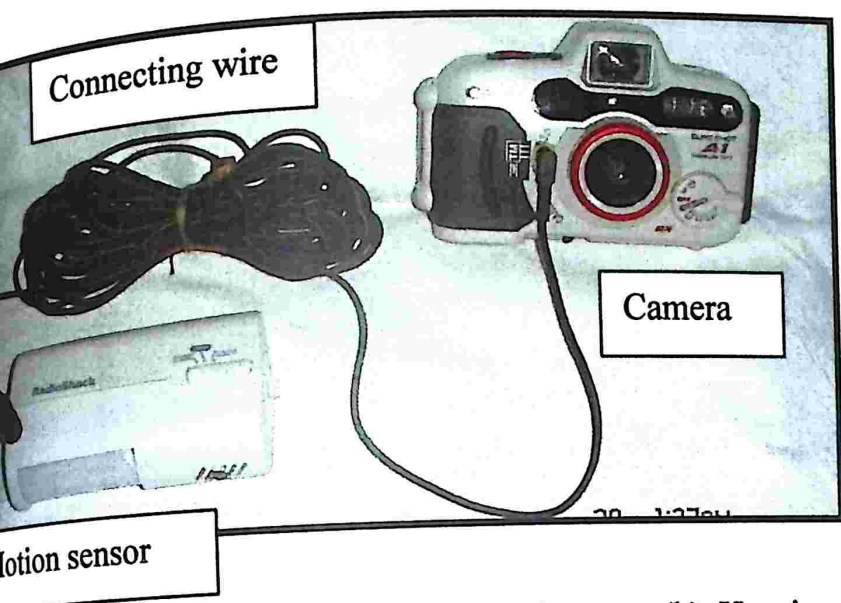
Year	Period	Sampled area	# of nights	# of trapping stations	# of trap nights
2003	8-22 December	7km <sup>2</sup>	4	10	40
2004	9-29 November	7km <sup>2</sup>	6	12-20	109
2005	12-24 January	7km <sup>2</sup>	4	10-12	43

**(b) Medium**

Year	Period	Sampled area	# of nights	# of trapping stations	# of trap nights
2003	23 March- 9 April	13km <sup>2</sup>	6	14-18	102
2004	7- 18 June	13km <sup>2</sup>	6	10-12	62
2005	13- 26 December	13km <sup>2</sup>	6	10-14	88

**(c) High**

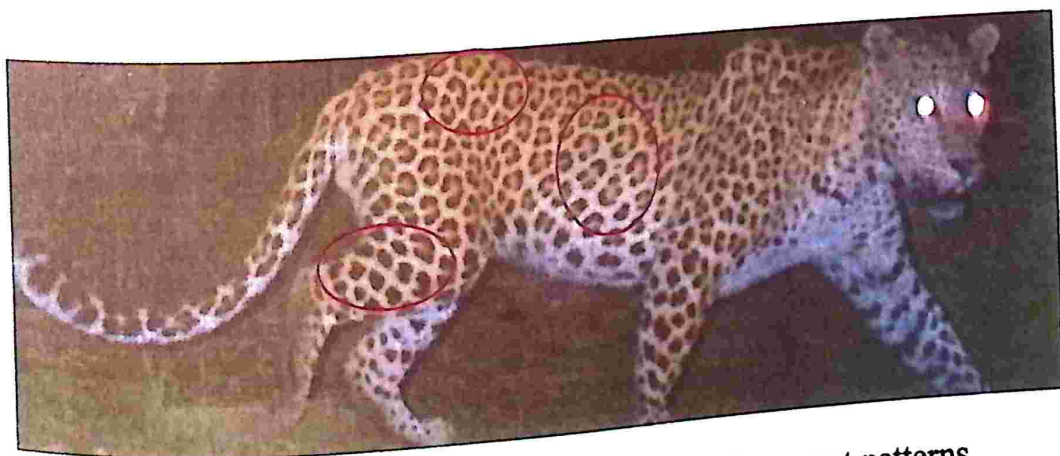
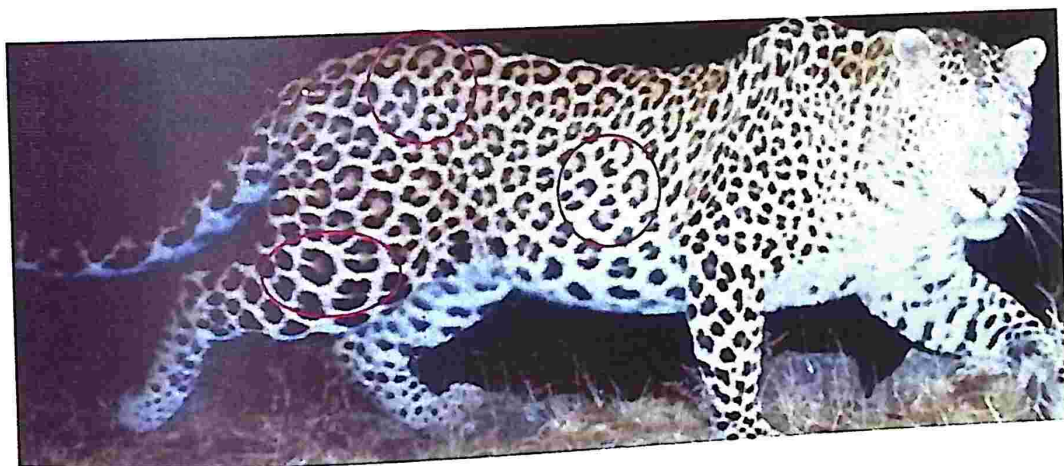
Year	Period	Sampled area	# of nights	# of trapping stations	# of trap nights
2003	16-28 October	6km <sup>2</sup>	4	10-12	42
2004	17 March -7 April	6km <sup>2</sup>	6	12-22	120
2005	2-12 November	6km <sup>2</sup>	4	10	40



(a). Radioshack Passive infra red motion sensor with camera kit

(b). Housing used for placement of camera

**Figure 3.4.** Camera trap system and iron housing used for placement.



**Figure 3.5.** Identification of same leopard based on spot patterns.

### 3.3. RESULTS

#### 3.3.1. Distribution of leopard in Pauri Garhwal

Leopard presence was recorded in all 1136 surveyed grids of fifteen administrative blocks. Leopard presence is expected based on different parameters (Fig. 3.6). During survey, leopard sign such as scat were recorded from 64 (252 sq km) grids. Scats were collected whenever they were encountered during survey while walking among the villages and distribution map has been prepared (Fig. 3.7).

The cases of leopard predation on livestock have been reported from all 1136 (4275.8 km<sup>2</sup>) surveyed grids whereas human deaths caused by leopards were only from 119 (435.3 km<sup>2</sup>) grids. Most (>80%) of these incidences were reported during last decade. Distribution map of leopard predation on livestock (Fig. 3.8) and human (Fig. 3.9) has been generated. Based on these parameters, leopard distribution map was prepared (Fig. 3.10).

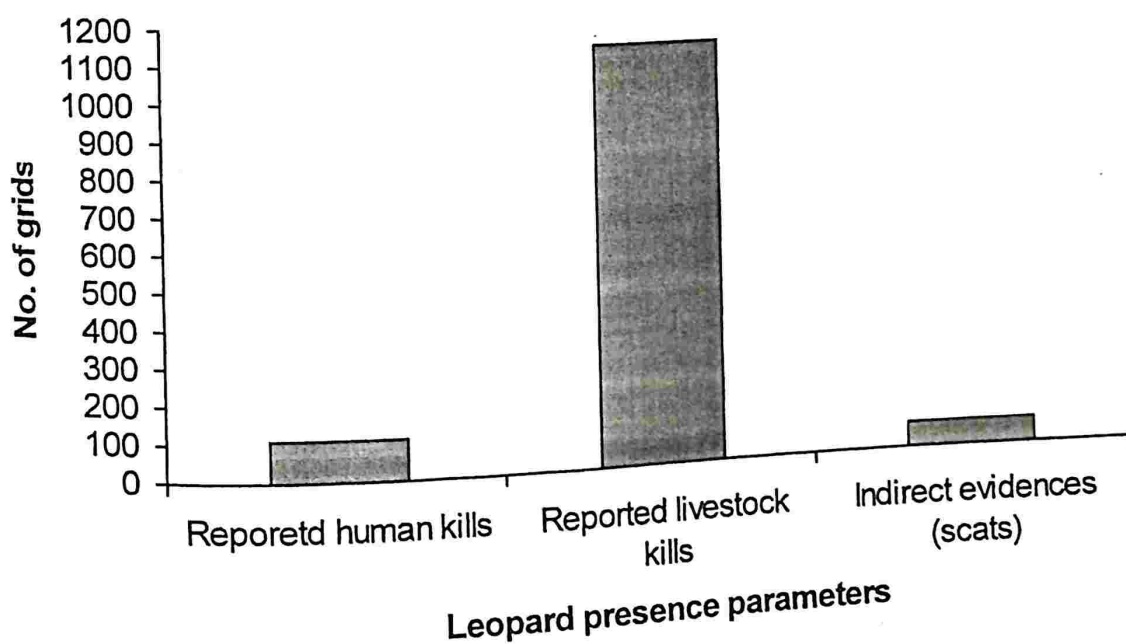
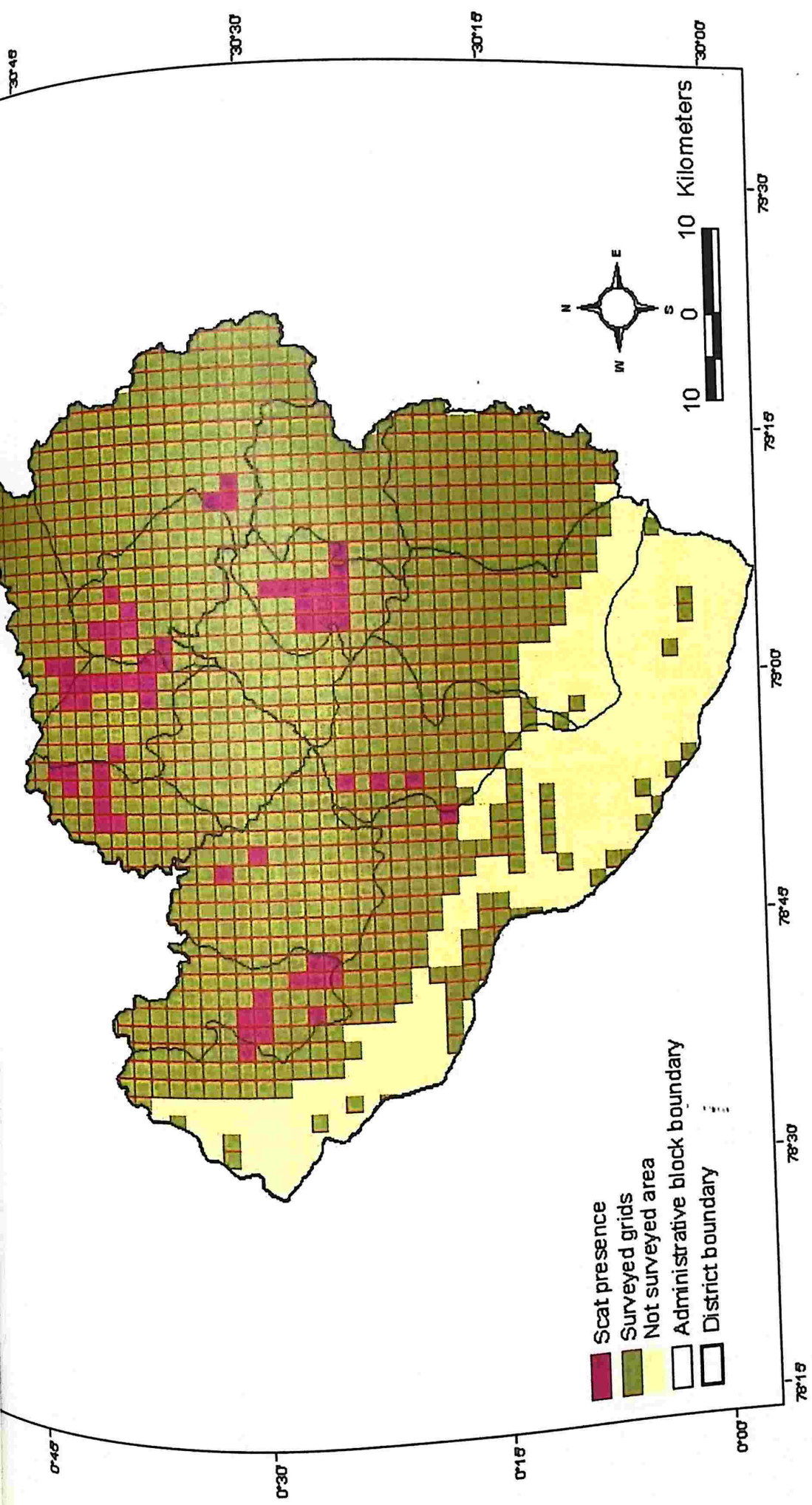
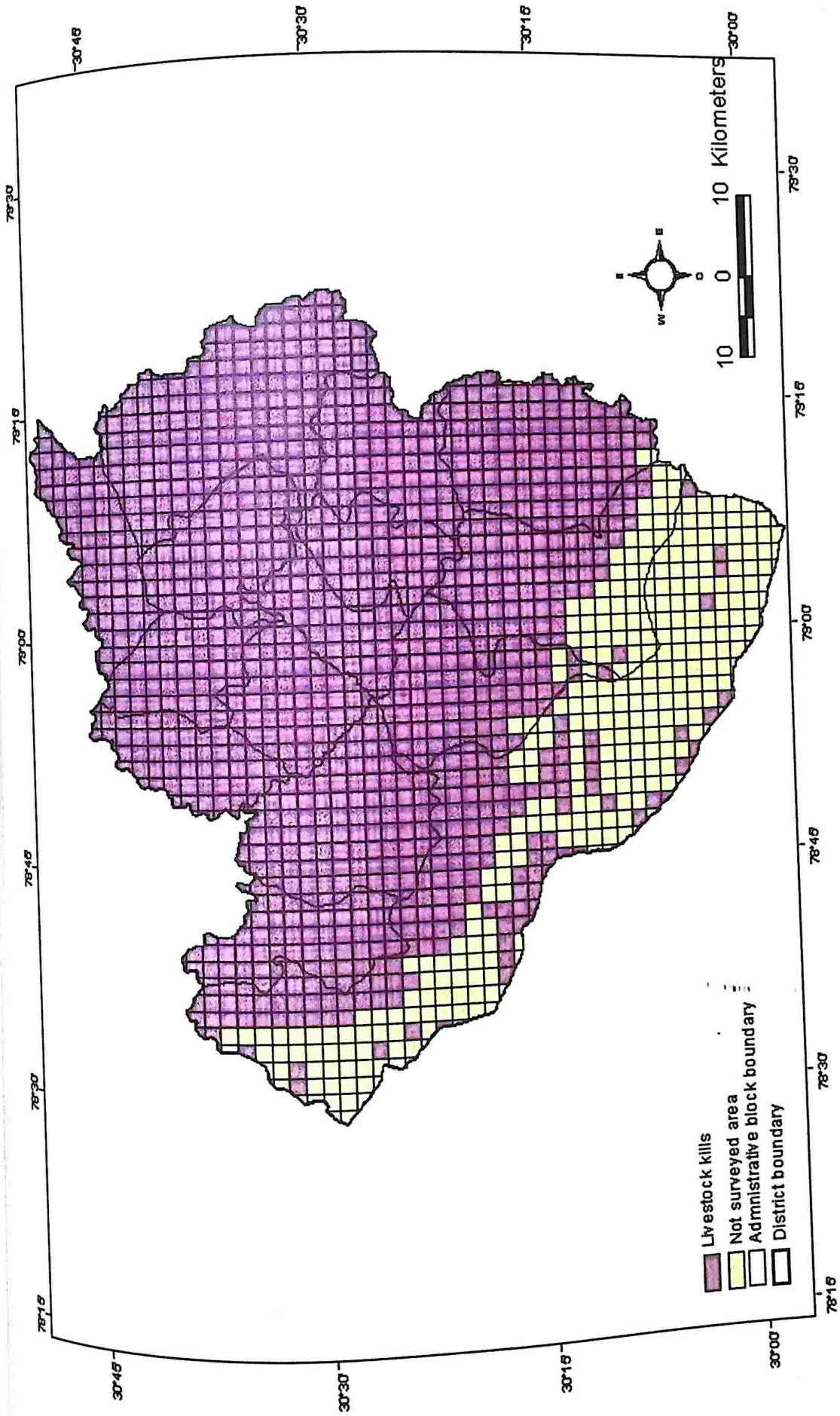


Figure 3.6. Different parameters used to ascertain leopard presence.



**Figure 3.7.** Distribution of scats recorded while during survey.



**Figure 3.8.** Reported livestock deaths from the study area.

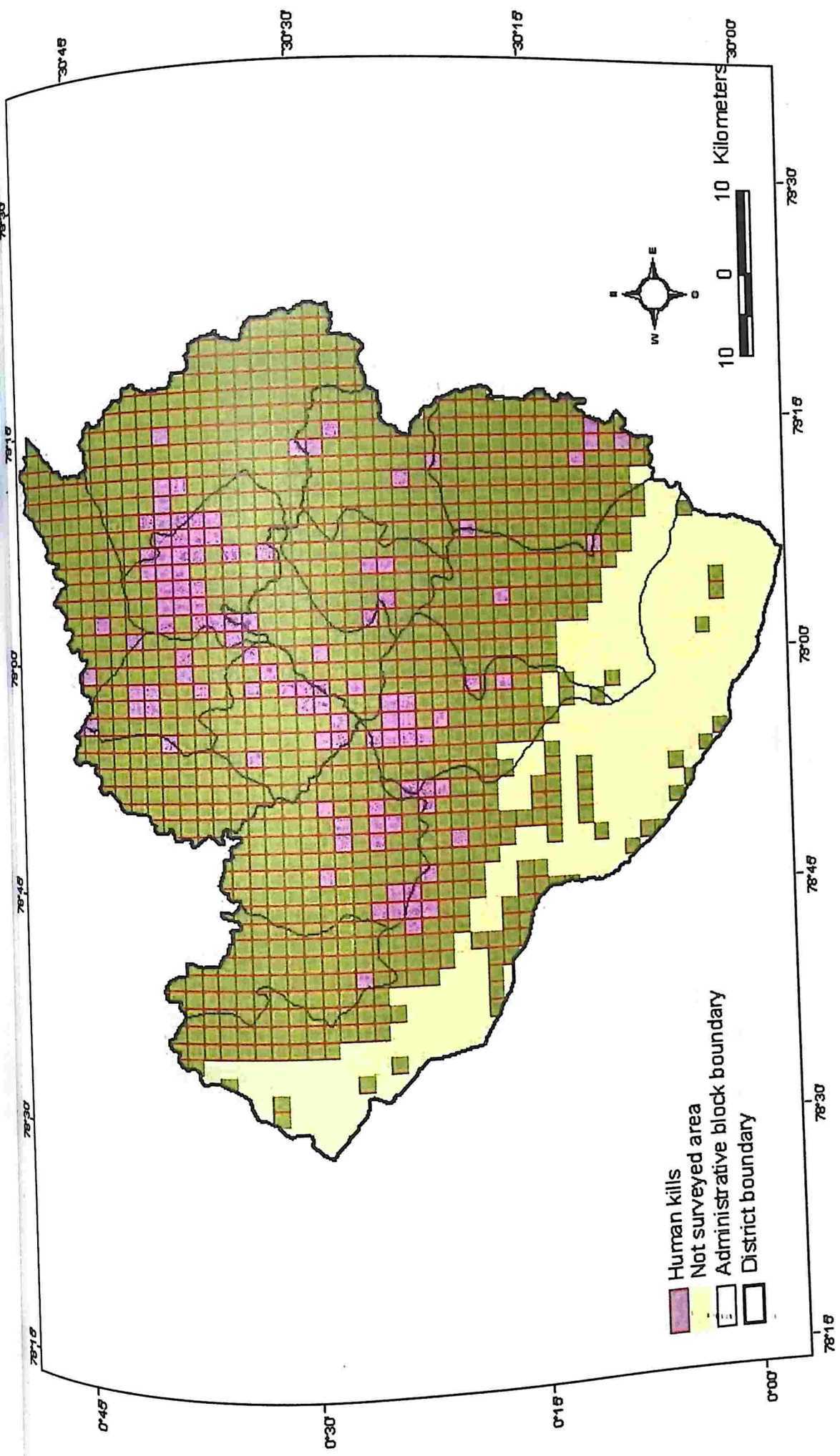
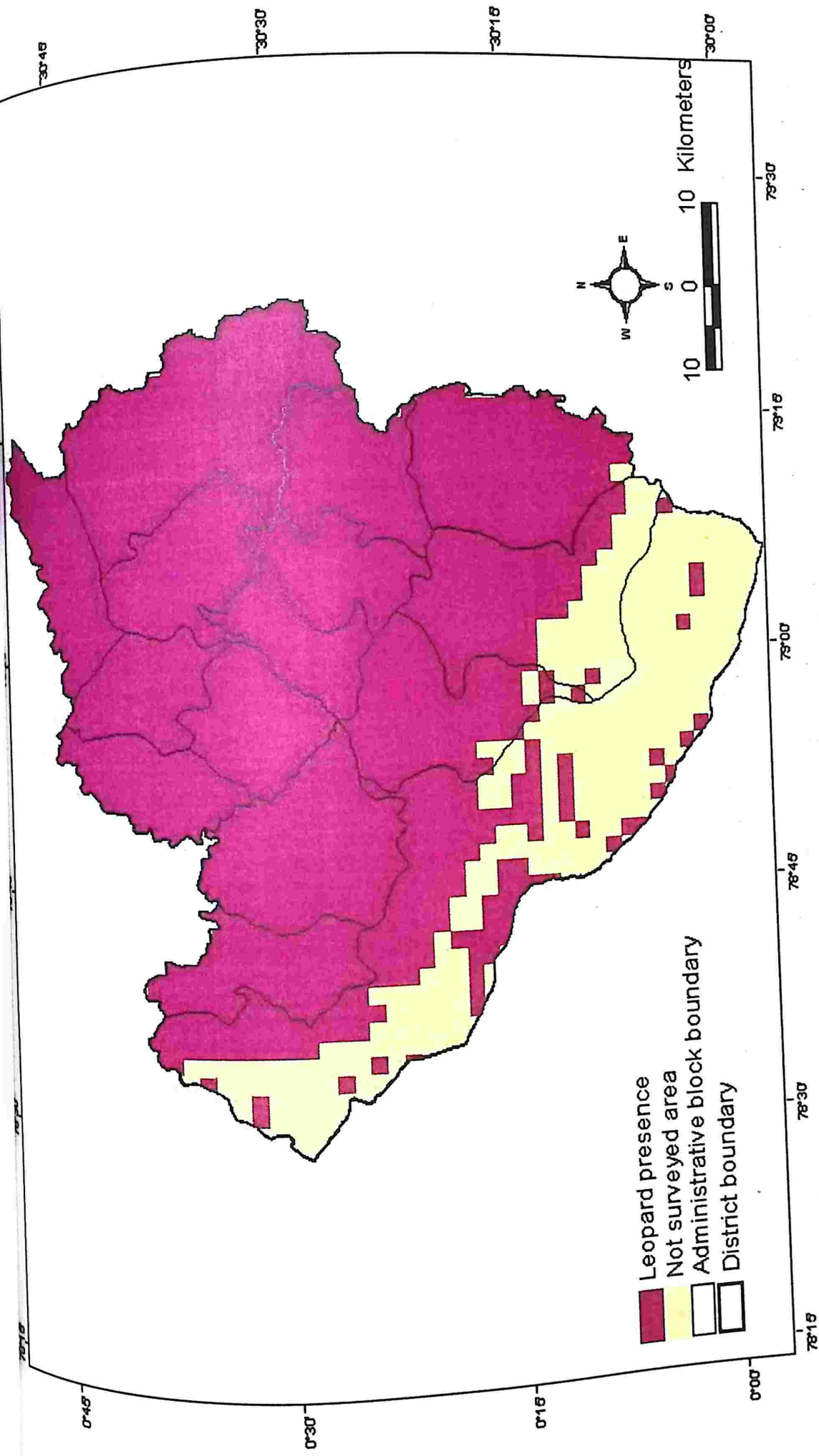


Figure 3.9. Reported human deaths from the study area.



**Figure 3.10.** Map showing overall leopard distribution in the study area.

### 3.3.2. Relative habitat use by leopard

#### 3.3.2.1. Land use patterns of study area

The major land use patterns of the study area have been forest scrub and human habitation. Forest class includes different vegetation types and based on dominating plant species, vegetation in Pauri Garhwal has been broadly classified into five vegetation types in present study (Table 3.3). Non-forest classes include human habitation and water bodies (Table 3.3). Different land use patterns in study area have been shown in Fig. 3.11. Fig. 3.12 -3.14 indicate observed land use characteristics in study area.

**Table 3.3.** Types and characteristics of forest and non forest classes.

#### (a) Forest classes

S.N.	Vegetation type	Characteristics
1.	Oak forest	Oak ( <i>Quercus leucotrichophora</i> and <i>Quercus incana</i> ) dominated mixed forest
2.	Pine forest	Pine ( <i>Pinus roxburghii</i> and <i>Pinus wallichiana</i> ) dominated mixed forest
3.	Sal forest	Sal ( <i>Shorea robusta</i> ) dominated mixed forest
4.	Scrub	Dominating by shrub/woody shrub, like <i>Lantana</i> , <i>Eupatorium</i> and <i>Xanthium</i>

#### (b) Non forest classes

S.N.	Classes	Characteristics
1.	Human habitation	Human settlement areas and agricultural land
2.	Water bodies	Streams (large) and lakes/reservoirs





**Figure 3.12.** Areas dominated with scrubs.



**Figure 3.13.** Areas dominated with forest.



**Figure 3.14.** Observed human settlements in study areas.

Of the 5540 sq km of the total area, scrub occupies 2612.3 sq km which is 48.2 % of total land cover. Forest cover has an extent of 1818.7 sq km which is 33.4% of total area. Human habitations occupy an area of 882.9 sq km which is 16.23 % of total land cover. The extent of scrub has highest across all the 15 administrative blocks in terms of percent land cover (Fig. 3.15). Of the 15 administrative blocks, 12 have more than 40% area under scrub.

Forest has been recorded as second major land use category. Of the 15 administrative blocks, 3 have relatively high forest cover ranged from 43.9-49.1% of their respective land cover. Remaining 12 blocks occupy less forest cover ranged from 15.2-38% of their total area.

Human habitation has been recorded as third major land use patterns. In 9 blocks, human habitation is covering more than 20% in terms of total land cover. While remaining 6 blocks have less habitation ranged from 6.1 to 16.8% of total area.

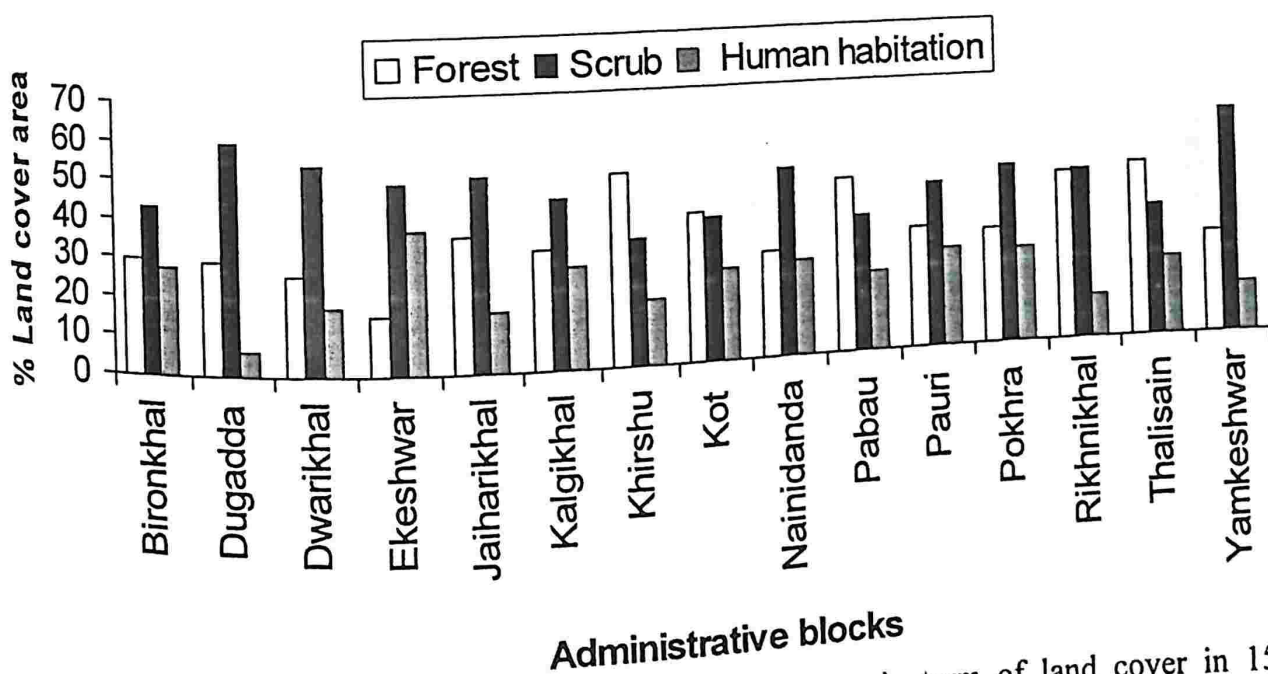


Figure 3.15. Proportion of different land use patterns in term of land cover in 15 administrative blocks of Pauri Garhwal district.

3.3.2.2.

**The habitat-availability utilization**

A total of 4155 cases of livestock deaths caused by leopards in 15 administrative blocks of Pauri Garhwal district from 1990 to 2000 were correlated to the major habitat types. Livestock deaths were positively correlated ( $r^2=0.87$ ;  $P<0.01$ ) with scrub cover in all 15 administrative blocks (Fig. 3.16).

