MONITORING PREY DYNAMICS AND DIET FLUCTUATIONS OF LEOPARD (*PANTHERA PARDUS*) IN DACHIGAM NATIONAL PARK, SRINAGAR, JAMMU AND KASHMIR

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DOCTOR OF PHILOSOPHY
IN
WILDLIFE SCIENCE
By

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Under the supervision of

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March 23rd, 2016

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Mr. Zaffar Rais Mir has put more than six terms of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted for any degree to any other University or Institution.

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"… I DEDICATE THIS THESIS TO PAPA AND AMMI"

Zaffar Rais Mir

EXECUTIVE SUMMARY

Leopard (*Panthera pardus)* is known for its ecological flexibility and wide distribution range. However, like other large carnivores, leopards are declining throughout their range due to habitat conversion, prey depletion, intense persecution and poaching for trade. In Kashmir valley leopard is at the top of the food chain and an apex predator that aids in regulating prey populations. Conservation and management planning of the leopards in Kashmir valley is impeded by the paucity of reliable empirical ecological information. There has been an increase in the human-leopard conflict in the valley which, if left unnoticed, will worsen the conservation prospects of this threatened felid. Hence, this study was initiated to investigate the feeding ecology of leopard in Dachigam National Park and the human carnivore conflict around the park. The objectives of the study were estimating seasonal density and spatial distribution of prey species of leopard, studying the food habits and prey selectivity of leopard and quantifying the nature and extent of human-carnivore conflict around Dachigam National Park.

The population of wild prey species was estimated in Dachigam National Park on seasonal basis using Distance sampling technique. In total 13 line transects (ranging from 1.5 to 2.5 km in length) were laid in different habitats covering a distance of 26.05 km. Each transect was walked 12-18 times in each season during morning hours and the total transect effort was 1499.1 km for all seasons. Transects were monitored in morning hours between 6.00 and 10.30 AM. At each sighting, the number of clusters detected, cluster size, cluster composition, sighting distance, sighting angle and geographic coordinates were recorded for each prey species encountered. The sighting distance and the angle for animals occurring in clusters were recorded from the perceived geometric center of the cluster. Density of rodents was estimated using live trapping at six different sites in the study area. Sherman live traps (n = 49; each with dimensions 5 cm x 6.5 cm x 16.5 cm) were used for 7 consecutive trap nights at each site in all the four seasons. Total sampling period amounted to 2058 trap nights per season. At each site, traps were placed in a concentric web design with a radius of 60 m covering an area of 1.1 hectare. Each trap station was established 10 m apart in the sampling area. Traps were set in the evening and checked for animals after sunrise the very next morning. Data was analyzed using program DISTANCE version 6.0 to estimate population densities of large prey as well as rodents in different seasons. The biomass (kg/km^2) of each prey species was calculated by multiplying the mean individual density (D) by its average estimated unit weight

Data from line-transect surveys was used in density surface modeling (DSM) framework also to model the distribution of hangul and Kashmir gray langur in the study area. Increase in sample size makes the models in DSM more robust, hence, the transect data of winter and spring seasons were clumped to represent wet half of the year as maximum precipitation in the study area is received in these two seasons. Similarly, data from summer and autumn seasons were clumped for the purpose of analysis to represent dry half of the year. For DSM analysis, line transects were subdivided into equal contiguous segments of 500 m each. And the sightings where assigned to respective segments accordingly. The covariates used consisted of geographic coordinates (latitude; y and longitude; x), terrain parameters (elevation and slope) and two variables representing vegetation characteristics (Normalized Difference Vegetation Index; NDVI and seasonality in NDVI; CVNDVI). Once models had been fitted, a prediction grid was developed by gridding the study region into 761 cells of 500 m^2 each using Arc GIS 10 (ESRI 2010). The geographical covariates were rescaled to a resolution of 500 m^2 from their original resolutions and the final generalized additive model (GAM) per species was used to generate a surface of density.

In total 5 large prey species (three ungulate species namely hangul, musk deer and wild boar, and two primate species namely Kashmir gray langur and rhesus macaque) were detected on line transects. Density of hangul and langur among large prey and rodents among small prey was estimated on seasonal basis. Other species are less common in the area and only a few sightings were recorded during our study, hence their densities could not be calculated. In total 170 groups of langur comprising of 2679 individuals and 206 groups of hangul comprising of 829 individuals were sighted in different seasons in the study area. Overall density (±SE) of langur was estimated to be higher (16.32 ± 1.87/km^2) than density of hangul (5.11 ± 0.51/km^2) in the study area. Both species showed seasonal variation in densities. Langur density was highest (22.05 ± 5.12/km^2) in winter season and lowest (9.35 ± 3.03/km^2) in summer season. While as hangul density was observed to be highest (9.51 ± 1.71/km²) in spring season and lowest (2.31 ± 0.51/km²) in summer season. Cluster size for the best selected model for langur was highest in summer season (18.65 ± 3.12) and lowest in autumn season (12.44 ± 1.24). In case of hangul cluster size was lowest in summer season (1.75 ± 0.16) and highest in winter season (4.44 ± 0.49). In total 576 individuals of rodents were captured by Sherman trapping, during this study. Rodent density was found to be highest in summer season (2014 ± 830.71/km²) followed by spring, autumn and winter (1172.6 ± 442.74/km²). In the present study, the total available prey biomass of large prey varied from 347.6 kg/km² to 886 kg/km² in different seasons, which is very less compared to studies conducted in other Himalayan ecosystems and rest of the Indian subcontinent

In DSM analysis the final selected models of GAMs accounted for 33.4 - 56.3% of the deviance in species data. In all the final models, elevation, mean of NDVI and CV of NDVI had a significant effect on species densities. With the exception of the langur in dry season, slope did not show any significant effects on species densities. The models indicated that the highest densities of hangul as well as langur in wet season occurred in lower elevations ranging from 1800-2200 m. In dry season it was observed that the densities of both the species in the study area decreased and both species were distributed across a wider area and higher elevation. Using the final models, species specific densities for each season were extrapolated over the 500 m^2 prediction grid across the study area.

Prey selection and food habits of leopard were studied using scat analysis technique. The scat samples were collected systematically as well as opportunistically along trails and roads in Dachigam NP. Systematic scat collection was done in 19 trails or roads with length ranging from 1.5 to 6.5 km. Scats were also collected by following GPS-collared leopards in the area. The scat samples were air-dried and preserved in tagged polythene bags and taken to the laboratory at Wildlife Institute of India, Dehradun for analysis. In the lab, all scats were oven dried at 60°C for 48 hours, subsequently broken and washed through 1 - 2 mm fine nylon sieve and prey remains such as hairs, bones, hooves, teeth, scales, claws, quills, etc. were separated for identification of prey eaten by leopards. The sieved prey remains were sun dried in paper bags for 3-4 days to avoid fungal growth. The dried scat samples were then labeled and stored in airtight bags. 20 hair samples randomly selected from each scat sample were then mounted on glass slide using a DPX mountant and examined under microscope with 100X and 400X resolutions. Prey species were identified by comparing key features such as general appearance, color, pigment, length, width, medullary width and cuticular patterns with reference hair samples.

Data is presented in terms of both frequency of occurrence (proportion of scats containing each food items) and relative frequency of each food item (number of times a specific item was found) as a percentage of all items identified. Frequency of different prey species in leopard scats were analyzed separately for all the four seasons of the year.

To minimize biases, we estimated relative proportions of biomass consumed by leopard using the Ackerman correction factor (Y= 1.98 + 0.035 X) where Y is the weight (in kg) of the prey consumed per scat and X is the average live weight of the prey. Estimates of Y is the biomass consumed per collectible scat for a prey species. The relative biomass of each prey species was calculated separately for all four seasons of the year. Leopard-specific biomass model developed recently by Chakrabarti *et al*. (2016) was also used for estimation of prey biomass consumed by leopards $Y = 2.171 - 1.671 \exp^{-0.056X}$ where Y is the weight (in kg) of the prey consumed per scat and X is the average live weight of the prey. The results where compared with estimates obtained using model developed by Ackerman et al. (1984). Both percent relative occurrence (RO) and percent relative biomass (RB) of food categories in the diet of the leopard were used to calculate its niche breadths in different seasons using standardized Levin's index (B_{sta}). In order to estimate prey selection by leopard, Jacobs' selectivity index was used to measure the preference for hangul, langur and rodents with respect to their available biomass in different seasons.

Overall 714 leopard scats were collected and 17 different prey items were identified from their remains in scats during this study. Small rodents contributed maximum (48.05%) to the leopard diet in terms of percent frequency of occurrence followed by langur (14.04%), sheep (*Ovis aries*), goat (*Capra aegagrus hircus*) and dog (*Canis lupus familiaris*). Rhesus macaque (0.10%) contributed least to the diet of leopard. Contribution of cattle species was very low to leopard diet (0.31%) as only three leopard scats contained remains of cow (*Bos primigenius*). Contribution of different prey items in leopard diet showed seasonal variation. Small rodents contributed highest to the leopard diet in summer season both in terms of percent occurrence (55.63%) as well as percent biomass consumed (53.77%) while as their contribution decreased in winter season. While in case of large prey, consumption was high in winter season when langur and hangul contributed 19.28% and 8.57% respectively in terms of biomass. In summer season langur and hangul composed only 10.83% and 1.59% of biomass consumed by leopard respectively. Comparison of two biomass estimation models given by Ackerman *et al.* (1984) and Chakrabarti *et al*. (2016) indicated the difference of 2-5% towards prey biomass contribution in case of small and medium sized prey which represents most of the leopard diet in this study. However the difference was higher in case of large prey. Levin's standardized index indicated that leopards had the most diverse dietary niche breadths in winter season (0.274833) while as least diversity was observed in summer season (0.141794). Jacobs' index was calculated from biomass availability and biomass consumption for hangul, langur and small rodents. It indicated that small rodents and langur were consumed more than their availability and hangul was consumed less than availability in all the four seasons. The index of prey selection by leopard at individual species level was in the following order: rodents > langur > hangul.

Data pertaining to the human-wildlife conflict, dependency of local communities on forest resources and their attitude towards wildlife was collected using semi-structured interviews. In total, 384 households from 19 villages within three ranges (administrative units) of the Central wildlife division were interviewed between June 2011 and August 2013. These three ranges (Ganderbal, Dachigam and Khrew range) encompass the boundary of Dachigam National Park in North, West and South directions. Each household was considered a sampling unit, and interviews were restricted to one respondent per household (preferably the oldest one). Households were selected randomly, and more than 60% of households were targeted for interviews. The semi-structured questionnaire was designed to collect information on respondents' (1) socioeconomic and demographic characteristics (education, livestock holdings, land ownership, income sources, and economic losses), (2) experiences of crop damage and livestock predation by wild animals in 2011 and 2012, (3) attitudes toward wildlife conservation, (4) actions reportedly taken to protect crops and livestock and (5) details of livestock husbandry techniques and (6) dependency of people on forest products. Data was analysed using the Statistical Package for Social Sciences (SPSS-16.0) and program R (Software for Statistical Computing). Generalized linear modeling (GLM) was used to determine factors influencing attitudes toward wildlife and its conservation.

Of 384 households interviewed, 165 were in the Dachigam range, 157 in Khrew, and the remaining 62 in Ganderbal. Men accounted for 65.48% of the interviewees; ages ranged from 18 to 90 years, with a median age of 35 years. Mean (± SE) family size was 7.16 ± 0.16 persons per household. The average female to male ratio in the population as a whole was quite unequal, with 56.30% of the population being men. Regarding literacy, 67.18% families had one or more male members who had studied at least through the primary level, whereas 39.06% families had one or more female members who had studied through the same level. The mean number of years of education for all respondents was 8.36 ± 0.27 years. In total, 91.66% of respondents owned farmland. The majority of the respondents (72.65%) practiced agriculture for income generation, while the rest (19.01%) grew crops for subsistence only. About 85.67% of interviewees owned livestock, with 60.76% using it only for subsistence and 24.91% using it for income generation. Overall, 74.71% of landowning families reported crop damage by wild animals. The average amount of crop damage per household varied, but not to a significant degree. The greatest damage was observed in the Khrew range (55.87 ± 2.35%), followed by Ganderbal (47.27 ± 2.57%) and Dachigam (39.36 ± 1.82%) (χ^2 = 2.8709, df = 2, P > 0.01). A total of 88 livestock predation incidents were reported for 2011 and 2012, resulting in the deaths of 107 head of livestock. Predation incidents by leopards (63.63%), black bears (28.40%), and jackals (7.95%) varied significantly (χ^2 = 48.32, df = 2, P < 0.001). About 84.18% of interviewees supported wildlife conservation, whereas 15.82% opposed it. The main reason given for the latter view was the conflict with wild animals and resulting economic losses. Generalized linear modeling results showed that the model that best explained respondents' attitudes toward wildlife conservation included four variables *viz* gender, crop damage, livestock predation, and total livestock holding.

Findings of this study indicate that leopards are facing prey scarcity in the area, thus making them to rely upon suboptimal prey. Leopards being opportunistic feeders have also started feeding on domestic prey in absence of sufficient wild prey, thereby elevating the human-leopard conflict in the region. The study also highlights low dependence of leopards on endangered hangul. This information is critical for planning conservation and recovery of this critically endangered ungulate. The study identified the need to use appropriate mitigation measures to minimize economic damage by wildlife in order to reduce negative local attitudes toward wildlife conservation. Human – animal conflict being the major threat to large carnivores all across their distribution range is a big impediment in leopard conservation in the study area as well.

CHAPTER 1

INTRODUCTION

1.1Background

Numerous human activities necessary for subsistence of mankind lead to biodiversity loss, and this tendency will likely continue in future (Diaz *et al*. 2006). Species extinctions may also occur due to natural causes; however the activities of people and the growth of human population have rapidly created a threat to the well being of wildlife and accelerated the process of extinction. International Union for the Conservation of Nature (IUCN) estimates that extinction rates are now 50 to 500 times higher than previous rates calculated from the fossil record (Baillie *et al*. 2004). People have only recently realized that most of wild species are facing population decline and this may lead to imbalance in the ecosystem. This concern has triggered numerous ecological studies across the globe, since ecological studies are vital for providing information that is needed to initiate conservation efforts that eventually help to soften the impact of developmental activities on the environment. Monitoring biological diversity has an important application of identifying species in need of conservation action and at times to check the effectiveness of restoration measures (Kery and Schmid 2004; Block *et al*. 2001). In addition population monitoring programs can help better understand population trends and the biology of the species, especially the fundamental processes of survival, reproduction and temporary emigration and immigration, along with their rates (Williams *et al*. 2002a)

Carnivore group has always been considered suitable for the development of predictive models of conservation (Cardillo *et al*. 2004). Large carnivore conservation is a global priority as they are crucial for the maintenance of biodiversity and ecosystem function. Many of them act as effective umbrella species, facilitating the conservation of their smaller brethren (Karanth 2003; Thorne *et al*. 2006). Umbrella species require large protected areas for sustaining viable populations and through their conservation they help protecting the habitat needed for other co-occurring species (Roberge and Angelstam 2004). Large carnivores have also an important ecological role as keystone species (i.e. a species which has larger effects on ecosystems than expected based on their relative abundance, Power *et al*. 1996). They play a significant role in delivering economic and ecosystem services via direct and indirect pathways that help maintain mammal, avian, invertebrate, and herpetofauna abundance or richness (Ripple *et al*. 2014). Through predatory activities, carnivores directly regulate prey populations (Estes *et al*. 1998; Schoener and Spiller 1999; Miller *et al*. 2001), thereby altering the structure and function of entire ecosystems (Estes *et al*. 1998; Berger *et al*. 2001; Terborgh *et al*. 2002; Treves and Karanth 2003). Moreover, the process of predation has dramatic impacts at organizational levels ranging from individual behavior to system dynamics, and on time scales that range from ecological to evolutionary (Estes *et al*. 2001). Ironically, until recently, knowledge about the impact of carnivores on different ecosystems remained uncertain. As a result they are presently among the most threatened mammals in the world (Ceballos *et al*. 2005). In many areas, they have already been eliminated or severely reduced in number (Weber and Rabinowitz 1996; Terborgh *et al*. 1999), since they are highly sensitive to human activities and their requirements often conflict with those of local people (Woodroffe 2000). Human-carnivore conflict has posed an urgent challenge worldwide as, in addition to being a threat to human life and property, these conflicts often put human communities against carnivores as well as against conservationists or managers (Torres *et al*. 1996; Berg 1998; Karanth and Madhusudan 2002) and often result in persecution of carnivores. Using data from 22 intensive studies, Woodroffe and Ginsberg (1998) concluded that humans are responsible for majority of the large carnivore deaths occurring inside protected areas. Large carnivore conservation in these conditions has become a challenging task for conservationists and policy makers, although it is an established fact that conservation plans focused on large carnivores will eventually protect most other species as well (Foreman 1992).

Even though it is difficult to study carnivores because of the necessary scale (temporal and geographical) and expenses (Estes 1996), having a sound knowledge of the distribution, abundance and response of species to various available resources is imperative in order to manage carnivore populations effectively. Low densities, large home ranges and elusive behavior of carnivores adds to the difficulty of monitoring their populations in natural environment. (Gittleman and Harvey 1982; Karanth and Chellam 2009). However, employing modern techniques for indirect observation such as camera trapping, telemetry and DNA scatology assists in collection of robust data from otherwise cryptic species. Ability of carnivores to structure ecosystems and their vulnerability to extinction makes their study exceptionally important. In a general review by Fuller (1995) he reported that 22 out of 30 large carnivore species belonging to five different families were cited as endangered by IUCN. Despite this status, more than half of carnivore species are ‘poorly studied’ and leopard (*Panthera pardus*) is one of them. Thus increasing the available knowledge about leopard ecology and reversing their decline are among the most urgent conservation challenges for management of leopard population in the Indian sub-continent.

Effective management of leopard populations is dependent on our understanding of their distribution, abundance and their response to various available resources. The availability and abundance of prey is one of the major factors that affect the community of large cats (Sunquist and sunquist, 1989; Bailey, 1993; Karanth and Sunquist, 1995; Khan, 2004; Kumar 2011). Studies have shown that prey depletion can be more important than poaching or habitat loss in reducing populations of large cats (Karanth and Stith, 1999). Thus it becomes imperative to have reliable data on prey diversity, distribution and abundance for effective conservation and management of leopards. Similarly studying foraging behavior of a carnivore is highly significant since trophic resources dominate most other aspects of carnivore biology (Bekoff *et al*. 1984). Knowledge gained on food habits of a carnivore has key contribution for conservation and management of the species and is vital for dealing effectively with human-wildlife conflict. Moreover, gaining insights about a generalist carnivore diet helps to recognize its plasticity in using the resources in various human altered landscapes, which has implications in effectively managing carnivore populations at human-wildlife interface.

1.2 Significance of Himalayan mountain ecosystems

About 10% of the world’s human population depends directly on mountain resources for their livelihoods and wellbeing, and an estimated 40% depend indirectly on mountain resources for water, hydroelectricity, timber, biodiversity and niche products, mineral resources, flood control, and recreation (Schild 2008). In India, the most prominent mountain chain which bisects the country from rest of the Asia is the Himalayan Mountain Range. Indian Himalaya (ca. 236,300 km^2), encompasses two biogeographic zones – Trans Himalaya and Himalaya, covering approximately 12 %

of geographical area of India (Ghosh 1996) and has direct control over the climate of Indian Planes (Gupta and Nair 2012), influencing the status and abundance of biodiversity. It covers fully or partially the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, West Bengal, Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Tripura and Meghalaya. The complex orogeny of the Himalaya, coupled with the ensuing climatic and edaphic factors has aided its colonization by the floral and faunal immigrants from the neighboring regions (Pandit *et al*. 2000). As a result Himalaya has become a repository of extremely rich and endemic biodiversity (Rau 1975; Nayar 1996; Pandit *et al*. 2000). On account of richness and uniqueness of biodiversity elements and wide-ranging indigenous knowledge systems on use of bioresources, the region has emerged as a global conservation priority (Dhar 1997, Rawal and Dhar 2001).

In order to promote in situ conservation and preserve rich repositories, the Protected Area Network (PAN) program was initiated in India (Rodger and Panwar 1988). Despite various conservative measures taken, the rate of deterioration of fragile Himalayan environment has increased tremendously in recent past, mainly attributed to ever increasing human population pressure. Habitat degradation and hunting has worst impact on large carnivores, as being slow-breeders they have low potential for population recovery over short time scale (Sodhi *et al*. 2009). Hence, it is crucial to understand and monitor the ecology of a top carnivore from one of the world's most diverse and fragile ecosystem such as the Himalayas.

1.3 Leopard

1.3.1 Study species

Panthera pardus belongs to order Carnivora, family Felidae and has 9 subspecies (Uphyrkina *et al*. 2001); 8 if *P. p. nimr* is included with *P. p. ciscaucasica* (Miththapala *et al*. 1996).

1) African leopard (*P. p. pardus*), (Linnaeus 1758) — inhabits sub-Saharan Africa;
2) Indian leopard (*P. p. fusca*), (Meyer 1794) — inhabits the Indian Subcontinent;
3) Javan leopard (*P. p. melas*), (Cuvier 1809) — inhabits Java, Indonesia.
4) Arabian leopard (*P. p. nimr*), (Hemprich and Ehrenberg 1833) — inhabits the Arabian Peninsula;

5) Amur leopard (*P. p. orientalis*), (Schlegel 1857) — inhabits the Russian Far East, Korean Peninsula and Northeast China;
6) North Chinese leopard (*P. p. japonensis*), (Gray 1862) — inhabits northern China;
7) Caucasian leopard (*P. p. ciscaucasica*), (Satunin 1914), later described as

   Persian leopard (*P. p. saxicolor*), (Pocock 1927) – inhabits central Asia: the Caucasus, Turkmenistan and northern Iran;

8) Indo-Chinese leopard *(P. p. delacouri*), (Pocock 1930) — inhabits mainland Southeast Asia;
9) Sri Lankan leopard (*P. p. kotiya*), (Deraniyagala 1956) — inhabits Sri Lanka.

In the present study, the Indian subspecies of leopard *Panthera pardus fu*sca was studied. This species was first described by Friedrich Albrecht Anton Meyer in 1794, in his first description of *Felis fusca*, in which he gave account of a panther-like cat from Bengal. Earlier Kashmir Leopard (*Panthera pardus millardi*), (Pocock 1930) was considered as a separate sub species but it was later on clubbed with *Panthera pardus fusca (*Miththapala *et al.* 1996).

1.3.2 General description

Leopard is a large spotted cat distinguished from other members of the genus *Panthera* by its distribution throughout sub-Saharan Africa and Asia and its characteristic dark, rosette spots. It is one of the most widely distributed and highly adaptable big cats that has pelage hues varying from pale yellow to deep golden or tawny color and are patterned with black rosettes which vary from individual to individual. Pocock (1932) described four different coloration patterns that correspond to the semi-desert, savannah, rainforest and high mountain leopards. The coat and color patterns vary widely across various types of habitat. Fur is generally soft and thick, with individuals living in colder climates having longer fur than those from warmer habitats (Turnbull-Kemp 1967). Melanistic forms occur throughout its range, mostly in humid areas (Seidensticker and Lumpkin 1991; Nowell and Jackson 1996). Albino leopards have also been reported from some places (Divyabhanusinh 1993; Stein and Hayssen 2013). The leopard shows considerable variation in its physical appearance, individual measurements can vary by geographic region with smaller individuals typically coming from Cape Province, South Africa, where adult male leopards have a mean mass of 31 kg (range, 20–45 kg), whereas the more typical masses for adult male leopards are reported from Zimbabwe as 60 kg (range, 52–71kg) with individuals up to 90 kg at some occasion (Kitchener 1991). Ranges of mean body mass (kg) for 34 females and 47 males from India, the Ivory Coast, Namibia, and South Africa were 21.2–54.0 and 30.9–62.6, respectively (Robinette 1963; Smithers 1983; Grimbeek 1991; Bailey 1993; Jenny 1996; Marker and Dickman 2005; Stein 2008, Stein and Hayssen 2013). Average adult weights obtained from Sri Lanka are 56 kg for males and 29 kg for females, while two males from Central India weighed 50 and 70 kg (Nowell and Jackson 1996). The body length of up to 8 ft has been measured from nose to tail (Daniel 1996). Weight of leopards from Dachigam National Park was reported ranging from 38 kg to 65 kg (n=4) and body lengths varied from 124 cm to 205 cm (Habib *et al.* 2014). Compared to other members of the Felidae family, the leopard has relatively short legs and a long body with a large skull. It is similar in appearance to the jaguar, but it is smaller and well built. Its fur is marked with rosettes similar to those of the jaguar, but the leopard's rosettes are smaller and more densely packed, and do not usually have central spots as the jaguar's do. Both leopards and jaguars that are melanistic (completely black or very dark) are known as black panthers. Average life span of a leopard in wild has been reported as 12 – 17 years. But, there are reports that at least 27 animals in zoos have lived for 20–27 years (Grassman and Larney 2002; Weigl 2005; Stein and Hayssen 2013).

1.3.3 Origin

Fossil records for the leopard as well as for other *Panthera* cats are controversial. The first felid like carnivores appeared in the Oligocene, approximately 35 million years ago. Living cat species (sub family Felinae) originated in the late Miocene and evolved into one of the world's most successful carnivore families, inhabiting all the continents except Antarctica (Nowell and Jackson 1996; Nowak 1999). However, the pantherine cats as a whole diverged about 6.37 million years ago while leopards diverged about 3.72 million years ago (Johnson *et al*. 2006). The oldest pantherine fossils occur in Africa but molecular phylogenies point to Asia as their region of origin (Tseng *et al*. 2013). This contradiction has been cleared by the recent discovery of a fossil pantherine from the Tibetan Himalayas, with the age of Late Miocene –

Early Pliocene, replacing African records as the oldest pantherine, thus clearing doubts and providing robust support for the Asian origin of the pantherines (Tseng *et al*. 2013). Leopards went to Europe during the middle of the Pleistocene. Their fossils have been found as far west as the British Isles. Later on they got extinct from Europe and many parts of Asia. The leopard, along with the lion (*Panthera leo*), tiger (*P. tigris*), jaguar (*P. onca*) and snow leopard (*P. uncia*) comprise felid genus *Panthera* thought to have diverged from a common ancestor 2–3 million years ago (Ma) (Hemmer 1976; Wayne *et al*. 1993; Johnson and O'Brien 1997).

1.3.4 Distribution

The leopard has the largest geographic distribution among all *Panthera* cats (Nowell and Jackson 1996), while as its distribution range (23.14×10^6 km^2) is second highest among all living wild cats (Brodie 2009). This success appears to be rooted in its generalist nature (Nowell and Jackson 1996) and adaptability to diverse habitats and a varied diet (Hayward *et al*. 2006a). The capacity of leopards to alter their behavior in close proximity to humans (Myer 1986; Hamilton 1976) enables them to occupy a wide array of anthropogenic landscapes (Henschel *et al*. 2008, Athreya *et al*. 2014). However its range has been reduced in recent times, although historically the leopard was distributed throughout northern Africa and over much of sub-Saharan Africa as remnant populations, Arabian Peninsula and Sinai/Judean Desert, south-western and eastern Turkey, and through Southwest Asia and the Caucasus into the Himalayan foothills, India, China and the Russian Far East, as well as on the islands of Java and Sri Lanka (Seidensticker and Lumpkin 1991; Nowell and Jackson 1996; Sunquist and Sunquist 2002). They are not found on the islands of Borneo or Sumatra (Nowell and Jackson 1996). The leopard is now near threatened and occupies only 65% of its historical range (Fig. 1). Leopards occur widely in the forests of the Indian sub-continent, through India and South-east Asia and are found in all forest types, from tropical rainforests to temperate deciduous, alpine coniferous, dry scrub and grasslands (Harrison and Bates 1991). In India, the leopards are found in all forested habitats across the country, absent only in the arid deserts and above the timber line in the Himalayas (Prater 2005).

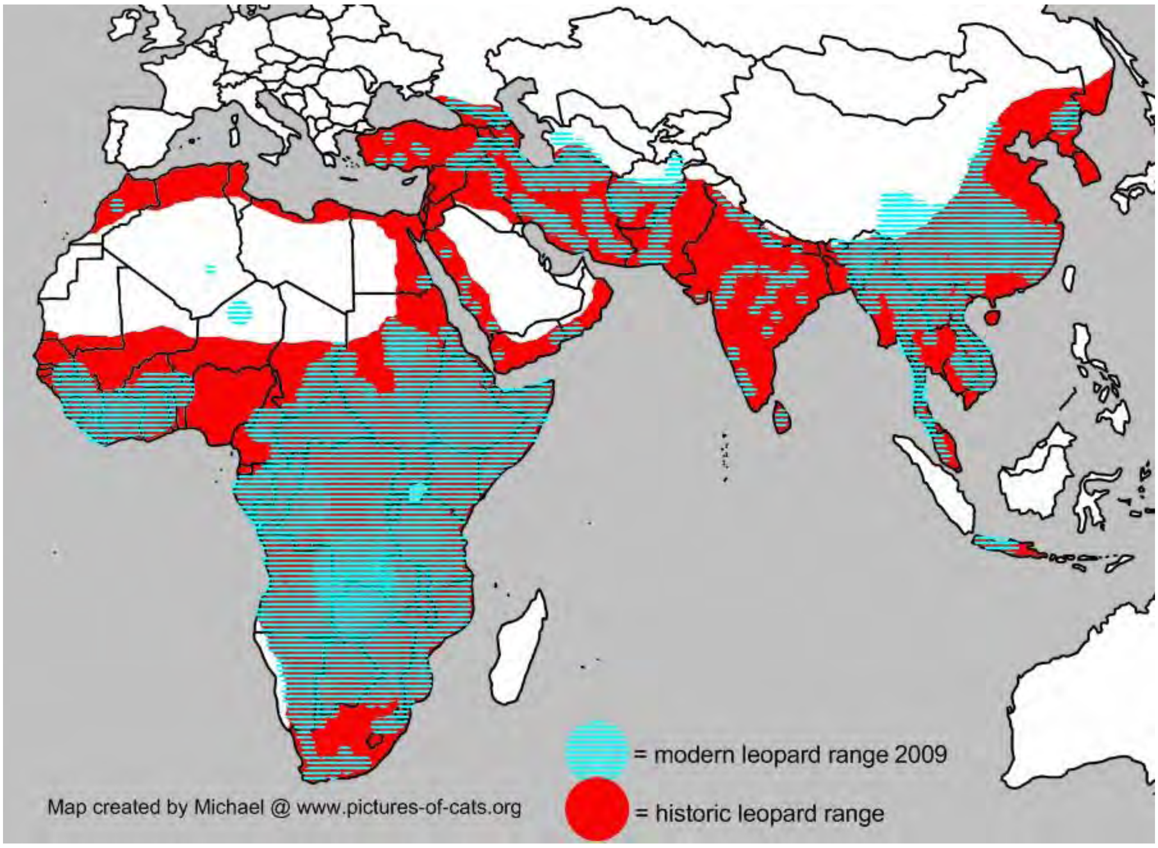

Fig.1.1 Modern and historic distribution range of leopard across the World.
(Map source: http://www.pictures-ofcats.org/Leopard-Habitat.html)

1.3.5 Conservation status and major threats

Worldwide, many large carnivore populations are threatened and humans are often the leading cause of large carnivore mortalities (Laliberte and Ripple 2004; Ripple *et al*. 2014). Like other large carnivores, leopards are declining throughout their range due to habitat conversion, prey depletion, intense persecution and poaching for trade (Nowell and Jackson 1996; Ray *et al*. 2005; Breitenmoser *et al*. 2007). Even with their remarkable adaptability, leopards have vanished from almost 40% of their historic range in Africa, and from over 50% of their historic range in Asia. Loss of habitat is the most serious long-term threat to leopards and their prey. Changing land use practices, soaring demands from our urban population and more recently fast expanding economic activity have started disturbing the delicate balance at which leopards survive (Wickramanayake *et al*. 1998; Ramesh 2010). A rapidly increasing threat to leopards is the poisoning of carcasses targeting carnivores, either as a means of predator control or the incidental cases (Henschel *et al*. 2008) and poaching for international trade (Breitenmoser *et al*. 2007).

The Wild Cat Status Survey conducted by the S*pecies Survival Commission (SSC)* Cat Specialist Group of the International Union for the Conservation of Nature (IUCN) has categorized leopard as one of the Near Threatened felids (Henschel *et al*. 2008). The leopard is placed in Appendix I in the Convention on International Trade in Endangered Species (CITES), and is protected under national legislation throughout most of its range (Nowell and Jackson 1996). In India, it is accorded highest level of protection by being listed under the Schedule I of the Indian Wildlife (Protection) Amendment Act, 2013.

1.3.6 Population status

Because of their widespread distribution and ecological adaptability leopards are considered to warrant low conservation priority. However, global population status is still uncertain because of difficulty in monitoring on account of their cryptic nature, low detectability and low population densities (Rabinowitz 1989; Bailey 1993; Nowell and Jackson 1996; Sharma 2005). Earlier, traditional pugmark census was used as the prime method of monitoring large cat abundances (Riordan 1998) which was later on largely criticized for lack of statistical robustness (Karanth 1995). Now, remotely used camera-traps in combination with standard capture-recapture population models (Seber 1982) provide useful and statistically robust alternative for non-invasive monitoring of large carnivores and their density estimates (Karanth 1995; Karanth and Nichols 1998; Jhala *et al*. 2008). Since individual leopards are readily identifiable using the rosette marks on the body (Schaller 1967, McDougal 1977, Karanth 1995), capture-recapture approach can be used to obtain reliable estimate of population parameters. Density estimates of leopards reported from different areas across the range vary from ~1 to 30.9 individuals 100/ km^2 with no evident relationship with broad habitat type (Kostyria *et al*. 2003; Khorozyan 2003; Chauhan *et al*. 2005; Spalton *et al*. 2006; Mondal 2006; Ngoprasert *et al*. 2007; Edgaonkar 2008; Henschel 2008; Sankar *et al*. 2008; Simacharoen and Dungchantrasiri 2008; Waseem 2008; Harihar *et al*. 2009a; Wang and Macdonald 2009; Riddhika 2009; Wegge *et al*. 2009; Chapman and Blame 2010; Stein *et al*. 2011; Majumder 2011; Selvan *et al*. 2014b, Athreya *et al.* 2013, Habib *et al*. 2014), but the site-specific factors such as levels of prey availability, fine-scale habitat variables, presence of co-predators and human disturbance might have an influence on the density. Population of leopards in the Russian Far East is estimated as a total of 60 individuals (Miquelle and Murzin 2003). Smaller populations are present in Thailand and Malaysia (Grassman 1999). The strong hold of leopards is in Africa, where large, continuous populations still exist (Henschel *et al*. 2008).

1.3.7 Diet and prey availability

As evident from its widespread distribution leopard can be found in different habitat types representing its wide habitat tolerance and versatility as a generalist predator (Nowell and Jackson 1996). The survival of any predator is directly related to the quality and quantity of its diet (Melville 2004). Distribution and abundance of carnivore species depends on the availability of different sized ungulate prey species (Karanth and Nichols 1998; Carbone and Gittleman 2002). However, information on the abundance of ungulate prey species is sparse in most of the Himalayan ecosystems (Seidentiscker 1976; Dinerstein 1980; Malla 2009; Wegge *et al*. 2009). Diet selection of leopard is primarily driven by opportunity to catch and maintain possession of its prey. Leopard's ability to survive on extremely small prey allows them to survive in places where large prey is unavailable or scarce. Bailey (1993) noted a minimum of 92 prey species were consumed by leopards in sub-Saharan Africa, and known prey ranges in size from arthropods (Fey 1964) to an adult male Sambar or Gaur (Seidensticker 1976a; Karanth and Sunquist 2000). Despite such an enormous prey size range, leopard diet is generally dominated by medium sized wild ungulates (<50 kg body weight) (Schaller 1967; Essenberg and Lockart 1972; Seidensticker 1976a; Johnsingh 1983; Rabinowitz 1989; Seidensticker *et al*. 1990; Johnsingh 1992; Bailey 1993; Karanth and Sunquist 1995; Edgaonkar 2008; Wang and Macdonald 2009). In mountainous and semiarid areas, leopards are known to preys upon small prey such as rock hyrax, bush duiker, and crested porcupine (Bothma and Le Riche 1984; Norton *et al*. 1986; Stuart and Stuart 1993; Stander *et al*. 1997a). Hayward *et al*. (2006a) reviewed 33 studies on leopard feeding ecology and found that leopards preferentially prey upon species within a weight range of 10 – 40 kg. Environments of lean resources or an absence of larger prey forces leopard to switch to more abundant sub optimal prey such as rodents (Ramakrishnan *et al*. 1999; Sankar and Johnsingh 2002;

Stuart and Stuart 1993; Hayward *et al*. 2006a) and/or secondary prey (livestock and dogs) (Seidensticker *et al*., 1990; Edgaonkar and Chellam, 2002; Goyal *et al*., 2007; Chauhan 2008; Shah *et al*. 2009). Leopard in general, does not target domestic stock or humans, but particular individuals may develop the habit of raiding livestock or human settlements (Corbett 1947; Turnbull-Kemp 1967; Mizutani 1999; Stein and Hayssen 2013).

1.3.8 Spacing and habitat utilization

Adult leopards are solitary with the exception of females rearing cubs and during mating when males and females associate for several days before separating again (Eisenberg and Lockhart 1972). Like other solitary carnivores, the female leopards are expected to space themselves according to resource availability, while the male spacing is based on both receptive female and availability of food resources. Generally home ranges of leopards are largest where prey availability is relatively low and ranges are smallest where prey availability is high and cover is available (Stein and Hayssen 2013). Reported home range of leopard varies from 6 km^2 (Seidensticker *et al*. 1990) to over 2,182 km^2 in African arid ecosystems (Bothma and Le Riche 1984), however generally male territories range between 30 and 78 km^2, whereas 15 – 16 km^2 are common for females (Nowell and Jackson 1996). In the Indian subcontinent, in Nepal Himalayan ecosystem, the ranges of the female leopards have been estimated to range 5.2 - 17km^2, whereas for male leopard it was a maximum of ~ 48 km^2 (Sunquist 1983; Seidensticker et. al.1990; Odden and Wegge 2005). Singh *et al*. (2004) recorded large home range for female leopard (76 km^2) in the Gir National Park and Sanctuary, Gujarat. In Wilpattu National Park, Sri Lanka, the home range of adult female was estimated to be 8-10 km^2 by Muckenhirn and Eisenberg (1973). Recent study from Dachigam National Park reported home range of male leopard as 145.4 km^2 and that of female leopard as 54.2 km^2 (Habib *et al.* 2014).

The leopard is a wide-ranging large carnivore and is a generalist with respect to habitat requirements as well as diet (Sunquist and Sunquist 2002). However, preference is shown to certain types of habitats over others. Habitats comprising mixed deciduous and dry ever green forest types, flat slope and stream channels are found to be preferred by leopards in Thailand (Simcharoen *et al*. 2008). Leopards are presumed to be tolerant of human disturbance and are reported to be found near agricultural fields and human habitations (Prater 2005). However, leopards largely prefer protected forest areas rather than disturbed human dominated areas and depend on a variety of wild prey base (Bailey 1993). Moreover leopard habitat use intensity increases positively with distance from the human disturbances (Ngoprasert *et al*. 2007). Presence of other large carnivores like tiger and lion has a significant impact on habitat use of leopards where ever these cats co-exist (Seidensticker 1976a). Some studies suggest that interference competition causes leopards to avoid tigers in both space and time (Odden *et al.* 2010; Carter *et al.* 2015), however others revealed high levels of spatiotemporal overlap between individuals of the two species (Karanth and Sunquist 2000; Ramesh *et al.* 2012a). Recent a study conducted by Maputla *et al.* (2015) concluded that movements of collared leopards were not strongly affected by lion presence, and suggested resource availability as the main driver of leopard movement patterns.

1.3.9 Human-leopard conflict

Leopards have always been associated with human settlements across India even from historical times (Daniel 1996). Human-leopard conflicts most commonly involve killing of livestock, occasionally involve attacks on humans and leopard persecution (Mizutani 1995; Nowell and Jackson 1996; Negi 1996; Edgaonkar and Chellam 1998; Mukherjee and Mishra 2001; Goyal *et al*. 2007; Kissui 2008; Tamang and Baral 2008; Chauhan 2008; Dar *et al*. 2009; Inskipp and Zimmerman 2009). Unless addressed equitably, such conflict places leopards at an increased risk of retributive killing or poaching may it be inside or outside the protected areas. Therefore, effective conflict management strategy is essential for conservation of leopards. Any attempts made to mitigate human - leopard conflict (Athreya and Belsare 2007) and improve the conservation status of the species should be based on an explicit understanding of the conflict patterns (Dar *et al*. 2009) and perceptions. Studying perceptions of people provides us insight about their tolerance towards economic losses caused by carnivores.

1.4 Past studies

Leopard is known to be the least studied species among the large carnivores. But the scenario is changing now as numerous studies are being conducted on different aspects of leopard ecology across its distribution. Most of the studies on leopards have been conducted in Africa (Schaller 1972; Hamilton 1976; Bertram 1982; Bothma and Leriche 1984; Grimbeek 1991; Bailey 1993; Jenny 1996; Laman and Knott 1997; Ray and Sunquist 2001; Uphyrkina *et al*. 2001; Henschel *et al*. 2005; Khorozyan *et al*. 2008; Stein 2008; Balme *et al*. 2010; Stein *et al*. 2011; Balme *et al*. 2012; Swanepoel *et al.* 2014a, 2014b; Balme *et al*. 2014; Braczkowski *et al.* 2015; Swanepoel *et al*. 2015). In India, leopards have been studied addressing human-leopard conflicts (Edgaonkar and Chellam 1998; Athreya and Belsare 2007; Goyal and Chauhan 2006; Kumar 2011), and other ecological aspects including diet population estimation and ranging (Johnsingh 1983; Sathyakumar 1992; Karanth and Sunquist 1995; Daniel 1996; Edgaonkar and Chellam 1998; Ramakrishnan *et al*. 1999; Sankar and Johnsingh 2002; Chauhan *et al*. 2005; Qureshi and Edgoankar 2006; Maheshwari 2006; Andheria *et al*. 2008; Arivazhagan *et al*. 2008; Edgaonkar 2008; Sankar *et al*. 2008; Chauhan 2008; Harihar *et al*. 2009b; Riddhika 2009; Wegge *et al*. 2009; Wang and Macdonald 2009; Ramesh *et al*. 2009; Majumder 2011; Kalle *et al*. 2011; Mondal 2012; Borah *et al.* 2013; Zehra 2013; Athreya *et al*. 2014). Leopard ecology has also been studied in Java, Indonesia (Santiapillai and Ramono 1992), Sri Lanka (Eisenberg and Lockhart 1972; Santipillai and Chambers 1982; Kittle 2014), Nepal (Seidensticker *et al*. 1990, Thapa *et al*. 2014), Bhutan (Wang 2008), Thailand (Rabinowitz 1989; Grassman 1999) and Pakistan (Waseem 2008; Shehzad *et al*. 2014; Chattha *et al*. 2015).

1.5 Studies carried out in Dachigam National Park and the origin of present study

Although, Dachigam National Park (Dachigam NP) is an ideal place for researchers owing to its rich biodiversity and unique ecosystem, it has almost been neglected in terms of research for long time because of more than two decades of socio-political turmoil in the state of Jammu and Kashmir. Some of the pioneering studies carried out here in the past include – observations on various behavioral aspects of the hangul deer (*Cervus elaphus hanglu*) like rutting, seasonal migration and food availability (Schaller 1969). Kurt (1977, 1978, 1979) estimated the food availability in winter and spring seasons by analyzing 180 plots along 8 transects through the lower Dachigam. Shah *et al*. (1983) studied the winter diet of the hangul. Manjrekar (1989) studied the food habits of the Asiatic black bear (*Ursus thibetanus*). After a long gap recently some more studies were conducted in Dachigam NP, like prey-predator relationships between hangul and leopard (*Panthera pardus*) were studied by Iqbal *et al*. (2005) and some ecological and conservation aspects of hangul were studied by Ahmad (2006) and Ahmad *et al*. (2009). Following this, a long term monitoring program was initiated by the Wildlife Institute of India to study ecological aspects of the Asiatic Black Bear which also looked into spatial organization of the black bears through satellite telemetry (Charoo 2012; Sharma 2012; Sathyakumar *et al*. 2013). Mukesh *et al*. (2013) studied genetic diversity and inbreeding of hangul in Dachigam NP. Mukesh *et al*. (2015) investigated the genetic variability and demographic history of the hangul population and found that it shows a relatively low genetic diversity estimates when compared to other red deer populations of the world. In addition to the studies conducted on mammalian guild some studies have also been conducted on the avifauna of Dachigam National Park (Katti 1989; Ahmad 1999; Wani 2012).

Strategic location of Kashmir in terms of leopard distribution across the globe makes this leopard population more important in terms of conservation. Leopards co-exist with other big cat species like Lions in Gir and Tigers in most of the tiger reserves but it is sole large predator in the state of Jammu and Kashmir. Though leopards are widely involved in conflict with humans in whole of the Jammu and Kashmir no initiative has been taken to study ecology of leopard and document status of its potential prey in the state over the years. A survey conducted in the state of Jammu and Kashmir on human-leopard conflict reported 60 cases of attacks on humans from 1999 – 2007 (Iqbal *et al*. 2005; Singh *et al*. 2007). Another study conducted on human wildlife conflict in Kashmir valley reported 73 cases of leopards attacks on humans since 1996 (Choudhury *et al.* 2008). The movement of the leopards outside the protected areas of Jammu and Kashmir is governed by various factors. Outside the state of J&K, crops like sugar-cane provide ample cover for the leopards to survive outside the protected areas (Athreya *et al*. 2011), but in the state of Jammu and Kashmir no such cover is available to leopards which make them more prone to the conflict. Harsh winters with low availability of prey base will defiantly govern some distinction in the ecology of the leopards here which needs to be studied.