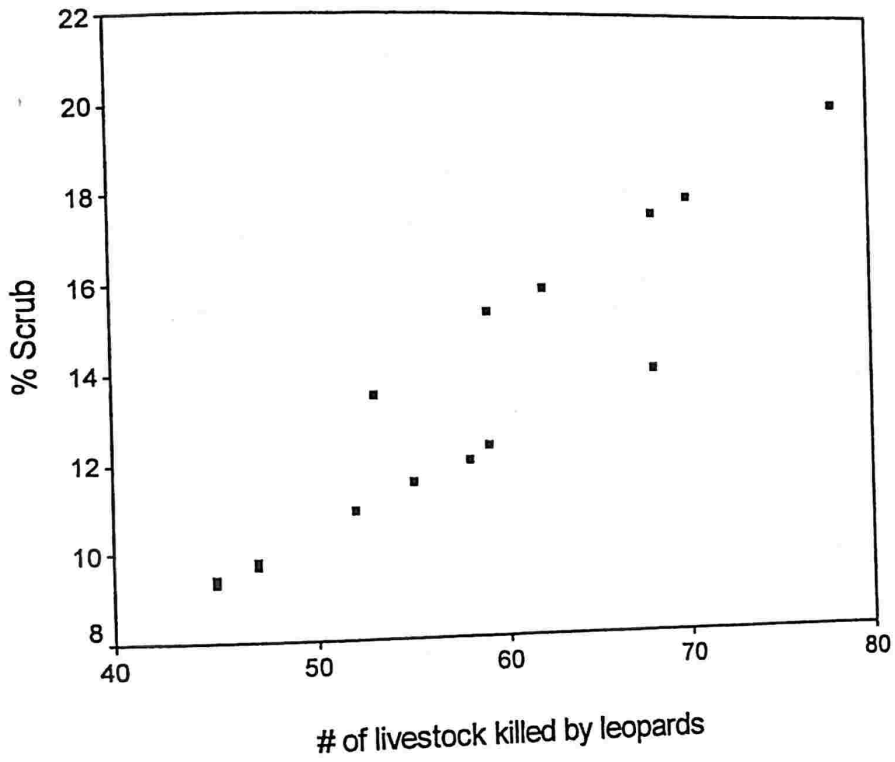


Figure 3.16. Relationship between number of livestock killed by leopards and observed scrub cover in administrative blocks of Pauri Garhwal.

The habitat-utilization data suggest that scrub is widely used. The major finding of utilization of different habitats by leopards in terms of their availability is summarized in Table 3.4 to 3.6. The grids having, 40 to 60% land cover as scrubs were used more than proportion to its availability. While dense scrub area where proportion of scrub is more than 70% was used less than proportion available. Similarly, the grids of scrub

cover below 30% were used less than proportion to its availability. While use of scrub cover in proportion to availability was found in grids having proportion of 30 to 40 %. The grids having scrub 60-70% were used in proportion to availability (Table 3.4). Spatial distribution of scrub availability-utilization by leopards has been shown in Fig. 3.17. Data indicates that leopards showing preference for human habitation areas. The grids, where 40-50% land cover occupied by humans were used more than proportion to its availability. Grids having total land cover occupied by human habitation below 30 or 30 to 40% were used in proportion to its availability. Similarly the grids having 50-60% habitation were used in proportion to its availability (Table 3.5). Human habitation availability utilization by leopards has shown in Fig 3.18. Use of forest cover was in proportion to its availability (Table 3.6). Availability-utilization of forest cover by leopard has been shown in Fig. 3.19.

Table 3.4. Use of scrub by leopards based on availability - utilization approach.

Scrub cover	Availability		Utilization		Lower limit	Upper limit	Intesity of use
	N	PROP	N	PROP			
0-10	116	0.078	79	0.019	0.013	0.025	-
11-20	67	0.045	100	0.024	0.018	0.031	-
21-30	141	0.095	319	0.077	0.065	0.088	-
31-40	244	0.164	746	0.180	0.163	0.196	*
41-50	316	0.213	1111	0.267	0.249	0.286	+
51-60	302	0.203	1126	0.271	0.252	0.290	+
61-70	186	0.125	562	0.135	0.121	0.150	*
70<	115	0.077	112	0.027	0.020	0.034	-

- used less then proportion available, \* used in proportion to availability, + used more then proportion available

**Table 3.5.** Utilization of human habitation by leopards based on availability utilization approach.

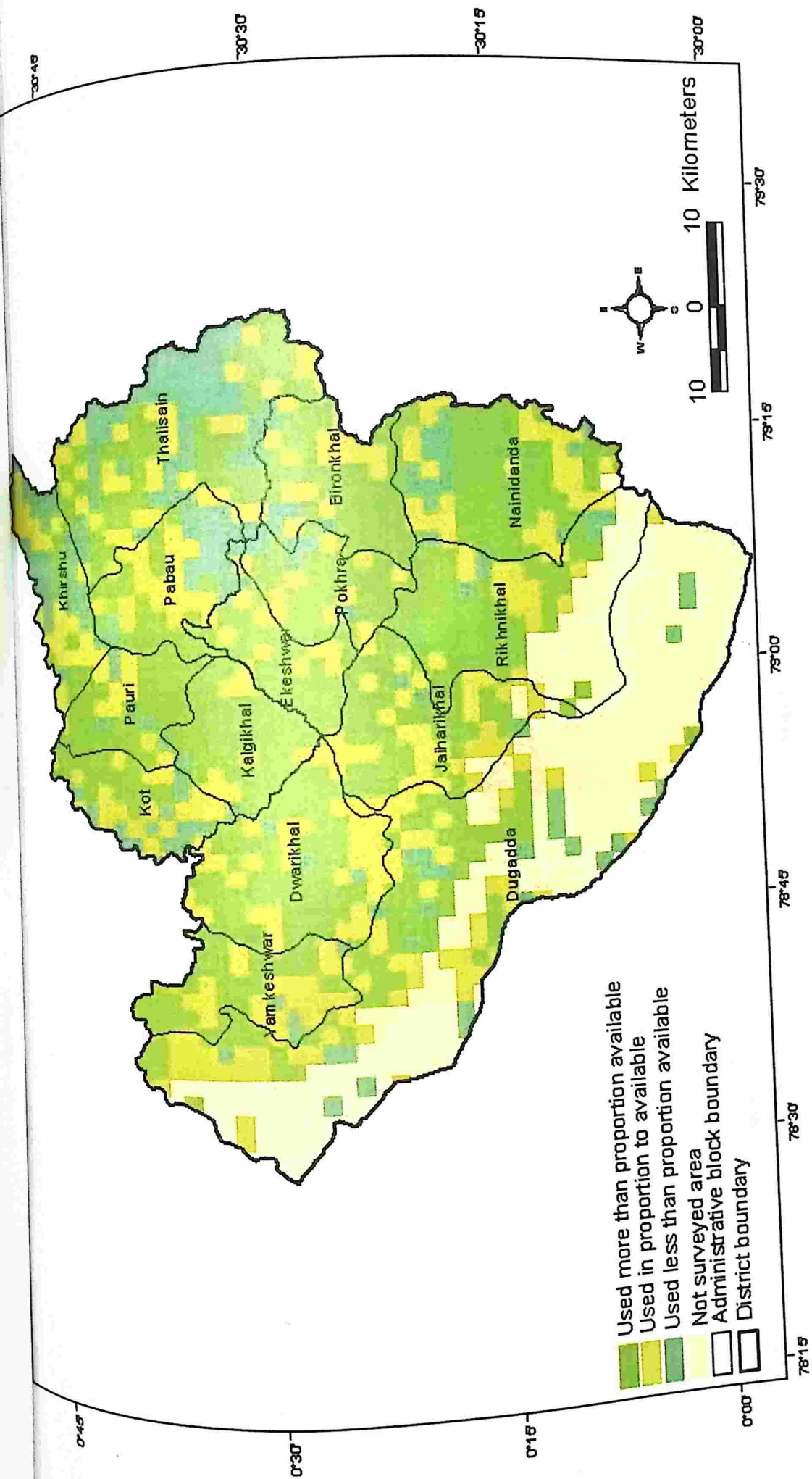
Human habitation	availability		utilization		lower limit	upper limit	Intensity of use
	N	PROP	N	PROP			
0-10	643	0.432	1423	0.342	0.221	0.419	-
11-20	308	0.207	513	0.123	0.112	0.193	-
20-30	266	0.178	433	0.104	0.097	0.157	-
30-40	214	0.143	629	0.151	0.137	0.165	*
40-50	45	0.030	277	0.056	0.063	0.093	+
50-60	11	0.007	49	0.011	0.002	0.019	*

- used less than proportion available, \* used in proportion to availability, + used more than proportion available.

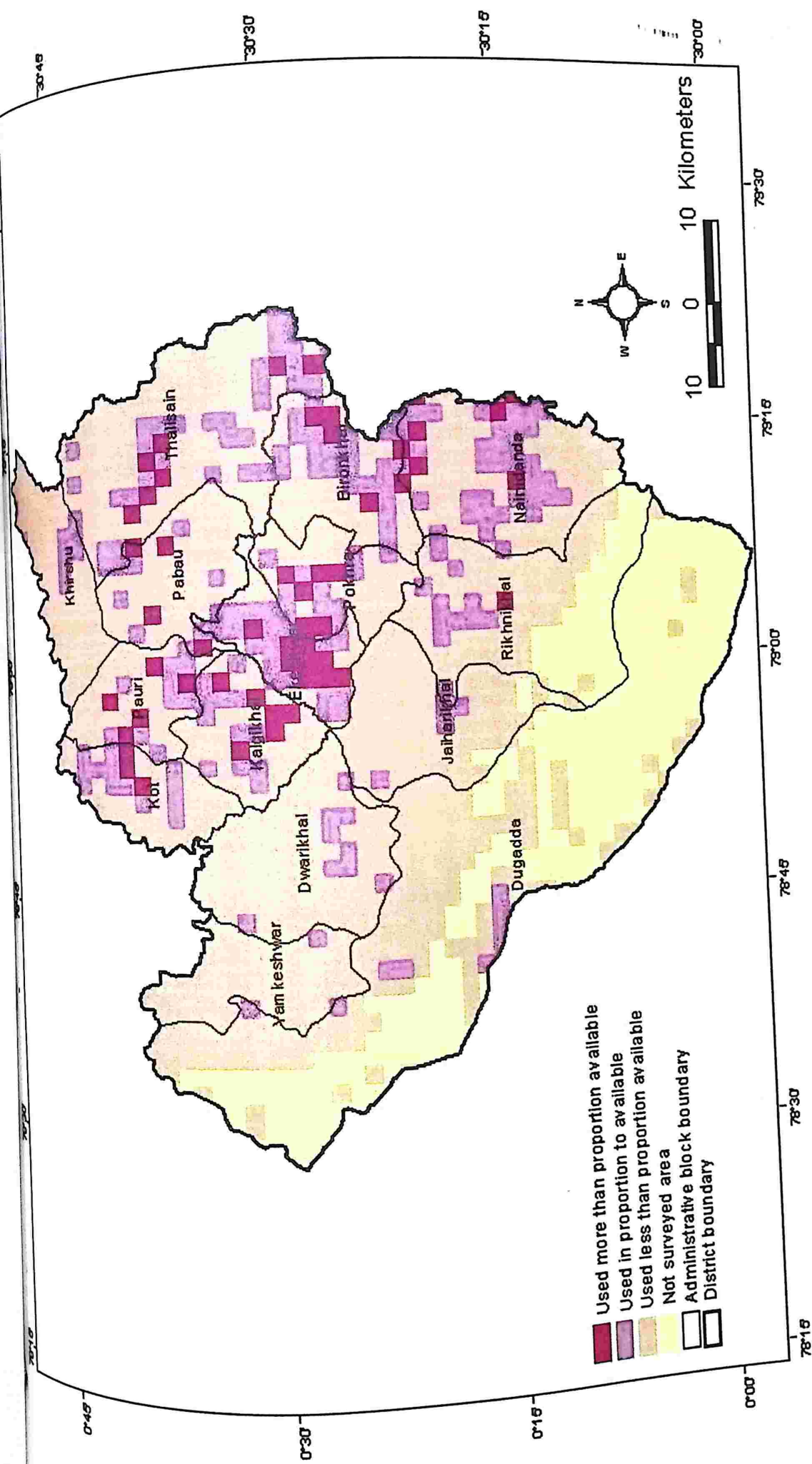
**Table 3.6.** Utilization of forest cover by leopards based on availability- utilization approach.

Forest cover	availability		utilization		lower limit	upper limit	Intensity of use
	N	PROP	N	PROP			
0-10	163	0.113	450	0.108	0.108	0.118	*
11-20	291	0.201	885	0.212	0.196	0.217	*
20-30	337	0.233	993	0.226	0.224	0.233	*
30-40	229	0.158	698	0.167	0.156	0.169	*
40-50	161	0.111	497	0.119	0.109	0.122	*
50-60	124	0.066	313	0.075	0.062	0.079	*
60<	143	0.099	437	0.105	0.094	0.108	*

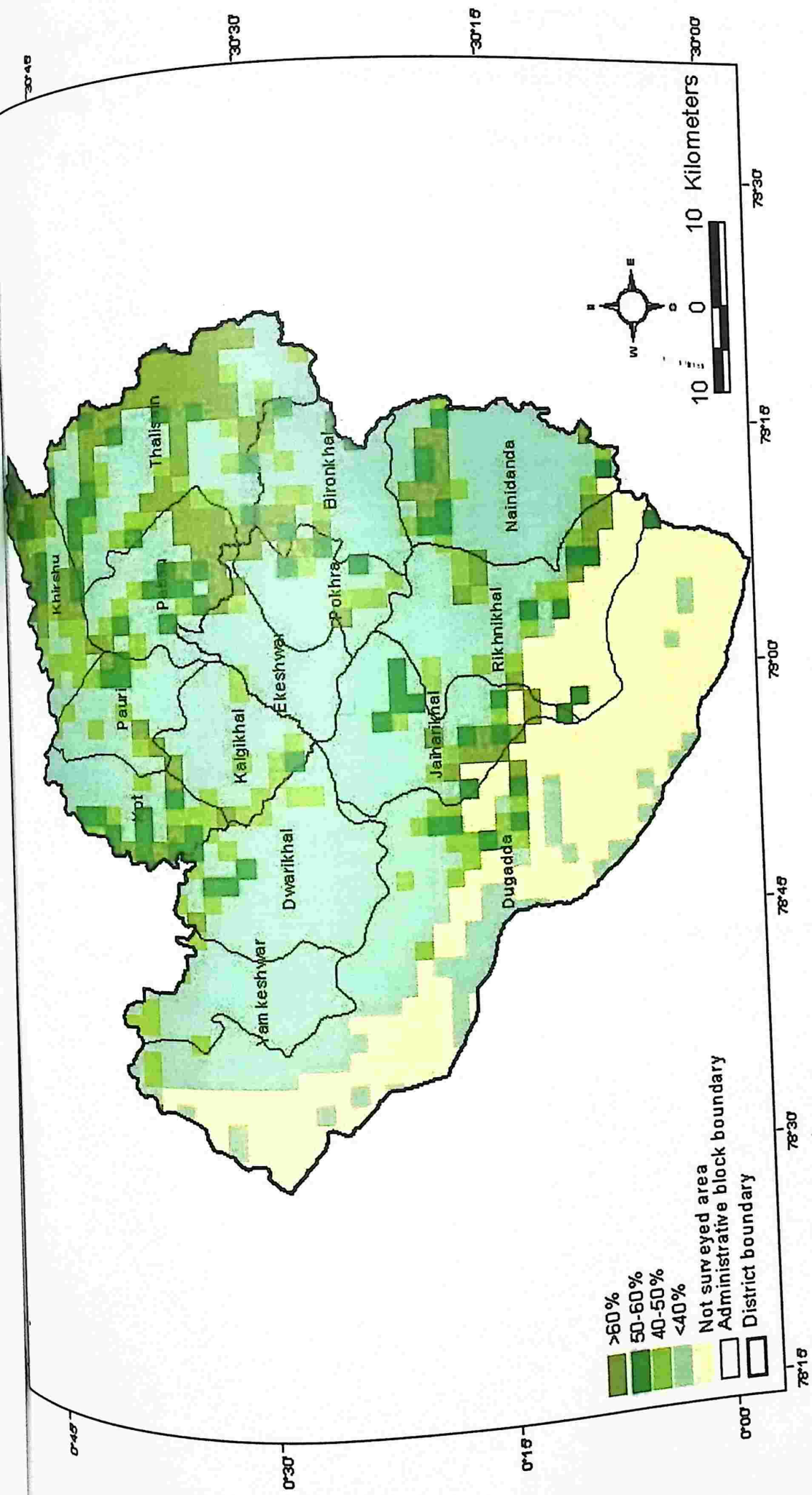
\*used in proportion to availability



**Figure 3.17.** Use of scrub cover by leopards based on availability-utilization approach.



**Figure 3.18.** Use of human habitation by leopards based on availability-utilization approach.



**Figure 3.19.** Use of forest cover by leopards based on availability-utilization approach.

Mean encounter rates of scats collected during survey were subjected to three major habitat types. Relative abundance of leopard scats varied for these habitat types (Fig. 3.20). Kruskal-Wallis test suggest that relative abundance of scats are significantly ( $P < 0.05$ ) associated with scrub and human habitation.

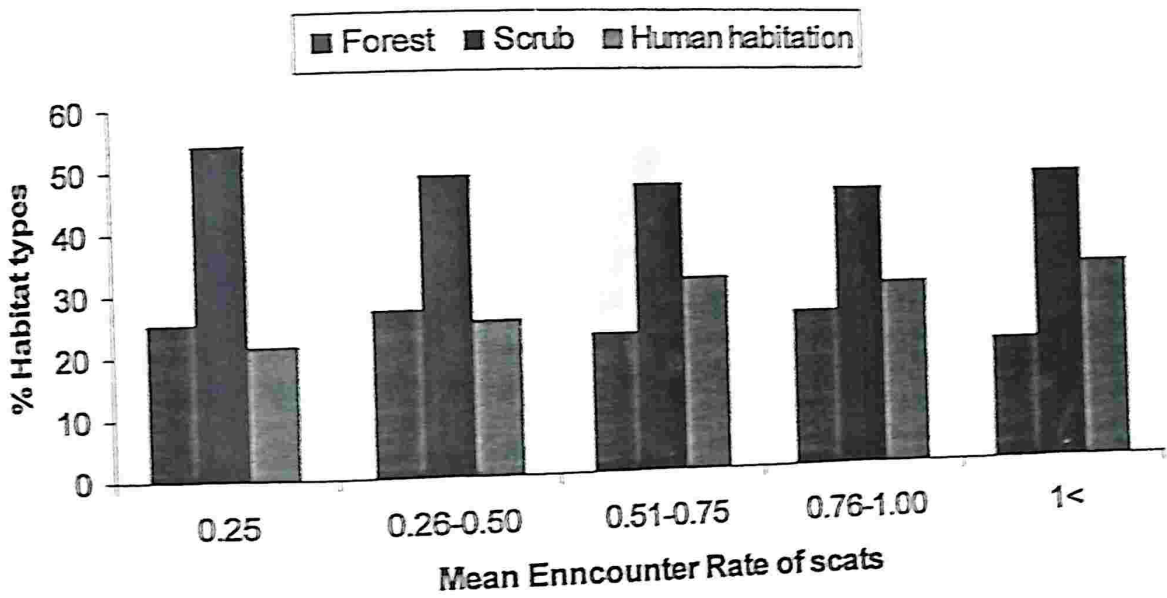


Figure 3.20. Mean Encounter rate of leopard scats (no./km) in relation to three different habitats.

### 3.3.3. Status of leopard in intensive study area of three conflict categories

#### 3.3.3.1. Encounter rate of leopard scats

Scats recorded on trails during 2002 to 2005 were used to understand the relative abundance of leopard in ISA of three conflict categories. A total of 278 scats were collected. Of the total scats, 116 and 86 scats were collected in ISA of medium and high conflict category respectively. While 76 scats were collected from ISA of low conflict category.

The average encounter rate of leopard scats observed in ISA of three conflict categories has been summarized in Table 3.7. The average encounter rate was significantly varied ( $\chi^2 = 34.4$ ;  $P < 0.01$ ) across the conflict categories. In ISA of low conflict category, the average encounter rate of scats ranged from 0 to 0.52/km during sampling periods. There was a significant variation in encounter rate of scats during sampled years ( $\chi^2 = 22.8$ ;  $P < 0.01$ ) in low conflict category. The average encounter rate of leopard scats ranged from 0 to 0.53/km during sampling periods in ISA of medium conflict category. The encounter rate is significantly different ( $\chi^2 = 20.17$ ;  $P < 0.01$ ) over the years in medium conflict category. The average encounter rate of leopard scat ranged from 0 to 0.55/km during sampling periods in ISA of high conflict category and significantly varied over the years ( $\chi^2 = 37.53$ ;  $P < 0.01$ ) in this category.

Table 3.7. Average (Mean±SD) encounter rate of scats observed in ISA of three conflict categories.

YEAR	SEASONS	Encounter rate of scats, no./km		
		LOW	MEDIUM	HIGH
2002	Winter	0.08±0.25	0.17±0.39	Not sampled
	Summer	0.8±0.29	0.53±0.55	0.33±0.44
	Rainy	0.52±0.55	0.47±0.38	0.55±0.49
	TOTAL	0.26±0.43	0.31±0.47	0.53±0.47
2003	Winter	0.14±0.32	0.12±0.2	0.06±0.16
	Summer	0.03±0.11	0.14±0.33	0.25±0.35
	Rainy	0.02±0.09	0.11±0.18	0.09±0.19
	TOTAL	0.06±0.20	0.12±0.27	0.10±0.21
2004	Winter	0.04±0.24	0.11±0.30	0.04±0.18
	Summer	0.05±0.32	0.12±0.31	0.09±0.27
	Rainy	0.04±0.13	0.00	0.00
	TOTAL	0.04±0.27	0.08±0.27	0.07±0.23
2005	Winter	0.22±0.21	0.14±0.25	0.07±0.26
	Summer	0.00	0.39±0.18	0.07±0.19
	Rainy	0.11±0.23	0.18±0.30	0.17±0.32
	TOTAL	0.14±0.220	0.19±0.272	0.096±0.24

Over all data of leopard scats observed during 3 seasons of four years indicates that average encounter rate of scats varied across the seasons within conflict categories (Fig. 3.21). In ISA of low conflict category, encounter rate of scat was highest during winter seasons and it was found statistically ( $\chi^2 = 6.8$ ;  $P < 0.04$ ) significant across seasons. In medium conflict category encounter rate of scat was highest in summer seasons and was statistically ( $\chi^2 = 8.68$ ;  $P < 0.01$ ) significant across seasons. While in ISA of high conflict category encounter rate of scats was relatively high during rainy and summer seasons but difference were not statistically significant.

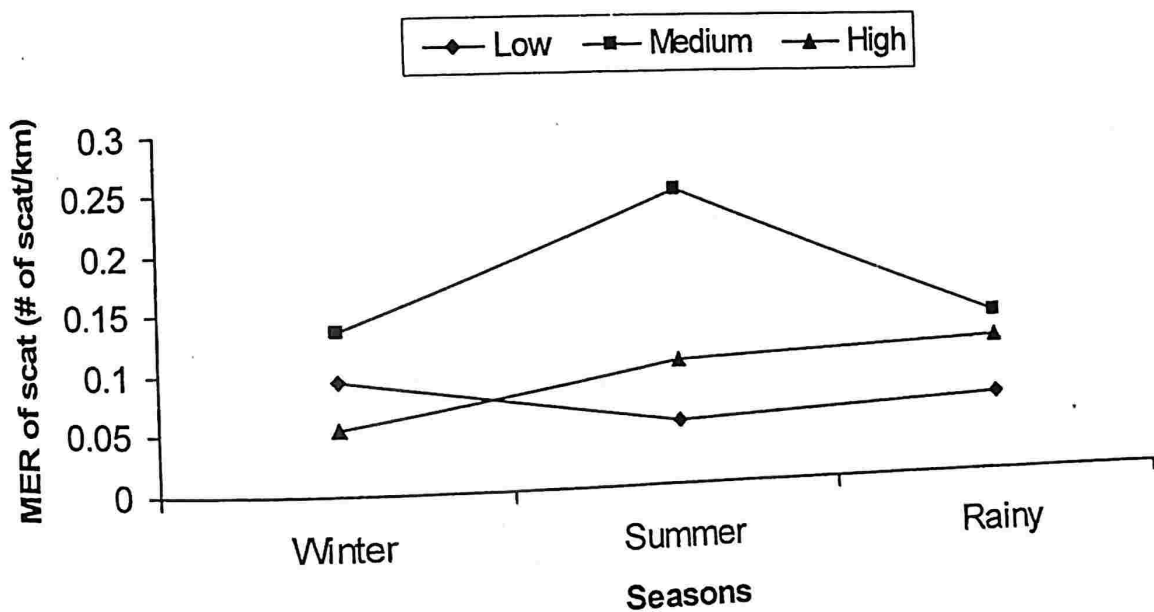


Figure 3.21. Variation in Mean Encounter Rate (MER) of leopard scats across the seasons among conflict categories.

### 3.3.3.2. Track index estimation

The estimated track index of leopards in ISA of three conflict categories has been summarized in Table 3.8. Estimated leopard track index in ISA of low conflict category has ranged from 0 to 0.55 during sampling periods. No significant variation was observed in track index within low conflict category across different years. In medium conflict category, estimated track index has ranged from 0 to 0.64 during sampling periods. Significant variation was observed in track index over the years ( $\chi^2=10.08$ ;  $P<0.01$ ) within medium conflict category. In ISA of high conflict category, estimated track index of leopards ranged from 0 to 0.22 during sampling periods. There is no significant variation in track index over the years within high conflict category.

Over all data indicates that track index varied across the seasons within low and medium conflict categories (Fig. 3.22). In low and high conflict categories, track index was recorded highest during summer season. But variation was significant only in high ( $\chi^2 =6.5$ ;  $P<0.03$ ) conflict category. In medium conflict category there was no much variation across the seasons and highest track index was recorded in rainy season.

There is a declining trend in track index from 2002 to 2005 during sampling periods. The leopard deaths were reported during sampling periods in surrounding of these study sites. These leopards were killed as declared man-eaters or found dead and some times killed by irate villagers (Table 3.9).

Table 3.8. Track index<sup>1</sup> (Mean±SD) of leopard observed in ISA of three conflict categories.

YEAR	SEASONS	LOW	MEDIUM	HIGH
2002	Winter	0.21±0.35	0.1±0.30	Not sampled
	Summer	0.00	0.08±0.27	0.00
	Rainy	0.00	0.64±1.107	0.00
	TOTAL	0.12±0.28	0.15±0.46	0.00
2003	Winter	0.14±0.50	0.15±0.34	0.00
	Summer	0.55±0.88	0.22±0.41	0.22±0.667
	Rainy	0.10±0.36	0.12±0.40	0.09±0.295
	TOTAL	0.23±0.60	0.17±0.385	0.085±0.314
2004	Winter	0.23±0.537	0.21±0.415	0.071±0.261
	Summer	0.17±0.415	0.10±0.459	0.18±0.439
	Rainy	0.30±0.377	0.22±0.413	0.22±0.392
	TOTAL	0.21±0.45	0.19±0.423	0.16±0.401
2005	Winter	0.00	0.05±0.226	0.071±0.267
	Summer	0.00	0.00	0.18±0.396
	Rainy	0.00	0.00	0.18±0.405
	TOTAL	0.000	0.029±0.169	0.15±0.364

<sup>1</sup> Track index = # of plots having sign/ total # of plots monitored

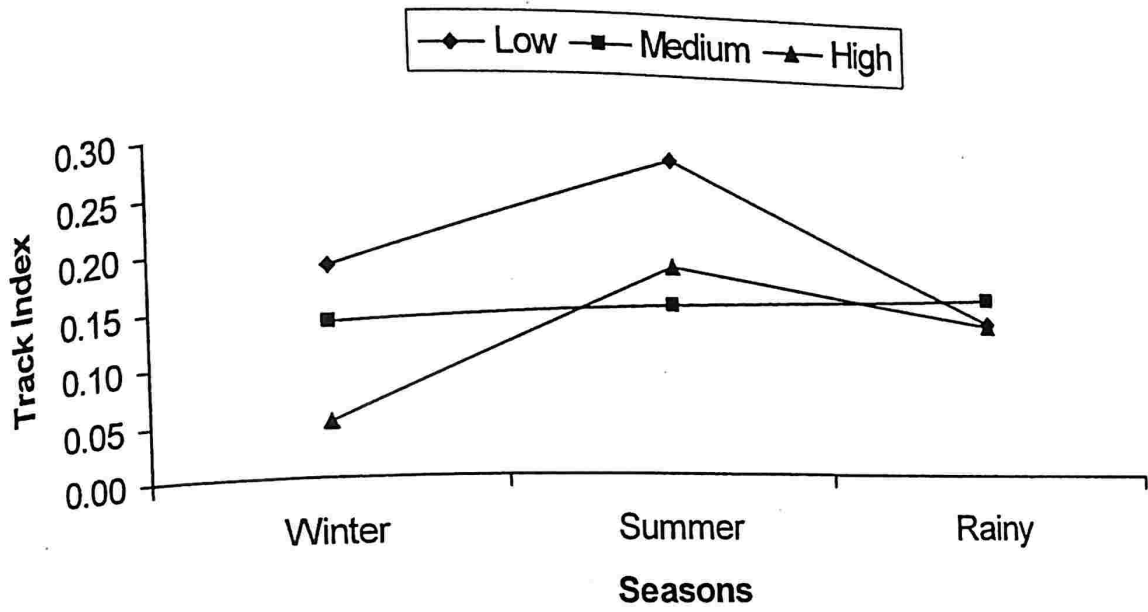


Figure 3.22. Variation in track index across the seasons among conflict categories.

Table 3.9. Number of leopard deaths reported from surrounding of three intensive study areas of three conflict categories.

Years	Low	Medium	high
2002	0	1	2
2003	1	2	1
2004	2	3	2
2005	0	1	1

### 3.3.4. Camera trapping

During camera trapping study (2003-2005) in ISA of low conflict category, a total of 15 leopard photographs were obtained with 11 right flank photographs belonging to 3 individuals and 4 left flank photographs of 2 individuals. While in ISA of medium conflict category, a total of 24 leopard photographs were obtained with 14 right flank photographs belonging to 8 individuals and 10 left flank photographs of 4 individuals. In ISA of high conflict category, a total of 21 leopard photographs were obtained with 11 left flank photographs belonging to 5 individuals and 10 right flank photographs of 3 individuals. Data indicates that probability of number of individuals increases along with photographs in three sampling sites (Fig. 3.23).

Identified individual leopards in ISA of three conflict categories during camera trapping efforts (2002-2005) have been shown in Fig. 3.24, 3.25 & 3.26.

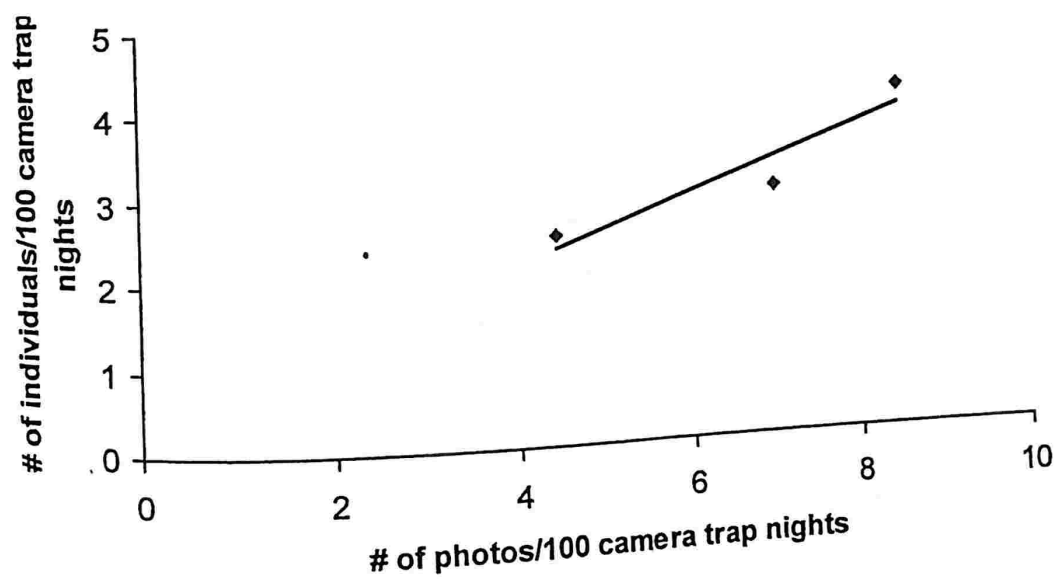


Figure 3.23. Relationship of individual leopards captured with increasing photographs.



**A (2003/2004/2005)**



**B (2004)**

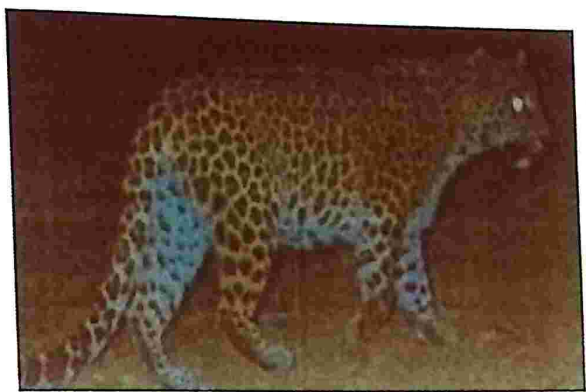


**C (2004)**

**Figure 3.24.** Identified individual leopards during camera trapping efforts (2003-2005) in ISA of low conflict category.



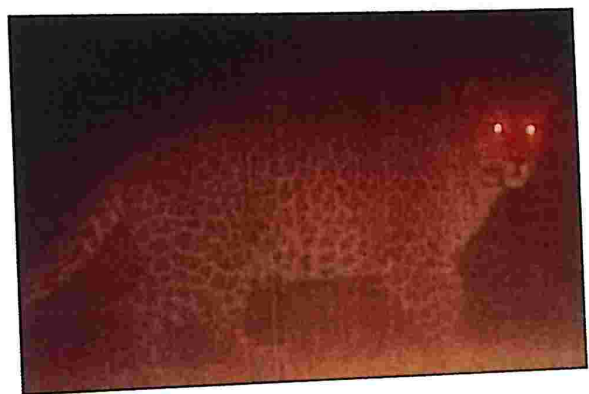
A (2003/2004/2005)



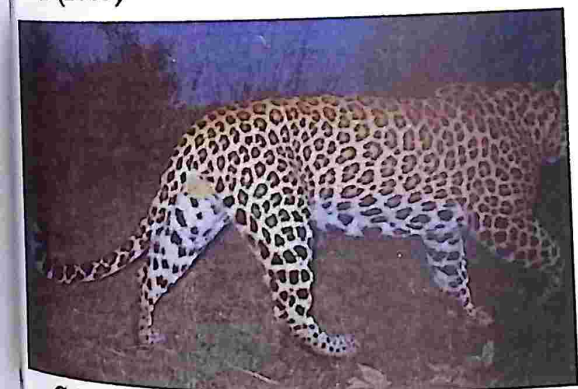
E (2003)



B (2003)



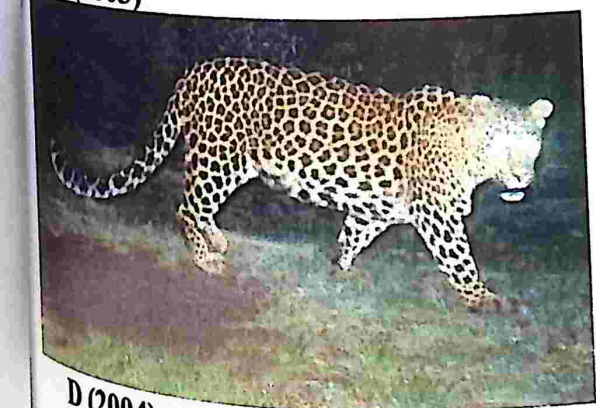
F (2004)



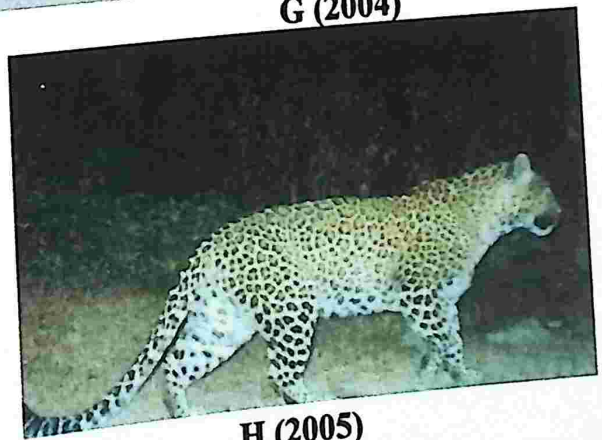
C (2003)



G (2004)



D (2004)



H (2005)

Figure 3.25. Identified individual leopards during camera trapping efforts in ISA of medium conflict category.



A (2004/2005)



B (2004)



C (2005)



D (2004)



E (2004)

Figure 3.26. Identified individual leopards during camera trapping efforts in ISA of high conflict category

#### 3.3.4.1. Capture frequency of leopards in ISA of three conflict categories

Capture frequency was estimated for leopard in ISA of each conflict category based on individual identified during trapping efforts. Results were compared using index determined as number of individuals/100 camera trap nights (Wallace *et al* 2003). Capture frequency of leopard photographed in ISA of three conflict category has been summarized in Table 3.10.

Capture frequency for leopard was highest in medium conflict category and ranged from 2.2 to 3.9/100 trap nights during trapping efforts. In high conflict category, estimated capture frequency ranged from 0 to 3.3/100 trap nights while it was 0 to 2.7/100 trap nights in low conflict category.

There is declining trend in capture frequencies from 2003 to 2005 in all conflict categories. The leopard deaths have been reported during trapping efforts in surroundings of all three study sites. It is presumed that capture frequency has been decreased probably due to leopard deaths (Table 3.11) in these study sites. Number of trappings stations and trap nights may also influence the capture frequencies of leopard in these study sites.

Data obtained could not be used for density estimation by using program CAPTURE as frequent leopard deaths were reported from all study sites during and in between trapping efforts.

**Table 3.10.** Capture frequency (# of leopard/100 camera trap nights) of leopard in three conflict categories.

Sampling Year	LOW		MEDIUM		HIGH	
	# of individual identified	Capture frequency	# of individual identified	Capture frequency	# of individual identified	Capture frequency
2003	1	2.5	4	3.9	0	0
2004	3	2.7	2	3.2	4	3.3
2005	1	2.3	2	2.2	1	2.5

**Table 3.11.** Capture frequency in relation to leopard deaths in ISA of three conflict categories.

Sampling Year	LOW		MEDIUM		HIGH	
	Capture frequency	Leopard deaths	Capture frequency	Leopard deaths	Capture frequency	Leopard deaths
2003	2.5	1	3.9	2	0	1
2004	2.7	2	3.2	3	3.3	2
2005	2.3	0	2.2	1	2.5	1

Movement of leopards in different conflict categories was observed by using maximum distance moved by individuals identified based on camera trap data (Table 3.12). Though data are limited but it indicates that the distance moved by leopards during trapping efforts was ranged from 1.20 to 1.40 km in low conflict category. While in medium conflict category distance moved ranged from 0.40 to 1.62 km during trapping efforts. In high conflict category, only one individual was recaptured and maximum distance moved by individual was only 0.28 km (Table 3.12).

**Table 3.12.** Leopard movement patterns and human deaths in various conflict categories (Leopard movement patterns observed based on individuals identified through camera trapping).

Sampling site	Maximum distance covered individual	Total sampled area (sq km)	Individual identified	Human deaths (1999 to 2005)
Low	1.20-1.40 km*	7	4	0
Medium	0.40 -1.62*	17	8	7 - 10
High	0.28 km**	06	5	25

\* two individuals were recaptured \*\*one individual was recaptured

### 3.3.4.2. The problems with use of camera traps in Pauri Garhwal district

#### (a) Theft or damage by local people

Local people visit forest areas for various purposes such as collection of firewood/cuttiing and grass cutting. During trapping efforts, I was not absolutely sure that somebody will not take or damage the camera trap device. Therefore, some of the sampling occasions were shorts and confined to the periods when we stayed in field and checked the camera everyday. Cameras trap device were kept alive during night hours only. People entering in the sampling sites were monitored and in this process more man power was required.

#### (b) Weather

During many sampling occasions, inconsistent weather (rainfall/snow fall) was a principal limiting factor. Radio shack heat based sensors used in this study were failed to work normally during rainy and snow fall periods.

### 3.4. DISCUSSION

#### 3.4.1. Distribution and habitat use

Results indicate that leopards are distributed throughout the study area. Although the distribution map is being based on different parameters but these parameters strongly support the presence of leopard in each surveyed grid. 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).

Habitat fragmentations affect species distribution and abundance (Crooks 2002). Fragmentation of habitat was one of the major cause of predator extinction across their ranges (Crooks 2002). Most of predator species 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; Marker and Dickman 2005). Studies have indicated that the distribution of species is positively correlated with habitat fragmentation (Vijayan and Pati 2002; Singh 2005). Data on distribution use by leopards in all surveyed grids in Pauri Garhwal of various habitat categories revealed that the species is quite flexible in its occupancy as reported by others (Seidensticker *et al.* 1990; 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 al.* 1990; Edgaonkar and Chellam 1998; Crooks 2002, Vijayan and Pati 2002). Previous studies suggested the adaptability of leopards in terms of diet and behavior and probably have

attributed their survival in unprotected areas (Hamilton 1976; Seidensticker *et al.* 1990; 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; Seidensticker *et al.* 1990; Edgaokkar and Chellam 1998; Mann and Chaudhry 2000).

In present study, leopards are widely preferred human habitation areas. Their preference to human habitation may probably due their dependency on domestic animals. Previous studies have found 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; Marker and Dickman 2005). Utilization of habitat types by carnivores is another important variable for their survival (Bailey 1993). Habitat types may influence predation rates as the density of vegetation can affect the delectability of both predator and prey (Bailey 1993). In present study, leopards significantly preferred scrub cover and was widely used by them throughout the study area (Table 3.4). Leopard scat encounter rate was highest in scrub habitat with comparison of other habitats (Fig. 3.16). A significant positive correlation was noted between livestock killed by leopards and scrub cover (Fig. 3.17). It corroborates to the findings reported in previous studies that leopard preferred to hunt relatively in dense cover. Bailey (1993) noted that most of the kills made by leopard during day time in Kruger National Park attributed to effective dense cover. In northern Bengal of India, incident of tea worker being mauled during day time, because leopard used cover afforded by such plantation and sometime 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 been reported to use sugarcane crop as permanent habitat and even breed in cultivated fields (Vijayan and Pati 2002; Singh 2005). Data on livestock kills in this study suggest that leopard used scrub cover to approach prey. Leopards probably remain concealed in these patches of scrub cover. These patches are probably providing ideal habitat for their litters.

### 3.4.2. Current status

If leopard scat data to be linked with their abundance, data in this study may suggest high abundance of leopard in high and medium conflict categories. Estimated track index was also relatively high in medium conflict category. High capture frequencies of leopards in medium to high conflict category also corroborate with scat data that leopard abundance appears to be relatively high in these categories with comparison to low conflict category. Variation in track index (Table 3.8) and capture frequencies (Table 3.10) over years were probably associated with leopard deaths in surroundings of study sites during sampling periods. However scat data have not shown similar trends (Table 3.7).

Individual identified based on photographed obtained through camera traps were observed moving short distances in medium and high conflict category in comparison to low conflict category. Bothma and Coertze (2004) suggested that in prey rich areas, leopard survival is ensured by energy –maximizing prey selective strategy. But in prey poor areas, leopards (specially lactating females) survive by moving shorter distances before making a kill and by regularly killing a high frequency of those types of smaller prey which are easier to kill. This hypothesis lends support to this study. In this study females are reported to causing more conflict. It is presumed that in these prey poor areas female leopards probably come more close to human habitations in order to increase their

hunting success. As females required more energy during gestation and lactation periods and they might predate frequently on domestic animals in the absence of wild prey species.

### 3.5. SUMMARY

1. Leopards are distributed throughout the surveyed area.
2. Major land use patterns in study area are scrub, forest and human habitation. Scrub is dominating with more than 50% of total land cover followed by forest 33.4%. Human habitation is covering 16.23 % of total land cover.
3. Leopard distribution is significantly associated with scrub and human habitation and scrub cover is widely used. Data indicates that the grids having scrub cover of 40-60% of total area were preferred by leopards. Similarly, grids having 40-50% habitation were preferred by leopards. Forest cover used by leopards was in proportion to its availability.
4. Leopard abundance is relatively higher in high to medium conflict categories. Mean encounter rate of scats was significantly higher in high conflict category and ranged from 0 to 0.20/km. Track index of leopard was also relatively high in medium conflict category. Thus capture frequency of leopard was highest in medium conflict category and followed by high conflict category.
5. There has been declining trend in track index and capture frequency from 2002 to 2005 in all conflict category which may due to leopard deaths in surrounding of sampling sites. But scat encounter rate has not shown such trend. Thus scats should be cautiously used during survey work as power of detection in change in leopard numbers may not be possible.

## CHAPTER 4 EXTENT AND SEVERITY OF LEOPARD-HUMAN CONFLICT PROBLEMS IN RELATION TO ITS ECOLOGICAL REQUIREMENTS, LAND USE PATTERNS AND HUMAN LIFE STYLE

### 4.1. INTRODUCTION

Three types of conflict with carnivores are common in unprotected area where human and livestock interface viz. human mortality by carnivores, livestock depredation and carnivore mortality by people (Chakrabarti 1992; Chellam and Johnsingh 1993; Saberwal *et al* 1994; Jhala and Shrama 1997; Rajpurohit 1999; Woodroffe 2000). Among these, livestock depredation is the most common type of conflict reported from various parts of world (Woodroffe 2000; Patterson *et al.* 2004). It is their reliance on livestock which bring carnivores into direct conflict with human, specially where native prey species have been extinct and replaced by domestic stocks (Patterson *et al.* 2004). When carnivore attacks human and livestock, campaigns to eradicate them are inevitable (Woodroffe 2000; Patterson *et al.* 2004). The conflict with people and predation on livestock is main cause of livestock mortality (Nowell and Jackson 1996; Sunquist and Sunquist 2002).

Due to urbanization in India, several wild species have declined across their range (Adrian and Karanth 2003). Habitat degradation has negative impact on ungulate species. But leopards still widely distributed due to their ability to adept to different challenges, both environmental and anthropogenic (Daniel 1996). These adaptations include variation in 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; Edgaonkar and Chellam 1998).

In many areas, significant population of leopard is outside the protected areas where they are sharing their living space with domestic animals and do occasionally or 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 problem of leopard-human conflict has been recently increased in the Indian Himalayan region due to change in land use patterns (Johnsingh *et al.* 1991; Negi 1996). The leopard interface with human in this region is not new (Corbett 1944, 1948, 1957). However in the past, leopards were confining their base in forest areas and leopards were not perceived as threats. Over the last two decades, a change in leopard behaviour to become extremely bold has been noticed and this may be due to habitat disturbance and loss of prey species as leopards is reported entering even in big towns. As human population grows and spreads ever outward into the natural habitat of the leopards, forests are cleared and natural prey are destroyed as a result in many of these areas. In this process, leopard are often pursued as predators of domestic animals and in some cases to human.

The number of reported incidences of human attacks by leopard has accelerated during last decade in Pauri Garhwal district of Uttarakhand (Negi 1996). Therefore it is important to understand the kind of circumstances in which human being are attacked. Understanding the situations that promote the greatest likelihood of attack is an

important component of wildlife management (Fitzhugh *et al.* 2003). More detailed information on the ecology and intensity of predation are important aspects for developing strategies for conserving both carnivore and wild lands (Polisar *et al.* 2003).

The main objective of this Chapter is to “*determine the extent and severity of leopards-human conflict problem in relation to its ecological requirements, land use patterns and human life style in Pauri Garhwal*”. The specific questions are:

1. What is the intensity of leopard predation on human and livestock across various administrative blocks in Pauri Garhwal?
2. What are the landuse characteristics related to leopard predation on human and livestock?
3. Is intensity of leopard predation on human is affected by leopard predation on livestock?
4. What is the mortality rate of leopard and which sex of leopard is coming into contact of human?
5. Is leopard mortality is affected by leopard attacks on human?
6. Which age and sex class of people are main victims and under what circumstances attacks were prominent?
7. What is the opinion of local people on leopard-human conflict?

## 4.2. METHODS

### 4.2.1. Extent and severity of leopard-man conflict in Pauri Gharhwal district

A survey was carried in 15 administrative blocks of Pauri Garhwal district to understand the status, extent and severity of leopard-human conflicts. Study area was divided into 2x2 grids and survey work was done in three or four villages from each grid forming at least 50% of villages in that grid. A total of 1202 villages were surveyed between February 2000 to October 2001. Structured questionnaire (Annexure-I) was designed to obtain information on different aspects related to leopard-human conflicts. These conflicts include incidents of leopard predation on human and livestock. Information such as frequency of leopard visit, livestock lifting and leopard predation on human was also collected by visiting villages in each grid. Information available with forest department was also noted. To assess implication of life style changes with reference to increase level of conflicts, information on general activities of hill people were also obtained through desired questionnaire, observations and interview with local people.

Intensity of leopard predation on livestock and human was determined in each surveyed grid. Based on these, entire area has been divided into three categories of conflict viz. (i) low (ii) medium and (iii) high as described under Chapter 3. Three conflict categories were correlated with respect to land use patterns and vegetation.

#### **4.2.2. Quantification of the circumstances of conflict**

Information collected on leopard deaths and their death pattern was quantified. Data collected on gender of man-eaters to clarify what sex of leopards is coming into conflict with human.

Leopard's victims data were interpreted with respect to sex, age and to different seasons. Severity of problem for each season was quantified. Places where leopards attacked on human during field study were visited and circumstances of each incident was recorded (Annexure-II). Vegetation was quantified at every 100 m having a transect of 500m at 14 places where human were killed by leopard during study period.

#### **4.2.3. Opinion of local people on ongoing conflict**

People opinion about ongoing conflict and their suggestion to minimize the problems were noted during survey work. A total of 1486 people were interviewed Information on issues associated with compensation such as amount, procedure, administrative delaying were also obtained.

### 4.3. RESULTS

#### 4.3.1. Extent and severity of leopard-human conflict

##### 4.3.1.1. Intensity of leopard attacks on human

Based on forest departments record, 191 humans were killed and 364 injured by leopards in Pauri Garhwal during 1998 to 2005 (Fig. 4.1). The systematic record of incidences occurred before 1995 was not available with forest department. Over the years, number of conflict incidences (killed/injured) ranged from 2 to 40 human per year. During past couple of years number of such incidences have increased and ranged from 19 to 40 per year.

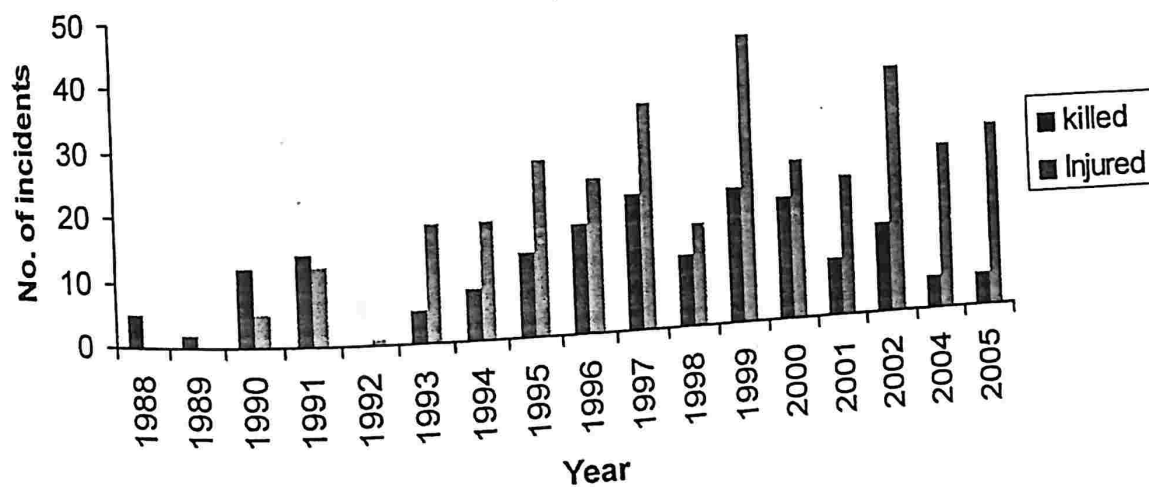


Figure 4.1. No. of human killed/injured in Pauri Garhwal district.

The incidences of leopard attacks on human have been reported from all administrative block. However severity of attacks varied across the administrative blocks (Fig. 4.2). Block such as Pabau, Dugadda, Pauri, Dwarikhal, Jahrikhal and Kalgikhal are highly affected in terms of human mortality by leopards. A total of 30.5% cases have been reported from Pabau block alone. 16.2% cases of were recorded in Dugadda block. Similary 11.9 and 9.2% of cases have been reported from Dwarikhal and Pauri block respectively. Block such as Yamkeshwar, Bironkhal, Khirsu and Pokhra was least affected in terms of human mortality.

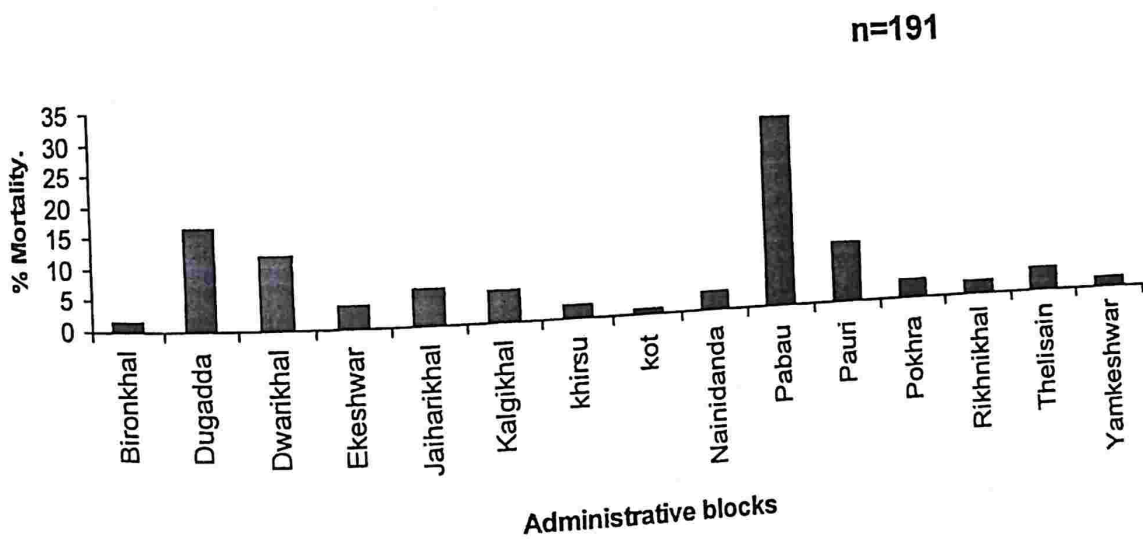


Figure 4.2. Percent human mortality across the administrative blocks in Pauri Garhwal.

### 4.3.1.2. Intensity of leopard predation on livestock

Leopard predations on livestock have been reported from all blocks in study area. According to information collected during village survey, average livestock lost to leopard is 260 individuals per year in Pauri Garhwal. However based on last ten years data of forest department records, the average livestock lost to leopard is 86.6 individuals per year. During last five years (1996-2000) such incidents have increased up to 130 individuals per year. Most of the time such cases go unreported due to following reasons: (i) earlier forest department was not providing compensation, therefore people were not giving information to the department and (ii) people living in remote villages are not aware of forest department's compensation scheme.

Proportion of livestock mortality is relatively high in blocks such as Thalissain Khirshu, Rikhnikhil and Pauri (Fig. 4.3).

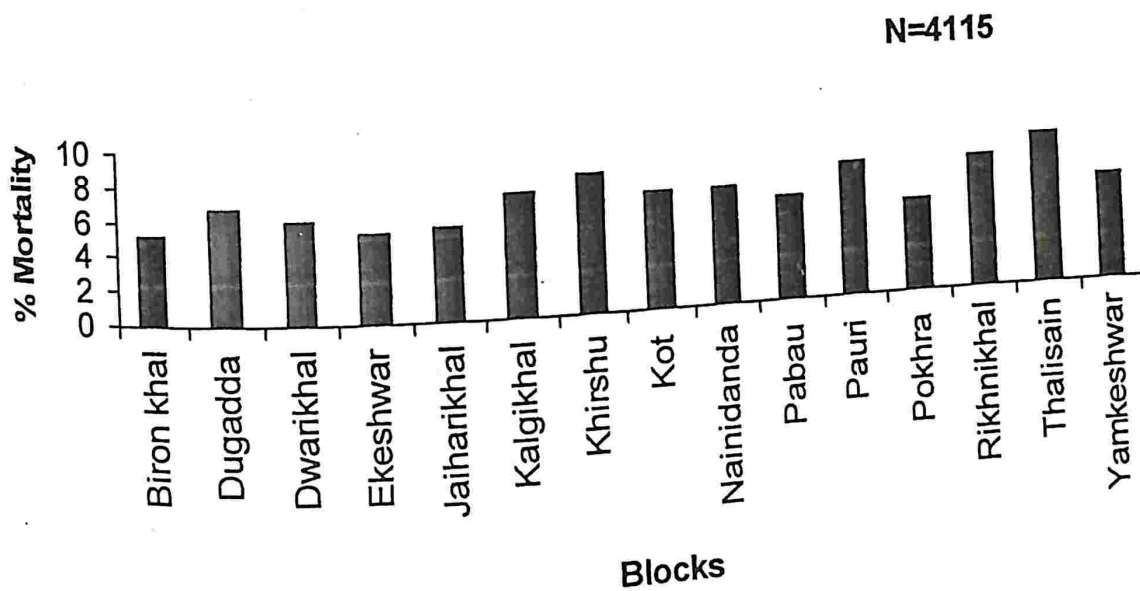


Figure 4.3. Percent livestock mortality across different administrative blocks in Pauri Garhwal.

There is a trend of declining leopard predation on human in those blocks where leopard predation on livestock is relatively high. Livestock mortality is negatively correlated ( $r^2=0.26$ ;  $P<0.05$ ) with human death in 15 administrative blocks (Fig. 4.4). Thus leopard predation on human might be affected by livestock availability in that area but such trend was not seen in Pabau block.