Dachigam National Park is one of the most important protected areas located in North western Himalaya as it holds the last viable population (~218 individuals; Charoo *et al*. 2011a) of Hangul – a sub-species of European Red Deer (*Cervus elaphus*), in the Indian subcontinent. Recent study on hangul conducted by Mukesh *et al*. (2015) strongly recommended for up-gradation in its conservation status owing to low genetic variability, imbalanced sex ratio, low recruitment rate and reduction in distribution range and population size. Population of hangul has shown a dwindling trend in the recent past and it was perceived that predation by leopard is responsible for the decline of hangul population in the area although there was no long term systematic study to validate or rule out this assumption. Thus study dealing with dietary habits of leopards in the park holds significance from hangul conservation point of view as well. Moreover, two decades of political instability in the region has put the wildlife research in remote corner creating a gap in the scientific knowledge on the wild fauna of the area, which needs to be filled for the effective conservation and management of the ecosystem as well as for managing carnivore populations proficiently. This generated a strong need and scope for research on understanding basic ecological aspects of top-carnivore of the region and studying its feeding ecology in relation to prey availability.

With this background, present study was initiated to collect empirical ecological information to aid in management of the leopard population in this biodiversity rich landscape. Diet of leopard with reference to potential prey availability in each season was studied. An attempt was also made to access the extent of human-carnivore conflict and attitudes of local people towards wildlife conservation around Dachigam NP. This would help in effective conservation of leopards, as the information that describe resource availability (prey abundance), resource utilization (diet), and the constraints (conflicts with humans) leopards are facing, is important requisite to devise the conservation strategy for the species and subsequent management planning and legislations.

1.6 Objectives

The present study on ecology of leopard in Dachigam NP, Jammu & Kashmir, was carried out with the following objectives:

1. To study the leopard prey availability and distribution across different seasons in Dachigam NP.

2. To study the food habits and prey selection of leopard in different seasons in Dachigam NP.

3. To quantify the nature and extent of human-carnivore conflict around Dachigam NP.

1.7 Study period

The study was conducted from December 2010 to December 2013 covering four different seasons, winter (December to February), spring (March to May), summer (June to August) and autumn (September to November). This study was a part of a research project, 'Ecology of leopard *Panthera pardus* in relation to prey abundance and land use pattern in Kashmir Valley' initiated by the Wildlife Institute of India, Dehradun funded by Department of Science and Technology, Govt. of India. All field equipments and logistic support required for this study were provided by the Wildlife Institute of India, Dehradun.

1.8 Instruments / equipments used

The following equipments were used to measure/quantify different geographical, climatic and ecological parameters:

1) Compass KB20 /360R Sunnto with 1^o accuracy for sighting angle and aspect categories. Aspect was measured on an eight point scale (North: 337°-22°, Northeast: 23°-67°, East: 68°-112°, Southeast: 113°- 157°, South: 158°-203°, Southwest: 204°-247°, West: 248°-292° and Northwest: 293°-336°) using a Sunnto compass

2) Bushnell Binoculars – 8 × 42 for field identification

3) LASER Range finder (Bushnell) for measuring sighting distances

4) Garmin Etrex H Handheld GPS for geographic position

5) Mercury thermometer with the range between - 20°C and 50°C for recording temperature

6) Nikon D 7000 SLR Camera with 55 - 300 mm lens for photo documentation

7) Sherman live traps for capturing rodents

1.9 Organization of the thesis

The thesis has been organized into five chapters. As a general introduction, Chapter 1 describes the background of this study, details in ecological aspects of leopard, describes the need of this study, the study objectives, the study period and the instruments/equipments used in the study. Chapter 2 deals with descriptive account of the study area, which includes the history, topography, climate, vegetation and available fauna in the study area. Chapter 3 deals with the abundance of different prey species in the study area. This chapter further describes trends in the density and spatial distribution of prey populations in different seasons. Chapter 4 describes seasonal food habits of leopard, which includes the percentage occurrence of each prey species in leopard's diet, proportion of their biomass consumption and prey selection by leopard. Chapter 5 attempts to assess the extent of human-carnivore conflict along the fringes of Dachigam NP. It further deals with studying attitudes of locals toward wildlife conservation in the area. Chapter 6 discusses major finding of this study and provides different recommendations based on them.

CHAPTER 3

SPATIAL MODELING OF PREY DENSITY

3.1 Introduction

The role of predator and prey in regulating the size, abundance, and distribution of each other has become a central tenet in all the ecological studies focusing on their mutual interactions. Various studies have demonstrated the influence that life history characteristics of both predator and prey can exert on ecosystem dynamics and the subsequent strength of "top-down" and "bottom-up" forces (Moran *et al*. 1996; Woodward and Hildrew 2002; Rosenheim *et al*. 2004). Top-down regulation is the controlling influence exerted by a species at higher trophic level (Carnivore) on the species at next lower level (their prey) and so forth down the trophic ladder (Estes 1996; Terborgh *et al*. 1999). Similarly bottom- up regulation deals with how resources (space and nutrients) influence higher trophic forms. Both these regulations are very critical for maintaining a proper balance in an ecosystem by shaping the dynamics of populations and communities (Borer and Gruner 2009). Distribution and abundance of carnivore species is highly dependent on the availability of their prey species (Karanth and Nichols 1998; Carbone and Gittleman 2002). Prey abundance is an index of the amount of energy available for a predator in an area (Sunquist and Sunquist 1989). Abundance as well as distribution pattern of different prey species in a multi-prey system plays a critical role in determining foraging behavior of a carnivore. This is especially true when carnivore involved is a generalist and can show prey switching according to the availability of optimal prey. Thus any effort towards ecological study of a large carnivore needs an equal scale study on prey density and distribution.

Prey - predator relationships are so sensitively balanced that the data on prey availability can be used to reliably predict predator densities of a particular area (Carbone and Gittleman 2002; Karanth *et al*. 2004a; Khorozyan *et al*. 2008). Thus, conservation of key prey species is crucial for the survival of any large predator as changes in preferred prey abundance could alter its population status (Hayward *et al*. 2006b; Hayward *et al*. 2007; Wegge *et al*. 2012). For making proper decisions about species conservation we need to have reliable data on population densities as well as spatial distribution of that species. Moreover, the impact of wild prey abundance and distribution on human carnivore conflict has become an important area of study owing to increase in the conflict rate in recent past. There are several studies emphasizing on correlation between low natural prey availability and high predation rates on domestic livestock (Woodroffe *et al*. 2005a; Kolowski and Holekamp 2006; Holmern *et al*. 2007).Thus it becomes imperative to acquire and maintain reliable database giving information regarding wild prey diversity and abundance in a particular area, so that it may be taken into consideration while devising conflict mitigation measures.

There are numerous population estimation methods employed by researchers to enumerate prey species. Suitability of these methods varies with environment and the species involved (Mandujano and Gallina 1995; Sinclair *et al*. 2006; Vine *et al*. 2009). Certain constraints need to be taken care of while selecting a population estimation method, like it must be relatively low cost, easy to use, effective for the labor input and must be repeatable. Ideally population estimation methods should be able to detect the presence of all other large terrestrial vertebrates in addition to the target species. Distance sampling (Buckland *et al*. 2001) is one the most widely used, practical, efficient and relatively inexpensive technique for sampling many biological populations. This method has been successfully used to estimate ungulate densities across the globe as well as within the Indian sub-continent. Early studies conducted for estimating population parameters of different prey species in south Asian forests include the studies from India (Schaller 1967; Berwick 1974; Johnsingh 1983; Mathur 1991), Srilanka (Eisenberg and Lockhart 1972) and Nepal (Seidensticker 1976b; Dinerstein 1980; Tamang 1982). Latter on various studies were conducted in India using robust DISTANCE sampling technique for prey population estimation (Karanth and Sunquist 1992; Varman and Sukumar 1995; Khan *et al*. 1996; Karanth and Nichols 1998; Biswas and Sankar 2002; Jathanna *et al*. 2003; Bagchi *et al* 2003; Karanth *et al*. 2004a; Harihar 2005; Edgaonkar 2008; Harihar *et al*. 2009b; Malla 2009; Ramesh 2010; Thapa 2011; Majumder 2011; Ramesh *et al*. 2012b; Mondal *et al*. 2012; Zehra 2013; Selvan *et al*. 2014a). However, information on the abundance of prey species is sparse in most of the Himalayan ecosystems (Seidentiscker 1976a; Dinerstein 1980; Tamang 1982; Malla 2009; Wegge *et al*. 2009; Selvan *et al*. 2014a; Harihar *et al*. 2014a). Prey density estimates have been used in various studies to calculate standing biomass availability in kilograms per square kilometer like Ramesh *et al*. (2009) reported prey biomass of 8365.02 kg/km² from Mudumalai Tiger Reserve, Edgaonkar (2008) in Satpura national park reported available biomass of 6611.96kg/km² and Ramesh *et al* (2012b) from Kalakad-Mundanthurai Tiger Reserve estimated prey biomass of 2614 kg/km². Recently Selvan *et al*. (2014a) studied biomass availability in Eastern Himalayan Pakke Tiger Reserve and reported standing biomass of 2182.56 kg/ km^2 from the area.

3.1.1 Present Study

Leopard has been reported to feed upon a wide variety of prey across its distribution range (Hayward *et al*. 2006a). Its diet varies from place to place mostly based on the availability of prey species in different habitats. The fauna in general and prey assemblage in particular is unique in the state of Jammu and Kashmir due to its geographical location; there is an influence of the Tibetan elements mixed with those of the Himalayan and the peninsular Indian elements (Kaul 2002). However, the basic information pertaining to distribution, abundance and ecology for many species in this Himalayan ecosystem is limited due to rugged terrain, low accessibility, extreme weather conditions, etc. (Schaller 1977). Till now, no systematic research has examined the abundance and structure of potential prey populations in Kashmir valley, except a few studies concentrated on ecology of hangul in Dachigam NP (Ahmad 2006; Ahmad *et al.* 2015) and ecology of markhor (*Capra falconeri*) in Pirpanjal range (Ranjitsinh *et al.* 2005, Ahmad 2014) leaving void in sound understanding of wildlife ecology.

Hangul in Dachigam National Park shows seasonal movement driven by climatic conditions. During the peak of winter, when the majority of Dachigam National Park remains snowbound, hangul congregate in low lying riverine habitats in search of forage and shelter (Ahmad *et al.* 2015). And later on in summer season they move to alpine pastures and birch forests at higher elevations (Farooq *et al.* 2012). In these conditions the study of biotic and abiotic factors that influence the seasonal distribution and abundance of this endangered species becomes vital for their effective conservation and management. And there is a need to relate density estimates to the spatial variables reflecting topography, habitat, and other factors that may be directly or indirectly affecting the animal population. Density Surface Modeling (DSM) approach provides a good framework for modeling spatial variation in animal density using standard generalized additive modeling (GAM). In this context, this study was initiated to assess prey abundance and spatial-distribution of prey including hangul using DSM approach in Dachigam NP. Preliminary dietary analysis of leopard during this study revealed presence of rodents in their diet, so rodent population density was also estimated in the study area on seasonal basis. Specifically this study was designed to answer following questions:

1. How does density of different prey species in Dachigam NP vary with seasons?
2. What is the spatial distribution of density of prey species in Dachigam NP?
3. What are the factors governing spatial distribution of prey in different seasons in the area?

3.2 Methodology

3.2.1 Prey abundance

In order to get a fair knowledge of the area, a reconnaissance survey was carried out in the early months of the study period in whole of the study area. The population of hangul and Kashmir gray langur were then estimated on seasonal basis using Distance sampling technique (Burnham *et al*. 1980; Buckland *et al.* 1993). In total 13 line transects (ranging from 1.5 to 2.5 km in length) were laid in different habitats covering a distance of 26.05 km (Fig. 3.1). Each transect was walked 12-18 times each season during morning hours (6:00 to 10:30 AM). Total transect effort was 1499.1 km for all seasons. In each monitoring, the number of clusters detected, cluster size, cluster composition, sighting distance (measured by a laser range finder), sighting angle (measured by compass - Sunto) and geographic coordinates (recorded by a GPS - Garmin eTrex) were recorded for each prey species encountered. The sighting distance and angle for animals occurring in clusters were recorded from the perceived geometric center of the cluster. Clusters were counted independently with distance of at least 40 - 50 meters from its nearest neighbor (Karanth and Sunquist 1992, Focardi 2002).

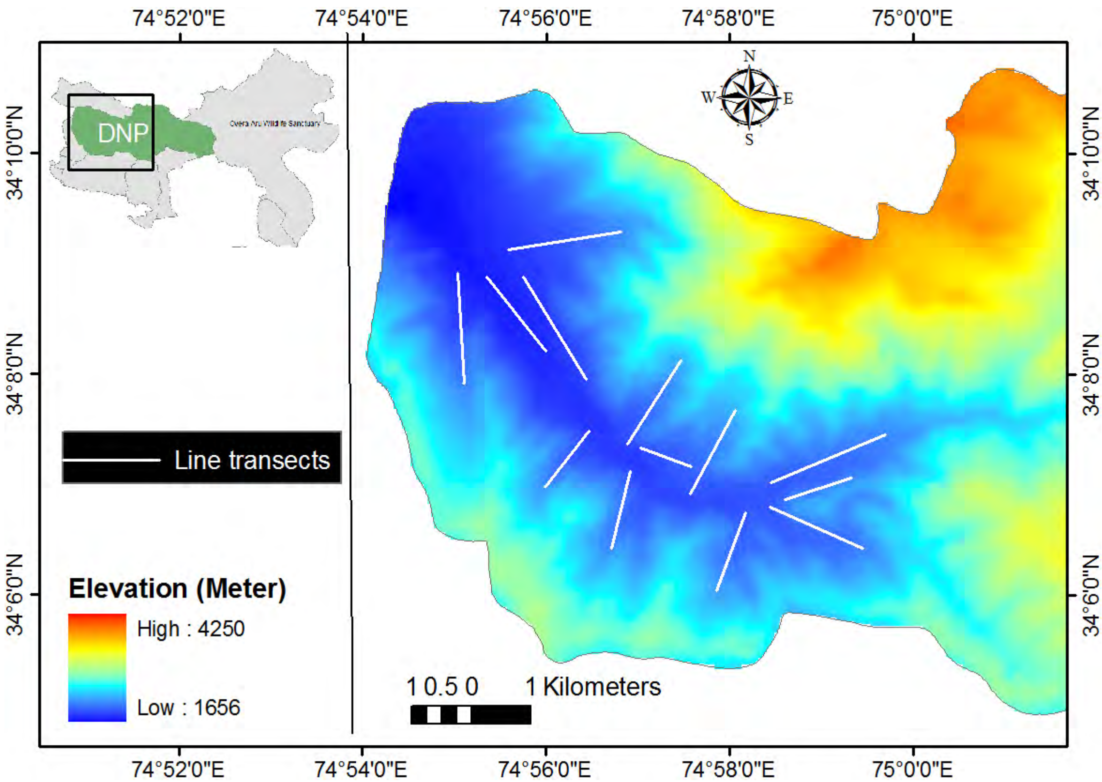

Fig. 3.1 Locations of line transects in Dachigam National Park

Table 3.1 Season wise details of sampling effort for monitoring of line transects

Season	**Total effort (km)**
Winter	312.6
Spring	449.4
Summer	416.8
Autumn	320.3
Total	1499.1

Density of rodents was estimated using live trapping at six different sites in the study area. Sherman live traps (n = 49; each with dimensions 5 cm x 6.5 cm x 16.5 cm) were used for 7 consecutive trap nights at each site in all the four seasons. Total sampling period amounted to 2058 trap nights per season. At each site, traps were placed in a concentric web design with a radius of 60 m covering an area of 1.1 hectare (Fig. 3.2). Each trap station was established 10 m apart in the sampling area. Peanut butter baits were used to trap rodents. Traps were set in the evening and checked for animals after sunrise the very next morning. The animals were then released at the spot of their capture.

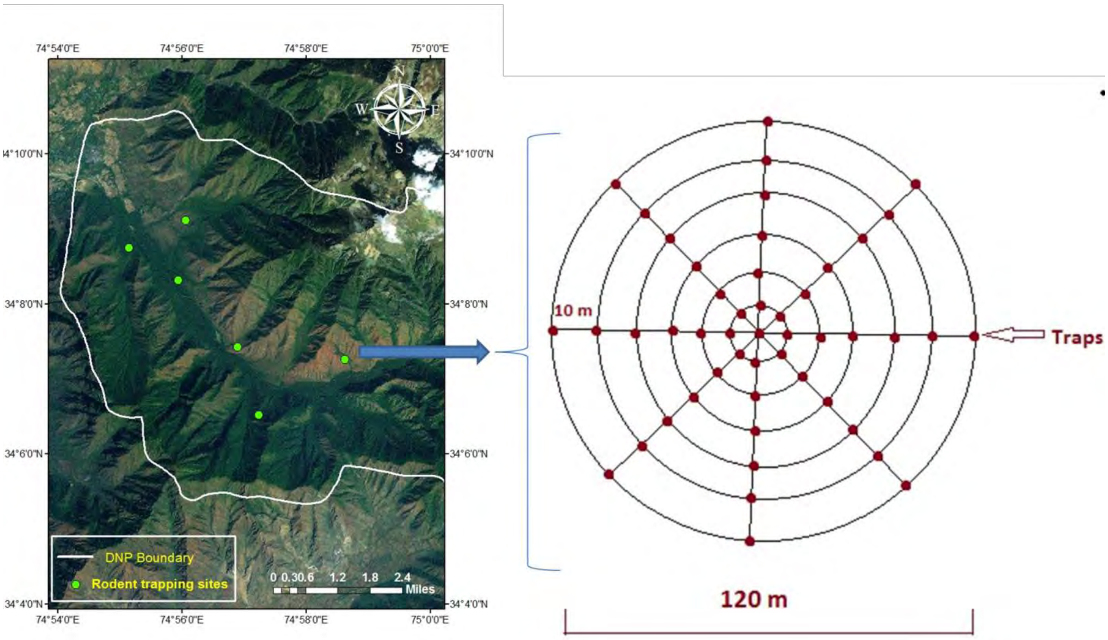

Fig. 3.2 Locations of Sherman traps placed in a web design

Data was analyzed using program DISTANCE version 6.0 to estimate population densities of langur, hangul and rodents in different seasons. Prior to generating final results, an exploratory analyses of the distribution of the distances was done on data and plotting the resulting histograms in program DISTANCE (Buckland *et al*. 2001) to detect for any evidence of evasive movement, 'rounding' and 'heaping' of data and to truncate outlier observations, if necessary, for improving model fitting (Jathanna *et al*. 2003; Edgaonkar 2008). An appropriate model (the best key function- with the appropriate adjustment term) was judged using Akiake's Information Criteria (AIC) values provided that the p-value for the chi-square goodness of fit for the model was greater than 0.05 (Burnham and Anderson 2002). Parameters such as encounter rate (n/L), strip width (ESW), average probability of detection (p), cluster density (DS), cluster size and prey density (D) were also estimated using program DISTANCE (Burnham *et al.* 1980; Buckland *et al*. 1993). Density estimates are presented on seasonal basis for langur, hangul and rodents.

The biomass (kg/km²) of each prey species was calculated by multiplying the mean individual density (D) by its average estimated unit weight (Wegge *et al*. 2009). The average body weights of prey species were taken from published references (Hayward 2006b; Macdonald 2001). Biomass availability was estimated for all the four seasons in the study area from year 2011-2013.

3.2.2 Age Structure and Sex ratio

During regular sampling of the line transects data on age and sex composition were also recorded. Individual animals were classified as adult male (AM), adult female (AF), sub adult male (SM), sub adult female (SF) and young (Y) on the basis of physical characteristics. Animals were categorized to sex and age classes using combinations of sexually dimorphic physical characteristics, such as morphological configuration, external genitalia, age-specific differences in body size, presence, shape and size of antlers and association with parents.

3.2.3 Spatial distribution of prey

3.2.3.1 A review of Density Surface modeling (DSM)

With the advancement in research and analytical techniques, there is a strong demand to extract more than just an abundance estimate from the sighting data obtained from line transect monitoring. Hedley (1999) and Hedley and Buckland (2004) working on cetaceans, for the first time developed methods (Density Surface Modeling) for modeling heterogeneity in the spatial distribution from standard line transect data. This approach enabled spatial variation in animal density to be modeled using standard generalized linear modeling (GLM; McCullagh and Nelder 1989) or generalized additive modeling (GAM; Hastie and Tibshirani 1990; Miller *et al*. 2013). The transect lines were divided into smaller discrete units, and the expected number of detections in each unit was modeled using explanatory spatial covariates. Royle *et al*. (2004) gave point-transect distance-sampling model for binned radial distances, in which it is easy to relate explanatory covariates to the expectation of abundance at small spatial scales. Katsanevakis (2007) and Winiarski *et al.* (2013) modeled density of *Pinna nobilis* and Common loons (*Gavia immer*) respectively using density surface modeling (DSM) approach. Harihar *et al.* (2014a) used this approach to model density of tiger prey over space in Western Terai Arc Landscape, India. Recently, Morgio *et al*. (2015) used DSM to monitor red deer population in the Italian Apennines. Density surface modeling and the inferred relations to spatial covariates might provide insights and act as the basis for further ecological investigations seeking causal relationships between abundance and environmental covariates.

3.2.3.1 Method (DSM)

Data from line-transect surveys was used in density surface modeling framework to model the distribution of hangul and Kashmir gray langur in the study area. DSM approach has been recently developed to model distribution of species by making use of different covariates in a generalized additive modeling framework (GAM) (Hedley *et al*. 1999; Hedley 2000; Hedley and Buckland 2004). DSM was basically developed to enable modeling of line transect data across regions with varying survey coverage and with over dispersed, zero-inflated data (Hedley and Buckland 2004). Spatial modeling like DSM has an advantage that it does not require that transects be located according to a formal sampling scheme (i.e. random or stratified). This is useful when the viable option is a nonrandom ground sampling on existing roads or tracks. DSM also allows correction for imperfect detection of data collected using line transect methods (Thomas *et al*. 2010).

Increase in sample size makes the models in DSM more robust, hence, the transect data of winter and spring seasons were clumped to represent wet half of the year as maximum precipitation in the study area is received in these two seasons. Similarly, data from summer and autumn seasons were clumped for the purpose of analysis to represent dry half of the year. Density surface models were developed for each species in two steps: (1) abundances were estimated from line transect data using distance sampling methods (Buckland *et al*. 2001), then (2) a generalized additive model (GAM; e.g. Wood 2006) was fitted to those abundances with explanatory variables provided by spatially referenced environmental covariates. And on the basis of those models species density maps of different seasons were developed for whole study area.