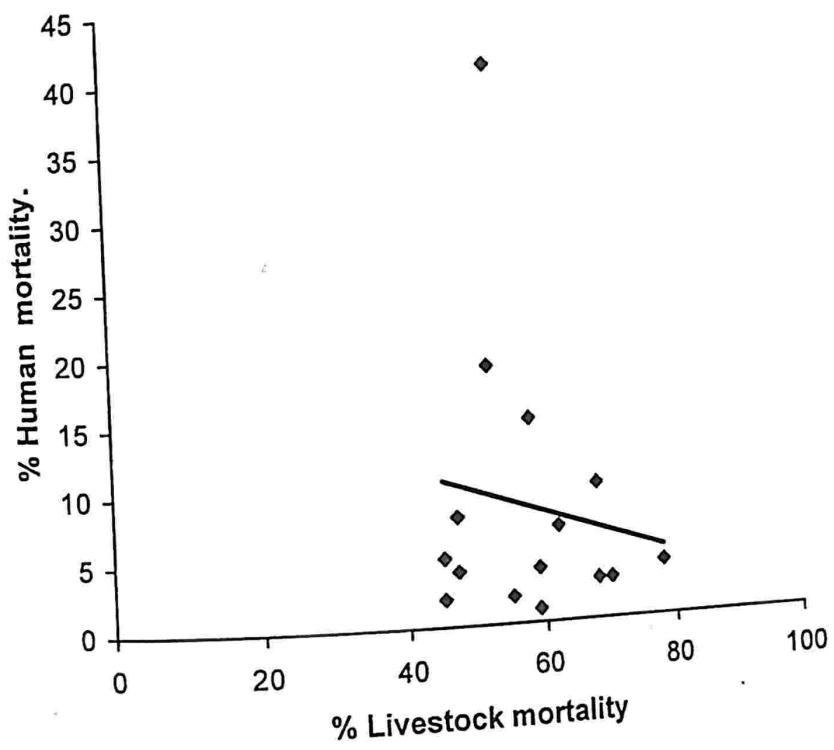
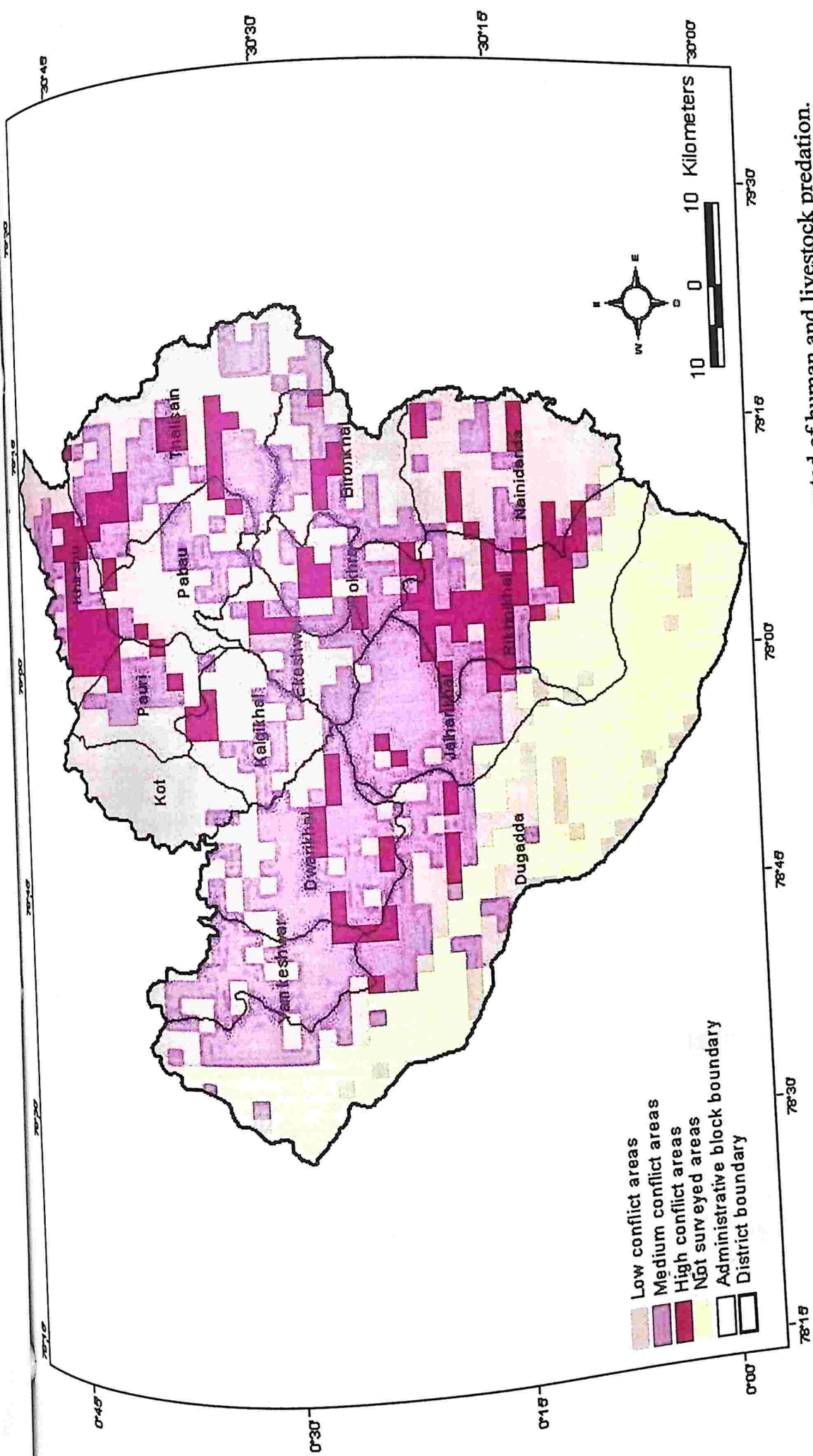


Figure 4.4. Relationship between human and livestock deaths in 15 administrative blocks of Pauri Garhwal.

#### 4.3.1.3. General distribution of leopard-human conflicts

Based on intensity of leopard predation on livestock and human in surveyed grids, entire study area was divided into three category of conflict viz. low, medium and high (Fig. 4.5). Of the total surveyed area, 46% consist of low conflict category. Medium conflict category was of 40.2% of total surveyed area whereas high conflict area was of 19.2% of total surveyed area.

Fig. 4.6, indicate that the extent of human-leopard conflict is less in block such as Kot, Pauri, Kalgikhal and Nainidanda, as large portion of these block consists of low conflict category. The extent of conflicts is highest in blocks such as Pabau and Riknikhal in terms of percent area. There has been increasing trend in conflicts in block such as Yamkeshwar Jaiharikhal, Thalissain, Dwarikhal and Pokhra as large portion of these blocks consist of medium conflict category. In future conflict might probably increase in these blocks.



**Figure 4.5.** General distribution of leopard-human conflict based on cases reported of human and livestock predation.

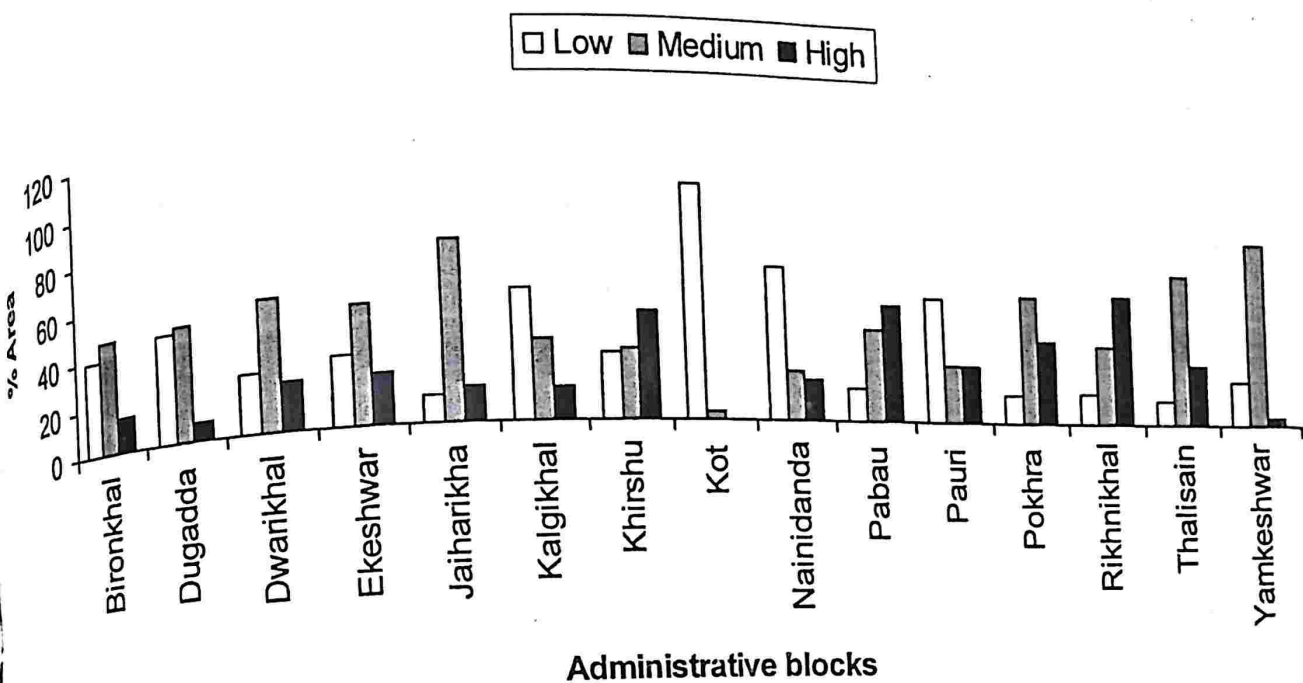


Figure 4.6. Extent of area (% of total surveyed area) under conflict category across the administrative blocks.

#### 4.3.1.4. Conflict in relation to land use patterns

The land use patterns for the conflict categories indicate that a total of 46.6% area is dominated by scrub in high conflict category (Fig. 4.7). Forest and habitation occupy 29.1% and 23.1% area respectively. Similarly in medium conflict categories, scrub occupy 49.2% area and followed by forest 29.5%. In low conflict category, forest covers 37.7% of area which is relatively higher than medium and high conflict categories.

Leopard predation on human and livestock is positively correlated ( $r^2=0.45$ ,  $P<0.01$ ) with scrub cover (Fig. 4.8). Proportion of livestock and human death is relatively higher in those blocks where large proportion of area is under scrub. Positive correlation has been observed between leopard-human conflict cases (livestock and human mortality) and human habitation. But statistically it is not significant (Fig. 4.9). It has been

observed that areas where the percentage of scrub and habitation areas are higher, there is high possibility of human-leopard conflict.

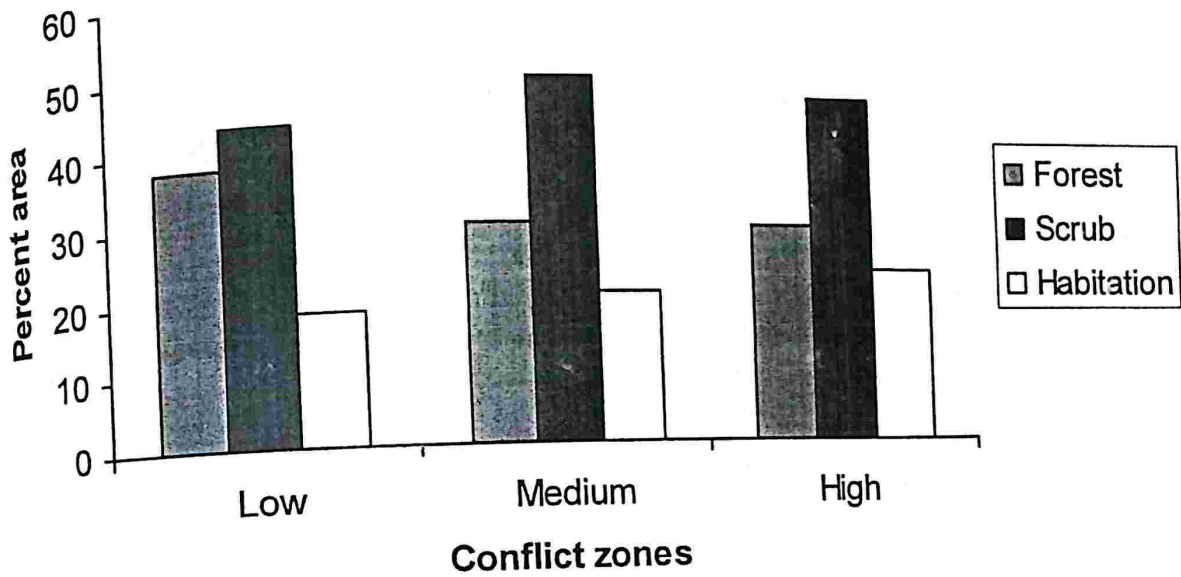


Figure 4.7. Proportion of different land use patterns in three conflict categories.

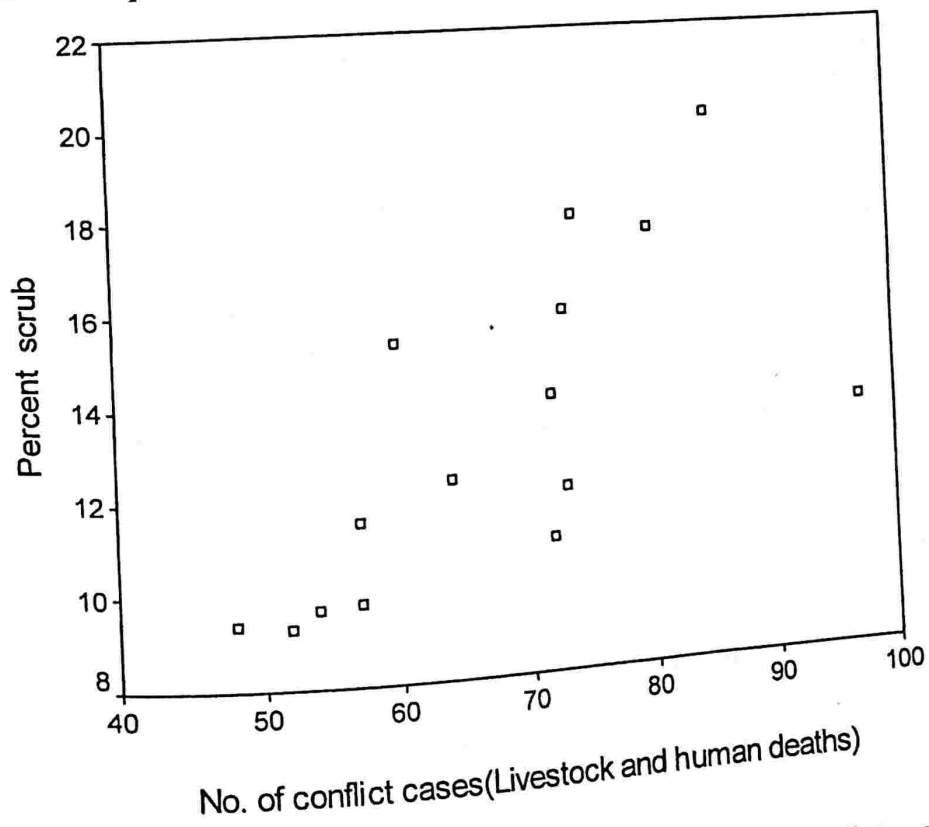


Figure 4.8. Correlation between percent scrub cover and conflict cases in 15 administrative blocks.

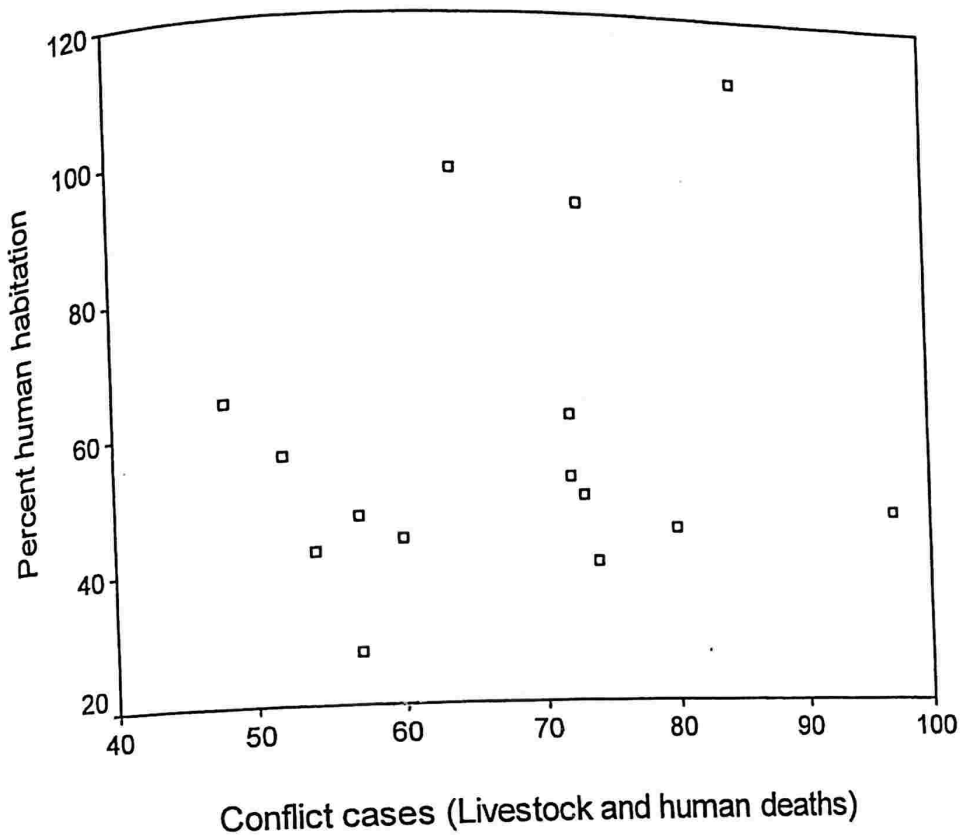
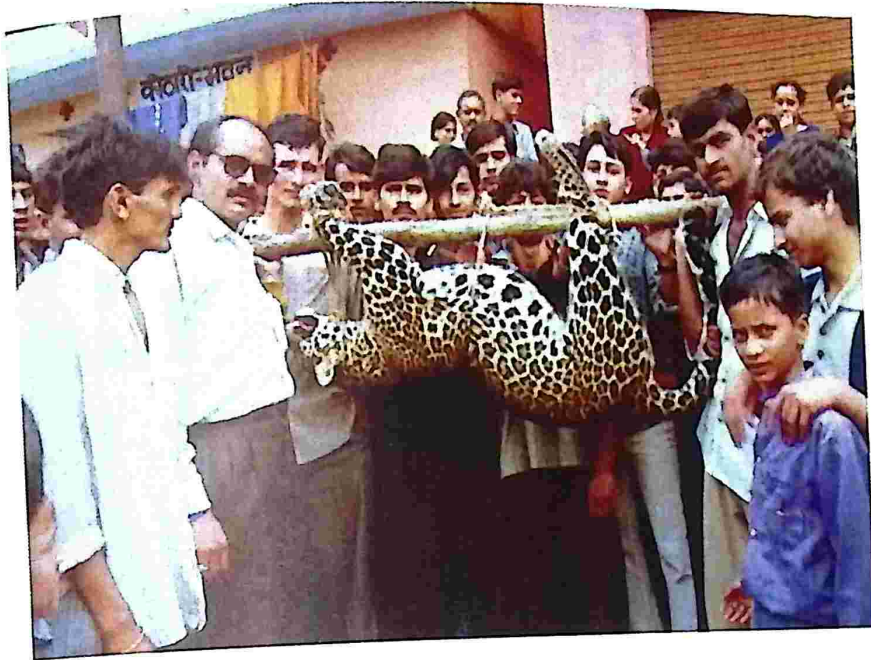


Figure 4.9. Correlation between percent human habitation and conflict cases in 15 administrative blocks.

#### 4.3.1.5. Intensity of leopard deaths in Pauri Garhwal

Leopard deaths in Pauri Garhwal have been either killed as man-eater or found dead and killed by irate villagers (Fig. 4.10). A total of 121 deaths have been reported from this area during 1990 to 2005. Among killed animals, 36% were killed as man-eaters where as 56% and 14% were found dead in suspect and killed by irate villagers respectively. Over the years, number of deaths has ranged from 2 to 16 per year but during last six years such incidences have increased and ranged from 12-16 leopards per year (Fig. 4.11). Intensity of leopard deaths is varied across the administrative blocks (Fig. 4.12). Highest (23.9%) deaths have been recorded in Pabau block, whereas 20.6% and 19.8% of total deaths were in Dugadda and Pauri block respectively.



(i). Killed as declared man-eater



(ii). Killed by irate villagers

**Figure 4.10.** Pattern of leopard deaths in Pauri Garhwal.

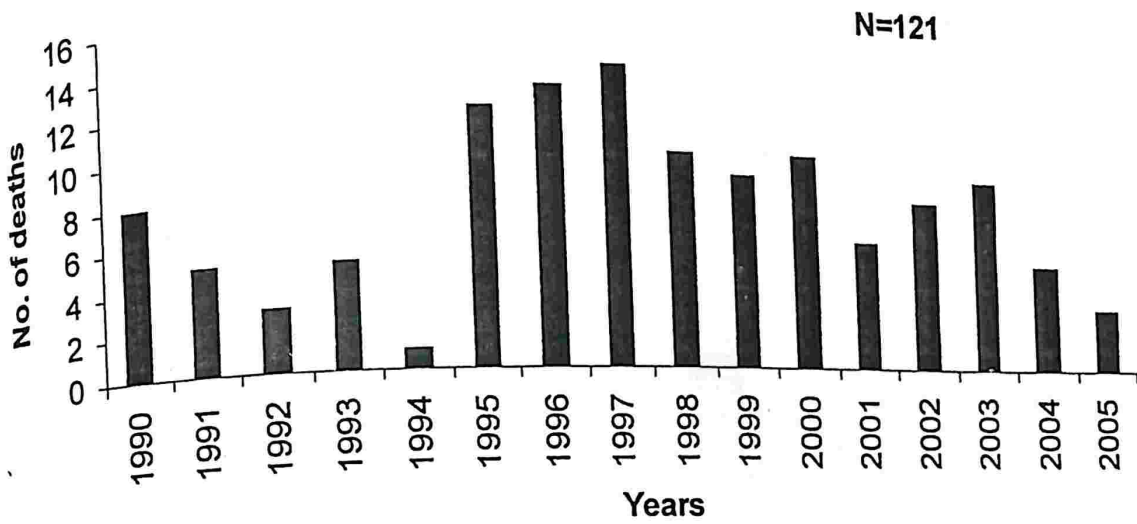


Figure 4.11. Number of leopard deaths over the years in Pauri Garhwal district.

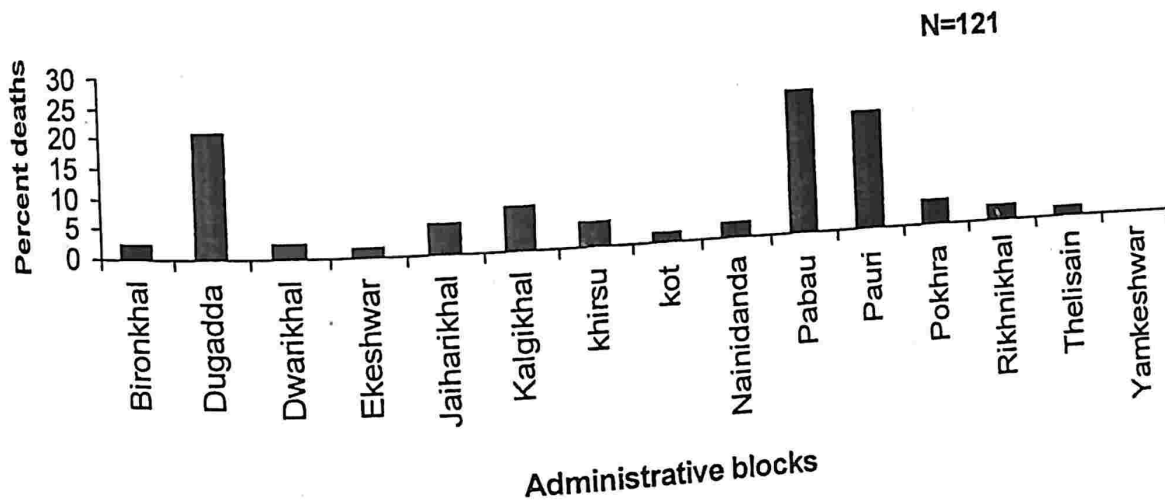
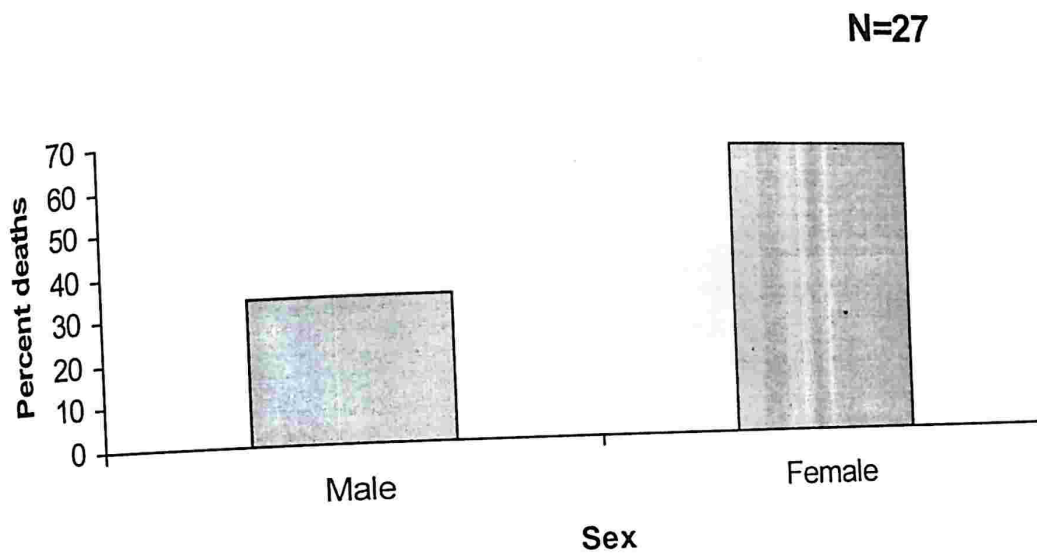


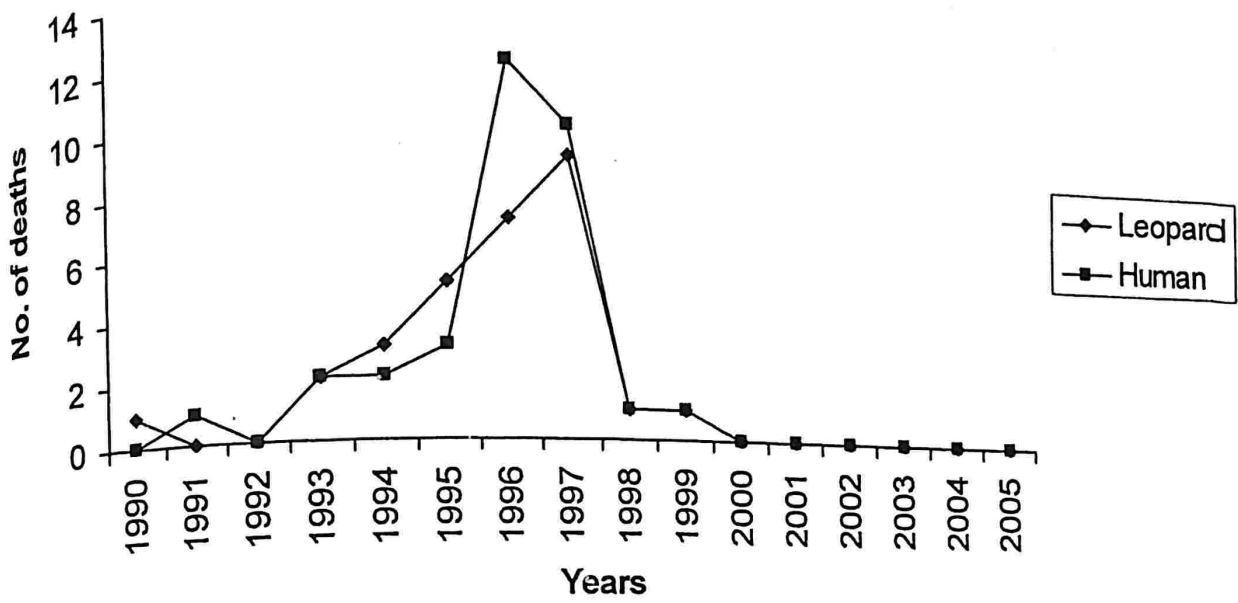
Figure 4.12. Proportion of leopard deaths across the administrative blocks.

Sex of animals killed as man-eaters were not recorded properly by forest department but limited data of 27 leopards killed (1996-2004) indicates that 18 of them were female (Fig. 4.13).

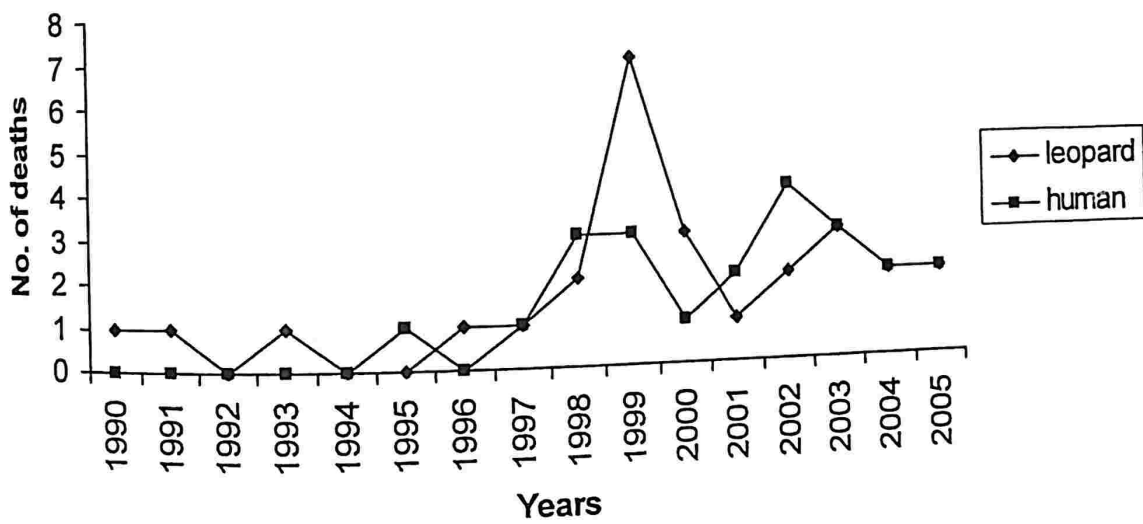


**Figure 4.13.** Sex of leopards killed as declared man-eaters.

A close analysis of leopard and human deaths in two highly affected blocks (Pabau and Dugdda) indicates that human deaths caused by leopard decreased as number of leopard death increased (Fig. 4.14). Once the large number of leopards in and around of Pabu blocks were killed by 1998, thereafter a few cases of man-eating have been reported from this area (Fig. 4.14a). In Dugadda block there is trend in declining human deaths during 1999 to 2001 as number of leopard deaths increased (Fig. 4.14b).



(a) Pabau block



(b) Dugadda block

Figure 4.14. Relationship between leopard and human deaths in two highly affected administrative blocks in Pauri Garhwal.

### 4.3.2. Quantification of the circumstances of conflict

#### 4.3.2.1. Age and sex of leopard victims

Based on forest department records, 68.6 % victims were children below 15 years where as cases have been reported in all age groups (Fig. 4.15). Predation on female is relatively high in comparison to males in all age group. Based on 24 incidents observed during field work also indicate that children are always more victims as 85.7% victims were below 15 years. In the hills, females have responsibility to do outdoor work, thus the probability of encountering with leopard is relatively higher by females than males. Similary, female children share a large work with her mother therefore, their probability of encountering with leopard is relatively higher then male children. 60% children were killed outside the houses whereas 40% were dragged from houses.

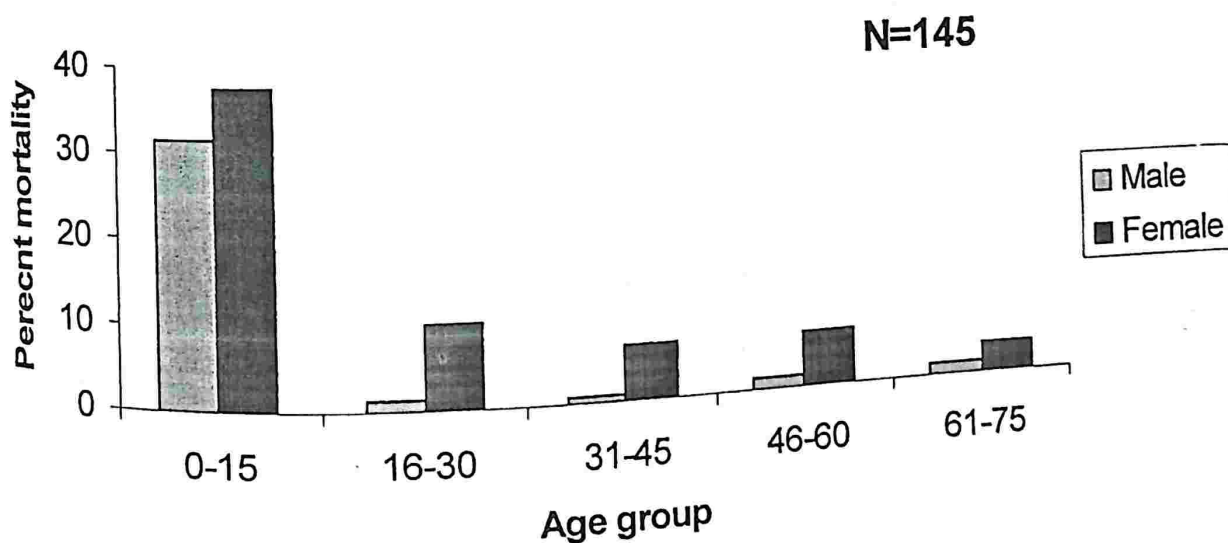


Figure 4.15. Age and sex of human killed by leopards.

#### 4.3.2.2. Seasonal patterns of human mortality

Leopard attacks on human vary across the season as 45.8 % and 42.2% cases were reported during rainy and winter season respectively (Fig. 4.16). It may be due to growing of weeds in rainy season and remained till winter which provides suitable habitat cover to leopards. Leopards come more close to human during these seasons where they seek opportunities to kill livestock and in this process some time human fall prey of them.

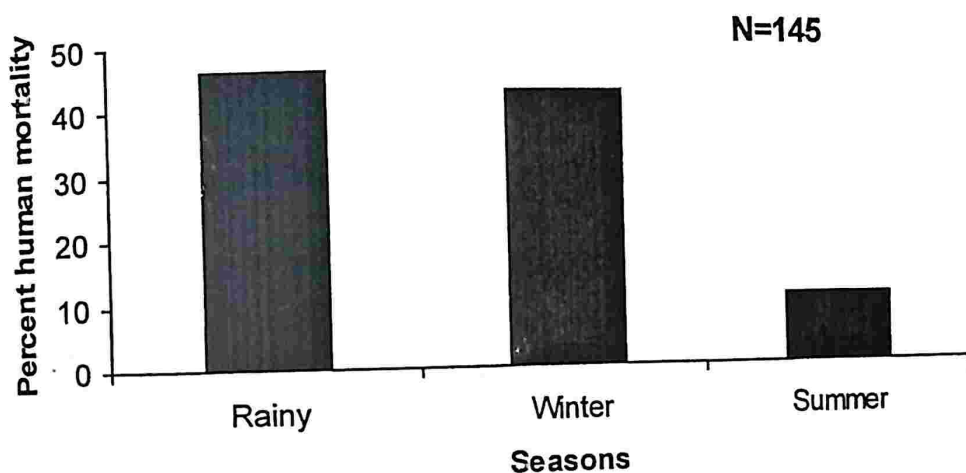


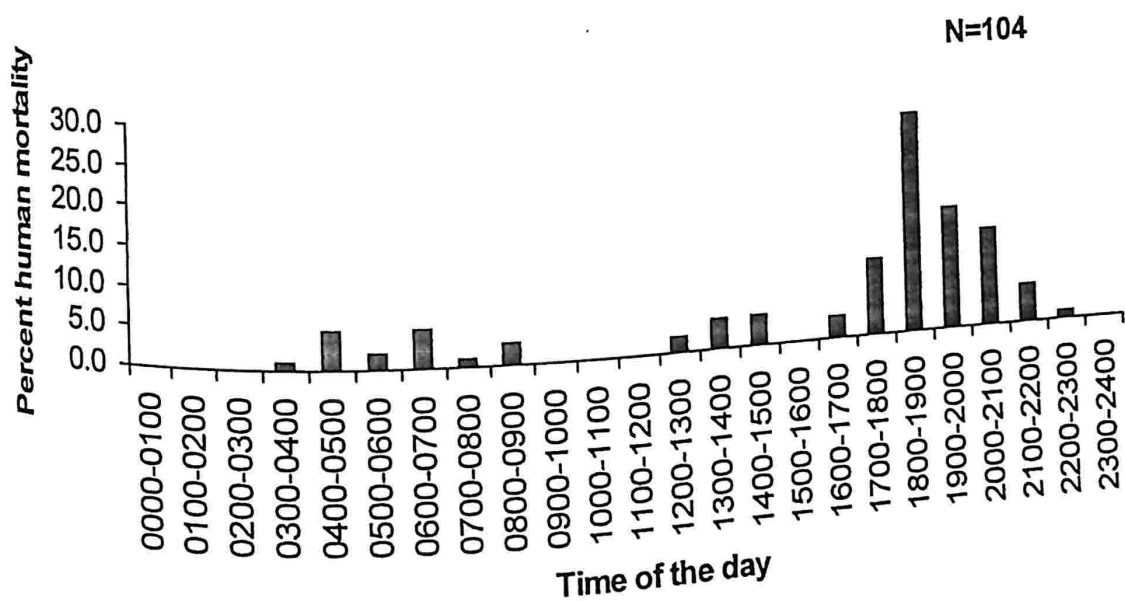
Figure 4.16. Seasonal patterns of human mortality.

#### 4.3.2.3. Leopard attacks with respect to time of the day and general activities of people

Leopard attacks are varied across the time of the day (Fig. 4.17). Frequencies of attack are relatively high during evening time, as 68.3 % attacks were between 1600-2100 hours. Timing of attacks seems to be correlated with general activities of hill peoples. During this period, many things are taking place together in this area viz. (i) children return from school and in some areas they have to travel a long distance to reach home

(ii) woman return from jungle/fields along with their cattle (ii) workers return from their work place (iv) people go for water (specially female children) and in this process some time they have to travel a long distances (Table 4.1). This is also coincided with their timing of toilet as in hills most of the families do not have toilet facilities and they often use open places for this purpose. Hill women as being shy in nature often go for toilet in late evening and early morning and use the area surrounded by relatively cover of weeds/shrub for toilet purposes.

16.4% incidents were between 0300-0800 hours which is also coincided with respect to toilet time. This is the time when children go to school, workers go for work and women go to jungle and fields. 7.7% cases were between 1300-1500 hours. It is the time when women work in jungle and fields. Based on 24 incidences observed during field work, these also corroborate with forest department data that leopard attacks are more prominent between 1600-2100 hours (67.8%). 17.3% attacks were between 0500-0600 hours. where as 10.8% attacks were between 1400-1500 hours.



**Figure 4.17.** Leopard attacks in relation to the time of the day.

Table 4.1. General activities of hill peoples.

Activities	Time of the day											
	0400-0600	0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800	1800-2000	2000-2200	2200-2400	0000-0200	0200-0400
Rest time												
Office/school time												
People (especially women and children) go for water												
Women go to fields or jungle for fuel wood and grass collection												
Women work in fields and jungle												
Children return from school and go to fetch drinking water												
Women return from jungle and fields												
Workers return from their work place												

4.3.2.4.

### Leopard attacks in relation to other factors

Based on incidents observed during field work, it was presumed that leopard attacks on human might be affected by some other factors such as presence of dog, electricity and distance of house from main village. It was also presumed that frequencies of attacks on children may be affected by presence of adult male in the house.

(a) Attacks with respect to house location

Leopard attacks on human were prominent in those houses, which were isolated where as predation was relatively low in houses, which were close to main village. One could expect to have low attacks on human close to main village, as there are different human activities taking place. Of the 16 incidents observed during study period, most of such predation (81.2%) has happened in or around isolated houses (Fig. 4.18).

N=16



Figure 4.18. Leopard attacks in relation to location of house.

A good proportion of shrub cover was observed around incident spots of human death made by leopard during survey work. Weed species such as *Lantana*, *Xanthium* and *Eupatorium* were major dominating species around villages. Shrub density within 100m of incident spot was relatively high at 14 incidents sites where human were killed by leopards during study period (Fig. 4.19). The surrounding vegetation of two houses where children were killed by leopards have been shown in Fig. 4.20.

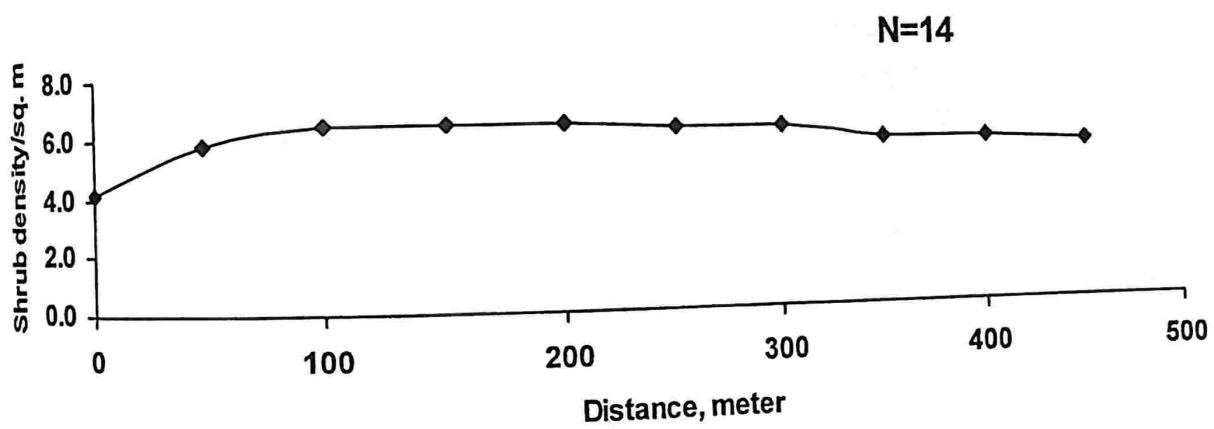


Figure 4.19. Density of shrub within 500 m at human killing sites (n=14)

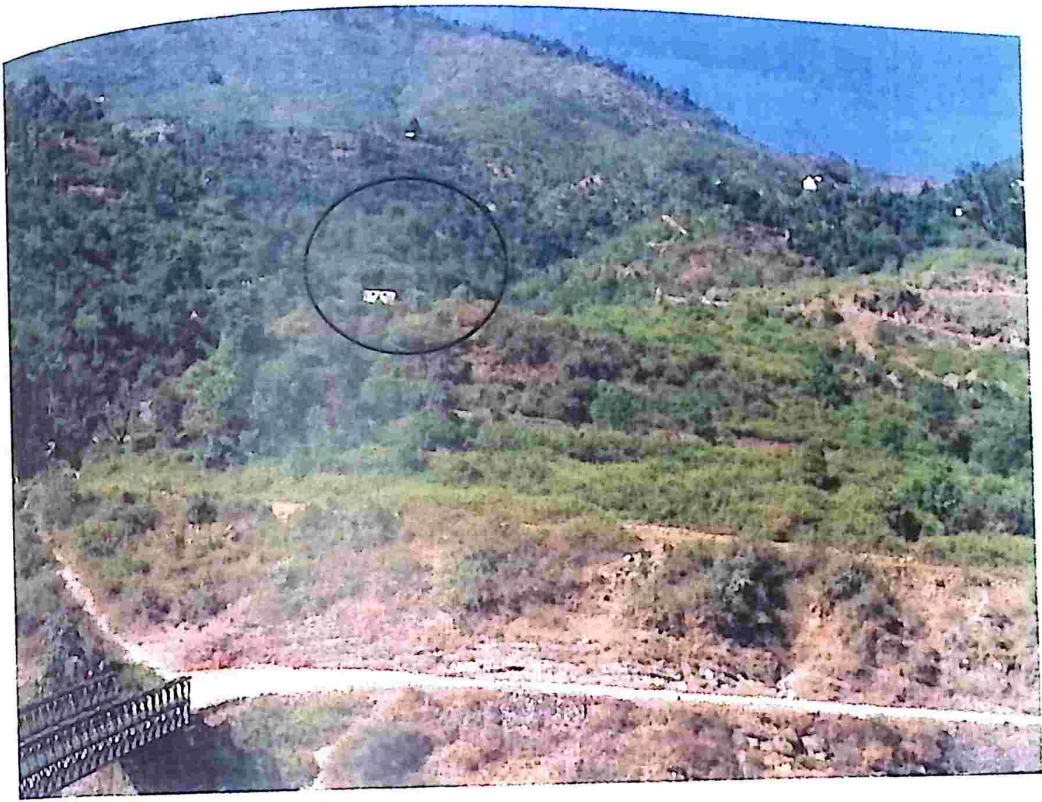


Figure 4.20. Surrounding vegetation of houses where human were killed by leopards.

(b) **Leopard attacks in relation to presence of electricity**

Based on 18 incidents observed during field work, 72.2% cases were in those houses where there was no electricity (Fig. 4.21). In villages, most of the people have very poor electricity facilities around houses.

(c) **Attacks on children in presence of adult male**

Frequencies of leopard attacks on children may be affected by the presence of adult males in house. Out of 22 children killed by leopard during survey, 77.3% cases were in houses where no adult male was present (Fig. 4.22). Of the six cases happened in the presence of adult male in houses, of which four could manage to survive.

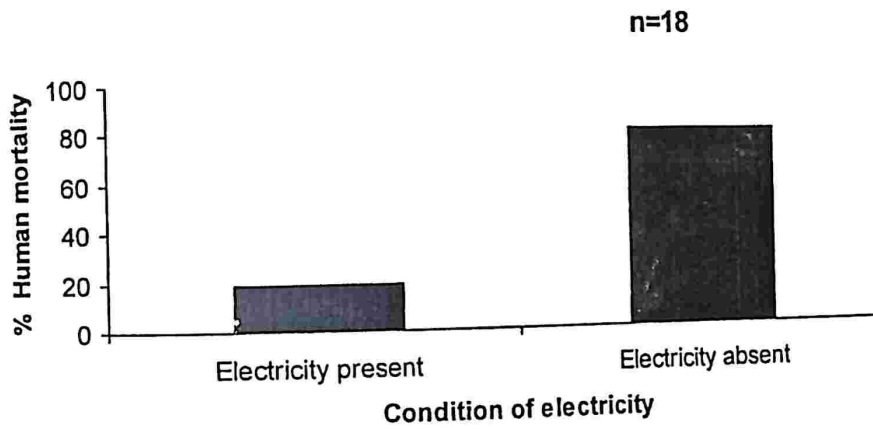


Figure 4.21. Leopard attacks on human in relation to presence of electricity.



Figure 4.22. Leopard attacks on children in relation to presence of adult male.

### 4.3.3. Opinion of local people on leopard-human conflict problems

Local people want a permanent solution of this problem as leopards have been killing human regularly. Most of the people (83%) think that leopard population is on increase in this region and this need to be checked immediately. Most of them said (76%) that after implementation of Wildlife (Protection) Act-1972, leopard population has reached beyond carrying capacity of the region. A total of 12% people believe in hypothesis that leopards have been turning to man-eaters due to scarcity of wild preys and depletion of habitats. While remaining 88% percentage of people neglected the hypothesis.

A large proportion of people (68%) opined that earlier leopards were timid and rarely seen in villages but now they have become bold and frequently roaming in villages and towns. People (61%) say government takes a long time to declare man-eaters and in this process many people fall the prey of leopards. People (35%) had shown no hesitation in killing leopards in cases where their relatives have been killed by leopards. People (45%) are demanding for guns from administration to tackle with man-eaters. People of affected areas (58%) demanded for electricity throughout the night, as attacks are prominent in absence of electricity.

Around 78% local people find it difficult to understand why they should not kill leopards that kill their children and livestock. Majority of villagers (93%) were not in position to sustain the livestock loss to leopard and they want a proper compensation amount for it.

## 4.4. DISCUSSION

### 4.4.1. Extent and severity of leopard-human conflict

Leopard predation on livestock has been reported from all surveyed administrative blocks. Leopard attack on human has been reported from Dugadda, Pauri, Pabau, Kalgikhal Jaiharikhal, Dwarikhal and Rikinikhal block. Pabau and Dugadda are worst affected in terms of human mortality caused by leopards.

Data indicates that there is a negative correlation between leopard predation on human and livestock. In blocks where leopard predation on livestock is relatively high, a few human deaths were recorded. It is probably due to their dependency on livestock. Therefore it is suggested that the abundance of livestock in an area may influence leopard attacks on human.

Scrub cover was correlated with livestock and human deaths in each block of Pauri Garhwal. Proportion of livestock and human death is relatively higher in those blocks where large proportion of area is covered by scrub. Data indicates that leopard attack on livestock and human is significantly correlated with scrub cover. Degraded forest cover has been replaced by dense scrub at many places in study area. Cover is an important to leopards for stalking preys (Bailey 1993). Therefore leopard takes the advantage of these features of the terrain to approach prey. Previous study has also suggested that leopard spent most of the day time in dense cover (Bailey 1993). The scrub area may provide most conducive habitat for their litter survival.

Leopard predation on human and livestock were positively correlated with human habitation areas. The human settlements areas are the places where the livestock movement is frequent. Thus leopard activities are set up around the habitation areas where they mainly hunt on livestock.

In some blocks, conflict problem seems to be on the decline after a large number of leopards are killed. Frequent human deaths were recorded in Pabu block during 1992 to 1996 of Pauri Garhwal district. Once the large numbers of leopard were killed in this area, a few conflicts have been recorded thereafter. Similar trend has also been seen in Dugdda block. It appears that there could be high survival rate of leopards around these blocks. Probability of conflict may be high in near future where leopard population has not been checked.

#### **4.4.2. Quantification of the circumstances of leopard conflict**

The majority of victims were children below 15 years. Previous studies have also shown that species involved in predator attacks significantly prefer the species smaller than their size. (Bailey 1993) However, young children do not have the benefit of large size to scare away potential predators. For this reason, a high proportion of predatory attacks on human might be directed at children, who are specially at risk when alone and undefended (Beier 1991).

A leopard attack on human vary across the season, as 46% and 43% cases were reported during rainy and winter season respectively (Fig. 4.16 ). It could be due to growing of weeds in rainy season and remained till winter and provides suitable habitat cover to leopards for stalking. Denser vegetation during these seasons may increase the opportunities for leopards to ambush livestock and humans. Leopards come more close to

human during these seasons where they seek opportunities to kill livestock and in this process some time human fall prey of them.

Leopard attacks are varied across the time of the day. Frequencies of attack are relatively high during either early morning before 0800 hours or during evening between 1600 to 2100 hours (Fig. 4.17). This is coincided with their timing of toilet as in hills most of the families do not have toilet facilities and they use open areas for this purpose. Majority of women fell victim during their daily routine works which are being taken by them alone. Adult males were killed during returning from their work place. It appears that leopards are adapted with all these habits of people and often look for the opportunities to kill human. Leopard attacks on human are prominent (80%) in those houses, which are isolated where as predation is relatively low in houses, which are close to main village. One could expect to have low attacks on human close to main village as there are lot of activities going on. Attacks on children were rarely successful in the presence of adult males. Majority (78%) of children were killed in the absence of adult male. Houses having no electricity are also more prone of such predation (Fig. 4.21).

#### **4.4.3. Opinion of local people on leopard-human conflict problems**

Local people have been crucial factors to ensure a long term viability of leopard in this area. Leopard's image in the minds of the villager is not a sympathetic one. A large number of leopard deaths in study area reflect the anger of people toward species. This is not acceptable to majority of people that hunting of wild ungulates may influence leopard-human conflicts. Majority of people have complained about the delay in disbursement of compensation. People living in remote areas often find it difficult to go to the forest office to follow the case which involves a lot of paper work. Paying

compensation for livestock lost would be helpful to encourage local people to tolerate leopards. Public awareness can play an important role in minimizing conflicts if proper communication strategies along with management interventions are adopted.

#### 4.5. SUMMARY

1. Conflicts have been reported from entire area but intensity is varied across the administrative blocks in Pauri Garhwal. Pabau, Kalgikhal, Dugadda, Jaiharikhal and Dwarikhal blocks are severely affected in terms of leopard attack on human. While blocks such as Thalissain, Khirshu and Rikhnikhal are worst affected in terms of leopard predation on livestock.
2. There is an increase in the frequencies of leopard attacks during last decade.
3. Human and livestock death area negatively correlated. There is low leopard predation on human in blocks where leopard predation on livestock is relatively high.
4. Conflict has been reduced in few blocks once the large number of leopards in and around of these blocks were killed.
5. Leopard predation on human and livestock were significantly correlated with scrub cover. Livestock and human death were also positively correlated with human habitation areas.
6. Female leopards were found to be more likely to cause of conflict.
7. Leopard attack on human vary across the seasons, Majority of conflict are reported during rainy (45.8%) and winter (45.2) season. Majority (68.6) of victims were children below 15 years. In all age groups, predation on female is relatively high in comparison to males. Leopard attacks are varied across the time of the day. Frequencies of attack are relatively high during either early morning (16.4%) before 0800 hours or during evening (68.3 %) between 1600 to 2100 hours. Houses on the fringe of villages which were isolated, without electricity and surrounded by heavy scrub cover were more prone to leopard attacks. Attacks on children were rarely successful in the presence of adult males.

## CHAPTER 5      FOOD HABITS OF LEOPARD IN RELATION TO PREY ABUNDANCE (WILD AND DOMESTIC)

### 5.1. INTRODUCTION

One of the major factor influencing the structure of large cats community is the abundance and availability of prey (Sunquist and Sunquist 1989; Bailey 1993; Karanth and Sunquist 1995; Khan 2004). Predator densities in an area are ultimately limited by food resources (Martin and de Meulenaer 1988; Karanth and Sunquist 1995; Carbone and Gittleman 2002). Prey population is a major factors driving the current decline of large cats worldwide (Seidensticker 1986; Rabinowitz 1993).

Availability of prey species in an area determine the overall prey selection by predators (Bailey 1993; Bothma and Coertze 2004; Khan 2004). Carnivores likely resort to secondary prey when primary prey is less available or vulnerable (Hamilton 1981; Seidensticker *et al.* 1990; Santiapillai and Ramono 1992; 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). An adequate wild prey abundance may reduce livestock predation by large carnivores (Hamilton 1981).

Leopard require between 1.6 to 4.9 kg of meat per day to maintain body mass (Bothma and Le Riche 1986; Bailey 1993). To achieve this food intake they 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 Coertze 2004). It is because female with young have to ensure their own survival by killing preys more frequently (Bothma and Coertze 2004).

Being a very widespread species, the leopard has a very variable diet. Leopards generally concentrate on prey items less than 50 kg (Muckenhirn and Eisenberg 1973; Seidensticker *et al.* 1990; Johnsingh 1992; Bailey 1993; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002). However larger body mass of male probably cause them to invest more energy in capturing larger prey than females (Bothma and Le Riche 1984).

The richness of leopard prey suggests that they are largely unselective. While 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; Bothma and Coertze 2004). Leopards appear to be more opportunistic than other cats and prey on a wider range of different species than other felids (Seidensticker *et al.* 1990; Johnsingh 1992; Bailey 1993). The wide geographic distribution of leopards is also attributed to their ability to co-exist with other large carnivores (Bailey 1993; Daniel 1996).

The leopard has 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). While studying African leopards, Bothma and Le Riche (1984) found that the prey species killed by leopard weighed less than 20 kg where large ungulates were unavailable. Studies on leopard in the Indian subcontinent indicate that medium sized ungulates were the principal prey items (Muckenhirn and Eisenberg 1973; Seidensticker *et al.* 1990; Johnsingh 1992; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002). In the Royal Chitwan National Park, prey includes wild pig sambar, axis deer, hog deer, barking deer and domestic cattle (Seidensticker *et al.* 1990). In the Wilpattu National Park, Sri Lanka, 60% of the 511 observed preys were axis deer (Muckenhirn and

Eisenberg 1973). In Bandipur National Park, India 65% of leopard's kills were ungulates, mainly chitals weighing about 50 kg (Johnsingh 1992). The average weight of prey species killed by leopard in Nagarahole National Park was 37.6 kg (Karanth and Sunquist 1995).

Leopard is well known for its use of habitat edges and its ability to live close to human habitation where livestock are available (Sediensticker *et al.* 1990; Santiapillai and Ramono 1992; Chellam and Johnsingh 1993). Livestock can be important prey for carnivores in areas where wild ungulates are not abundant (Hamilton 1986; Sediensticker *et al.* 1990; Santiapillai and Ramono 1992). Hamilton (1986) reported that leopard population subsisting mainly upon livestock in western Kenya. In certain areas of Java island of Indonesia, leopards are largely subsisting upon cattle, village dogs and chickens (Santiapillai and Ramono 1992). Variation in diet of the leopard between areas was most likely due to its opportunistic behavior, resulting in a diet that closely link prey use with availability (Bailey 1993).

Information on food habits of leopard may provide useful information for management of species in order to minimize human-leopard conflicts. The main objective of this chapter is to study "*Food habits of leopard in relation to prey abundance (wild and domestic) and habitat characteristics*". The research questions are:

1. What is the relative abundance of different (wild and domestic) prey species?
2. What are the proportions of different prey species in leopard diet?
3. Are there any variation in selection of prey (wild & domestic) across different conflict categories?
4. Does prey availability has any effect on prey selection?

## 5.2. METHODS

### 5.2.1. Relative abundance of prey species (wild and domestic)

#### 5.2.1.1. Wild prey species

As being hilly terrain it was not feasible to mark and monitor straight line transects. Therefore relative abundance of wild and domestic ungulate and other prey species such as barking deer, wild pig and pheasants etc was estimated by walking on forest trails. Trail ranging from 1 to 3.5 km were identified in selected Intensive Study Areas (ISA) within three conflict categories. These trails were monitored throughout the year during 2002-2005. In ISA of low conflict category 5-12 trails were monitored. A total of 291 days were walked to monitor these trails and a distance of 662 km distance was covered. In ISA of medium conflict category, 7-18 trails were monitored and a total of 270 days were walked while covering 953.5 km distance. In ISA of high conflict category 5-16 transects were monitored. A total of 348 days were walked by covering distance of 713.5 km in this category. Details of trails monitored across the conflict categories have been summarized in Table 5.1.

Relative abundance of wild prey species on each trail was determined by using three parameters viz. direct sighting, tracks counts and pellet group counts.

#### (a) Abundance based on direct sighting

Trail monitoring was carried out in morning to get direct sighting of wild prey species.

For every observation of wild prey species, total numbers were noted.

Encounter rate was estimated for each trail visited within each conflict category by using following formula:

$$ER_{(1,2 \dots X)} = n/d$$

where, ER= Encounter rate, n=Total observation, d= distance (km) walked

$$\text{Mean Encounter Rate (MER)} = \sum ER_{(1,2 \dots X)} / X$$

where X= no. of trails in each conflict zone.

(b) **Abundance based on track and pellet groups/faecal matter**

Systemic tracks count on the track plots was found to be the best way and cost effective to get information. To record the tracks of different prey species, track plots were prepared at every 250m on the forest trails. During 2002-2005, a total 665 plots (5-12 trails) were monitored in ISA of low conflict category (Table 5.1). While in medium and high conflict categories, 814 (7-18 trails) and 778 (5-16 trails) track plots were monitored respectively during 2002 to 2005 (Table 5.1). Tracks of each species on track plots were converted into index of abundance by using formula:

$$\text{Track Index} = \# \text{ of plots having sign} / \text{Total \# of plots monitored}$$

Pellet groups/faecal matter were collected systematically within 1 meter in both of the sides of trail and old pellet group/faecal matter was removed immediately after data collection. Pellet groups/faecal matter was converted into abundance by using following calculation:

$$\text{Encounter Rate (ER)} = \# \text{ of pellet groups or fecal matter} / \text{distance covered (km)}$$

$$\text{Mean Encounter Rate (MER)} = \sum ER_{(1,2 \dots X)} / X$$

where X= no. of monitored trails in each conflict category

## Domestic prey species

### 5.2.1.2.

To estimate the relative abundance of domestic prey species in ISA of these conflict categories, roadside counts were carried out between 2003-2004. Road side transects ranging from 1.5-4 km were covered in intensive study area of each conflict category. Each transect was visited at least three time in a seasons to understand the seasonal abundance of domestic prey species. A total of 214 km distance was covered across 19 transects in ISA of low conflict category. In medium conflict category, 14 transects were monitored and a total of 97 km distance was covered. In high conflict category, a total of 192 km distance was covered while walking across 26 transects. A detail of roadside transects monitored in ISA of three conflict categories has been summarized in Table 5.2. Encounter rate of each species was estimated in ISA of each conflict category by using following formula

$$\text{Encounter Rate (ER)}_{(1, 2 \dots X)} = n/d$$

where, ER= Encounter rate, n=Total observation, d= distance (km) walked

$$\text{Mean Encounter Rate (MER)} = \sum ER_{(1, 2 \dots X)} / X$$

where X= no. of trails in each conflict zone.

In order to check whether there was any significant difference in prey abundance across the ISA of three conflict categories, the non-parametric test was preferred due to different sampling intensity in terms of total vist and number of forest trail (wild prey species) and road side (domestic prey species) transects across conflict categories. Kruskal-Wallis, one of the non-parametric tests equivalent to the one-way ANOVA, was performed to test whether there are significant differences present among the mean encounter rates of the direct sightings, and indirect signs of the prey across the ISA of three conflict categories.

**Table 5.1.** Summary of forest trails monitored during 2002 to 2005 in conflict categories for estimating relative abundance of wild prey species.

Year	LOW						MEDIUM						HIGH					
	# of transects	# of days walked	Distance covered, km.	# of track plots	# of transects	# of days walked	Distance covered, km	# of track plots	# of transects	# of days walked	Distance covered, km	# of track plots	# of transects	# of days walked	Distance covered, km	# of track plots		
2002	5	16	37	39	10	67	164.5	164	5	11	30	20						
2003	12	112	260.5	223	18	153	400	350	16	90	180	204						
2004	12	142	321.5	347	18	81	217	161	16	195	395	435						
2005	5	21	43	46	7	69	172	139	6	52	108.5	119						

**Table 5.2.** Summary of road side transects monitored 2003-2004 in conflict zones for estimating domestic prey species.

Year	Low			Medium			High		
	# of transects	Total distance Covered, km	# of transects	Total distance Covered, km	# of transects	Total distance Covered, km			
2003	11	113	9	83	9	73			
2004	8	101	5	14	17	119			

### 5.2.2. Food habits

Scats have been widely used to determine the food habit of carnivores, as it is non-destructive technique (Mukherjee *et al.* 1994; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002). In the present study, a total of 428 scats were analysed to understand the food habits of leopard. Of the 428 scat analysed, 150 scat were collected during survey where as remaining 278 scats were collected from three intensive study sites.