For DSM analysis, line transects were subdivided into equal contiguous segments of 500 m each. And the sightings where assigned to respective segments accordingly. Distance analysis of data was then performed using package Distance (Miller *et al*. 2013) in the statistical software ‘R’ (R Development Core Team 2012). To account for variations in body sizes and grouping behavior of the species, I modeled the smooth function of perpendicular distances from line transects specific to each species, using uniform key with cosine adjustments, half-normal key with cosine or Hermite polynomial adjustments and hazard-rate key with simple polynomial adjustments as candidate forms of detection function. Data were examined for signs of evasive movement and the need for truncation was tested by examining the effect of removing 5–10% farthest sightings on estimates of the probability density function. Following this, models were selected on the basis of reliable fit of detection functions using Akaike Information Criterion (AIC) (Buckland *et al*. 2001).

For the spatial modeling process, the 'count method' was used (Hedley and Buckland 2004) and incorporated the segment area, as the offset term. Counts of individuals (per species) obtained along segmented transects were modeled as a function of segment-specific covariates indexing habitat variables. As modeling aim was to predict density over space by identifying the factors influencing abundance, covariates were chosen based on their potential predictive capability and availability across the entire study (Table 3.2). The covariates used consisted of geographic coordinates (latitude; y and longitude; x), terrain parameters (elevation and slope) and two variables representing vegetation characteristics (Normalized Difference Vegetation Index; NDVI and seasonality in NDVI; CVNDVI).

Generalized additive models, with quasipoisson error distribution and logarithmic link function was used to relate the estimated abundance values in each segment with spatial covariates. The optimal degrees of freedom for the smoothed function in GAMs were defined by generalized cross validation (GCV). Species-specific models were fit using forward–backward covariate selection, in which each forward step was followed by a backward step to remove any variables in the model that were no longer significant (Pearce and Ferrier 2000) and the best-fit models were selected on the basis of lowest GCV value. Once models had been fitted, the residuals were checked for spatial autocorrelation by inspecting the correlogram, which showed the behavior of the correlation between segments at a series of lags. Smooth functions were modeled as splines, providing flexible one dimensional and two dimensional curves that describe the relationship between the covariates and the response. The fitting of GAMs was carried out in the 'R' package dsm (Miller *et al*. 2013) and mgcv (Wood 2011).

Finally, a prediction grid was developed by gridding the study region into 761 cells of 500 m^2 each using Arc GIS 10 (ESRI 2010). The geographical covariates were rescaled to a resolution of 500 m^2 from their original resolutions and the final GAM per species used to generate a surface of density (Williams *et al*. 2011). Thereby, maps of species densities were produced for different seasons.

Table 3.2 Predictor variables used in the generalized additive models to estimate spatially explicit densities of prey species in Dachigam National Park.

Variable	**Description**
Elevation (Elev)	Derived from ground elevation data at 30-m resolution from the Shuttle Radar Topographic Mission dataset (SRTM; Jarvis *et al*. 2008)
Normalized Difference Vegetation Index (NDVI)	Derived from Landsat 4–5 Thematic Mapper imagery (30 m resolution) of the study area (mean of all the four seasons). Used as a measure of vegetation productivity (Pettorelli *et al*. 2009)
Seasonal variation in vegetation productivity (CV NDVI)	Calculated as the coefficient of variation in NDVI using data of four seasons. Landsat 4–5 TM imagery. Used as a measure of vegetation deciduousness.
Slope	Derived from ground elevation data at 30-m resolution from the Shuttle Radar Topographic Mission dataset (SRTM; Jarvis *et al*. 2008)
Geographic Coordinates (Latitude and Longitude)	Obtained using Global Positioning System

3.3 Results

3.3.1 Prey abundance

In total 5 large prey species (three ungulate species namely hangul, musk deer and wild boar, and two primate species namely Kashmir gray langur and rhesus macaque) were detected on line transects. Density of hangul and langur among large prey and rodents among small prey was estimated on seasonal basis. Other species are less common in the area and only a few sightings were recorded during this study, hence their densities could not be calculated. In total 170 groups of langur comprising of 2679 individuals and 206 groups of hangul comprising of 829 individuals were sighted in different seasons in the study area. Overall density (±SE) of langur (Fig. 3.3) was estimated to be higher ($16.32 \pm 1.87/km^2$) than density of hangul ($5.11 \pm 0.51/km^2$) (Fig. 3.4) in the study area.

3.3.2 Seasonal variation

Density of langur was higher than hangul in all the four seasons. Both species showed seasonal variation in densities. Langur density was highest ($22.05 \pm 5.12/km^2$) in winter season and lowest ($9.35 \pm 3.03/km^2$) in summer season (Table 3.3). While as hangul density was observed to be highest ($9.51 \pm 1.71/km^2$) in spring season and lowest ($2.31 \pm 0.51/km^2$) in summer season. Density, average group size, encounter rate and other parameters of hangul in different seasons are given in (Table 3.4). Effective strip width (ESW) varied from season to season as well as with species. For hangul ESW was highest in winter and lowest in summer. While in case of langur it was highest in winter and lowest in autumn season. Cluster size for the best selected model for langur was highest in summer season (18.65 ± 3.12) and lowest in autumn season (12.44 ± 1.24) (Table 3.3). In case of hangul cluster size was lowest in summer season (1.75 ± 0.16) and highest in winter season (4.44 ± 0.49) (Table 3.4).

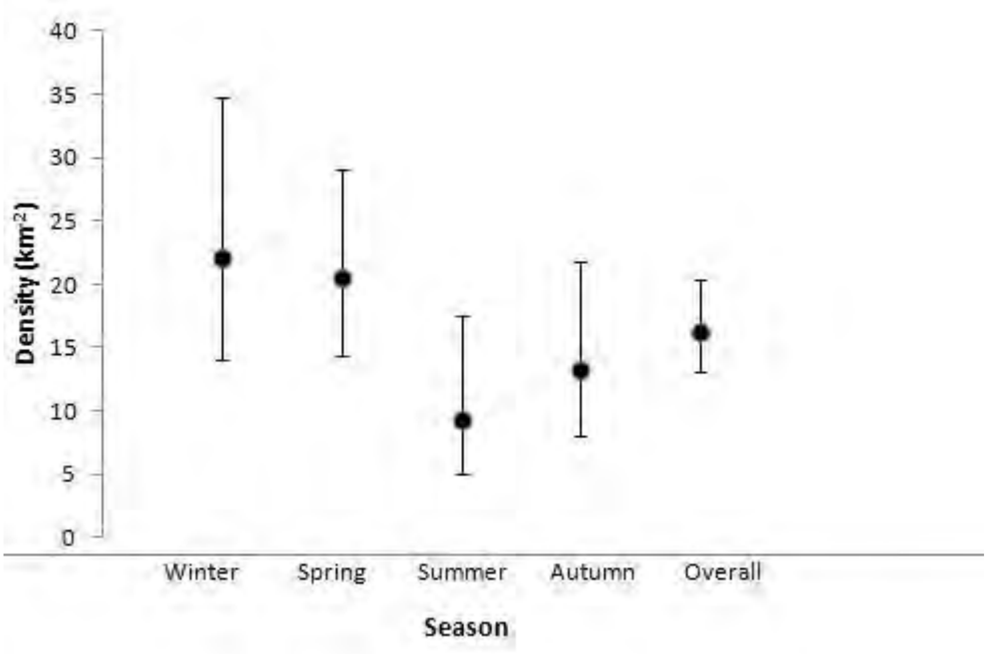

Fig. 3.3 Seasonal variation in individual density (km^{-2}) of Kashmir gray langur with 95% confidence intervals.

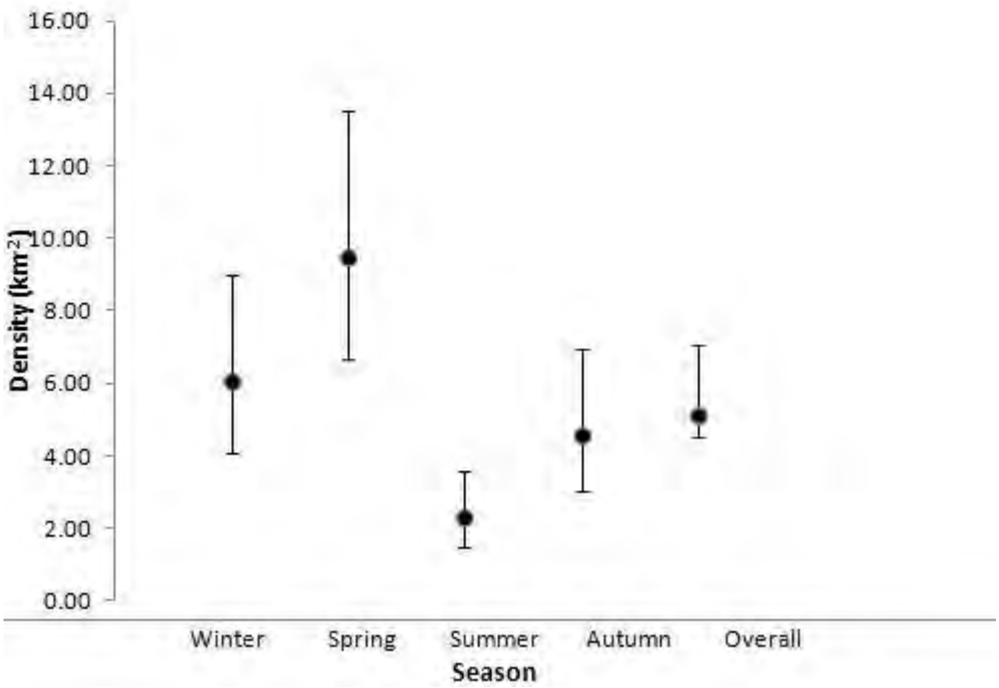

Fig. 3.4 Seasonal variation in individual density (km^{-2}) of hangul with 95% confidence intervals

3.3.3 Rodent density

In total 576 individuals of rodents were captured by Sherman trapping, during this study. Rodent density estimated by program 'DISTANCE' was found to be highest in summer season (2014 ± 830.71/km²) followed by spring, autumn and winter (1172.6 ± 442.74/km²). Effective detection radius (EDR) also varied with seasons, highest being in winter (28.73 m) and lowest in summer (25.47 m) (Table 3.5).

3.3.4 Prey biomass estimation

Overall prey biomass estimates showed that hangul formed bulk of the prey in all seasons except summer season. Hangul biomass density varied from 254.1 kg/km² in summer to 1046.1 kg/km² in winter, followed by biomass density of rodents which was highest in summer season (402.90 kg/km²) and lowest in winter season (234kg/km²). Langur contributed least to biomass availability in all the four seasons as its biomass varied from 93.50 kg/km² to 220.50 kg/km² (Table 3.6). Fig. 3.5 gives relative biomass availability in terms of langur, hangul and rodents.

Table 3.3 Estimation of Individual Density, Group density, Effective strip width, Average Cluster Size and Encounter Rate (ER; n/km) of Kashmir gray langur in different seasons inside Dachigam National Park, Srinagar. Parameter estimates and associated measures of variance were based on the model with least Akaike's Information Criteria (AIC) value

Parameters	Winter	Spring	Summer	Autumn	Pooled
No. of sightings	57	61	23	29	170
Individual Density (No. of individual/km²)	22.05	20.48	9.35	13.29	16.32
Standard Error	5.12	3.67	3.03	3.35	1.87
Percent CV	23.22	17.96	32.47	25.27	11.49
Group Density (No. of Groups/km²)	1.21	1.3	0.5	1.06	0.99
Standard Error	0.18	0.19	0.13	0.24	0.08
Percent CV	14.94	14.81	27.82	23.2	8.97
Effective Strip Width (m)	72.42	53.34	54.98	42.37	56.81
Standard Error	7.42	5.26	10.81	6.75	3.35
Percent CV	10.26	9.87	19.68	15.95	5.91
Average Group Size	18.154	15.66	18.65	12.44	16.43
Standard Error	3.22	1.59	3.12	1.24	1.17
Encounter Rate (No. seen/km Walk)	0.17	0.13	0.05	0.09	0.11
Percent CV	10.86	11.04	19.67	16.85	6.76
Detection Probability	0.45	0.44	0.36	0.32	0.28

Table 3.4 Estimation of Individual Density, Group density, Effective strip width, Average Cluster Size and Encounter Rate (ER / km) of hangul in different seasons inside Dachigam National Park, Srinagar. Parameter estimates and associated measures of variance were based on the model with least Akaike's Information Criteria (AIC) value.

Parameters	Winter	Spring	Summer	Autumn	Pooled
No. of sightings	49	76	36	45	206
Individual Density (No. of animal/km^2)	6.05	9.51	2.31	4.59	5.11
Standard Error	1.22	1.71	0.51	0.97	0.51
Percent CV	20.24	18.06	22.16	21.15	10.12
Group Density (No. of Groups/km^2)	1.36	2.29	1.32	1.32	1.49
Standard Error	0.23	0.33	0.26	0.22	0.11
Percent CV	16.94	14.40	20.00	17.03	7.99
Effective Strip Width (m)	53.99	39.14	32.60	52.81	45.02
Standard Error	6.26	4.00	4.22	5.95	2.36
Percent CV	11.60	10.22	12.97	11.28	5.23
		`			
Average Group Size	4.44	4.14	1.75	3.45	3.41
Standard Error	0.49	0.45	0.16	0.43	0.21
Encounter Rate (No. seen/km walk)	0.14	0.17	0.08	0.14	0.13
Percent CV	12.35	10.14	15.23	12.76	6.03
Detection Probability	0.49	0.32	0.46	0.50	0.40

Table 3.5 Estimation of Individual Density and Effective detection radius of rodents in different seasons inside Dachigam National Park, Srinagar. Parameter estimates and associated measures of variance were based on the model with least Akaike's Information Criteria (AIC) value.

Parameter	Winter	Spring	Summer	Autumn
No. of captures	79	94	103	86
Individual Density (No. of Animal/km²)	1172.6	1588	2014.5	1302.2
Standard Error	442.74	626.46	830.71	501.44
Percent CV	37.76	39.45	41.24	38.51
Effective Detection Radius (m)	28.73	26.42	25.47	27.38
Standard Error	3.58	2.68	2.30	3.05
Percent CV	12.48	10.17	9.06	11.17
Probability of greater chi square value, P	0.87	0.79	0.6	0.87
Detection Probability	0.22	0.19	0.17	0.2

Table 3.6 Seasonal biomass estimates of available prey in Dachigam National Park.

Season	Hangul		Langur		Small Rodents	
	Density ± SE (km^{-2})	Biomass (kg/km²)	Density ± SE (km^{-2})	Biomass (kg/km²)	Density ± SE (km^{-2})	Biomass (kg/km²)
Winter	6.05 ± 1.22	665.5	22.05 ± 5.12	220.50	1172.6±442.74	234.52
Spring	9.51 ± 1.71	1046.1	20.49 ± 3.67	204.90	1588.0±626.46	317.60
Summer	2.31 ± 0.51	254.1	09.35 ± 3.03	093.50	2014.5±830.71	402.90
Autumn	4.59 ± 0.97	504.9	13.29 ± 3.35	132.90	1302.2±501.44	260.44

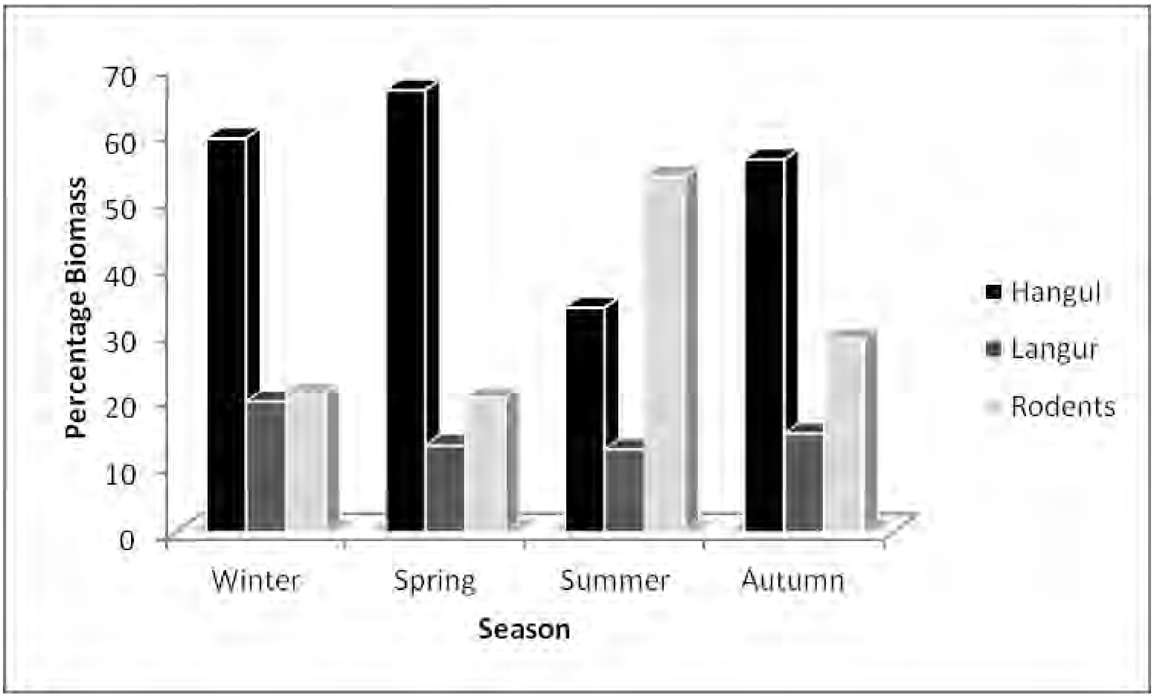

Fig. 3.5 Proportions of the standing biomass of available prey species in Dachigam National Park.

3.3.5 Age structure and Sex Ratio

The proportionate representation by different age classes in the population of hangul and langur in different seasons is given in Table 3.7 – 3.8. The overall adult sex ratio of hangul turned out to be 23.31 males per 100 females and fawn to female ratio was recorded as 24.94 fawns per 100 females. However both the ratios varied over the seasons. The lowest male to female ratio (19.57 males per 100 females) was recorded in spring and the highest (32.52 males per 100 females) in autumn. Similarly lowest fawn to female ratio (21.69 fawns per 100 females) was recorded in spring and highest ratio (34.28 fawns per 100 females) was recorded in summer season (Table 3.9).

In case of langur the overall adult sex ratio was recorded as 38.11 males per 100 females and young to female ratio was recorded as 30.03 young ones per 100 females. Both the ratios showed seasonal variation with the lowest male to female ratio (33.08 males per 100 females) was recorded in winter and the highest (44.72 males per 100 females) in spring. Similarly lowest young to female ratio (23.74 young ones per 100 females) was recorded in winter and highest ratio (37.17 young ones per 100 females) was recorded in summer season (Table 3.9).

Table 3.7 Season wise age structure of Hangul in Dachigam National Park (2011-2013)

	Percentage of Individuals Sighted					
Season	Adult Male	Adult Female	Sub Adult Male	Sub Adult Female	Fawn	Unidentified
Winter	10.53	53.07	3.51	11.40	13.16	8.33
Spring	10.03	51.22	2.71	9.49	11.11	15.45
Summer	15.87	55.56	1.59	4.76	19.05	3.17
Autumn	16.96	49.12	4.09	5.85	14.04	9.94

Table 3.8 Season wise age structure of Langur in Dachigam National Park (2011-2013)

	Percentage of Individuals Sighted					
Season	Adult Male	Adult Female	Sub Adult Male	Sub Adult Female	Young	Unidentified
Winter	13.89	41.99	8.80	20.78	9.97	4.56
Spring	16.10	36.00	7.00	23.00	12.20	5.70
Summer	14.11	35.42	8.78	22.57	13.17	5.96
Autumn	14.15	40.77	8.15	19.18	12.95	3.84

Table 3.9 Season wise sex ratio and female: fawn or young ratio of Hangul and Langur in Dachigam National Park. (2011 – 2013)

Species	Season	Male	Female	Fawn or Young
Hangul	Winter	19.83	100	24.79
	Spring	19.57	100	21.69
	Summer	28.57	100	34.28
	Autumn	32.52	100	28.57
Langur	Winter	33.08	100	23.74
	Spring	44.72	100	33.89
	Summer	39.82	100	37.17
	Autumn	34.71	100	31.76

3.3.6 Spatial distribution of prey

3.3.6.1 Fitting of detection function

On the basis of AIC values of different models fitted on detection function of the data from wet and dry seasons, Half normal model with or without cosine adjustments was finally selected for both hangul and langur (Fig. 3.6 and Table 3.10).

3.3.6.2 Generalized additive modeling (GAM)

The final selected models of GAMs accounted for 33.4 - 56.3% of the deviance in species data in different seasons (Table 3.10). The models indicated that the relative importance of each variable was different for each species in different seasons. In all the final models, elevation, mean of NDVI and CV of NDVI had a significant effect on species densities (Table 3.10). With the exception of the langur in dry season, slope did not show any significant effects on species densities.

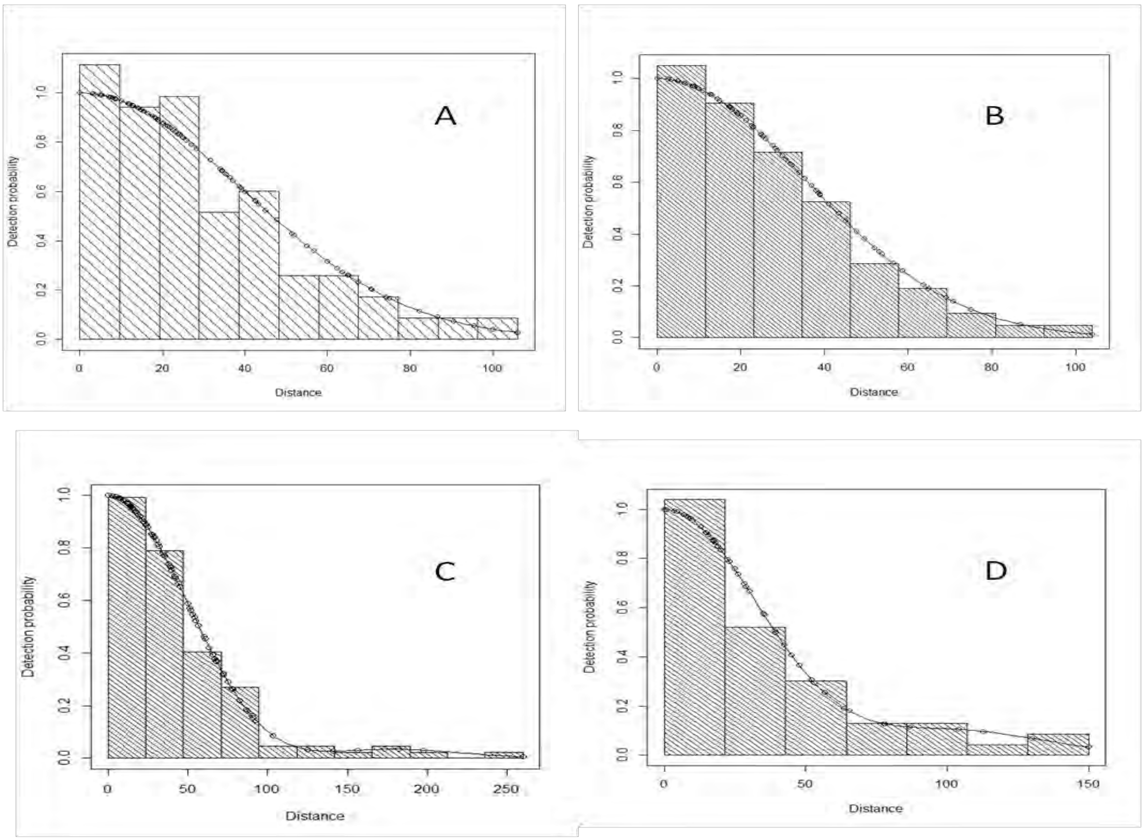

Fig. 3.6 Histograms of the distance data and the corresponding 'best' models among the set of candidate models (half-normal) : A) Hangul in wet season B) Hangul in dry season C) Langur in wet season D) Langur in dry season

The models estimated that the highest densities of hangul as well as langur in wet season occurred in lower elevations ranging from 1800-2200 m. In dry season it was observed that the densities of both the species in the study area decreased and both species were distributed across a wider area and higher elevation (Fig. 3.7 - 3.8). In wet season, with increase in NDVI as well as CV NDVI hangul density showed a decreasing trend while langur density showed an increasing trend Fig. 3.9 - 3.12. Response patterns of densities to various covariates are shown by three dimensional heat maps (Fig. 3.13 - 3.16). Using the final models, species specific densities for each season were extrapolated over the 500 m^2 prediction grid across study area (Fig. 3.7 - 3.8).