#### 5.2.2.1. Collection and identification of leopard scats

Scats of leopard were identified by size, colour, shape and associated signs (scrape and tracks). Since the leopard is the only large carnivore species in most part of the study area, therefore leopard scats could be identified without any confusion. Since a small part of the study area is adjacent to two national parks (Corbett National Park and Rajaji National Park), so there was a possibility of visiting other carnivore species like tiger and hyena in adjoining areas. In these areas, scats were differentiated from any other co-existing carnivore species based on diameter (Norton *et al.* 1986; Rabinowitz 1989). Diameter of thickest part of scat was measured by digital Vernier Caliper. Measurements were then incorporated into 2mm diameter classes.

#### 5.2.2.2. Collection of reference hair samples and examination of hair characteristics

Reference hair samples were collected from all domestic livestock species representing the study area. Hairs were collected in complete tufts from different body parts, which include a representative of all hair types. Reference hair samples of wild ungulate species were collected from laboratory of Wildlife 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; Mukherjee *et al.* 1994).

(a) **Medullary patterns**

Cleaned hair sample was placed on microscopic 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. Medullary patterns of different wild and domestic prey species have shown in Fig 5.1.

(b) **Cuticular characteristics**

Gelatin 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 hairs were placed on the slide and then allowed to dry. Hairs were than removed by using forceps and scale patterns 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 Fig 5.2.

5.2.2.3. **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 65<sup>0</sup> C. Components of sample including hair, bones, teeth, feathers, scales, claws, and hooves remains were than separated and stored in individual plastic bags. To create permanent slides for species identification, five slides were made per scat sample. Fifteen hair 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. Hair was identified by comparison with 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.

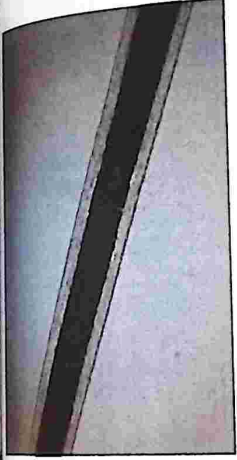
The frequency occurrence of various prey species in scats analyzed was determined. The remains of one prey species in each scat was considered as frequency one. One way ANOVA was applied to study the variation in leopard food habit across the different conflict categories (low, medium, high). To determine whether the scat sample size is sufficient, the method followed of Mukherjee *et al.* (1994) was adopted. They studied the effect of scat sample size on frequency occurrence of prey species and determined the minimum number of sample size is needed which does not cause any further changes in prey species with increase in sample size. For this, scat samples were taken randomly and checked for the corresponding changes in the percentage of the frequency of the leopard's prey species in scats with the increase in number of scat samples.



**Barking deer**



**Sambar**



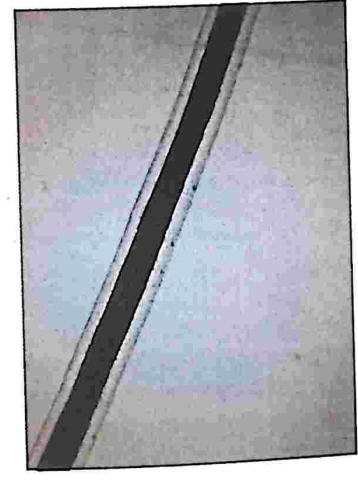
**Goral**



**Wild pig**



**Rodent**



**Dog**



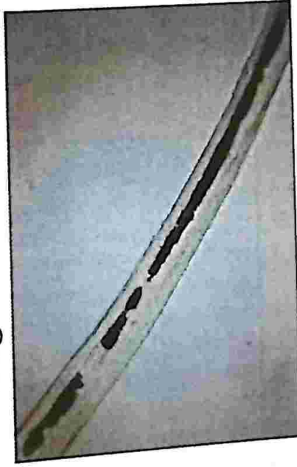
**Cattle**



**Buffalo**



**Goat**

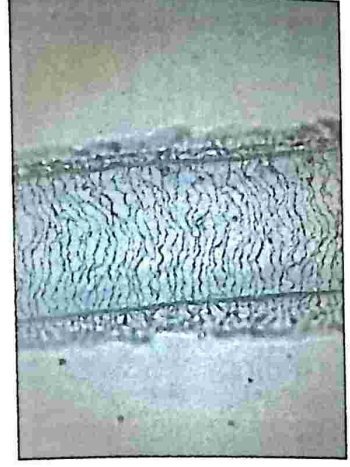


**Sheep**

**Figure 5.1. Medullary patterns of wild and domestic prey species.**



**Wild pig**



**Buffalo**



**Goral**



**Cattle**



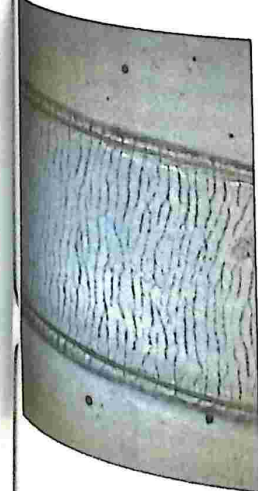
**Sambar**



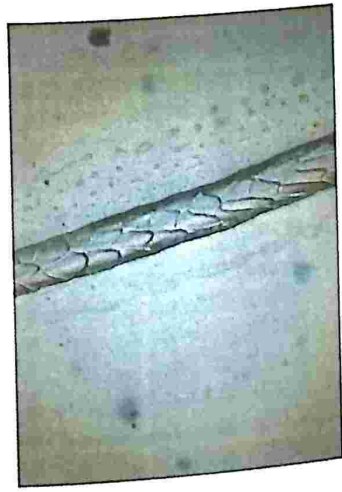
**Dog**



**Sheep**



**Barking deer**



**Rodent**



**Goat**

**Figure 5.2.** Cuticular characteristic (magnification 400X) of wild and domestic prey species.

## 5.3. RESULTS

### 5.3.1. Relative abundance of wild prey species in ISA of three conflict categories

#### (a) Comparison of different methods for estimating relative abundance of wild prey species

It was planned to understand the relative abundance of existing wild prey species by using three different methods viz. direct sighting, track count and pellet group counts. Among wild prey species, barking deer wild pig, porcupine using different methods was compared. The relative comparison of different methods used for recorded prey species has been shown in Table 5.3. The sampling method that allows detecting the changes in population was considered best way to determine the relative abundance of each recorded species. Based on relative comparison of three methods, direct sighting method was considered to be best for estimating relative abundance of barking deer. While track count method was suitable for understanding the relative abundance of other reported species such as wild pig, porcupine and pheasants.

Table 5.3. A comparison of different methods used for estimating relative abundance.

Species	Direct sighting (no./km)	Track Index*	Pellet groups count (no./km)
Barking deer	0.020	0.002	0.003
Wild pig	0.008	0.014	0.005
Porcupine	0.00	0.006	0
Pheasants	0.112	0.152	0

\* Track index= # of plots having signs/ total # of monitored

**(b) Relative abundance of barking deer based on direct sighting across the three conflict categories**

The average encounter rate (no./km) of barking deer across conflict category has been summarized in Table 5.4. The observed average encounter rate of the barking deer in ISA of low conflict category was relatively high and ranged from 0 to 0.2/km during sampling periods. There is no significant annual variation was detected in mean encounter within low conflict category.

The observed average encounter rate of barking deer in ISA of medium conflict category ranged from 0 to 0.049/km. There was significant variation ( $\chi^2 = 11.437$ ;  $P < 0.01$ ) in encounter rate over the years in this conflict category. However encounter rate was not varied significantly across the seasons.

The observed encounter rate in ISA of high conflict category has ranged from 0 to 0.040/km and it was significantly varied across the ( $\chi^2 = 6.44$ ;  $P < 0.05$ ) seasons. No significant variation was observed in mean encounter rate of barking deer within high conflict category over the years.

The result of Kruskal-Wallis test has shown that there are significant differences among the encounter rates ( $\chi^2 = 13.09$ ;  $P < 0.01$ ) across the conflict categories. Though a very low encounter rate of barking deer was observed, but there was probably a relatively high abundance of barking deer in ISA of low conflict category.

Table 5.4. Average Encounter Rate, no. /km (Mean  $\pm$  S.D) of barking deer in ISA of three conflict categories observed during 2002 to 2005

Year	Season	Low (n=5-12)	Medium (n=7-18)	High (n=5-16)
2002	Winter	0.00 (10)	0.000 (40)	not sampled
	Summer	0.000 (1)	0.000 (20)	0.000 (1)
	Rainy	0.000 (5)	0.000 (7)	0.000 (10)
	TOTAL	0.000 (16)	0.000 (67)	0.000 (11)
2003	Winter	0.012 $\pm$ 0.069 (34)	0.033 $\pm$ 0.102 (63)	0.028 $\pm$ 0.136 (24)
	Summer	0.028 $\pm$ 0.103 (29)	0.049 $\pm$ 0.188 (50)	0.000 (9)
	Rainy	0.088 $\pm$ 0.251 (49)	0.017 $\pm$ 0.074 (40)	0.000 (57)
	TOTAL	0.049 $\pm$ 0.180 (112)	0.034 $\pm$ 0.131 (153)	0.007 $\pm$ 0.070 (90)
2004	Winter	0.015 $\pm$ 0.078 (52)	0.008 $\pm$ 0.051 (42)	0.040 $\pm$ 0.183 (42)
	Summer	0.063 $\pm$ 0.245 (68)	0.000 (19)	0.000 (121)
	Rainy	0.018 $\pm$ 0.085 (22)	0.033 $\pm$ 0.103 (20)	0.000 (32)
	TOTAL	0.039 $\pm$ 0.180 (142)	0.012 $\pm$ 0.063 (81)	0.009 $\pm$ 0.086 (195)
2005	Winter	0.000 (7)	0.000 (38)	0.000 (14)
	Summer	0.200 $\pm$ 0.283 (4)	0.000 (10)	0.019 $\pm$ 0.096 (27)
	Rainy	0.000 (9)	0.000 (21)	0.000 (11)
	TOTAL	0.022 $\pm$ 0.094 (21)	0.000 (69)	0.010 $\pm$ 0.069 (52)

Values in parenthesis are number of days walked  
n= number of forest trails used

(c) **Relative abundance of wild pig, porcupine and pheasants based on track index across the conflict categories**

The track index indicates the presence of wild pig in all conflict categories. Estimated track index of wild pig across the conflict categories has been summarized in Table 5.5. Estimated track index of wild pig in low conflict category has ranged from 0 to 0.044 during sampled periods. In medium and high conflict categories, the track index has ranged from 0 to 0.036 and 0 to 0.045 respectively. Non-parametric test has shown that there was no any significant variation in track index in either conflict category over the years.

Estimated track index of porcupine across the conflict category has been summarized in Table 5.6. The observed track index of porcupine in low and medium conflict category has ranged from 0 to 0.20 whereas observed track index in high conflict category was from 0 to 0.37 during sampling periods. The results of non-parametric test has not shown any significant variation in track index of porcupine in any conflict category over the years.

Pheasants tracks were found more often than any other recorded species (wild pig and porcupine). Estimated track index of pheasants across the three conflict categories has been summarized in Table 5.7. The observed track index of pheasants in low conflict category has ranged from 0 to 0.25 during sampled periods. No significant difference has been observed within low conflict category over the years. In medium conflict category, the observed track index during sampling period has ranged from 0 to 0.28. The track index of pheasant has been found significantly different ( $\chi^2 = 13.09$ ;  $P < 0.05$ ) across the seasons within medium conflict category. The observed track index of pheasants in high

conflict category has ranged 0 to 0.20. Statistically no temporal significant variation was observed within high conflict category.

Table 5.5. Track index of wild pig (Mean±S.D.) observed in ISA of three conflict categories.

Year	Season	Low (n=5-12)	Medium (n=7-18)	High (n=5-16)
2002	Winter	0.000 (10)	0.000 (40)	not sampled
	Summer	0.000 (1)	0.000 (20)	0.000 (1)
	Rainy	0.000 (5)	0.000 (7)	0.000 (10)
	TOTAL	0.000 (16)	0.000 (67)	0.0 (11)
2003	Winter	0.044±0.14 (34)	0.008±0.06 (63)	0.000 (24)
	Summer	0.017±0.09 (29)	0.010±0.071(50)	0.000 (9)
	Rainy	0.010±0.07 (49)	0.013±0.07 (40)	0.018±0.09 (57)
	TOTAL	0.022±0.10 (112)	0.010±0.07 (153)	0.011±0.07 (90)
2004	Winter	0.000 (52)	0.036±0.17 (42)	0.020±0.09 (42)
	Summer	0.033±0.14 (68)	0.026±0.11 (19)	0.023±0.10 (121)
	Rainy	0.000 (22)	0.000 (20)	0.000 (32)
	TOTAL	0.016±0.10 (142)	0.025±0.13 (81)	0.019±0.09 (195)
2005	Winter	0.000 (7)	0.026±0.11(38)	0.000 (14)
	Summer	0.000 (4)	0.000 (10)	0.000 (27)
	Rainy	0.000 (9)	0.000 (21)	0.045±0.15 (11)
	TOTAL	0.000 (21)	0.014±0.08 (69)	0.010±0.06 (52)

Values in parenthesis are number of days walked  
n= number of forest trails used

Table 5.6.  
categories.

Track index of porcupine (Mean±S.D.) observed in ISA of three conflict

Year	Season	Low (n=5-12)	Medium (n=7-18)	High (n=5-16)
2002	Winter	0.000 (10)	0.013±0.079 (40)	not sampled
	Summer	0.000 (1)	0.000 (20)	0.000 (1)
	Rainy (5)	0.000 (5)	0.000 (7)	0.000 (10)
	TOTAL (16)	0.000 (16)	0.007±0.061 (67)	0.000 (11)
2003	Winter	0.015±0.086 (34)	0.000 (63)	0.014±0.068 (24)
	Summer	0.017±0.093 (29)	0.020±0.141 (50)	0.000 (9)
	Rainy	0.020±0.100 (49)	0.000 (40)	0.009±0.066 (57)
	TOTAL	0.018±0.093 (112)	0.007±0.081 (153)	0.009±0.063 (90)
2004	Winter	0.010±0.069 (52)	0.000 (42)	0.000 (42)
	Summer	0.000 (68)	0.000 (19)	0.000 (121)
	Rainy	0.011±0.053 (22)	0.000 (20)	0.000 (32)
	TOTAL	0.005±0.047 (142)	0.000 (81)	0.000 (195)
2005	Winter	0.000 (7)	0.013±0.081(38)	0.000 (14)
	Summer	0.000 (4)	0.000 (10)	0.037±0.192 (27)
	Rainy	0.000 (9)	0.000 (21)	0.000 (11)
	TOTAL	0.000 (21)	0.007±0.060 (69)	0.019±0.139 (52)

Values in parenthesis are number of days walked  
n= number of forest trails used

Table 5.7.  
categories.

Track index (Mean±S.D.) of pheasants observed in ISA of three conflict

Year	Season	Low (n=5-12)	Medium (n=7-18)	High (n=5-16)
2002	Winter	0.050±0.158 (10)	0.219±0.284 (40)	not sampled
	Summer	0.000 (1)	0.100±0.205 (20)	0.000 (1)
	Rainy	0.000 (5)	0.000 (7)	0.000 (10)
	TOTAL	0.031±0.125 (16)	0.160±0.256 (67)	0.000 (11)
2003	Winter	0.132±0.256 (34)	0.184±0.280 (63)	0.090±0.184 (24)
	Summer	0.207±0.341(29)	0.170±0.227 (50)	0.028±0.083 (9)
	Rainy	0.153±0.274 (49)	0.104±0.255 (40)	0.148±0.247 (57)
	TOTAL	0.161±0.286 (112)	0.158±0.258 (153)	0.120±0.224 (90)
2004	Winter	0.168±0.349 (52)	0.149±0.276 (42)	0.135±0.250 (42)
	Summer	0.176±0.306 (68)	0.289±0.384 (19)	0.177±0.287 (121)
	Rainy	0.045±0.125 (22)	0.150±0.286 (20)	0.120±0.190 (32)
	TOTAL	0.153±0.305 (142)	0.182±0.309 (81)	0.159±0.265 (195)
2005	Winter	0.071±0.122 (7)	0.184±0.271 (38)	0.202±0.228 (14)
	Summer	0.250±0.354 (4)	0.050±0.158 (10)	0.204±0.286 (27)
	Rainy	0.000 (9)	0.143±0.280 (21)	0.114±0.303 (11)
	TOTAL	0.056±0.137 (21)	0.152±0.262 (69)	0.184±0.273 (52)

Values in parenthesis are number of days walked

n= number of forest trails used

### 5.3.2. Relative abundance of domestic prey species

Among the domestic species, cattle dog, goat sheep and buffalo were sighted on roadside transects during sampled periods. Mean encounter rate of cow is highest and followed by goat (Fig. 5.3). CV indicates their consistent availability in study area across the seasons (Table 5.8).

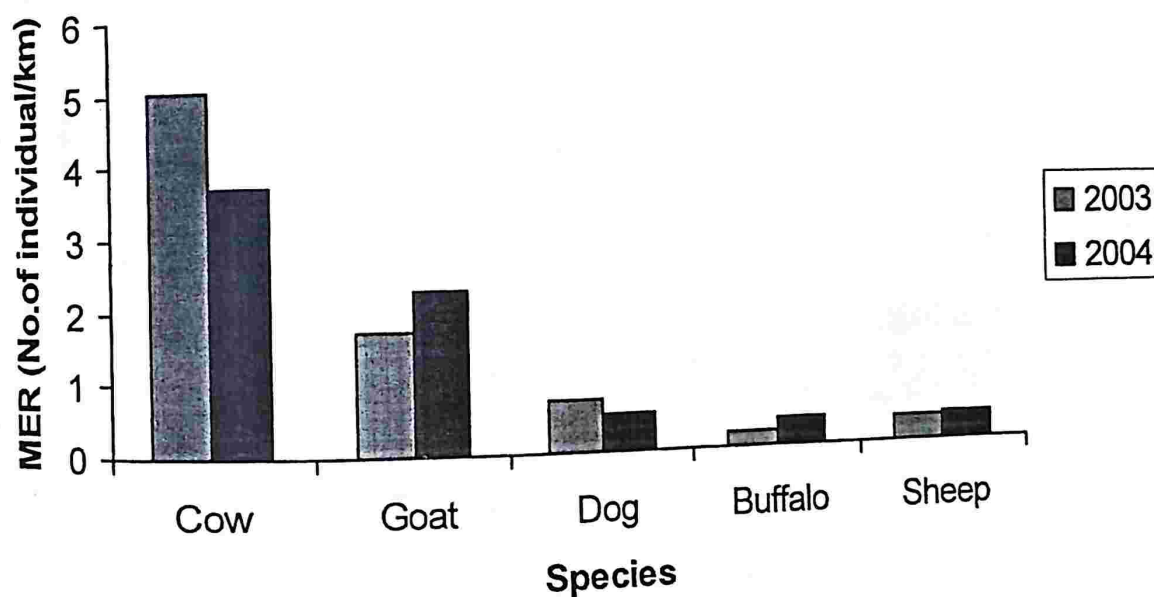


Figure 5.3. Mean encounter rate of domestic species observed during 2003-2004.

**Table 5.8.** The average encounter rate (Mean± S.D) of domestic species in ISA of three conflict categories

Species	Low		Medium		High	
	Mean	CV	Mean	CV	Mean	CV
Cow	4.87±2.20	45.17	4.59±1.96	42.72	3.93±2.43	61.79
Dog	0.58±0.56	94.93	0.80±0.90	112.32	0.61±0.47	77.48
Goat	1.57±1.73	110.35	1.02±1.18	115.49	2.66±2.10	78.98
Sheep	0.21±0.57	265.98	0.50±0.97	195.14	0.39±0.67	174.55
Buffalo	0.09±0.24	281.96	0.00±0.00	0.00	0.58±0.69	119.42

Average encounter rate (no./km) of domestic species sighted across the conflict categories has been summarized in Table 5.8. The average encounter rate of cattle was highest in all conflict categories. These encounter rates of the domestic species were tested with Kruskal-Wallis test to check whether these values had significant differences across conflict categories. The results of the Kruskal -Wallis test has shown that the encounter rates of species like cattle, dog and sheep have no significant difference across the conflict categories. But the average encounter rates of goat ( $\chi^2 = 6.40$ ;  $P < 0.041$ ) and buffalo ( $\chi^2 = 15.86$ ;  $P = 0.00$ ) differ significantly across the conflict categories.

### 5.3.3. Food habits

A total 428 scats were analysed in the study of which 150 scats were collected in 2001 while carrying survey and remaining 278 scats were from three intensive study sites monitored during 2002-2005.

#### 5.3.3.1. Variation in size and weight of leopard scats

All the dried scats were classified on the basis of size and weight. Of the total 428 scats, it was possible to measure the diameters of 206 scats. Measurements were then incorporated into 2mm diameter classes. Fig 5.4 indicates the distribution of scat diameter measurements in terms of percent frequency of occurrence.

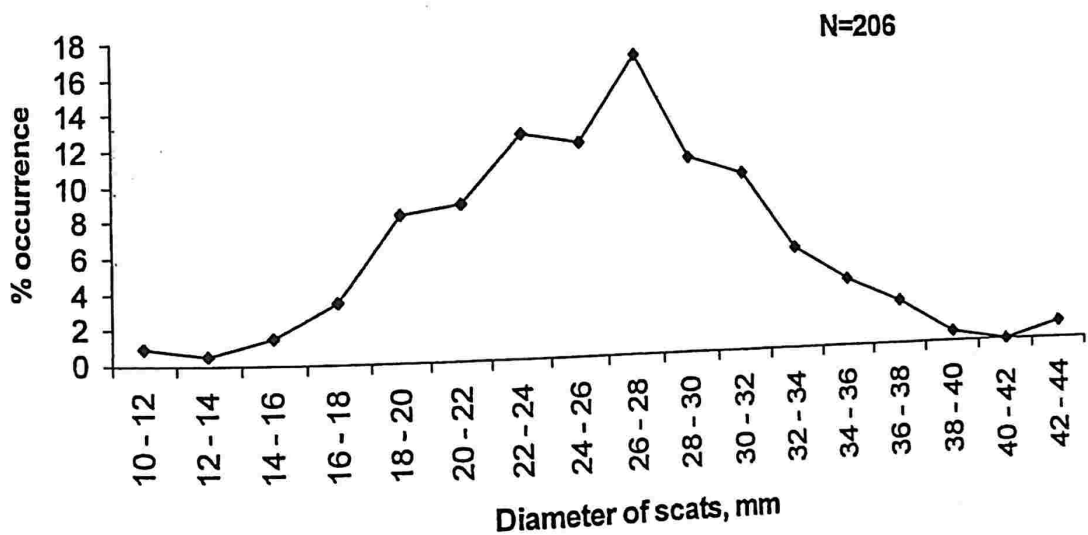


Figure 5.4. Variation in diameter of leopard scats in Pauri Garhwal.

About 14.6% of scats were in the range of 12-20 mm in diameter. It was seen that about 50.5% of the scats' diameters measured around 20-28 mm and about 35.5% of the scats ranged between 18-26 mm. If there is a relationship with diameter of scat and age

classes or body size, data probably indicate presence of a large number of young or sub-adult as well as many large sized leopards in the study area. But this assumption needs further verification.

Fig. 5.5 indicates that about 48%, 68% and 47% of the scats collected from the high, medium and low conflict categories respectively were in the diameter range of 20-30 mm. The proportion of scats lay in the diameter range of 30-40 mm was relatively higher in low conflict category.

The oven dried weights (ODW) of all the scats were measured with an accuracy of 0.01 gm by using digital balance (Mettler PM 16) and categorized into weight classes of 5 gm interval and the frequency of occurrence (%) was calculated. Fig. 5.6 indicates that out of the 249 leopard scats, 72.3 % weighed within 40 gm whereas 19.3 % weighed between 40 to 80 gm.

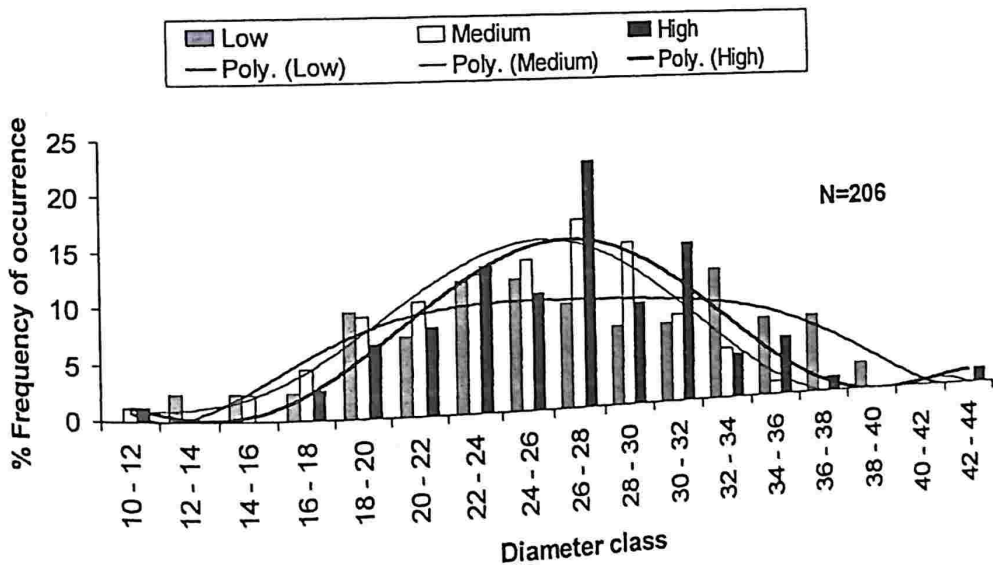


Figure 5.5. Frequency of occurrence (%) and normal distribution of diameter of leopard scats across the various conflict categories.

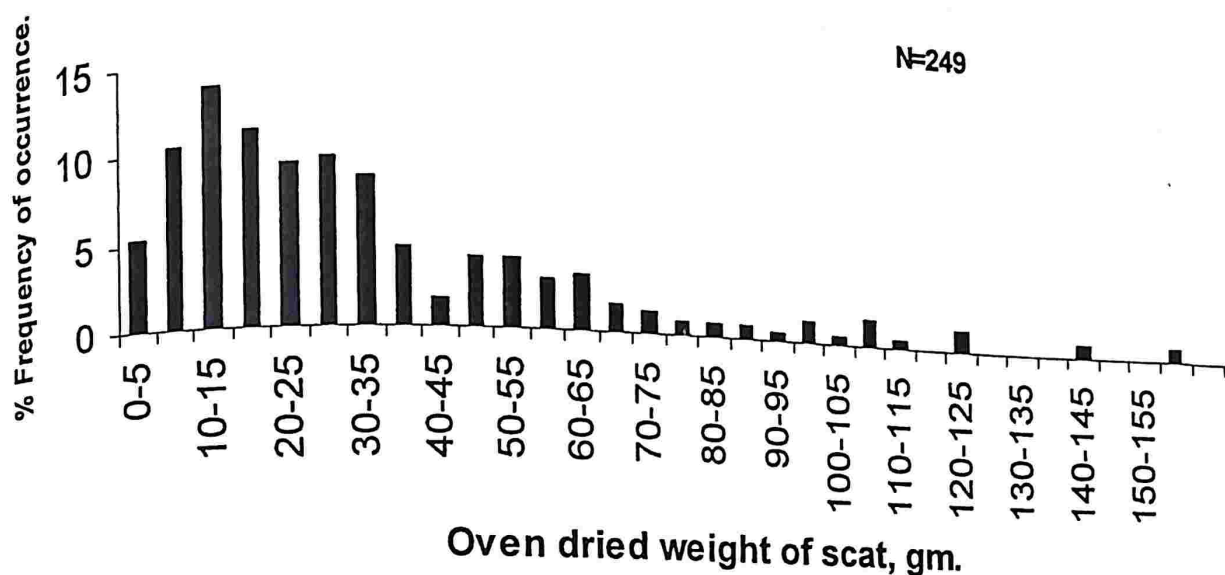


Figure 5.6. Variation in weight (oven dried) of leopard scats collected from Pauri Garhwal.

### 5.3.3.2. Minimum sample size determination

One of the important aspects in food habits of carnivores is to know the numbers of scats analyzed are adequate to reflect an accurate picture of the diet of the leopard (Mukherjee, *et al.*, 1994; Edgaonkar and Chellam, 1998). For this purpose an observation area curve in terms of frequency of occurrence of species was calculated at an interval of every five scats for 100 randomly selected leopard scats (Mukherjee, *et al.*, 1994; Edgaonkar and Chellam, 1998). Fig. 5.7 indicates the minimum sample size of the scats needed for the determination of the proportion of different prey species in the scats.

From Fig. 5.7, it is observed that after 60 scats the curve flattened out for the three major prey species viz. cattle, dog and goat, and there is no increase in percent occurrence inspite of increase in sample size. Other studies have also reported that

minimum 55-80 scats are needed to determine the diets of leopard (Edgaonkar and Chellam, 2002; Mukherjee *et al.*, 1994).