Table 3.10 The best-supported model for each species. Presented per species are the number of detections (n), the best-fit detection model with AIC values, the significant smooth functions (with estimated degrees of freedom) included in the final generalized additive model, percentage deviance explained by the final model for both species.

Species	**Hangul**		**Langur**	
Season (n)	Wet(119)	Dry(81)	Wet(118)	Dry(52)
Detection model	Half-normal key function	Half-normal key function	Half-normal key function with cosine adjustment	Half-normal key function with cosine adjustment
AIC	1041.18	695.48	1128.40	479.39
GAMs				
GCV	1.84	1.02	6.89	4.32
Intercept (± S.E)	-16.32*** (± 0.16)	-14.82*** (± 0.16)	-15.07*** (±0.12)	-15.70*** (±0.19)
s(x,y)	17.18**	8.82**	7.47*	—
s(elevation)	6.13***	7.26*	6.27***	5.9**
s(slope)	—	—	—	5.65*
s(meanndvi)	1.00**	5.26*	1.51**	7.11*
s(cvndvi)	1.00**	6.30*	4.17*	7.73*
Deviance explained (%)	56.3	48.1	45.8	33.4

Significance codes: 0 '*' 0.001 '**' 0.01 '*' 0.05**

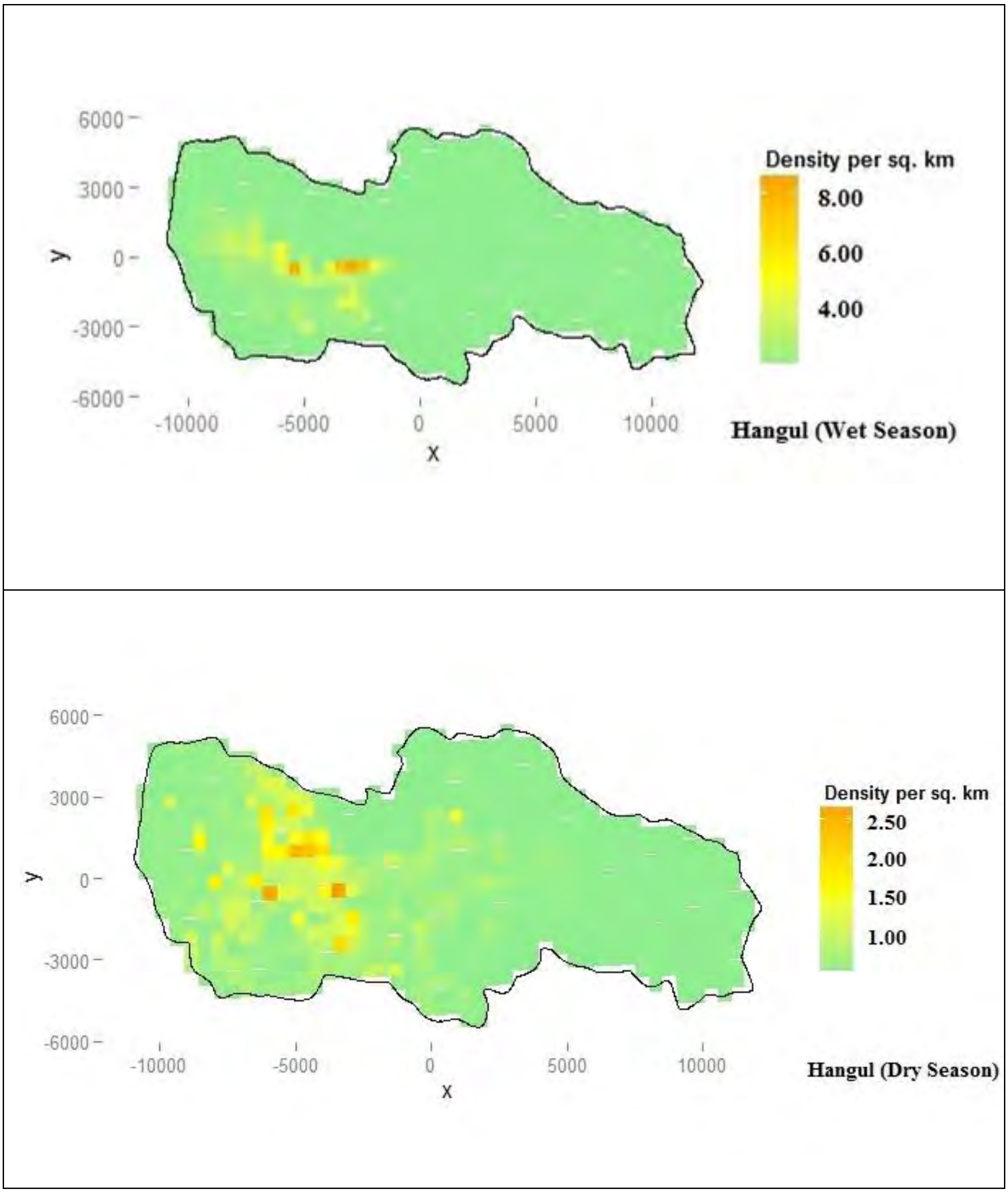

Fig. 3.7 Distribution of individual density of hangul over 500 m^2 grid cells across Dachigam National Park in wet and dry season

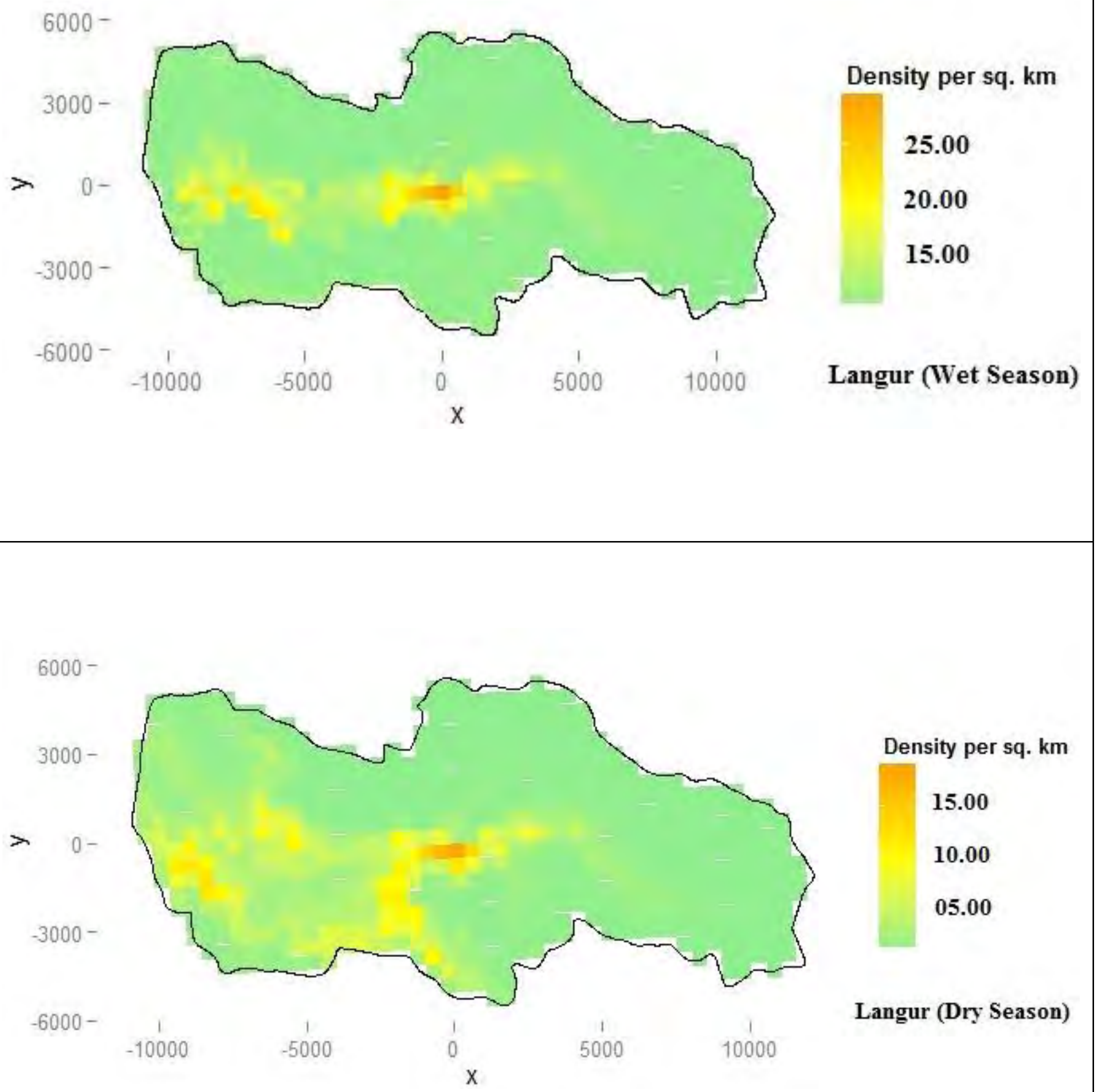

Fig. 3.8 Distribution of individual density of Kashmir gray langur over 500 m^2 grid cells across Dachigam National Park in wet and dry season.

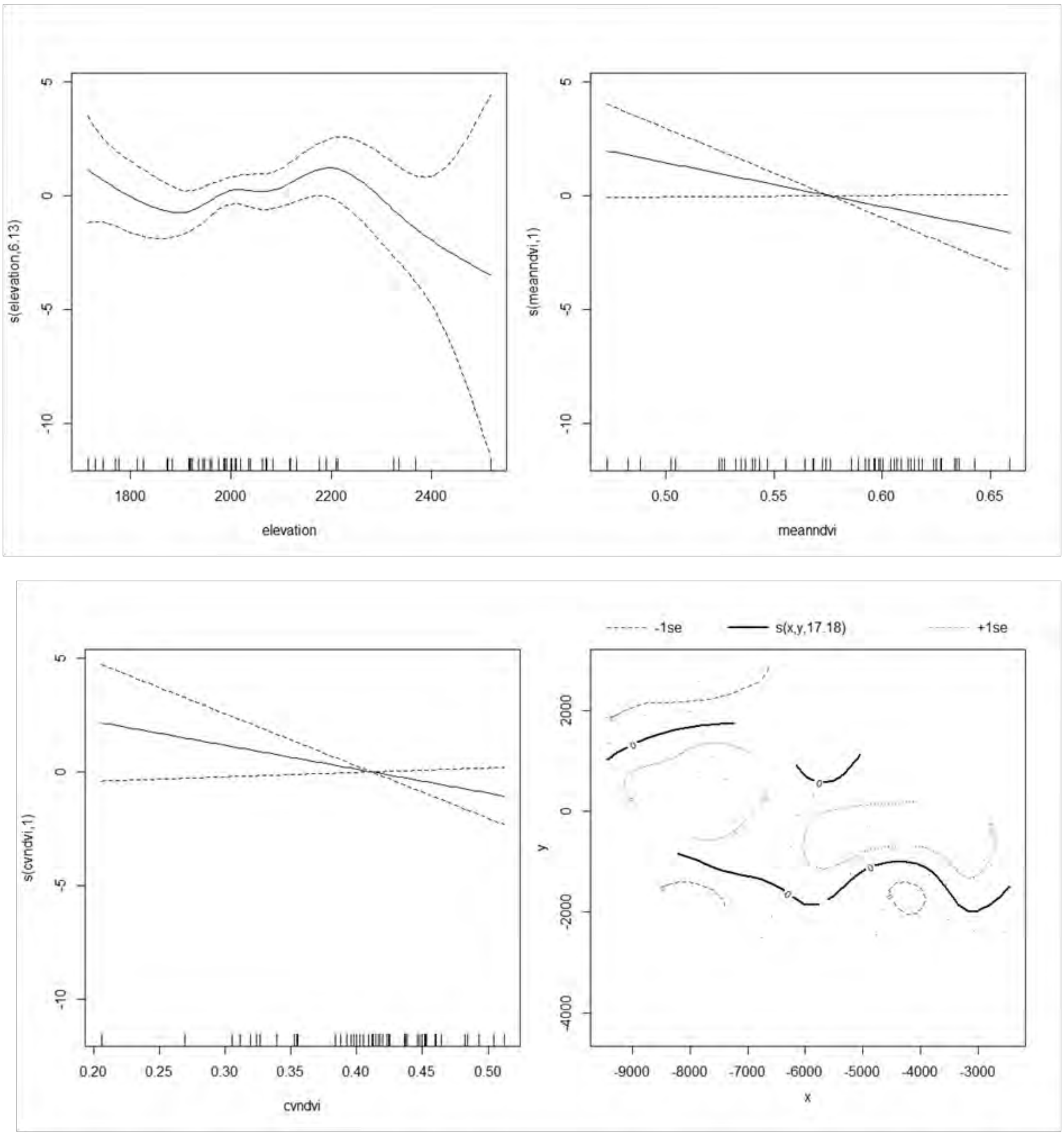

Fig. 3.9 Generalized additive model response curves (solid lines) with 95% confidence intervals (dashed lines) presented for each of the covariates in the linear predictor scale from the best-fit for hangul in wet season. A one-dimensional scatterplot is given at the bottom of each graph, using a vertical bar as the plotting symbol, which illustrates the distribution of available data.

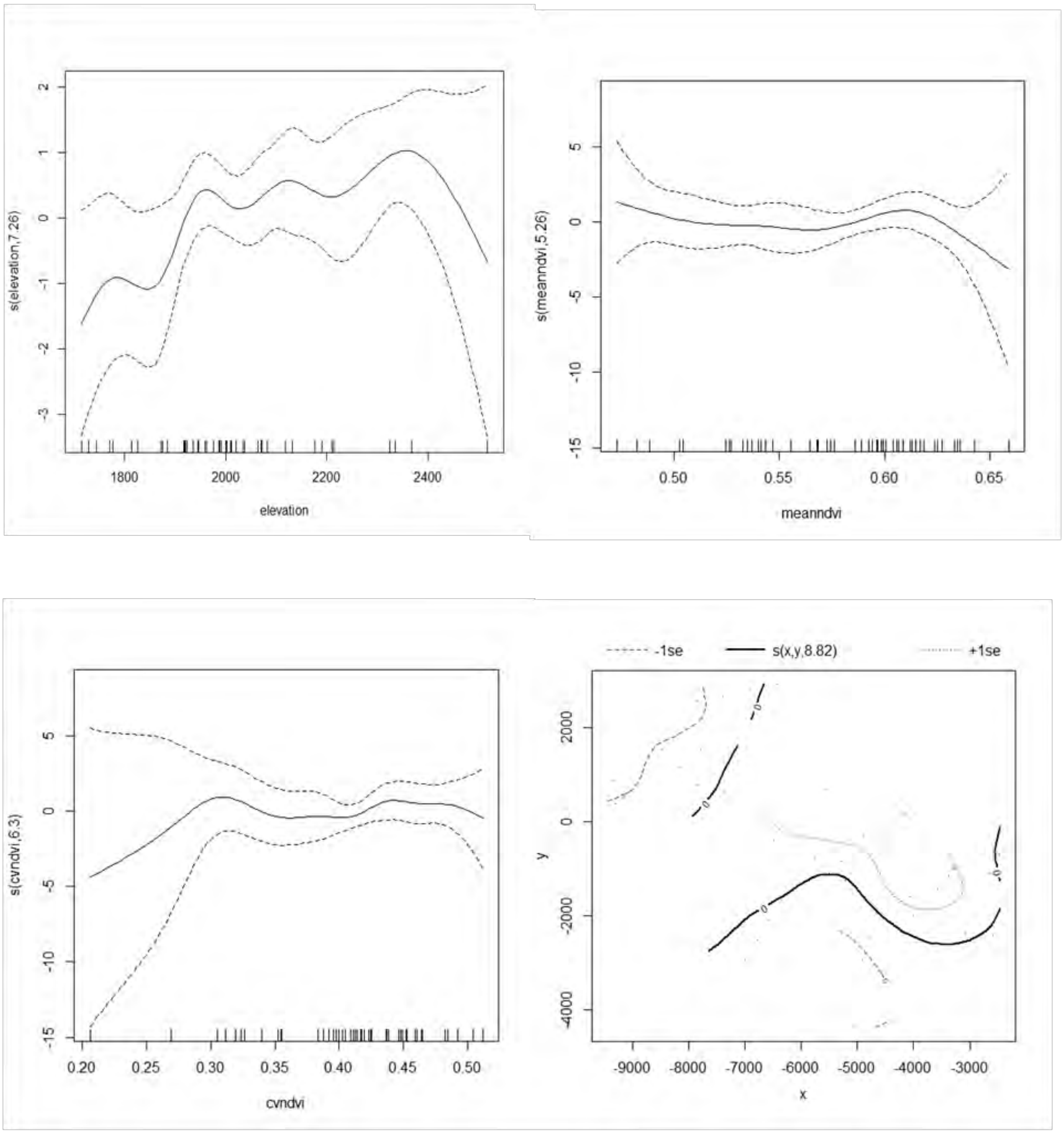

Fig. 3.10 Generalized additive model response curves (solid lines) with 95% confidence intervals (dashed lines) presented for each of the covariates in the linear predictor scale from the best-fit for hangul in dry season. A one-dimensional scatterplot is given at the bottom of each graph, using a vertical bar as the plotting symbol, which illustrates the distribution of available data.

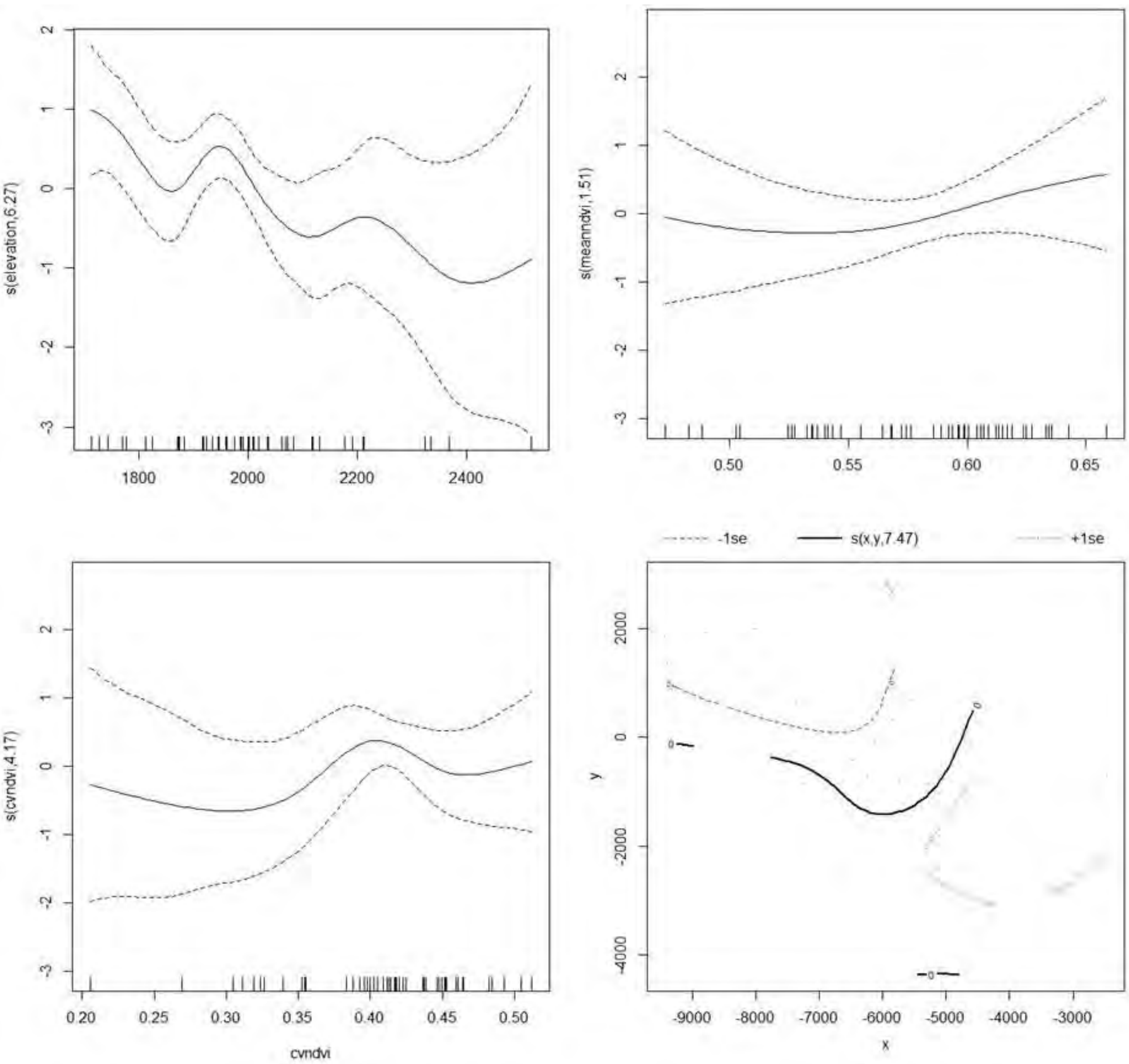

Fig. 3.11: Generalized additive model response curves (solid lines) with 95% confidence intervals (dashed lines) presented for each of the covariates in the linear predictor scale from the best-fit for langur in wet season. A one-dimensional scatterplot is given at the bottom of each graph, using a vertical bar as the plotting symbol, which illustrates the distribution of available data.

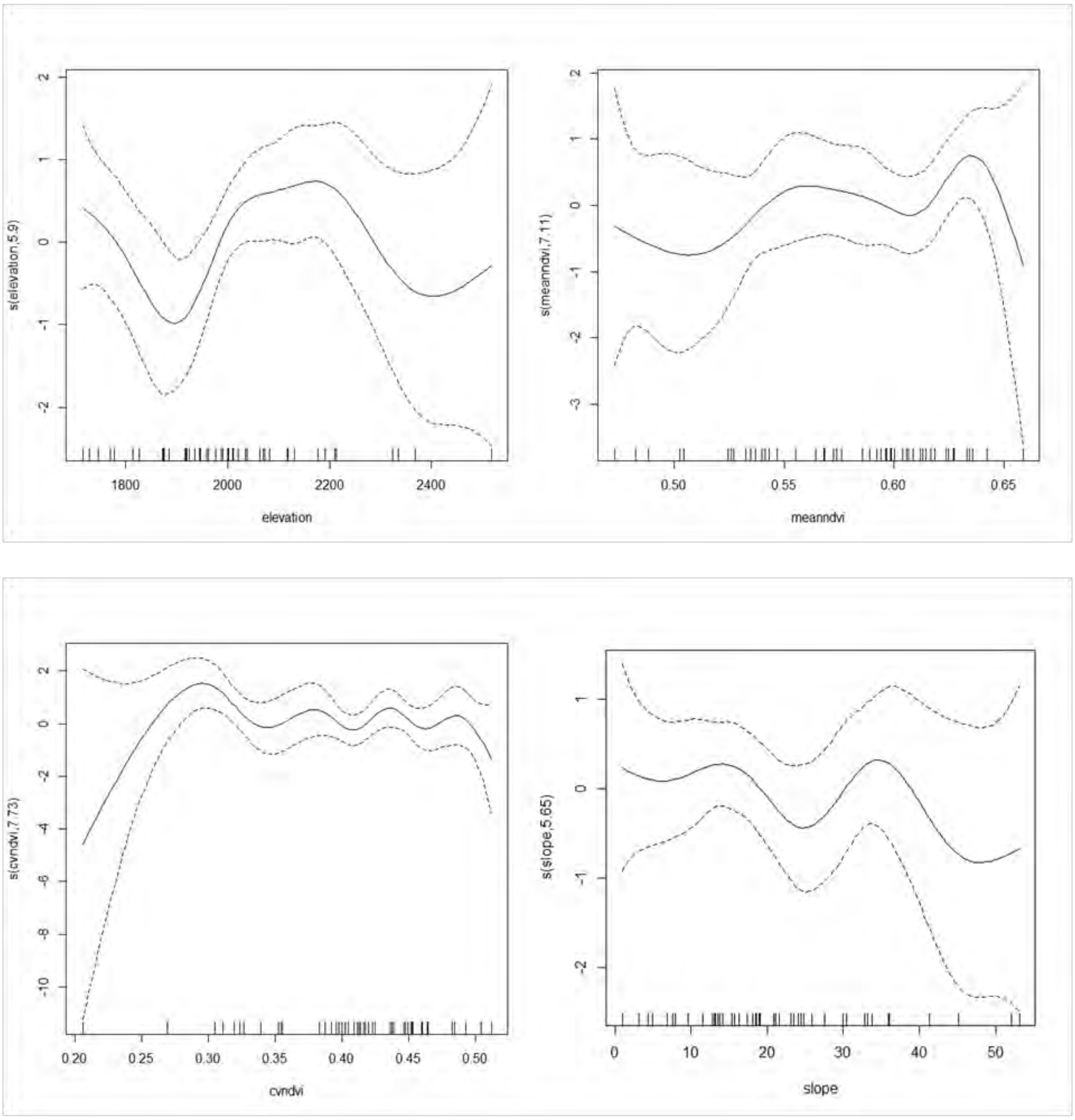

Fig. 3.12 Generalized additive model response curves (solid lines) with 95% confidence intervals (dashed lines) presented for each of the covariates in the linear predictor scale from the best-fit for langur in dry season. A one-dimensional scatterplot is given at the bottom of each graph, using a vertical bar as the plotting symbol, which illustrates the distribution of available data.

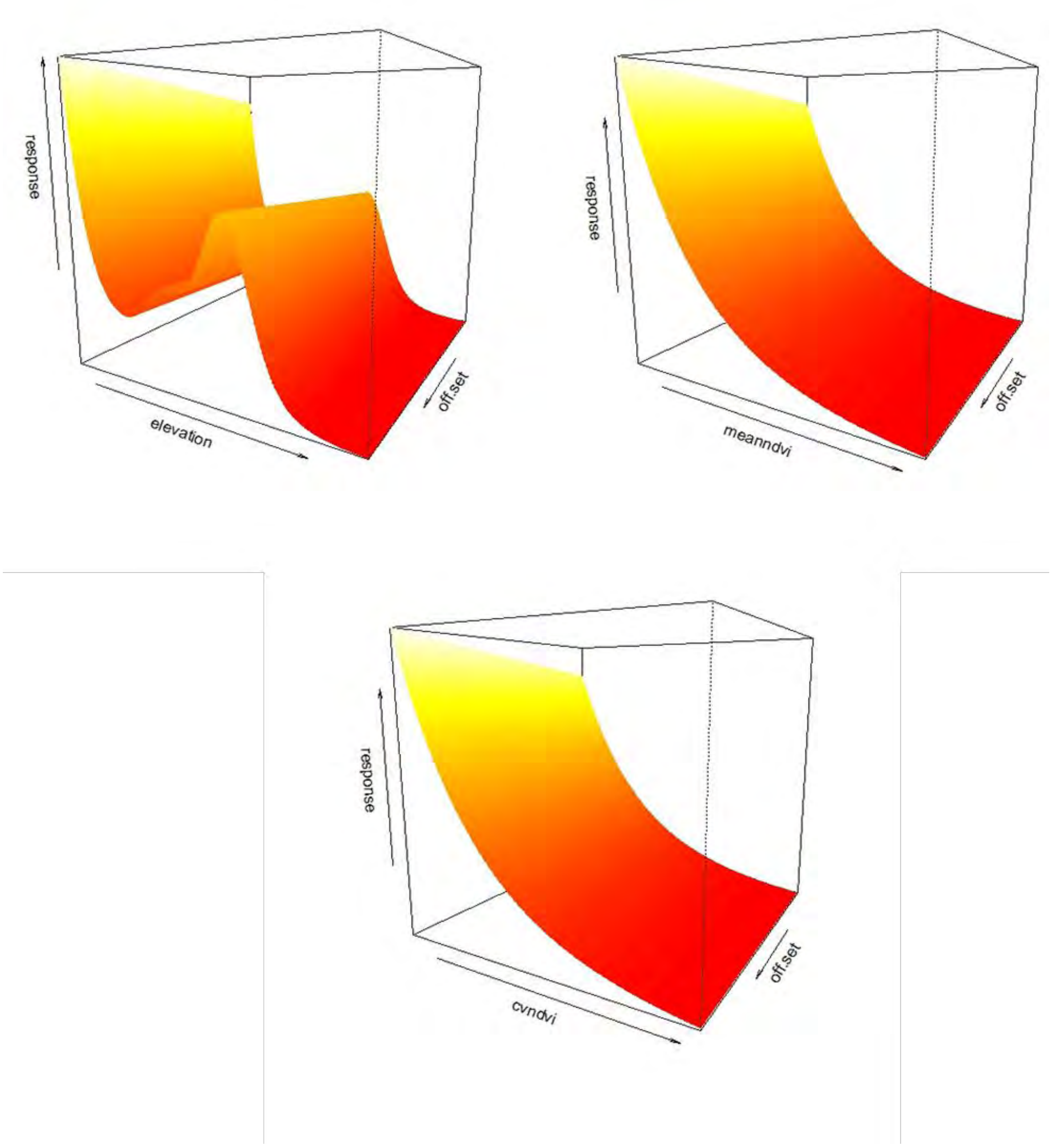

Fig. 3.13 Three dimensional heat maps showing response of hangul density to different covariates in wet season

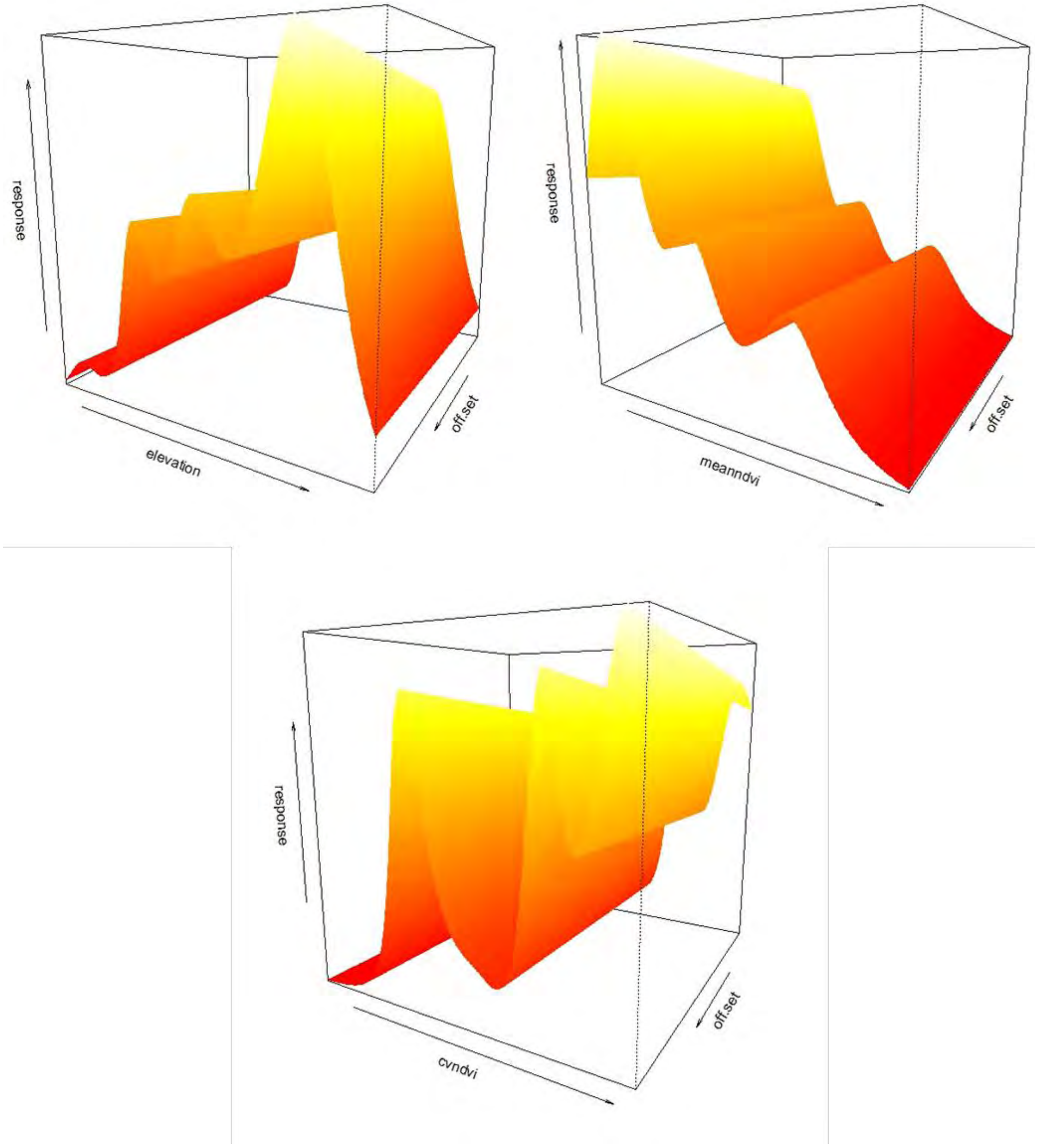

Fig. 3.14 Three dimensional heat maps showing response of hangul density to different covariates in dry season

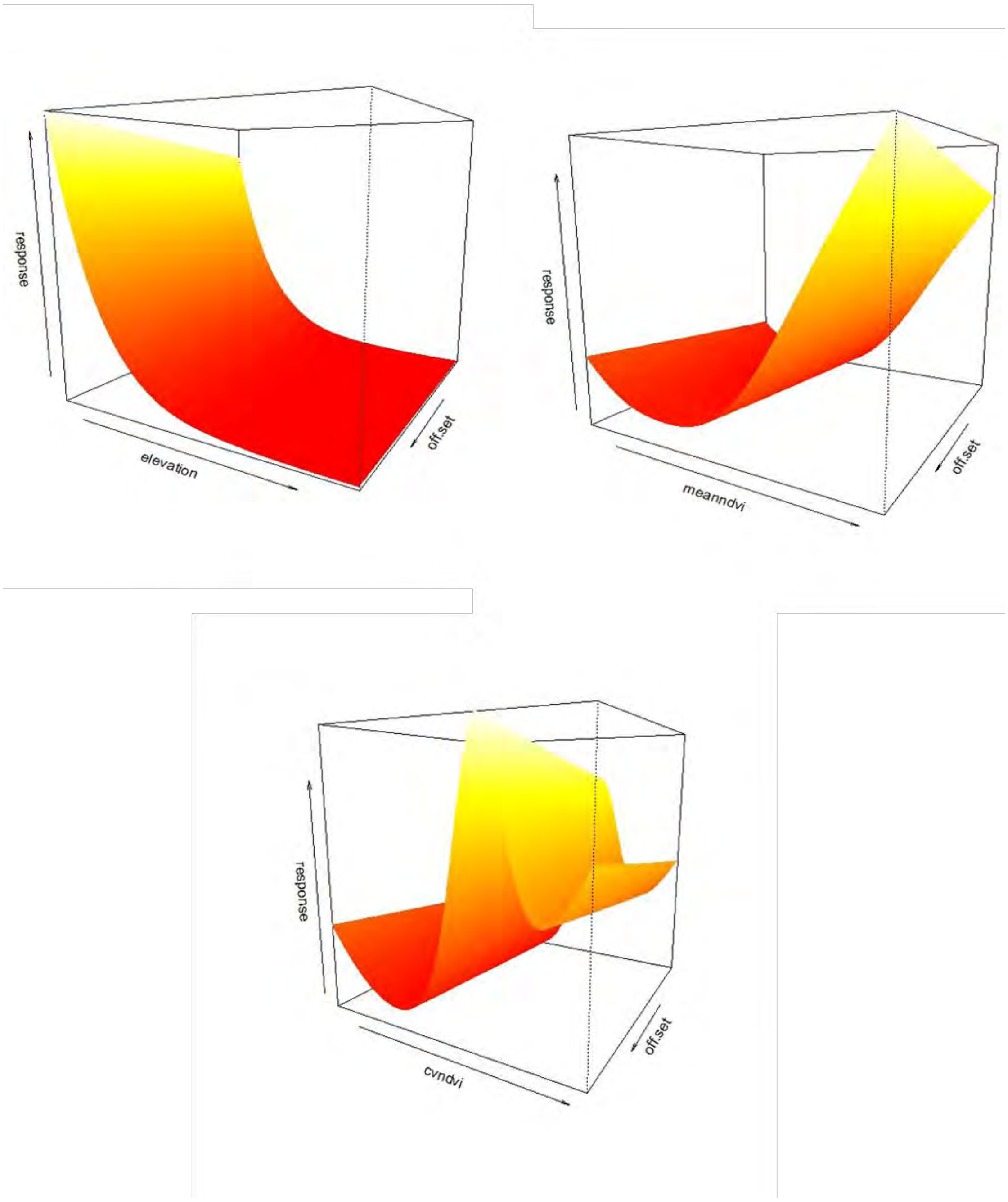

Fig. 3.15 Three dimensional heat maps showing responses of langur density to different covariates in wet season

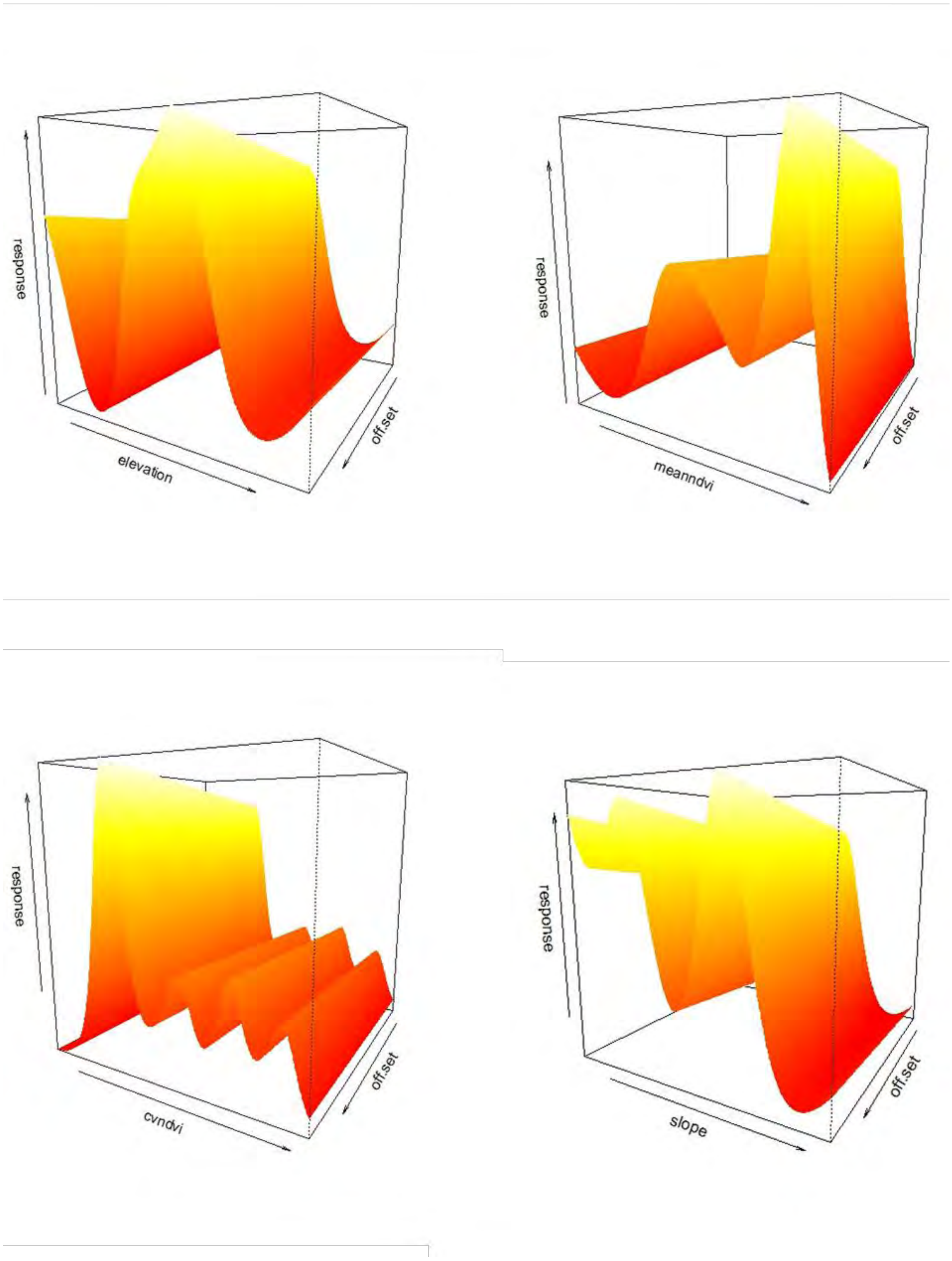

Fig. 3.16 Three dimensional heat maps showing responses of langur density to different covariates in dry season

3.4 Discussion

3.4.1 Prey density and biomass

Overall prey availability in Dachigam NP was found to be low. Only two potential large wild prey species are available in the form of hangul and Kashmir gray langur with low population densities. Hangul density varied in different seasons with highest density in spring and lowest in summer season. In the recent past, hangul population has shown a drastic decline from 3000 individuals reported in 1947 to around 218 animals estimated in 2011 (Ahmad 2006; Ahmad *et al*. 2009; Qureshi *et al*. 2009). This decline may be attributed to large scale biotic interference, habitat fragmentation and degradation (Qureshi *et al*. 2009). The low fawn/ hind ratio is also considered as a major concern as high recruitment rate is essential for long term survival of any species (Qureshi *et al*. 2009). Summer range of the deer is heavily stocked with cattle, sheep and goat, acting as a major disturbance to hangul, moreover posing a threat of diseases transmission like rinderpest and John's disease from livestock to hangul (Schaller 1969).

Hangul density estimated in this study was lower than density of Red deer reported from other studies *viz* density of 15-20 deer /km^2 was reported by Clutton-Brock and Albon (1989) from Scotland and Red deer densities ranging from 7 deer/km^2 in Central Alps (Bocci and Lovari 2011) to 26 deer/km^2 area have been reported from Sardinia (Lovari *et al*. 2007). Hangul density in this study also showed seasonal variation with lowest density recorded in summer season and highest in spring season. This can be attributed to seasonal movements of hangul governed by resource availability. Prey species in other areas have also been reported showing such seasonal movements in relation to resource availability (Fuller 1991; Peterson 1977).

Average group size of hangul was estimated to be 3.14± 0.21 which varied with seasons. The changes in group sizes with seasonal and regional variations in availability of food and with variations in predation threats and sex ratio have been demonstrated in Red deer early also (Rose *et al*.1998). Group size variation in this study clearly infers that hangul tend to form strong associations in spring and winter months and segregate into smaller groups in hotter months. The main reason might be that clumped resources lead to increased group size in winter season. Lowe (1966) also reported that deer appear to live in small groups and sexes are usually segregated when food and shelter is abundantly available. Ahmad *et al.* (2015) has also reported that hangul moved in larger groups in winter and spring season compared to other seasons in Dachigam National Park.

Since there has been no previous study on population status of langurs in Dachigam NP the population trends in past are not clear. In this study overall population density of langurs was estimated to be 16.32 individuals/km² which is almost same as density of Kashmir gray langurs (16.01 /km²) reported from the similar Himalayan ecosystem of Machiara National Park, Pakistan (Minhas *et al*. 2012). Seasonal fluctuation in density of langur can be attributed to the movement of langurs from upper areas including some adjacent protected areas towards lower comparatively less hostile areas of DNP in the winter months. Minhas *et al.* (2012) has also reported fluctuation in langur population in Machiara NP due to the migration of troops. Genus *Semnopithecus* has been studied extensively in Indian subcontinent, especially the species *S. entellus* (Hanuman langur or gray langur). The density of langurs in this study was estimated to be lower than densities of gray langur reported from other food abundant habitats of the country. Bagchi *et al*. (2003) estimated 21.7 individuals/km² in Ranthambore, Edgaonkar (2008) reported 28.3 individuals/km² in Bori-Satpura tiger reserve, Narasimmarajan *et al*. (2012) reported 42.92 individuals/km² from Melghat Tiger Reserve, Maharashtra and the highest density of 82.5 individuals/km^2 was estimated in Pench tiger reserve by Majumder *et al*. (2010).