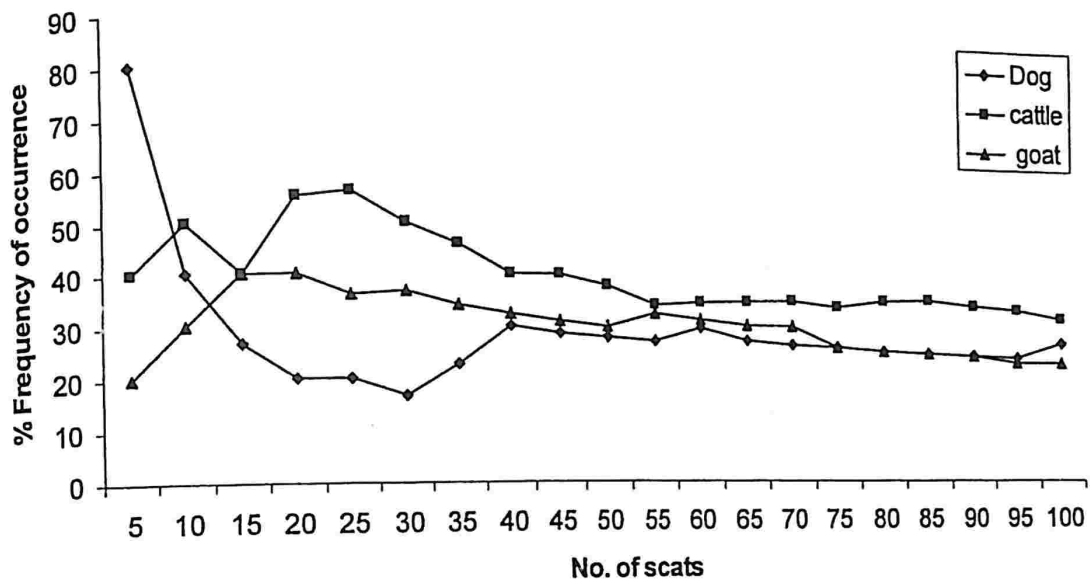
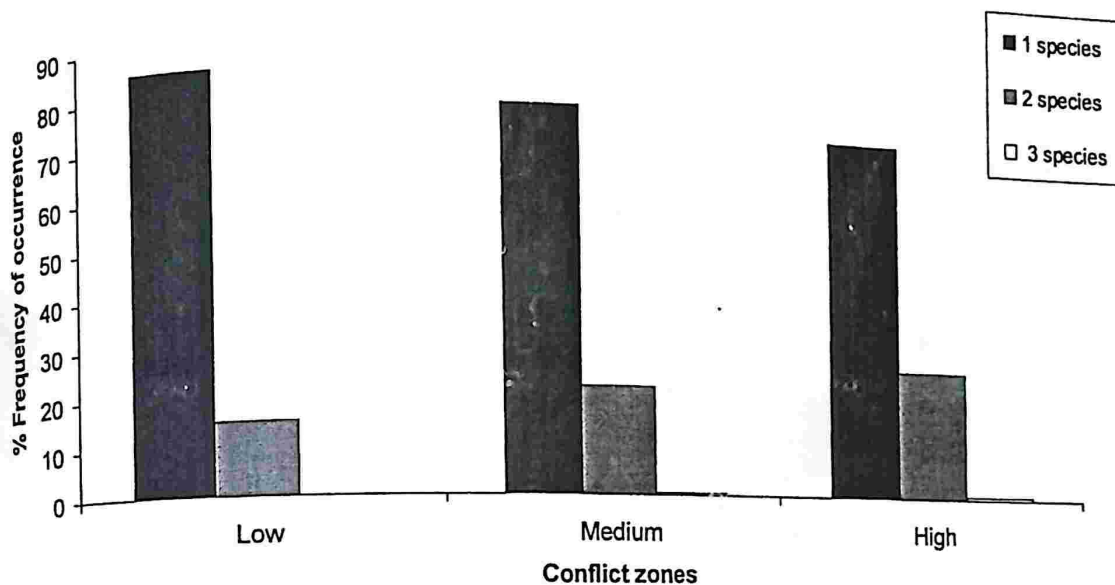


Figure 5.7. The relationship between the number of scats and the percent frequency occurrence of three major prey species (dog, cattle and goat).

### 5.3.3.3. Number of prey species

It is observed from the Fig. 5.8 that about 85%, 78% and 73% of leopard scats collected in low, medium and high conflict categories respectively contain single prey species. 15%, 21.8% and 26.4% of leopard scats collected in low, medium and high conflict category respectively, contain two prey species whereas 0.4 to 0.7% leopard scats collected from medium and high conflict categories contain three prey species. Data

clearly reveals a trend of multiple species in the diet of leopard from high and medium conflict categories, than species found in low conflict category.



**Figure 5.8.** Number of prey species in leopard scats across the three conflict categories.

#### 5.3.3.4. Prey selection

A minimum 9 different prey species were identified in leopard diet (Fig. 5.9). The diet composition of leopard is dominated by domestic species. Leopard mainly preyed on domestic animal such as dog, cattle goat and sheep which made up 93% of leopard diet in terms of frequency of occurrence while wild species contributed <3% of leopard diet. Among livestock species, dog is contributing 45 % of total diet in terms of frequency of occurrence and is followed by cattle (mainly cow) which contributes around 42% of total diet. Other species such as goat, sheep and buffalo were also the part of leopard diet but were less than 10% (Fig. 5.9).

Among wild prey species, barking deer and wild pig contribute 0.7 % and 0.5 % of total diet respectively. Leopards also prey upon pheasants and making up 0.9% of the total diet. Rodents were also part of leopard diet and contributing around 4.9 % of total diet (Fig. 5.10).

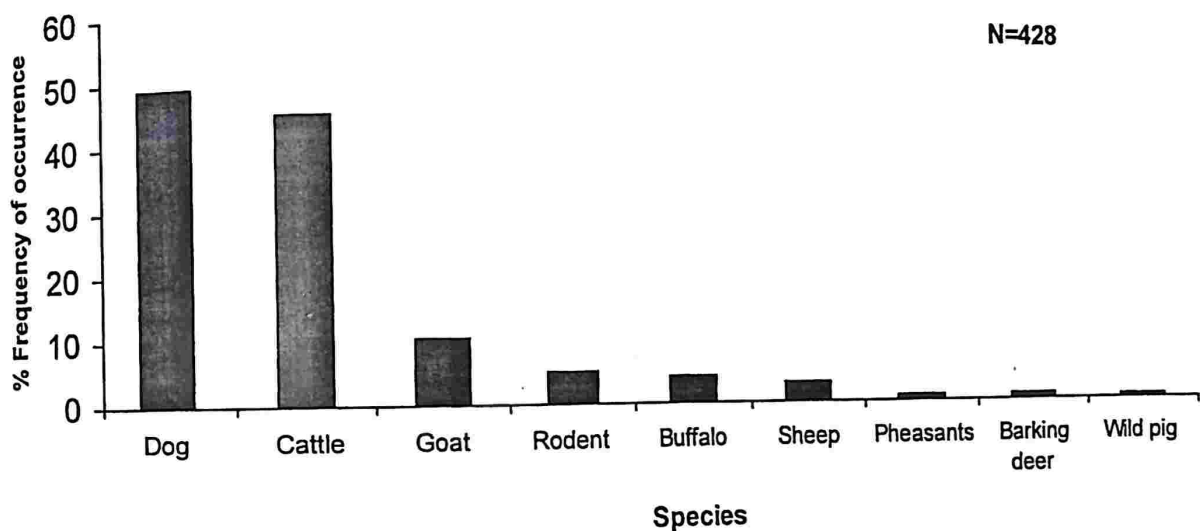


Figure 5.9. Proportion of different prey species in leopard diet determined from scats.

#### 5.3.3.5. Temporal and spatial variation in leopard diet

Data indicates that the most frequently prey species taken by leopard were cattle and dog during the sampling periods. No seasonal differences in prey selection was identified for most of the prey species. Buffalo predation differ significantly over the years ( $\chi^2=13.20$ ;  $P<0.04$ ). Leopard predation on cattle was relatively high during winter and rainy season (Fig. 5.10) but statistically it is not significant. The proportion of different prey species

during different seasons has been summarized in Table 5.9. The species contributed more than 10% diet of the leopards during entire sampling periods are cattle and dog. Leopard predation was infrequent on species such as goat, sheep and buffalo and they contribute <10% of leopard diet during sampling periods.

Non-parametric test have not shown any significant variation in the diet of leopards across the sites. Spatial distribution of scats having two major prey species (cattle and dog) has been shown in Fig. 5.11.

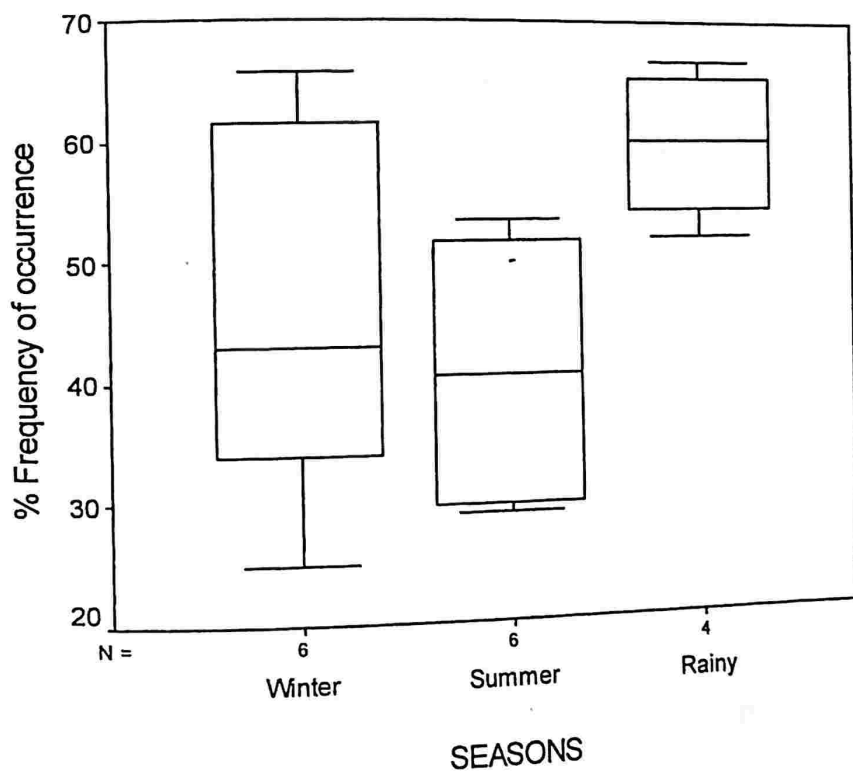
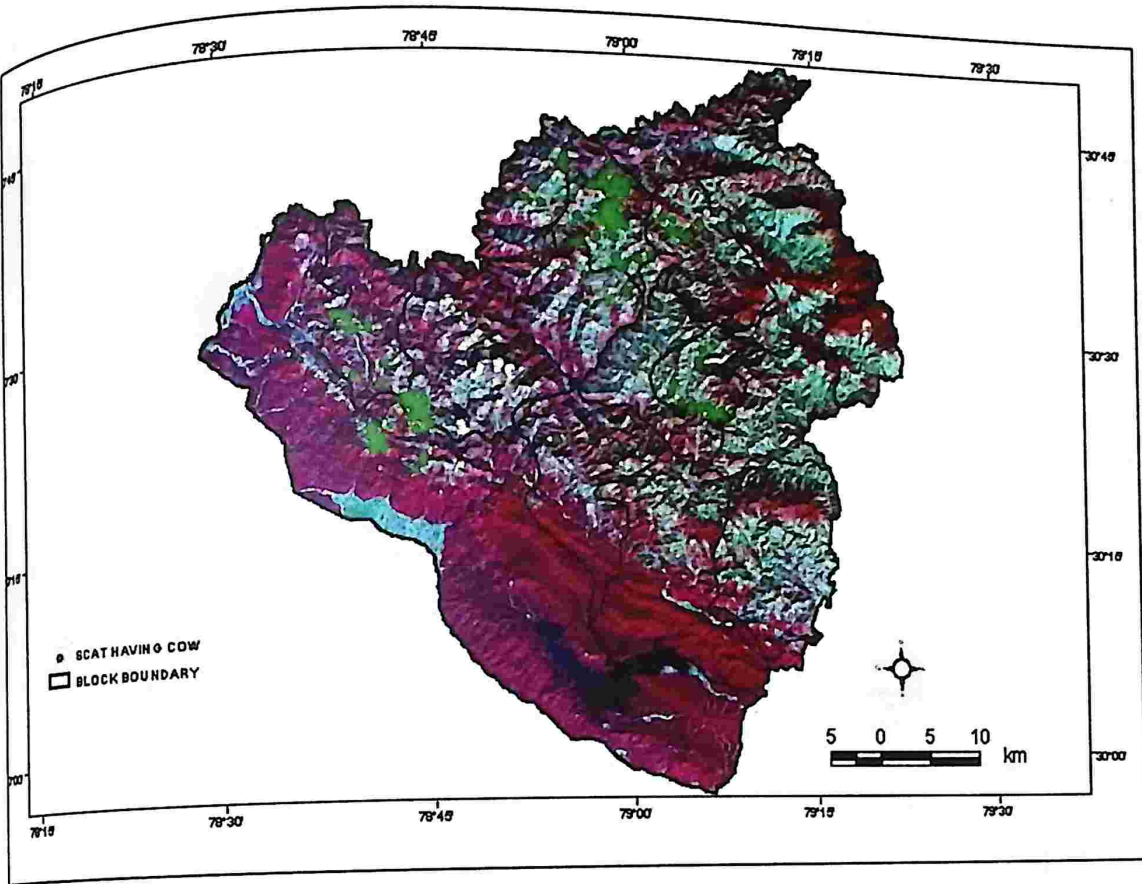


Figure 5.10. Leopard predation on cattle in terms of frequency occurrence in leopard diet across the seasons.

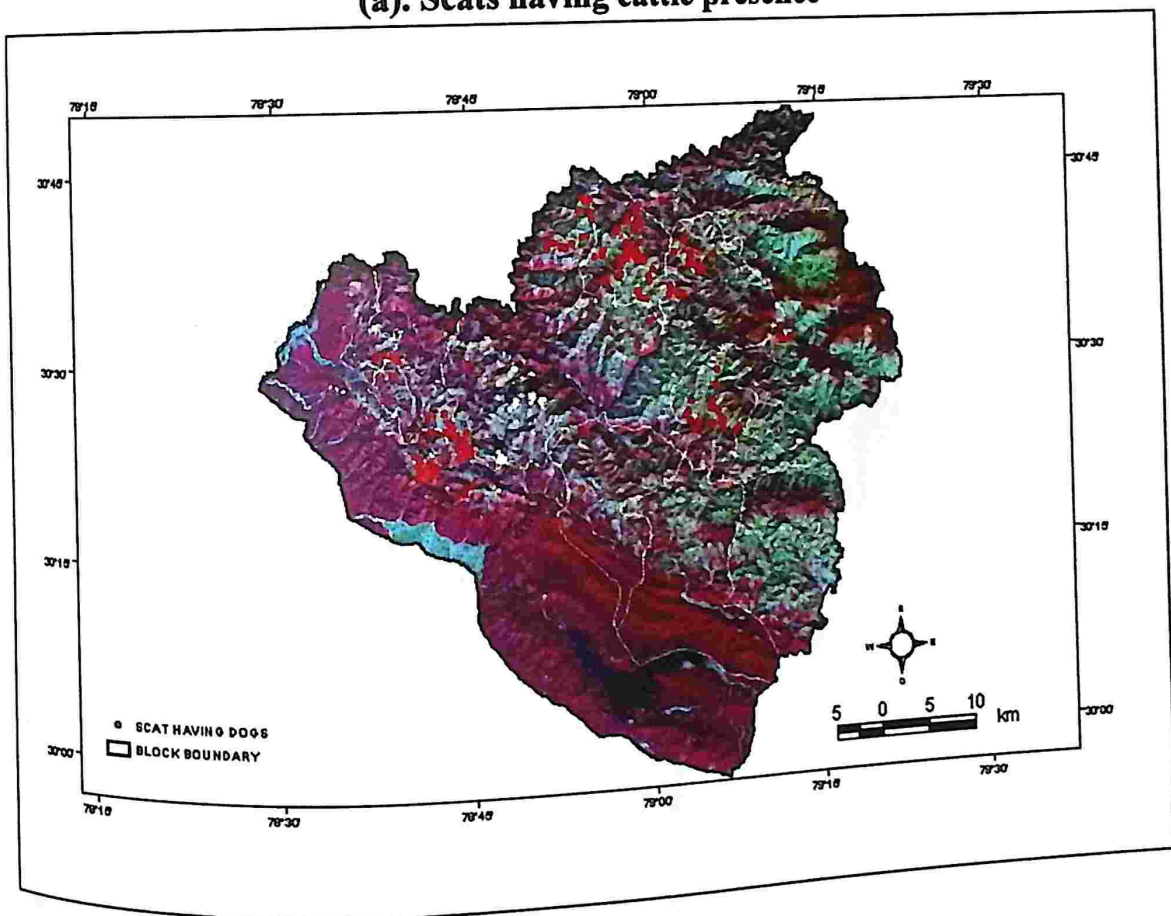
**Table 5.9.** Seasonal variation in the proportion of different prey species remains in terms of frequency of occurrence in leopard diet observed during 2001 to 2005.

Species	2001			2002			2003			2004			2005		
	W (n=59)	S (n=91)	R (n=33)	W (n=13)	S (n=31)	R (n=33)	W (n=38)	S (n=22)	R (n=27)	W (n=19)	S (n=38)	R (n=6)	W (n=20)	S (n=15)	R (n=16)
Dog	37.3	72.5	39.4	23.1	51.6	39.4	23.7	45.5	37.0	26.3	28.9	16.7	90.0	80.0	81.3
Cattle	33.9	29.7	63.6	61.5	51.6	63.6	65.8	36.4	51.9	47.4	44.7	66.7	25.0	53.3	56.3
Goat	15.3	13.2	0.0	7.7	0.0	0.0	5.3	9.1	3.7	21.1	13.2	16.7	5.0	20.0	18.8
Sheep	0.0	2.2	0.0	0.0	0.0	0.0	5.3	0.0	0.0	10.5	10.5	0.0	10.0	0.0	6.3
Buffalo	6.8	2.2	15.2	7.7	9.7	15.2	0.0	4.5	0.0	0.0	0.0	0.0	5.0	6.7	0.0
Rodent	3.4	6.6	6.1	7.7	9.7	6.1	0.0	9.1	3.7	5.3	0.0	0.0	10.0	0.0	6.3
Wild pig	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	2.6	0.0	0.0	0.0	0.0
Barking deer	1.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0
Birds	1.7	1.1	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0

W= winter, S= summer, R= rainy  
n= number of scats examined



(a). Scats having cattle presence

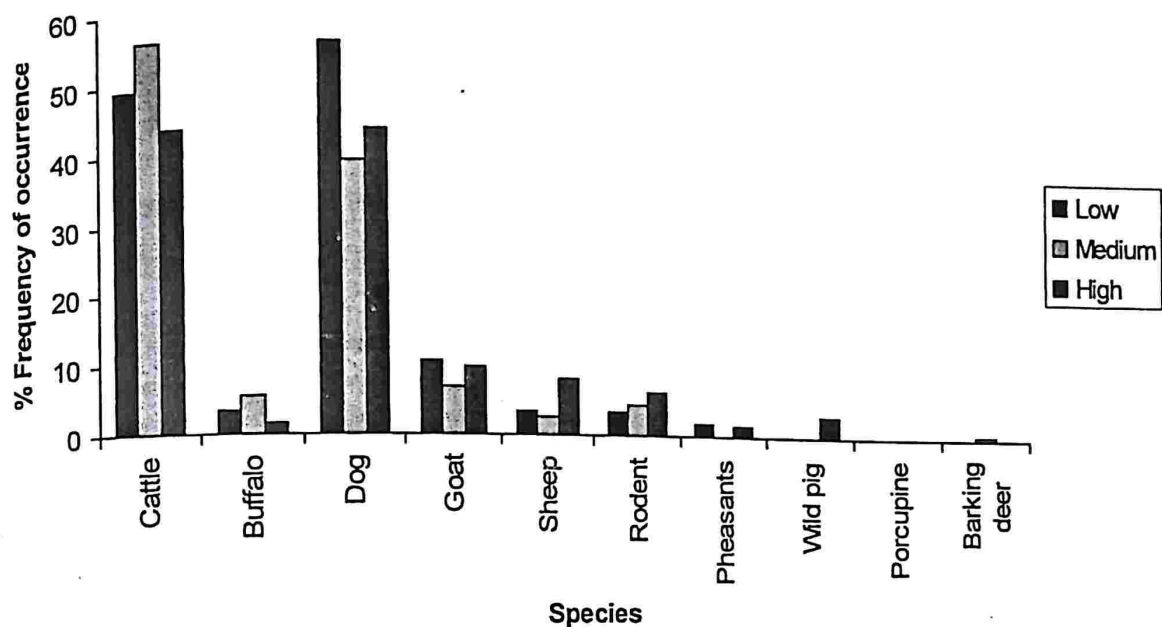


(b). Scats having dog presence

Figure 5.11. Spatial distribution of scats having remains of two major prey species.

#### 5.3.3.6. Prey use across three conflict categories

In low conflict category, dog was frequently taken prey species with 56.1% frequency of occurrence and followed by cattle (49.1%) (Fig. 5.12). In medium conflict category, cattle was preyed upon relatively high with 55.9% frequency of occurrence than followed by dog with 33.9%. In high conflict category cattle and dog were preyed upon with same (43.3%) frequency of occurrence. Other domestic prey species that were preyed during sampling periods in all conflict categories were goat, sheep and buffalo. Rodents were preyed with 6.45% frequency of occurrence in high conflict category which was relatively higher in comparison of medium (4.4%) and low (3.5%) conflict categories. Wild pig was present in leopard diet only in high conflict category with 3.2% occurrence. Pheasant was also preyed upon with <2% frequency of occurrence in high and low conflict category while it was absent in leopard diet in medium conflict category. Barking deer was only preyed upon in medium conflict category with <1% frequency of occurrence. Most preyed species have not shown significant variation across seasons and over the years in either conflict categories. But Frequency of occurrence of buffalo in leopard diet is significantly vary ( $\chi^2 = 7.932$   $P < 0.05$ ) over the years in medium conflict category.



**Figure 5.12.** Proportion of different prey species in terms of frequency of occurrence across the three conflict categories.

Proportion of different prey species remains in terms of frequency of occurrence in leopard diet across the conflict (low, medium and high) categories have been summarized in Table 5.10. Cattle and dog were frequently taken prey in all conflict categories over the sampled period. They are making a bulk of leopard diet in all conflict categories throughout the sampling years.

Proportion of cattle remains in leopard diet observed during sampling periods was relatively low in high conflict category than other categories and ranged from 14.3 to 54.5% in terms of frequency of occurrence. While proportion of dog remains in leopard

diet was relatively higher in high conflict category and ranged from 31.3 to 85.7% in terms of frequency of occurrence. The proportion of cattle remain in leopard diet was relatively high in medium conflict category and ranged from 47.2 to 60.0% over the years. But proportion of dog remains in medium conflict category was relatively low and ranged from 15.2 to 28.8% over the years. In low conflict category cattle and dog have equally contributed in terms of frequency of occurrence. Proportion of rodents in leopard diet over the years was relatively higher in high conflict category.

Proportion of each prey species in leopard diet was compared with their abundance across the conflict categories to understand whether there is any relationship between selection and abundance. When proportion of different prey species in leopard diet was compared with their abundance, data indicates a linear relationship in case of cattle and dog in low conflict category (Fig. 5.13). In medium and high conflict category an inverse relationship was observed in case of cattle and dog while comparing their proportion in leopard diet as per availability (Fig. 5.14 & 5.15). No relationship was observed among other prey species in any conflict category.

Data indicates that proportion of all prey species in leopard diet was much higher in comparison to their abundance in all three conflict categories (Fig. 5.16). Most of the species were preyed more than expected on the basis of their relative abundance.

**Table 5.10.** Proportion of different prey species in terms of frequency of occurrence remain in leopard diet over the sampling periods in ISA of low, medium and high conflict categories.

(a). Low conflict category

Year	# of scats	Cattle	Buffalo	Dog	Goat	Sheep	Rodent	Peasants	Wild pig	Barking deer
2002	21	57.1	9.5	52.4	0.0	0.0	9.5	4.8	0.0	0.0
2003	9	66.7	0.0	33.3	0.0	0.0	0.0	0.0	0.0	0.0
2004	12	41.7	0.0	33.3	25.0	0.0	0.0	0.0	0.0	0.0
2005	15	33.3	0.0	86.7	20.0	13.3	0.0	0.0	0.0	0.0

(b). Medium conflict category

year	# of scats	Cattle	Buffalo	Dog	Goat	Sheep	Rodent	Peasants	Wild pig	Barking deer
2002	45	60.0	13.3	31.1	2.2	0.0	6.7	0.0	0.0	0.0
2003	66	56.1	1.5	31.8	4.5	3.0	3.0	0.0	0.0	0.0
2004	19	47.4	0.0	15.8	21.1	10.5	5.3	0.0	0.0	0.0
2005	29	55.2	6.9	82.8	10.34	0.00	3.43	0.00	0.00	3.44

(c). High conflict category

year	# of scats	Cattle	Buffalo	Dog	Goat	Sheep	Rodent	Peasants	Wild pig	Barking deer
2002	11	54.5	9.1	54.5	0.0	0.0	9.1	0.0	0.0	0.0
2003	12	33.3	0.0	41.7	16.7	0.0	8.3	0.0	8.33	0.00
2004	32	50.0	0.0	31.3	9.4	12.5	0.00	3.1	3.125	0
2005	7	14.3	0.0	85.7	14.3	0.0	28.6	0.0	0.0	0.0

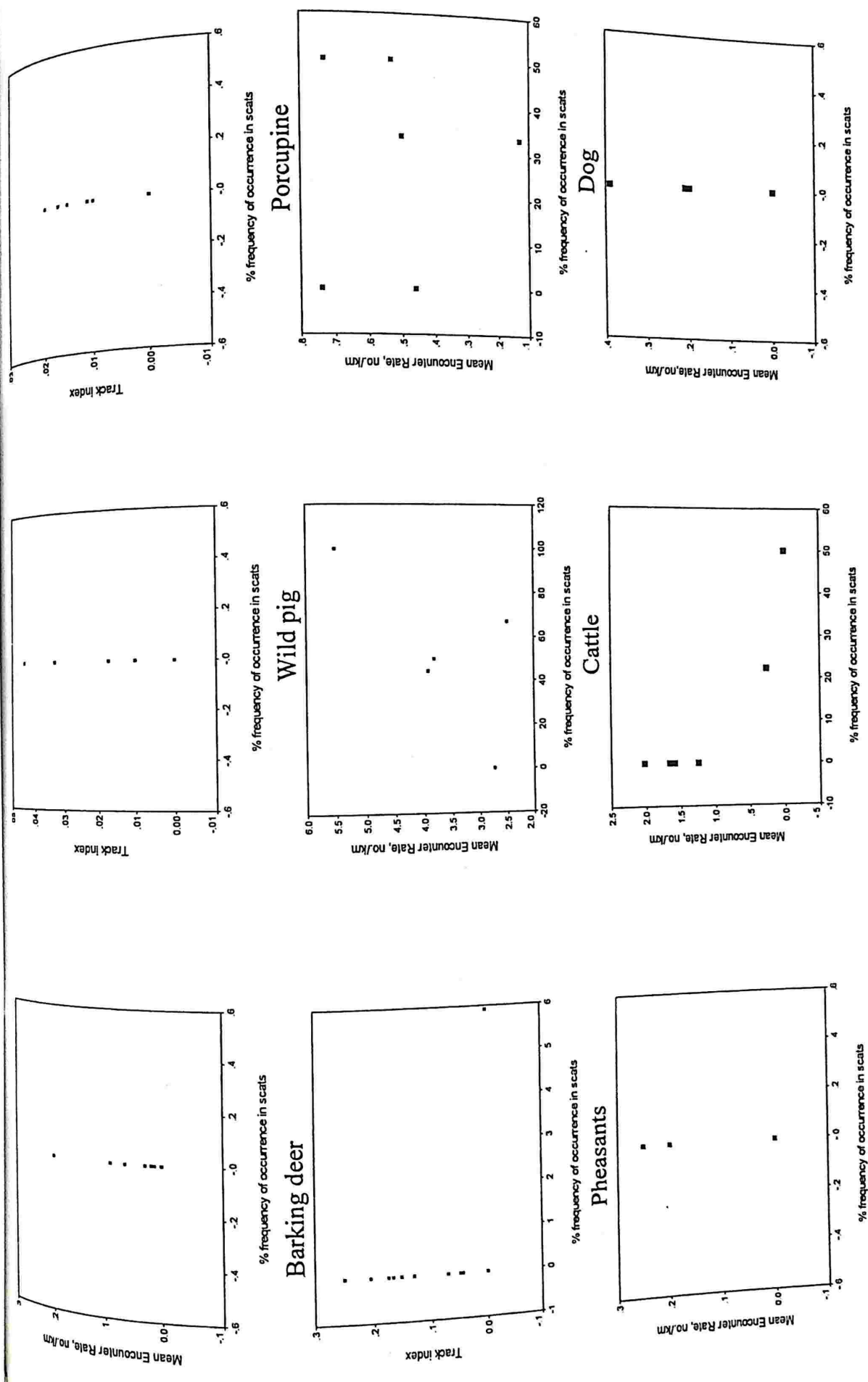


Figure 5.13. A comparison of prey species abundance and their proportion in terms of frequency of occurrence in leopard diet in low conflict category.

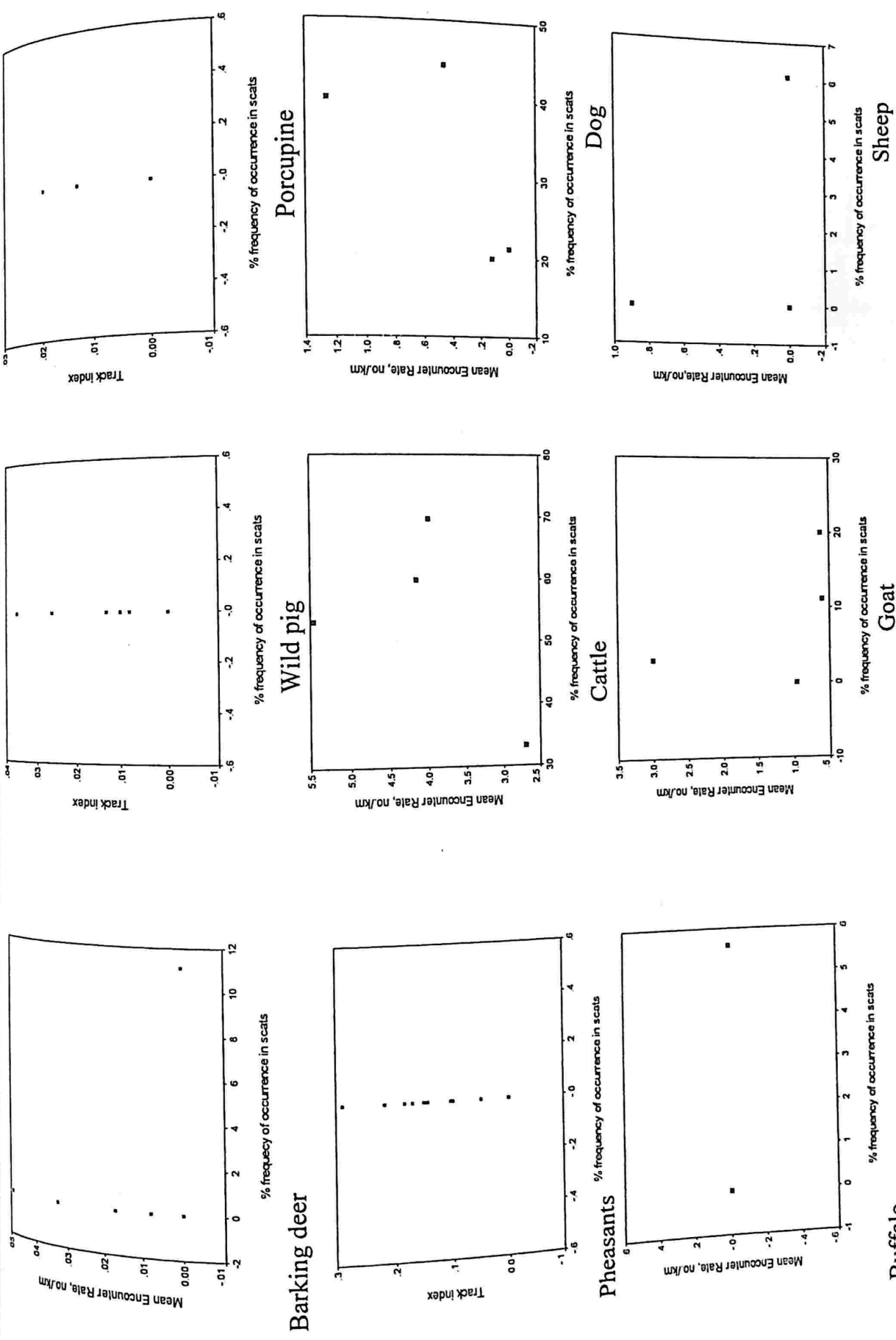


Figure 5.14. A comparison of prey species abundance and their proportion in terms of frequency of occurrence in leopard diet in medium conflict category.