Rodent density estimated during this study ranged from 11.72 animals /hectare to 20.14 animals /hectare which is higher than rodent density (5.16 animals/ ha) reported by Gupta (2011) from Sariska Tiger Reserve, Rajasthan. Low density in winter season is probably due to low temperatures and snow cover which may decrease rodent movements and hence trapping rate of rodents. Significance of rodents for the survival of carnivores has been highlighted by a study from peninsular Spain (Moreno-rueda and Pizarro 2010). The study suggests that the conservation of rodents in general could be useful for the conservation of the entire carnivore group. And the conservation of rodent habitats, in order to generate environmental diversity might relax competition among carnivore species, facilitating their coexistence. In case of

Dachigam NP rodents have significant role to play since large prey is scarce altogether.

Population size though a good indicator of the abundance of prey in a particular area does not give an accurate comparative biological parameter because it does not take animal mass into consideration while biomass estimation gives such a comparative factor and the animals are converted into the same units (Kahurananga 1981). Prey biomass availability is crucial for sustaining big cat distribution and abundance. Low biomass availability has adverse effects on space requirement as well as reproductive potential of big cats. Cats are likely to be more susceptible to dwindling prey resources than to direct human effects because they are able to withstand quite high human densities under favorable conservation and management policies (Karanth and Stith 1999; Linnell *et al*. 2001). In the present study, the total available prey biomass of large prey varied from 347.6 kg/km² to 886 kg/km² in different seasons, which is very less compared to studies conducted in other Himalayan ecosystems and rest of the Indian subcontinent like Ramesh *et al*. (2009) reported standing prey biomass of 8365.02 kg/km² from Mudumalai Tiger Reserve, Edgaonkar (2008) in Satpura national park reported available biomass of 6611.96kg/km² and Ramesh *et al*. (2012b) from Kalakad-Mundanthurai Tiger Reserve estimated prey biomass of 2614 kg/km². The lowest prey biomass (379 kg/km²) has been reported in the Eastern Himalayas at Jigme Singye Wang chuck National Park in Bhutan (Wang 2010). In this study rodent biomass was estimated to be higher than hangul and langur in summer season while as hangul biomass was highest in all other seasons. High rodent density can be attributed to low ungulate densities as it has been reported that ungulates can compete with rodents for forage, and reduced ungulate densities can increase rodent numbers (Keesing 2000).

Overall sex ratio of hangul in this study was recorded as 23.31 males per 100 females. Sex ratio showed seasonal variation with highest ratio in autumn (32.52:100) and lowest in spring season (19.57:100). This variation might be due to strong aggregation of males and females in autumn for mating purpose and segregation in winter and spring. Another reason might be that in the mating season roaring males are more easily spotted or recorded than the silent females and fawns. Fawn to female ratio of hangul also showed seasonal variation and lowest ratio was recorded in spring season indicating low survival rate of fawns in harsh winters. Substantial loss of calves has been reported in many deer populations due to high predation on young ones (Fuller 1990). Sex ratio of langurs was female biased in agreement with previous studies and did not show much seasonal variation ranging from 33.08 to 44.72 males per 100 females. Earlier studies have reported sex ratio of grey langurs varying from 17.85 to 55.55 males per hundred females (Winkler 1981; Newton 1984; Rajpurohit 1992; Chhagani 2002). In case of langurs, young ones are usually born between January and March (Prater 2005) until June. This might be the reason of highest young to female ratio of langurs in summer and spring season.

3.4.2 Spatial distribution of prey

Density surface modeling employs model-based inference for abundance and density distribution in the study area. With DSM, abundance is related to spatial covariates and the distribution of the species may be visually depicted. The inferred relationships between population density and other ecologically meaningful covariates has immense biological significance and could be of more importance from management point of view than simply abundance estimation. In the present study, a marked difference was noted between species distribution pattern in wet and dry seasons. The results of density surface models and distribution maps ensued from them, suggest that hangul as well as langur occupy low altitude areas of the park in winter and spring season. While as they spread to a wider area with higher altitude and might be moving to adjacent protected areas also in summer and autumn season as it is clear from low densities and distribution pattern shown by the species in dry season. The main reason for this pattern might be that during heavy snowfall in wet season the species come down to less hostile low altitude areas to exploit the available food resources, as lower areas experience lesser snowfall. Moreover temperature in lower areas also remains a little on higher side as compared to upper areas. Earlier findings have also reported the similar pattern of local migration in red deers (Palmer and Truscott 2003; Bocci *et al*. 2012). Charoo *et al*. (2010) reported hangul movement towards higher elevations and adjacent protected areas during summer and to lower elevation in winter possibly for exploitation of quality forage. Studies of Gee (1965) and Schaller (1969) have also reported hangul using higher altitude coniferous forests and alpine meadows in summer, and valley bottoms of lower Dachigam in winter.

Similar pattern is shown by Sika deer in the central North Island as they utilize valley bottoms in spring because of early plant growth there (Davidson 1973). Black-tailed deer have also been reported to change their spatial distribution to concentrate their populations at high elevations during summer season (Allen *et al*. 2014). Altitudinal migration in Kashmir gray langur has also been reported from Machiara National Park, Pakistan where langurs where seen to prefer the moist temperate coniferous forests interspersed with deciduous trees in winter, while in the summer season they preferred to migrate into the subalpine scrub forests at higher altitudes (Minhas *et al*. 2010).

Mean of NDVI and CV of NDVI were also found to be important predictors effecting density distribution of hangul and langur. Various studies have shown that NDVI acts as a surrogate of climatic variables (e.g. rainfall and evapo-transpiration) and other environmental factors (Cihlar *et al.* 1991) and is related to the distribution of both plant and animal species diversity (Walker *et al*. 1992). NDVI correlates directly with photosynthetically active biomass or vegetation productivity and also indicates presence or absence of cover for animals (Tucker and Sellers 1986; Reed *et al*. 1994; Mondal 2012). Density of hangul showed a decreasing trend with increase in mean NDVI as well as CV NDVI in wet season indicating that hangul mostly occupied open grassland areas located on sun-exposed south facing aspects of Dachigam NP during this period. High utilization of lowland grasslands in spring and higher-altitude grasslands in summer by red deer has also been reported in New Zealand (Nugent and Fraser 2005). High utilization of open areas in winter and spring when they occur in higher density in the area may be helping them to avoid predation by leopards also, since leopards are widely perceived to favor the densest habitats available for hunting (Bailey 2005). Langur density showed an increasing trend with increase in NDVI and CV NDVI, indicating that langurs preferred to occupy densely forested areas in both wet and dry season. Langurs being arboreal species, they highly prefer the areas with high tree densities, which are found along the riparian and evergreen forests.

Leopards being dependent on cover for predation cannot access the prey easily in high altitude alpine grasslands in summer season. Ranging pattern of leopards in Dachigam NP was studied using GPS collars and results showed that leopards were restricted to lower Dachigam in all the seasons and home range was largest in summer and smallest in winter (Habib *et al*. 2014) (Fig. 3.17 - 3.18). Thus winter season which may otherwise be considered as resource crunch period becomes resource rich period for leopards in terms of prey availability and the summer season becomes prey scarce period for the leopard.

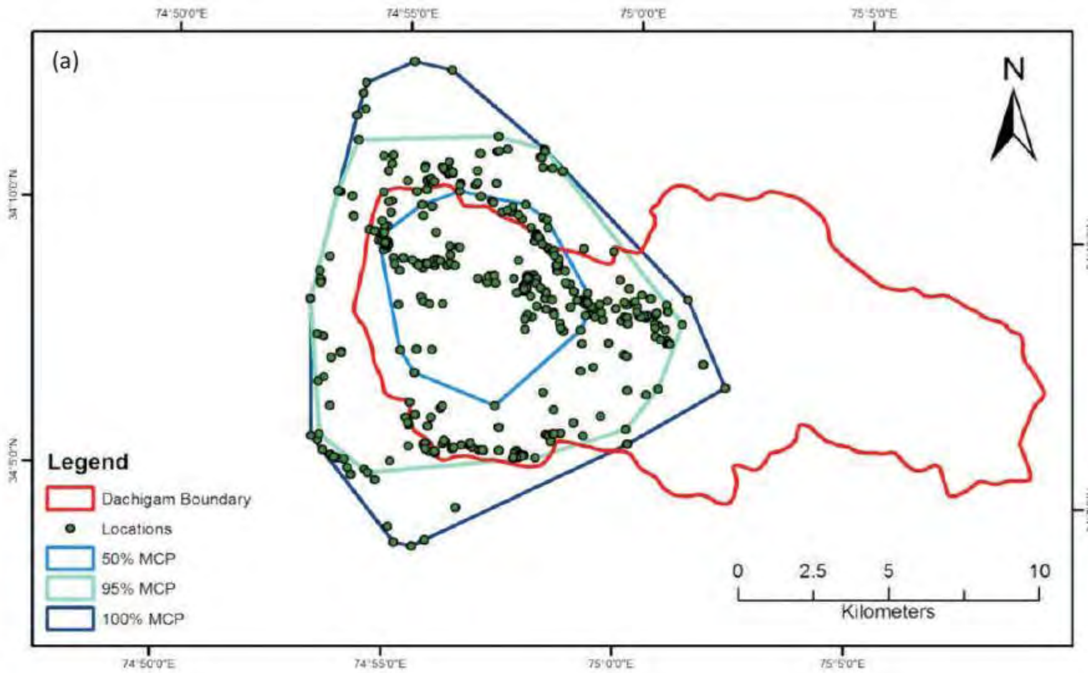

Fig. 3.17 100% MCP home range of male leopard in Dachigam NP

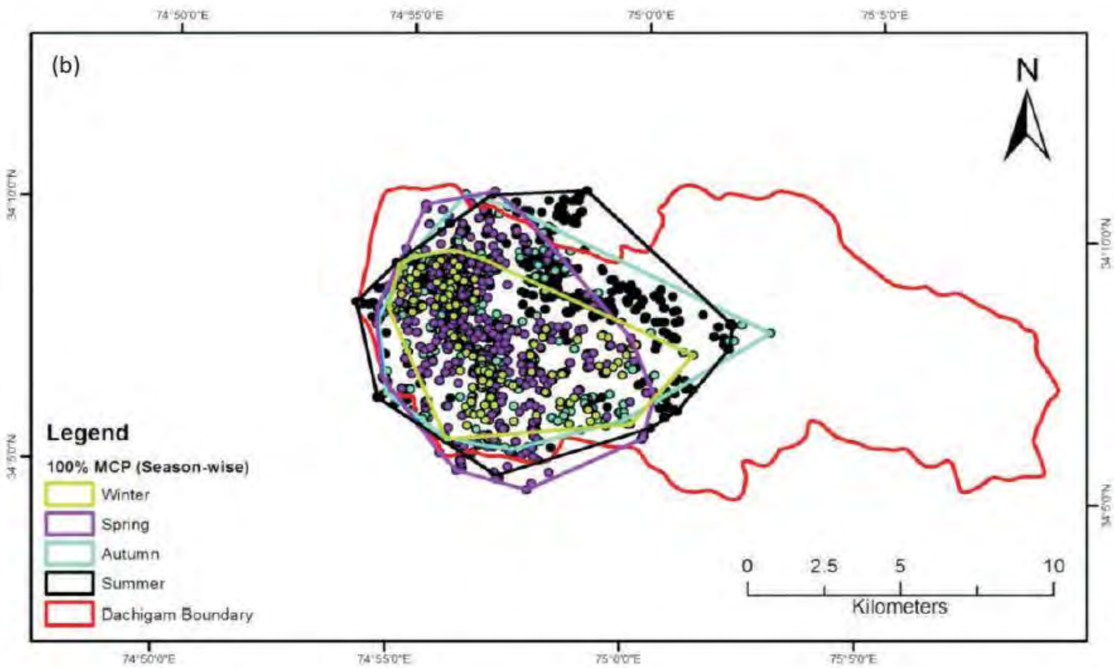

Fig. 3.18 100% MCP home range of female leopard in Dachigam NP

Home ranges of leopards in Dachigam were found to be larger compared to other studies which may be again explained by low prey availability in the area. And home range of leopard was largest in summer season coinciding with lowest large prey availability. The seasonal variation in prey density and distribution in the park is expected to have pronounced effects on leopard diet. Understanding how animals utilize available space is important for their conservation, as it provides insight into the ecological needs of the species. It also gives an idea of inter and intra-specific interactions occurring in that space. To conserve a viable carnivore population and reduce the livestock depredation, wild prey species density needs to be managed effectively (Wang 2006). Results from density surface modeling may allow wildlife managers to make best use of the available spatial data to understand patterns of abundance and hence make better decisions for the conservation of endangered hangul and langur. Further research must be oriented to identify migrations routes and summer range of the species outside the park, to evaluate protection degree currently offered by natural reserve area and the presence of potential threats, in order to ultimately develop effective site-specific strategies for the conservation of the species.

CHAPTER 4

FEEDING ECOLOGY OF LEOPARD

4.1 Introduction

Studying carnivore diet is an essential step in investigating carnivore ecology (Mills 1992), as diet directly reflects resource use and can provide crucial information regarding habitat utilization and competitive interactions (Litvaitis 2000). Diet studies form basis for understanding population-level impacts that carnivores may have on prey populations (Owen-Smith & Mason 2005; Owen-Smith 2008). Studying prey selection is critical for understanding life history strategies of any carnivore (Miquelle *et al*. 1996). Thus, to get a detailed account of carnivore ecology we need to study its prey profile as well as prey preference in detail. There are numerous techniques available for the assessment of carnivore diets which include highly invasive stomach content analysis (Smuts 1979), moderately invasive continuous direct observations (Mills 1984; Mills and Shenk 1992) and non-invasive faecal analysis (Johnsingh 1983; Karanth and Sunquist 1995; Edgaonkar 2008), carcass observation (Lehmann *et al*. 2008), spoor tracking (Stander *et al*. 1997b) and radio tracking (Seidensticker 1976a). Each of the approaches has its advantages and disadvantages. Among them a widely used field technique for understanding predator diets is the non-invasive faecal analysis method owing to its effectiveness in case of elusive species as well as rugged terrain. It involves identification of recognizable parts of prey that have passed through predator's digestive systems and comparison with reference collections of potential food items (Koppikar and Sabnis 1976; Putman 1984; Mukherjee *et al*.1994; Edgaonkar and Chelam 2002; Edgaonkar 2008). Furthermore, advanced analytic methods (Floyd *et al*. 1978; Ackerman *et al*. 1984; Reynolds and Aebischer 1991; Trites and Joy 2005) can be applied to such scat data to obtain accurate prey profiles.

Leopard is the most widespread member of the large felids (Myers 1986) and even persists in the areas devoid of other large carnivores. It occurs throughout sub-Saharan Africa, India and southern Asia (Nowell and Jackson 1996). This wide geographic range has been mainly attributed to its highly adaptable hunting and feeding behavior (Bertram 1999; Norton *et al*. 1986). Leopard exhibits one of the broadest diet ranges of the large predators and have been recorded feeding on 92 different species in sub-Saharan Africa alone (Hayward *et al.* 2006a). Bodendorfer *et al.* (2006) reported thirty two prey species in leopard's diet in Marahoue National Park, West Africa. It displays localized approach in foraging behavior, with a varying diet composition among ecosystems depending upon prey assemblages and prey abundances (Seidensticker *et al.*1990). Variety of leopard prey items as per studies ranges from arthropods, small birds, rodents, catfish and hares to animals as large as giraffe calves, adult male eland and adult male Sambar or Gaur (Fey 1964; Seidensticker 1976a; Kingdon 1977; Mitchell *et al.* 1965; Scheepers and Gilchrist 1991; Karanth and Sunquist 2000; Ott 2004). The richness of leopard prey suggests that they are largely unselective; however, it seems likely that their morphology and solitary hunting strategy imposes limitations on the prey they can capture (Hayward *et al.* 2006a).

A number of studies have been conducted to study diet of leopard across its distribution range (Kruuk and Turner 1967; Pienaar 1969; Schaller 1972; Bailey 1993; Henschel *et al.* 2005; Hoppe-Dominik 1984; Ray and Sunquist 2001). Some important studies on leopard diet in Asia have been reported from areas like, Wilpattu National Park, Sri Lanka (Eisenberg and Lockhart 1972), Ruhuna National Park, Sri Lanka (Santiapillai *et al.* 1982), Bandipur National park, Karnataka, India (Johnsingh 1983), Royal Chitawan National Park, Nepal (Seidensticker *et al.* 1990, Thapa 2011), Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu (Sathyakumar 1992), Wolong Reserve, China (Johnson *et al.* 1993), Nagarahole National Park, Karnataka (Karanth and Sunquist 1995), Sariska Tiger Reserve, Rajasthan (Sankar and Johnsingh 2002; Mondal *et al.* 2011; Mondal *et al.* 2012), Sanjay Gandhi National Park, Maharashtra (Edgaonkar and Chellam 2002), Satpura-Bori conservation area, Madhya Pradesh (Qureshi and Edgaonkar 2006), Garhwal Himalaya (Das 2006), Pauri Garhwal District, Uttaranchal (Goyal and Chauhan 2006), Mudumalai Tiger Reserve, Tamil Nadu (Ramesh *et al.* 2009), Pench Tiger Reserve, Madhya Pradesh (Majumder 2011), Gir Lion Sanctuary, Gujarat (Zehra 2013). Ahmed and Khan (2008) studied the food habits of leopard in Duduwa National Park, India, and found 20 prey items in 74 scats. Hayward *et al.* (2006a) studied prey preference of leopard by reviewing 29 published and 4 unpublished studies of leopard diets from 25 different conservation areas located in 13 countries of Africa and Asia. According to this study preferred prey weight of leopards range from 10 kg to 40 kg but their most preferred prey items were found to be the species with a mean body mass ranging between 23 kg and 25 kg that are found in small herds, dense habitat and afford the lowest risk of injury during capture. Hayward *et al*. (2006a) also found that medium sized antelope such as impala, bushbuck and common duiker are significantly preferred by leopards as prey, other species such as warthog, porcupine and klipspringer were taken in accordance to their abundance but species such as plains zebra, blue wildebeest and baboon that are restricted to open vegetation or have significant anti-predator strategies are significantly avoided.

4.1.1 Leopard diet in prey scarce conditions

Leopards tend to be more flexible in their diet as compared to other large carnivores like tigers under deteriorating habitat conditions (Johnsingh 1983). The diversity of prey species taken by leopards means that they can live wherever there is sufficient hunting cover and an appropriate prey base (Hayward *et al*. 2006a). Studies have shown that leopards require 1.6 kg to 4.9 kg of meat per day to maintain their body mass (Bothma and Le Riche 1986; Bailey 1993; Stander *et al*. 1997b). To achieve this leopards prey upon a wide variety of prey, and in the habitats with low densities of optimum sized prey, they commonly feed upon more abundant sub optimal prey (small mammals) < 20kg (Grobler & Wilson 1972; Bothma and Le Riche 1984; Norton *et al*. 1986; Ray and Sunquist 2001; Sankar and Johnsingh 2002; Henschel *et al*. 2005) and/or secondary prey (livestock and dogs) (Seidensticker *et al*. 1990; Edgaonkar and Chellam 2002; Goyal *et al*. 2007; Chauhan 2008; Shah *et al*., 2009). For predators, the upper size limit for the prey consumed is set by how successfully larger animals can be captured and subdued, while the lower size limit depends upon how frequently smaller dietary morsels can be found and eaten (Elton 1927). Thus, the high incidence of predation on smaller bodied prey may indicate its high level of abundance and/or profitability in a particular habitat (Ray and Sunquist 2001). For example, in certain mountainous regions like the Cederberg Mountains of South Africa, leopards mostly have access to smaller species, like klipspringers (*Oreotragus oreotragus*, ~12.5 kg) and rock hyrax (*Procavia capensis*, ~3.2 kg). And these two species alone contributed 35.2% to the biomass consumed by leopards in the area (Martins *et al*. 2011). Similarly, in Comoe National Park in Ivory Coast, leopards were found to prey predominantly on medium-sized (5-20 kg) to large (>20 kg) ungulates over a three-year period, but when populations of these taxa dwindled due to heavy poaching, leopard predation on large rodents, birds and reptiles increased significantly (Bodendorfer *et al*. 2006). A number of dietary studies have been undertaken on leopards inhabiting mountainous habitats in South Africa (Grobler 1972; Stuart and Stuart 1993; Nemangaya 2002; Power 2002; Schwarz and Fischer 2006; Ott *et al*. 2007). Research conducted on leopards in the granite hills of the Rhodes Matopos National Park in Zimbabwe (Grobler 1972) found that both hyrax species, (*Procavia capensi)* and (*Heterohyrax brucei*), were the most frequently occurring prey in leopard scats (51%). Norton *et al*. (1986) also reported that hyrax made up about 52% of prey items of leopard in the south western Cape Province in South Africa. The high frequency of small prey in the diet of leopards in mountainous areas having low prey abundance emphasizes on its flexibility of diet. Similar results have been reported from Himalayan ecosystems, for example, Johnson *et al*. (1993) studied leopard food habits in Wolong Reserve, China and found a significant contribution of rodents in leopard diet. Sankar and Johnsingh (2002) also reported high occurrence of rodent species in leopard diet from Sariska National Park, India. Leopards may also take domestic animals to fulfill energetic requirements when wild prey is scarce. Livestock become easy catch, having less handling time than wild prey and fewer anti-predator strategies (Woodroffe *et al*. 2005a). Chauhan *et al*. (2000) reported that leopards indulge into conflict with humans to make up for low wild prey availability in Garhwal Himalayas. According to Mizutani (1995) female leopards with cubs were more likely to raid livestock than those without them, particularly if the core area of their home ranges or den sites were in a habitat frequently used by sheep. He also reported that livestock were killed more frequently in densely vegetated habitat than in open savannah habitat. Woodroffe *et al*. (2007) studied the effectiveness of traditional livestock husbandry in reducing predation by wild carnivores and found that the risk of predator attack by day was lowest for small herds that were accompanied by dogs and human herders and were grazed in open habitat. At night, the risk of attack was lowest for herds held in *'bomas'* (confinements) with dense walls that were pierced by few gates. Many studies have highlighted occurrence of domestic dogs in the diet of leopards when sufficient wild prey is not present like Edgaonkar and Chellam (1998) studied food habits of leopard in Sanjay Gandhi National Park and reported more than 60% occurrence of domestic dog in leopard's diet. Recently Athreya *et al*. (2014) reported high contribution of dogs in the diet of leopard from a human-dominated landscape in western Maharashtra, India. Similarly Shehzad *et al*. (2014) studied leopard diet using DNA-based diet analysis technique in Ayubia National Park, Pakistan and found high occurrence of domestic goat (64.9%) in leopard diet. Recently, Chatta *et al*. (2015) studied leopard diet in Machiara National Park by analyzing 105 scats and found that among 19 items identified from leopard scats Indian pika (*Ochotona Roylei*) was the most frequently occurring species in summer season while as grey goral occurrence was high in winter.