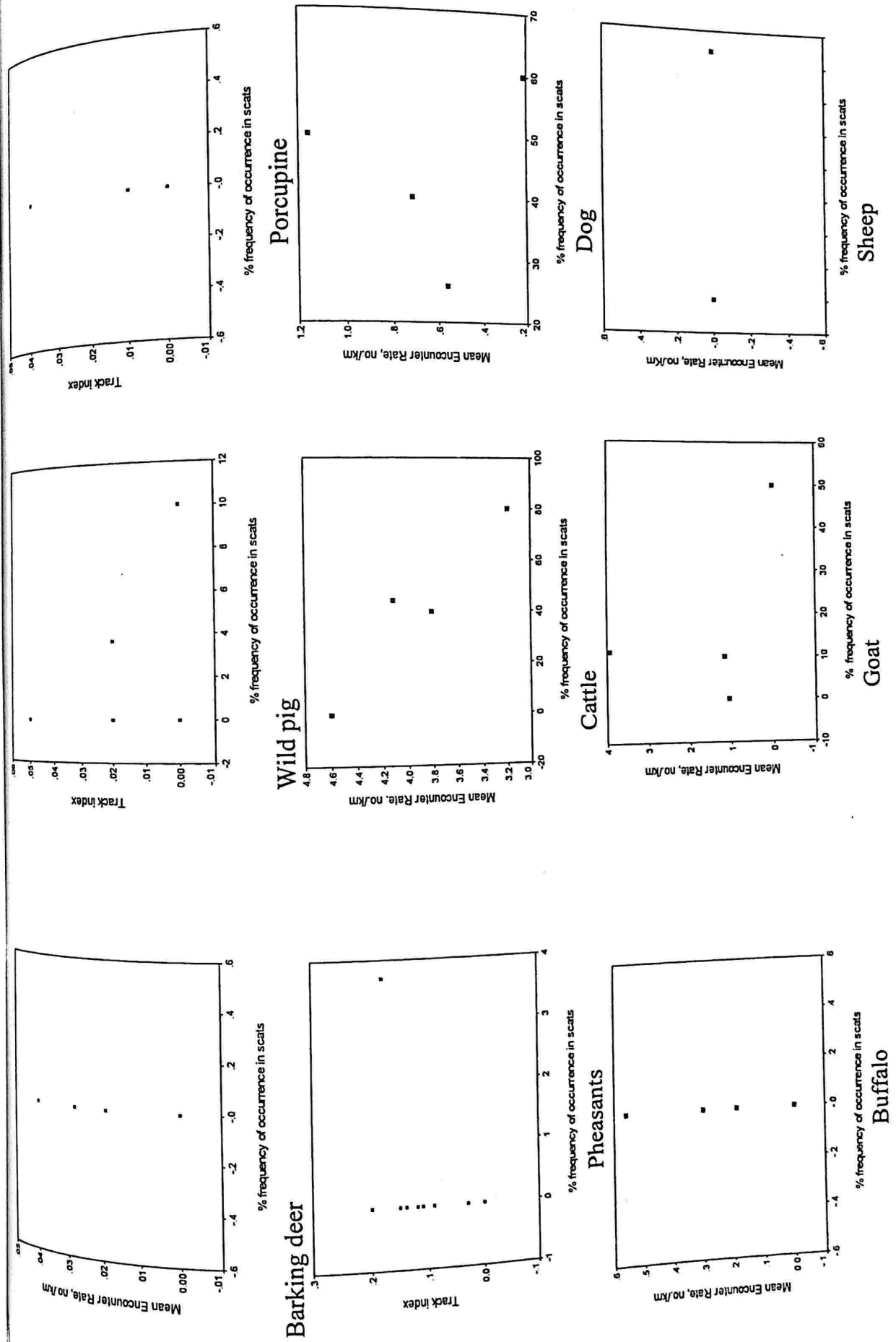
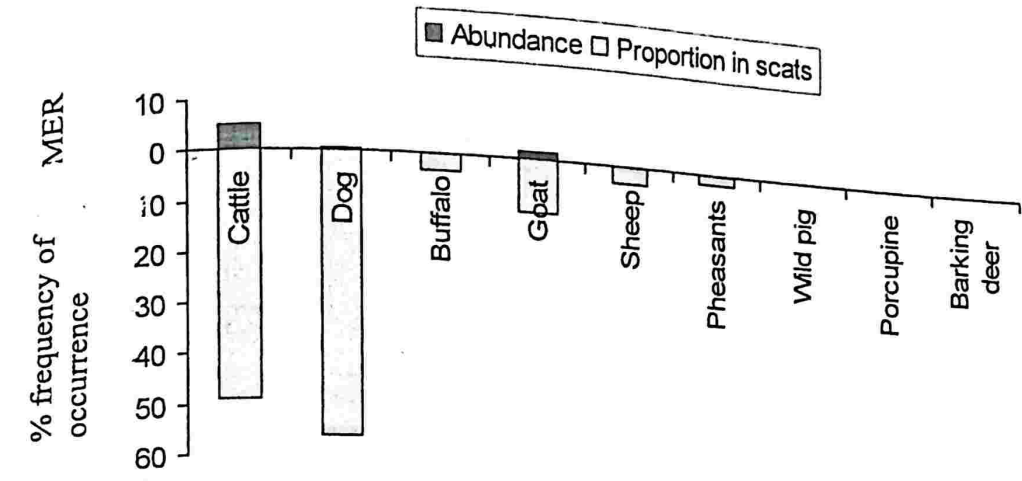
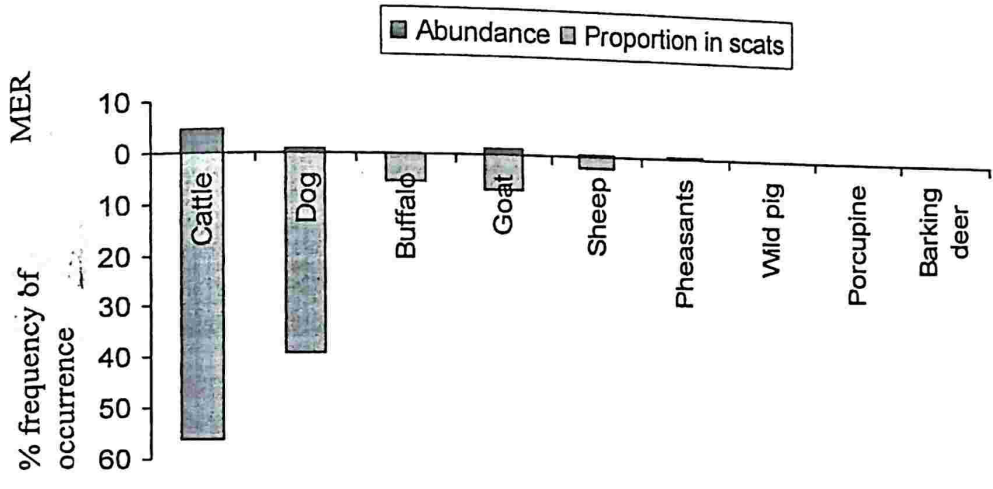


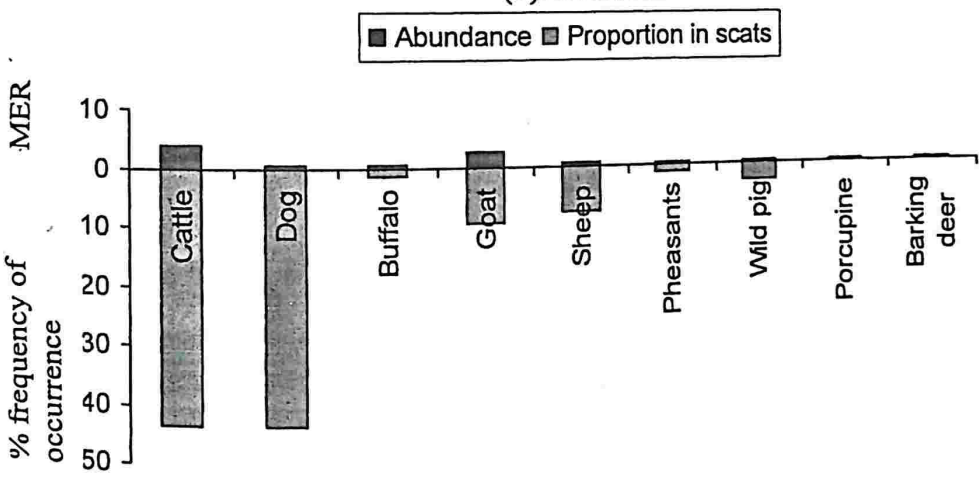
Figure 5.15. A comparison of prey species abundance and their proportion in terms of frequency of occurrence in leopard diet in high conflict category.



(a). Low



(b). Medium



(c). High

Figure 5.16. Percent proportion of prey species in scats in relation to prey abundance (MER= Mean Encountre Rate).

## 5.4. Discussion

### 5.4.1. Prey abundance

Use of track index together with pellet group count and direct sighting of species were investigated as a means of establishing an index of prey species presence and relative abundance. While comparing the results of different methods (track index/pellet group count and direct sighting) used in this study, it was found that track index method is reliable and effective means of recording presence and estimating relative abundance of prey species in Himalayan region. Track index method is better as it can be applicable throughout the year and provide a quick means of establishing an index of species presence and relative abundance.

Previous studies have shown that despite the variety of field techniques for mammals survey, not all can be efficiently applied in every ecosystem and for all species (Smallwood and Fitzhugh 1995; Silveira *et al.* 2003). A track index method was likely to be applicable for three recorded species in this study viz. wild pig, porcupine and pheasants. While direct sighting method was found suitable and effective for estimating relative abundance of barking deer. Since barking deer is territorial that could be one of the reasons that track index or pellet group count are not best way of estimating relative abundance in such hilly terrain. In hills inconsistent whether had been constraint throughout sampled periods.

In this study one of the important objectives was to understand the prey species (wild and domestic) abundance in stratified (low, medium and high) human-leopard conflict categories. The highest encounter rate of barking deer was recorded in low conflict category and ranged from 0 to 0.20/km during sampling periods. In medium and

high conflict category maximum encounter rate (no./km) observed during sampling periods was only 0.049 and 0.040 respectively. Average encounter rate of barking deer is significantly higher in low conflict category indicates its high relative abundance in comparison of medium and high conflict category. Estimated track index of wild pig and porcupine was not much varied across the conflict category.

Sambar and chital were identified as major prey species of leopard among previous studies carried out in different protected areas across the country (Johnsingh 1983; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002). The higher frequency of these species taken by leopards is probably related to their abundance. Among other small ungulates, barking deer and wild pig appear to form a part of leopard diet in a few study sites (Ramakrishna *et al.* 1999). In comparison with densities of these species, it is evident that species were taken in accordance with their abundance (Table 5.11). Chital were most abundant and followed by sambar across the study sites. But in present study chital and sambar were not recoded and it indicate that these species are either locally extinct or their numbers are too low. Data also indicates low abundance of wild pig and barking deer in present study area in comparison of other study sites.

In this study, domestic animal relative abundance was estimated by direct count while walking on roads side transects. Most of the observed species have not shown any significant variation across the conflict categories. No seasonal variation detected for most of the observed species as no migratory patterns was recorded in either conflict category. The relative abundance of cattle is highest in all conflict categories. Their availability is not significantly varied over the sampling period in either conflict category.

Data indicates that road side appears to be inapplicable for estimation of dog abundance as fewer individuals were observed in all categories.

**Table 5.11.** Comparison of density estimates (individual/km<sup>2</sup>) of major prey species of leopard in different study sites.

Species	Rajaji National Park <sup>1</sup>	Rantambore Tiger Reserve <sup>2</sup>	Sariska Tiger Reserve <sup>3</sup>	Pench Tiger Reserve <sup>4</sup>	Kanha Wildlife Sanctuary <sup>5</sup>	Gir Lion Sanctuary <sup>6</sup>	Bandipur Tiger Reserve <sup>7</sup>	Pauri Garhwal district (MER, no./km)*
Chital	18.5-19.6	31.0	30.7-76.8	80.7	49.7	25.2	43-45	0.0
Sambar	5.7-24.2	17.1	10.8-15	6.1	1.5	1.8	8-9	0.0
Wild pig	3.6-5.4	9.8	5.2-11.1	2.6	2.5	2.1	2.5	0.009
Barking deer	0.5-3.9	-	-	-	-	-	1.0	0.020

MER= Mean Encounter Rate

<sup>1</sup> Singh *et al.* (2005), <sup>2</sup> Bagchi *et al.* (2004), <sup>3</sup> Sankar (1994), <sup>4</sup> Biswas and Sankar (2002),

<sup>5</sup> Schaller (1967), <sup>6</sup> Khan (1997), <sup>7</sup> Johnsingh (1983). \* Present study

#### 5.4.2. Food habits

In this study, leopards are entirely dependant on domestic species that form the bulk of leopard diet. Across its distribution range, leopard reported to prefer kill medium sized prey between 10 and 40 kg (Johnsingh 1983; Santiapillai *et al.* 1982; Bailey 1993). Previous studies on leopard in India indicate that chital was preferred among wild prey species (Johnsingh 1983; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002). Leopard preference for this species is probably resulted from their ideal size and grouping tendency (Bailey 1993). Among other ungulates species, sambar was significantly preferred (Johnsingh 1983; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002). Wild pig and barking deer are other ungulate species that satisfy the criteria for leopard predation. But a few studies have suggested that wild pigs are too aggressive and dangerous to become prey of leopard (Eisenberg and Lockhart 1972; Ramakrishnan *et al.*, 1999). Three published studies have also not reported significance of wild pig and barking deer in the diet of leopard (Johnsingh 1983; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002).

In present study, dog and cattle are most frequently eaten prey species. Leopard preference for these species could be resulted from their availability and ideal size. The intensity of leopard predation on cattle and dog was high because abundant prey will be encountered more frequently than scarce prey (Bailey 1993). No significant variation in selection of prey species across the season and landscape was observed. This was probably as a result of the sedentary prey base (domestic animals) present in the study area.

Diets of leopards varied across the study sites in terms of species and their proportion (Table 5.12). The difference in composition of the diet of leopard in various areas was probably due to differences in availability of prey species proportion. While leopard predation on domestic species in other study site is either low or they were never preyed. In present study, low abundance of wild prey species may have influenced the intensity of leopard predation on domestic species.

Previous studies have suggested that in absence of wild prey, the leopards have adapted to live on domestic prey. Such ability was undoubtedly a reason why leopard survive close to human settlement areas (Sediensticker *et al.* 1990). Hamilton (1986) reported that leopard population subsisting 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). Sediensticker *et al.*, (1990) concluded that availability of domestic livestock allowed leopards to live at a higher density than could be supported by wild prey.

The frequency of occurrence of more than single prey species were relatively higher in high to medium conflict categories. This was probably due to their regularly killing high frequencies of prey in these categories. Bothma and Coertze (2004) observed that leopard regularly killing high frequency of prey species in Southern Kalahari region of Africa where population of prey species has been declined. Study also suggested that killing of high frequency of small prey by leopard may be one of the survival strategies in prey poor areas.

**Table 5.12.** Percent frequency occurrence of major prey species in leopard scats reported from different study sites.

Species	Sariska Tiger Reserve <sup>1</sup>	Mudumalai Wild life Sanctuary <sup>2</sup>	Mundanthurai Plateau <sup>3</sup>	Bandipur Tiger Reserve <sup>4</sup>	Pauri Garhwal District*
Chital	20.8	67.22	24.32	51.0	0.0
Sambar	20.0	11.66	9	14	0.0
Rodents and Insectivores	45.6	1.67	7.41	0.0	4.9
Nilgai	7.2	0.0	0.0	0.0	0.0
Hare	2.4	3.35	13.89	11.42	0.0
Common langur	6.4	0.0	0.0	10	0.0
Nilgiri langur	-	0.0	8.33	-	-
Wild pig	0.0	1.11	3.70	0.0	0.5
Barking deer	0.0	2.33	8.33	0.0	0.7
Porcupine	0.0	0.56	5.55	0.0	
Domestic dog	0.0	2.79	6.48	0.0	48.8
Domestic cattle	0.0	6.14	8.33	6.0	44.6
Domestic ungulates (goat & sheep)	0.0	0.0	0.0	0.0	13.3

<sup>1</sup> Sankar and Johnsingh (2002) <sup>2</sup> Ramakrishnan *et al.*(1999) <sup>3</sup> Johnsingh (1983)

\* present study

## 5.5. SUMMARY

1. Track index was found quick and effective means to estimate relative abundance of wild prey species such as wild pig, porcupine and pheasants. While direct sighting method was found suitable and effective method for estimating barking deer abundance.
2. Among wild prey species, barking deer, wild pig were recorded in all conflict categories and their relative abundance was low in comparison to abundance reported from other study sites across the country. Barking deer encounter rate was significantly high in low conflict category than other categories and ranged from 0 to 0.2/km during sampling periods. Track index of wild pig, porcupine and pheasant was not varied across the conflict categories.
3. Domestic species (cattle, dog, goat sheep and buffalo) were sighted on roadside transects in all conflict category. Most of the observed domestic species have not shown any variation across the conflict categories. Data indicates that dog abundance can not be monitored using road side transects.
4. Leopards are subsisting largely upon domestic prey species (93%) and wild prey constitute  $< 3\%$  in their diet. Rodents were also part of leopard diet and contributed maximum up to 4.9 % of total diet. The most common prey species in the diet of leopard are cattle and dog and constituting more than 70% of diet during sampling periods in all conflict categories.
5. Wild prey species were not significant part of leopard diet in any conflict category
6. Percent contributions of more than single prey species in leopard diet were relatively more in high to medium conflict categories than low conflict category.
7. There is no seasonal and spatial variation in leopard diet across the conflict categories.
8. Proportions of prey species in scats was more than their availability in all conflict categories.

## CHAPTER 6 FACTORS RESPONSIBLE FOR LEOPARD-HUMAN CONFLICT

### 6.1. INTRODUCTION

Large carnivores are specially sensitive to human activity; because their requirements often conflict with those of local people (Woodroffe 2000). Habitat degradation is more common in and around Protected Areas as well as in Reserve Forests due to people dependency on natural resources and developmental project and has changed the landscape world wide (Crooks 2002; Johnson *et al.* 2006). Natural habitat fragmentation generated through human has been leading to widespread incidences of human-wildlife conflicts (Cobbs 1981; Green 1987; Seidensticker *et al.* 1990; Adrian and Karanth 2003). This problem is aggravated along tropical deforestation frontiers where large felids often shift to both small and large livestock prey because of increased proximity to human agriculture (Adrian and Karanth 2003).

In the present conservation scenario, habitat loss and fragmentation are among the most evident threats to the wild species. Habitat loss, which reduces area of suitable habitat, may also lead to fragmentation of the habitat into small, isolated remnants (Fahrig and Merriam 1994). Habitat fragmentation could strongly affect the amplitude of local predator-prey dynamics (Myres 1976; Johnsingh *et al.* 1991; Thomas 2000).

In many areas, large carnivore population is also determined as much by anthropogenic factors, such as local tolerance of their presence, as by ecological factors such as prey abundance and habitat requirement (Marker and Dickman 2005).

## 6.2. Major factors leading leopard-human conflict

The results from this study indicate that three factors leading leopard-human conflict in this region. The first factor is habitat degradation followed by depletion of prey species. Third factor is a relatively high leopard population to some extent at few sites.

### (i) Habitat degradation

Habitat loss and degradation are among the most evident threats to the wild prey species. A large scale of deforestation has destroyed the potential habitats of ungulate species. Scrub is dominating and occupies more than 50% of total land cover. Dominating different shrub species are mostly unpalatable such as *Lantana*, *Xanthium* and *Eupatorium* around villages as well as in Reserve Forests. Leopards have shown their significant preference to scrub cover. Degradation of habitats may have negative impacts on ungulate species but it may provide better opportunities for leopards. Scrub may provide ideal habitat for leopard breeding and their litter survival (P. C. Dass, in litt 1987; D.K. Lahiri Choudhery, in litt., 1987; Vijayan and Pati 2002; Singh 2005).

Scrub cover was correlated with livestock and human deaths due to leopard in each administrative block of Pauri Garhwal. Proportion of livestock and human death was relatively higher in those blocks where large proportion of area was under scrub cover. GIS vegetation map indicate that forest areas are degrading and being replaced by scrub. Reported high conflicts were in areas with high degradation of habitat and very low wild prey abundance. Leopard-human conflict was more prominent during rainy and winter season. It could be due to weeds growing in rainy season remained till winter which provided suitable habitat cover to leopards for stalking. Leopards come more close

to human during these seasons where they seek opportunities to kill livestock and in this process some time human fall prey of them.

(ii) **Depletion of prey**

The second and likely most crucial factor leading conflict is depletion of wild prey. Previous studies suggested that although leopard prey on a wide variety of species, they rely largely on ungulates (Johnsingh 1983; Bailey 1993). During four sampling years, only three wild prey species recorded were barking deer, wild pig and porcupine and were in a very low abundance. In previous studies on food habits of leopard in protected areas of India, chital and sambar have been identified important prey species of leopard (Johnsingh 1983; Ramakrishnan *et al.* 1999; Sankar and Johnsingh 2002). In present study, sambar presence could not be rerecorded due to either their low presence or probably locally extinct. The relative abundance of recorded wild prey is low. The abundance of wild prey was consistently low such that leopard were largely dependant on livestock and dogs. Data indicates that there was low leopard predation on human in blocks where leopard predation on livestock was relatively high.

Our data on track index indicate a very low abundance of wild prey species and may be one of the causes of such high conflict. Leopards have shown significant preferences to the human habitation and this is probability due to their dependency on domestic prey species.

Most likely factor affecting wild prey population is hunting and habitat degradation. Most of the ungulates species have become extinct due to habitat depletion, deforestation and illegal hunting and the small number of available prey is not sufficient for the existing leopards in this area. Attacks on human are more prominent in those areas

where livestock killing by leopard is relatively low. Due to decrease in wild prey species, leopards are being forced to change their diet and their habitat.

Lower cattle abundances in the high conflict areas are leading to higher predation on dogs. In search of dogs, leopards are possibly venturing into human habitations in high conflict areas, thereby increasing the probability of leopard human encounters and resulting into casualties.

### (iii) Leopard population

The final factor leading conflict is probably due to relative high abundance of leopards. Probably Pauri district did represent a perfect habitat for leopards in the past, so a large number of leopards were able to live and sustain on sufficient number of preys. Due to habitat degradation over the years, number of prey species have decline drastically. Due to this, leopard have changed their food habits and switched to domestic animals. Leopard can survive in disturbed areas or even marginal habitat as long as relative broad prey base is present. (Norton *et al* 1986).

Previous studies have suggested that livestock can be an important prey for leopards in areas where wild prey is not abundant (Hamilton 1986; Sediensicker *et al.* 1990, Santiapillai and Ramono 1992). Abundance of domestic prey species may increase leopard population. Sediensicker *et al.*, (1990) concluded that availability of domestic livestock allowed leopards to live at a higher density than could be supported by wild prey. In urban areas of western Kenya, leopard population increased by subsisting on domestic animals (Hamilton 1986). In Java island of Indonesia leopards are surviving by predating on cattle, dog and chickens (Santiapillai and Ramono 1992).

Leopard population might have increased in Pauri Garhwal district after implementation of Wildlife (Protection) Act 1972, as leopard killing by local people went down. But it has now changed in past couple of years as people are now killing the leopards. In some areas man-eating problem seems to be on decline after a large number of leopards are killed. Leopard-human conflict has been linked with their high population in many places in India (Singh 2005).

Leopard abundance was relatively higher in medium and high conflict categories and animals found to move shorter distances. These animals are probably killing regularly higher frequency of easier prey as observed by Bothma and Coertze (2004) for leopard living in poor prey environment. Leopards are shifting from forest to human settlement areas where they seek opportunities to kill livestock and some time human.

### **6.3. Circumstances which provoking leopard attacks on human**

Based on observation during field work, following circumstances may probably leading leopard-human conflict:

1. Most of the victims were women and children where as cases have been reported in all age group. Most of the children were killed under poor parental care conditions. Attacks on children were rarely successful in the presence of adult males. Most women fell victim during their daily routine work which they often perform alone. Some people were killed when they were going to fetch drinking water in early morning. Most of the time women were usually attacked during their return to home from jungle as they were carrying firewood and grasses which makes them more vulnerable and leopard takes advantage of such opportunity to attack. Adult males were killed while returning from their work places during evening.

2. Leopard attacks vary across the time of the day. Frequencies of attack are relatively high during either early morning before 0800 hours or during evening between 1600 to 2100 hours. This is coincided with their timing of toilet as in hills most of the families do not have toilet facilities and they use open places for this purpose. Large proportions of attacks were on while people going to toilet in open areas. Women being shy in nature go to toilet in early morning and late evening and always use places for toilet, which are relatively surrounded by bushes. In this process they often become victim of leopards. Leopards have adapted to this habit of hill people.

3. Houses on the fringe of villages which were isolated, without electricity and surrounded by heavy scrub cover were more prone to leopard attacks.

#### **6.4. Mitigatory measures to minimize leopard-human conflict**

Based on this study following mitigatory measures have been suggested in order to minimize leopard-human conflicts in this area:

1. There is an urgent need to restore the wild prey species, control illegal poaching of wild prey species and public awareness for the consequences of poaching leading to such conflicts.

2. Leopard attacks on livestock are frequently reported from all villages surveyed. Predation on livestock can not be eliminated but it can be minimized if this area is intensively managed for wildlife. Thus there is need to take steps to improve the prey population.

3. Scrub cover found within 200 m circumferences of isolated houses should be cleared specially during rainy and winter season so that leopards do not get any ambush cover.

4. Women and children below 15 years should be told to move in groups. Parents should not leave their children unattended during early morning and late evening specially in isolated houses. Children should reach home from school or any other work before 1600 hours to minimize such conflicts. If needed, school timings may be changed. In most of the villages in Himalaya, children have to travel a long distances to reach school, thus they are always vulnerable to man-eaters. Sending them school under the supervision of some adult person is suggested. Women should move in groups whenever they go to jungle and cultivated field and they should return home before 1600 hours.

5. In most of the villages, people have to travel a long distance to fetch drinking water. They often go for water late in evening and early morning hours and in the process they are vulnerable to leopard predation. It would better, if people can arrange water before 1600 hours.

6. In this region, most of the people do not have any toilet facilities and they use open places for this purpose. It would be better if district administration can provide toilet facilities at least for villages of conflict zone. Different NGOs, who have been operating in this region, can make their contribution to build toilets for villagers suffering from man-eating problems.

7. Proper electricity around houses might reduce leopard attacks, as attacks were more prominent in the absence of electricity. It would better if administration can provide electricity.

8. Most of the local people are unaware about the basic facts of leopard-human conflict problems. A public awareness program should be planned at village level in which some basic ecological reasons of man-eating (such as scarcity of natural prey and depletion of habitat) need to be conveyed. How local people can contribute to minimize the conflict should be explained. It is noted that despite the best effort of the Forest Department, illegal hunting is still going on in these areas, whereas local villagers do not realize that scarcity of natural preys could be one of the factors of conflict. To save the both leopard and human, massive reforestation and habitat restoration programs are needed.

9. State Forest Department has been giving compensation for human life lost to leopards. It is difficult for the Forest Department to sustain the increasing amount of compensation to be paid, which is now above four lakhs per year during last couple of years. But it is also necessary to compensate the local people for livestock lost to leopards as most of the people are living below poverty line. It was noted during survey work that most of the injured human were not in a position to afford the expenditure of treatment. Thus compensation to the injured should be given immediately to ensure better treatment. Proper compensation to victim's families will be helpful in improving Forest Department relation with local people. Ecodevelopment programs for the villagers that should include compensation for loss of cattle and human to leopards.

10. There is no systematic population estimation of leopard and other prey species from this region. Therefore a detail study on these aspects should be undertaken to understand the predator-prey relationship in this region and ranging patterns of leopard in high and medium conflict areas.

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### Questionnaire for village survey

Village.....

Villager.....

Date.....

1. Number of human killed/injured by leopard during past ten years.....
2. When man-eating problem has begun.....
3. What was victim's activity during leopard attacks.....
4. Timing of attacks on human.....
5. No. of livestock killed by leopards during past 10 years.....
6. Where were livestock killed.....
7. Timing of attacks on livestock.....
8. Annual livestock lost to leopards.....
9. Which species were frequently killed by leopards.....
10. Have villagers killed any leopard in the past.....
11. How leopard was killed (gun /poison/other means).....
12. How often do you see leopard in surrounding of villages .....
13. Timing of leopard visits in and surrounding of villages.....
14. Surrounding vegetation of the village (thick, sparse tall grasses and tree etc).....
15. What is proportion of non-cultivated land in the village.....
16. How often you see other wild species and what area those species.....
17. How often do you use natural resources and what area these resources.....

18. Social life of villagers

- Economic condition.....
- Total No. of families.....
- Sex ratio.....
- Total No. government employees in the village.....
- No of livestock pre family.....

19. Opinion on leopard-human conflict.....

20. Suggestion to minimize such conflict.....

21. Disbursement of compensation amount to victims families.....

22. Other information (if aviliable).....

**Detailed of circumstances of leopard attack on human during field work**

1. Place/area.....
2. Timing of attacks.....
3. Parental care condition (where victim was child) .....
4. Electricity condition (If incident happened during night hours).....
5. Dog presence in house.....
6. House location .....
7. Surrounding vegetation.....
8. Was there any previous incident reported from this area? If yes when did it  
happen.....