4.1.2 Present Study

In Kashmir valley Leopard is at the top of food chain as other large felids are absent. In spite of this only a little information is available regarding the feeding ecology and predatory patterns of leopard in Kashmir valley (Shah *et al.* 2009; Iqbal 2005). Himalayan ecosystems generally have low large prey availability as reported by Aryal and Kreigenhofer (2009) from Dhorpatan Reserve Nepal. The situation in Dachigam National Park is somewhat similar, where prey is scarce and large prey shows seasonal migration due to pronounced climatic seasonality (Chapter 3). Leopards being generalists are expected to shift their diet to suboptimal prey species in the conditions of low prey availability. Studying diet of a predator may have significant implications for modeling predator-prey dynamics, particularly when evaluating the effects of predation on a rare prey species (Ross *et al*. 1997; Elbroch and Wittmer 2013). In case of this study hangul is the rare prey species involved, whose population is dwindling from past few decades and it is presumed that leopard is responsible for its decline. Keeping this in mind the current study was envisaged to understand the foraging ecology of leopard by comparing diet composition in prey rich and prey poor seasons. Specifically, the study: (1) determines the diet of leopard on seasonal basis; (2) ascertains the relative biomass of principal prey in leopard diet in different seasons and (3) estimates selectivity of major prey species by leopard.

4.2 Method

4.2.1 Food habits of leopard

4.2.1.1 Scat sample collection

The scat samples were collected systematically as well as opportunistically along trails and roads in Dachigam NP. Systematic scat collection was done in 19 trails or roads with length ranging from 1.5 to 6.5 km (Fig. 4.1). Scats were also collected by following GPS-collared leopards in the area. Leopard scats were identified from other coexisting carnivore species based on their size, shape and adjacent signs of leopard presence (tracks or scrapes).

The location, date, approximate age, associated marking signs and geographic coordinates were recorded for each scat using handheld eTrex Global Positioning System receiver. These scat samples were preserved in tagged polythene bags, labeled with unique scat IDs. Reference samples of potential wild and domestic prey species were prepared from hair samples of known species obtained from dead animals from the field; and domestic animals from villages around the Dachigam NP. In order to prepare good quality reference slides, the hairs were cleaned with water followed by xylene-alcohol mixture and dried on blotting paper. Hair profile, cuticular and medullar slides were prepared according to the methodology of Teerink (1991). Hair samples were examined grossly and microscopically with features such as color, thickness, medullar configuration, and cuticular scale patterns (Brunner and Coman 1974; Amerasinghe 1983; Teerink 1991; Oli 1993; Mukherjee *et al*. 1994; De Marinis and Asprea 2006).

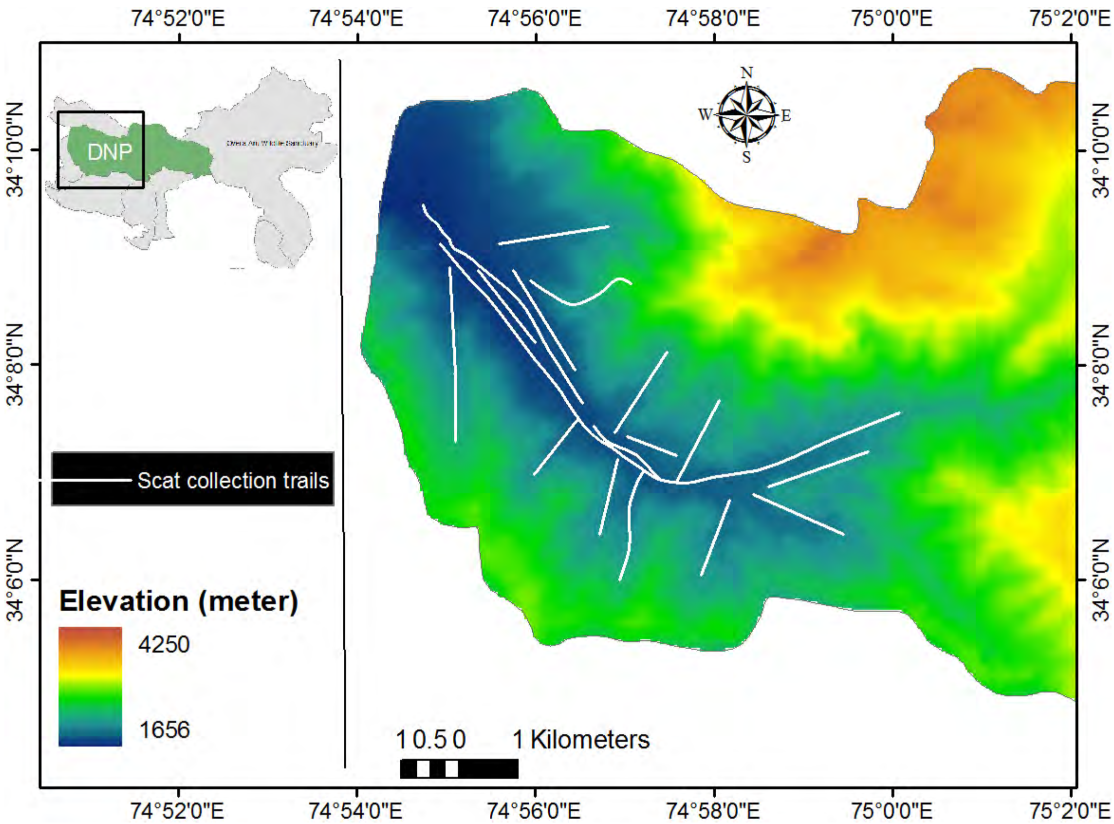

Fig.4.1 Locations of trails along which scats were collected.

4.2.1.2 Scat analysis

Air- dried scats were taken to the laboratory at Wildlife Institute of India, Dehradun. In the lab, all scats were oven dried at 60°C (Sankar and Johnsingh 2002) for 48 hours, subsequently broken and washed through 1 - 2 mm fine nylon sieve and prey remains such as hairs, bones, hooves, teeth, scales, claws, quills, etc. were separated for identification of prey eaten by leopards (Grobler and Wilson 1972; Mukherjee *et al.* 1994; Henschel and Ray 2003). The sieved prey remains were sun dried in paper bags for 3-4 days to avoid fungal growth. The dried scat samples were then labeled and stored in airtight bags. Following Mukherjee *et al.* (1994), 20 hair samples randomly selected from each scat sample were then mounted on glass slide using a DPX mountant and examined under microscope with 100X and 400X resolutions. Prey species were identified by comparing key features such as general appearance, color, pigment, length, width, medullary width and cuticular patterns with reference hair (Mukherjee *et al.* 1994; Bonnin 2008). Rodents and bird taxa were not identified to species level.

4.2.2 Data analysis

4.2.2.1 Sample size adequacy

Sample adequacy analysis was carried out to ensure sufficiency of collected scat samples for each season following Mukherjee e*t al*. (1994). Minimum sample adequacy of scats to study food habits of leopard for each season was calculated by selecting random sets of five scats each until all scats within a season were analyzed. This was plotted cumulatively to reach an asymptote which was considered sufficient to quantify the diet of leopard.

4.2.2.2 Frequency of occurrence of prey

Data is presented in terms of both frequency of occurrence (proportion of scats containing each food items) and relative frequency of each food item (number of times a specific item was found) as a percentage of all items identified (Ackerman *et al*. 1984). Prior to calculating the frequency of occurrence, scats containing more than one prey item were given equal values by counting each prey items as 1/2 (or 0.5), if two food items occurred in one scat, and 1/3 (or 0.33), if three species/taxa occurred, and so on (Karanth and Sunquist 1995). Frequency of different prey species in leopard scats were analyzed separately for all the four seasons of the year.

4.2.2.3 Prey biomass and Niche breadth

Although frequency of occurrence has been widely used to quantify carnivore diet, however, if the body sizes of different prey items are highly variable this measure can overestimate the presence of small sized prey (Ackerman *et al*. 1984) and underestimate the presence of large sized mammalian prey (Weaver 1993). Smaller sized prey species with more surface area in relation to volume produces more scats per unit prey weight consumed and are overestimated in carnivore diets (Floyd *et al*. 1978; Ackerman *et al*. 1984).

To minimize biases, relative proportions of biomass consumed by leopard was estimated using the correction factor:

$$Y = 1.98 + 0.035\,X$$

developed by Ackerman *et al*. (1984) from feeding trails on cougar (*Felis concolar concolar*) where Y is the weight (in kg) of the prey consumed per scat and X is the average live weight of the prey. Estimates of Y is the biomass consumed per collectible scat for a prey species. The relative biomass of each prey species was calculated separately for all four seasons of the year.

In addition to this, leopard-specific biomass model developed recently by Chakrabarti et al. (2016) was also used for estimation of prey biomass consumed by leopards and the results where compared with estimates obtained using model developed by Ackerman et al. 1984. The correction factor given by Chakrabarti et al. (2016) is:

$$Y = 2.171 - 1.671 \exp^{-0.056X}$$

where Y is the weight (in kg) of the prey consumed per scat and X is the average live weight of the prey

Both percent relative occurrence (RO) and percent relative biomass (RB) of food categories in the diet of the leopard were used to calculate its niche breadths in different seasons using standardized Levin's index (B_{sta}) (Levins 1968; Colwell and Futuyama 1971). The Levins' index formula is:

$$B = \frac{1}{\sum_{i=1}^{n} p_i^2}$$

where *n* is the number of food categories and *p* is the proportion of records in each food category (*i*) set at 100%. The standardized Levins' index is calculated as:

$$B_{sta} = \frac{(\mathrm{B} - 1)}{(\mathrm{B}_{\max} - 1)}$$

where *B* is the Levins' index (Levins 1968; Krebs 1989) and B_{max} is the total number of food categories recognized. The index values range from 0 to 1.

4.2.2.4 Prey selection

In order to estimate prey selection by leopard, Jacobs' selectivity index (Jacobs 1974) was used to measure the preference for hangul, langur and rodents with respect to their available biomass in different seasons. Jacobs' index standardizes the relationship between the relative proportion that each species makes up of the leopard's diet *r* and prey relative abundance *p* (i.e. the proportion that each species makes up of the total abundance of all prey species at a site). The formula for Jacobs' index is:

$$D = \frac{(r_i - p_i)}{(r_i + p_i - 2r_i p_i)}$$

Where r_i is the relative biomass proportion of prey species *i* in the carnivore scats and p_i is the proportion of biomass of the prey species *i* in the available prey community. The resulting values range from +1 to -1, where +1 indicates maximum preference and -1 indicates maximum avoidance. Prey selectivity was then assessed by chi-square ratio test between the observed (biomass consumed) and expected (biomass available) contribution by each prey species.

4.3 Results

Overall 714 leopard scats were collected during this study, among which 189 scats were collected in winter season, 284 in spring, 117 in summer and 124 scats in autumn season. Seventeen different prey items were identified from their remains in scats during this study. Number of prey items per scat showed considerable seasonal variation. In winter season 78.83% analyzed scats contained only a single prey item, 19.04% contained two prey items while as 2.11% contained three prey items. In summer season the percentage of scats containing single prey item decreased to 53.84% and percentage of scats containing double and triple prey items increased to 40.17% and 5.98% respectively (Fig. 4.2).

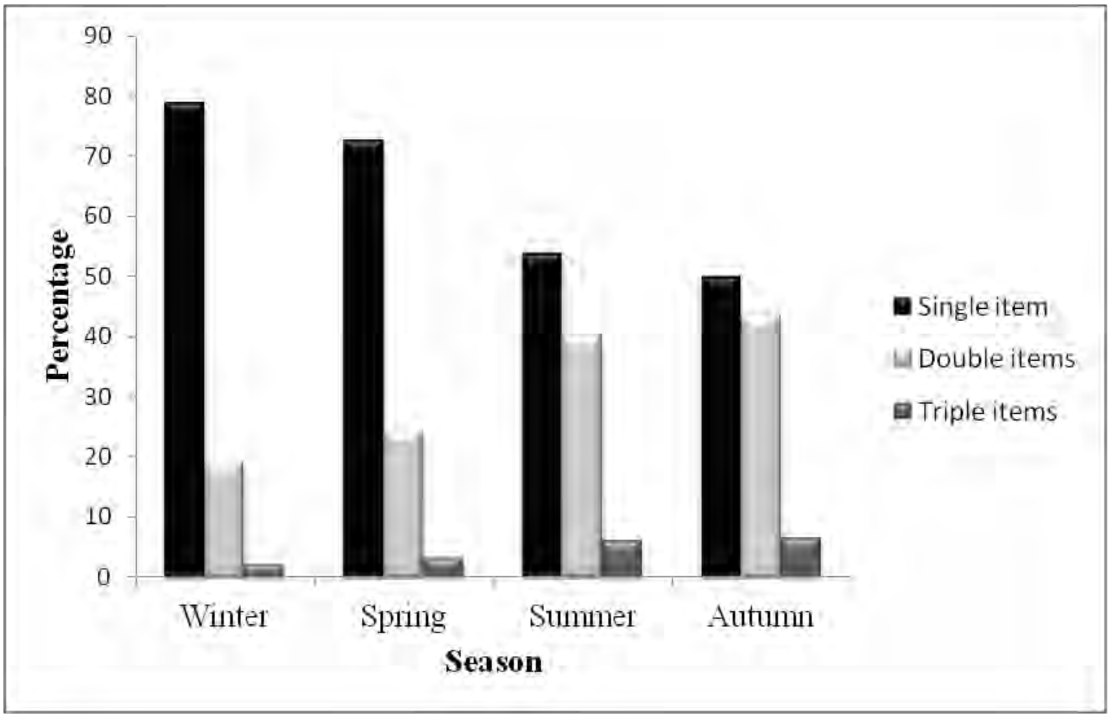

Fig. 4.2 Number of prey items detected per leopard scat in different seasons (n = 714) from year 2011-2013.

4.3.1 Frequency of occurrence of prey

Frequency of occurrence and percentage occurrence of different prey items identified in the leopard scats collected during this study are given in Table 4.1. Small rodents contributed maximum (48.05%) to the leopard diet in terms of percent frequency of occurrence followed by langur (14.04%), sheep (*Ovis aries*), goat (*Capra aegagrus hircus*) and dog (*Canis lupus familiaris*). Hangul contributed 2.05% while serow (0.20%) and rhesus macaque (0.10%) contributed least to the diet of leopard. Contribution of cattle species was very low to leopard diet (0.31%) as only three leopard scats contained remains of cow (*Bos primigenius*). Study of sample adequacy to determine leopard diet revealed that a minimum of 66 to 86 scat samples are required to study food habits of leopard in different seasons (Fig. 4.3). Thus scat samples collected and analyzed in all the four seasons were sufficient to document prey selection pattern of leopard.

Table 4.1 Frequency of occurrence and proportion of biomass consumed by leopard for different prey species (2011-2013).

Species	Count	Freq. of occurrence	% Occurrence	% Biomass consumed
Small Rodents	469	65.69	48.05	43.71
Langur	137	19.19	14.04	14.97
Sheep	74	10.36	7.58	9.30
Goat	67	9.38	6.86	8.42
Dog	59	8.26	6.05	6.64
Grass	39	5.46	4.00	--
Black Bear	24	3.36	2.46	5.38
Hangul	20	2.80	2.05	5.47
Arthropods	20	2.80	2.05	--
Bird	18	2.52	1.84	1.70
Jackal	15	2.10	1.54	1.64
Porcupine	13	1.82	1.33	1.46
Unidentified	10	1.40	1.02	--
Fish scales	5	0.70	0.51	--
Cow	3	0.42	0.31	0.77
Serow	2	0.28	0.20	0.43
Rhesus macaque	1	0.14	0.10	0.10

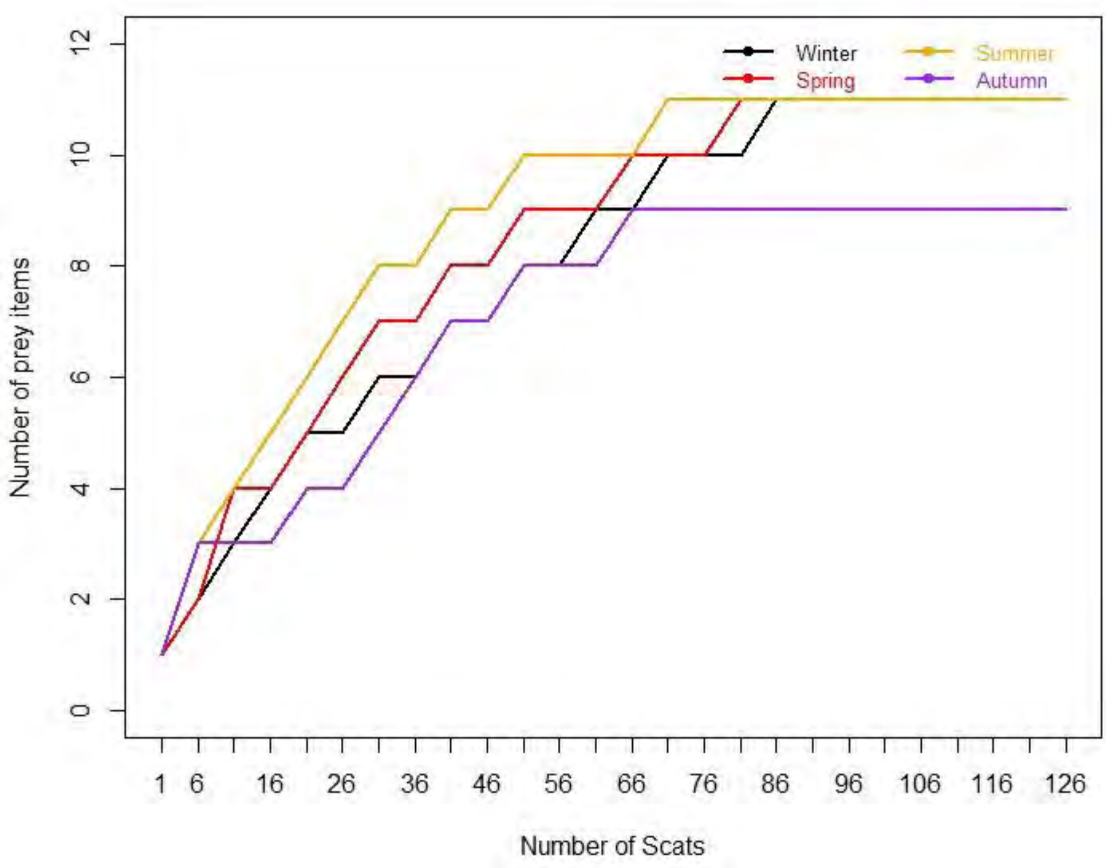

Fig. 4.3 Relationship between number of scats analyzed and number of prey species found in leopard diet.

4.3.2 Seasonal variation

Contribution of different prey items in leopard diet showed seasonal variation. Small rodents contributed highest to the leopard diet in summer season both in terms of percent occurrence (55.63%) as well as percent biomass consumed (53.77%) while as their contribution decreased in winter season. While in case of large prey, consumption was high in winter season when langur and hangul contributed 19.28% and 8.57% respectively in terms of biomass. Consumption of large prey decreased in summer season (Fig. 4.4). Langur and hangul composed only 10.83% and 1.59% of biomass consumed by leopard respectively in summer season. Tables (4.2 - 4.5) give a detailed account of frequency of occurrence, percent biomass consumed and number of prey individuals taken by leopard in different seasons. Levin's standardized index indicated that leopards had the most diverse dietary niche breadths in winter season (0.274833) while as least diversity was observed in summer season (0.141794) (Table 4.7).

Table 4.2 Percentage frequency of occurrence (FOO) and proportion of biomass consumed and number of individual consumed by leopard for different prey species in winter season (2011-2013).

Animal	Wt. (kg)	FOO (%)	% Relative estimated bulk	Collectable Scats/ Kill	Biomass/ 100 Scats	% Biomass eaten	No. of Individuals eaten/100 Scats
Small Rodents	0.2	38.20	40.53	0.10	80.53	32.52	402.63
Langur	10	19.31	20.49	4.29	47.73	19.28	4.77
Dog	12	8.85	9.39	5.00	22.53	9.10	1.88
Goat	20	7.73	8.20	7.46	21.98	8.88	1.10
Sheep	20	6.87	7.29	7.46	19.53	7.89	0.98
Hangul	110	3.43	3.64	18.87	21.21	8.57	0.19
Black Bear	80	3.00	3.18	16.74	15.21	6.14	0.19
Birds	0.85	3.00	3.18	0.42	6.40	2.58	7.53
Jackal	10	2.15	2.28	4.29	5.31	2.15	0.53
Cow	100	0.86	0.91	18.25	5.00	2.02	0.05
Porcupine	12	0.86	0.91	5.00	2.19	0.88	0.18
Rhesus macaque	7	0.00	0.00	3.15	0.00	0.00	0.00
Serow	75	0.00	0.00	16.29	0.00	0.00	0.00

Table 4.3 Percentage frequency of occurrence (FOO) and proportion of biomass consumed and number of individual consumed by leopard for different prey species in spring season (2011-2013).

Animal	Wt. (kg)	FOO (%)	% Relative estimated bulk	Collectable Scats/ Kill	Biomass/ 100 Scats	% Biomass eaten	No. of Individuals eaten/100 Scats
Small Rodents	0.2	50.94	55.42	0.10	110.11	46.55	550.55
Langur	10	14.02	15.25	4.29	35.53	15.02	3.55
Sheep	20	7.28	7.92	7.46	21.22	8.97	1.06
Goat	20	5.12	5.57	7.46	14.93	6.31	0.75
Dog	12	4.31	4.69	5.00	11.25	4.76	0.94
Black Bear	80	2.70	2.94	16.74	14.04	5.94	0.18
Hangul	110	2.43	2.64	18.87	15.38	6.50	0.14
Jackal	10	2.16	2.35	4.29	5.47	2.31	0.55
Porcupine	12	1.35	1.47	5.00	3.52	1.49	0.29
Bird	0.85	1.08	1.17	0.42	2.36	1.00	2.78
Serow	75	0.54	0.59	16.29	2.70	1.14	0.04
Cow	100	0.00	0.00	18.25	0.00	0.00	0.00
Rhesus macaque	7	0.00	0.00	3.15	0.00	0.00	0.00

Table 4.4 Percentage frequency of occurrence (FOO), proportion of biomass consumed and number of individual consumed by leopard for different prey species in summer season (2011-2013).

Animal	**Wt. (kg)**	**FOO (%)**	**% Relative estimated bulk**	**Collectable Scats/ Kill**	**Biomass/ 100 Scats**	**% Biomass eaten**	**No. of Individuals eaten/100 Scats**
Small Rodents	0.2	55.62	61.11	0.10	121.43	53.77	607.17
Langur	10	9.55	10.49	4.29	24.45	10.83	2.44
Sheep	20	7.87	8.65	7.46	23.18	10.26	1.16
Goat	20	6.74	7.41	7.46	19.85	8.79	0.99
Dog	12	3.93	4.32	5.00	10.36	4.59	0.86
Black Bear	80	2.25	2.47	16.74	11.82	5.23	0.15
Porcupine	12	1.69	1.86	5.00	4.46	1.97	0.37
Bird	0.85	1.12	1.23	0.42	2.47	1.10	2.91
Jackal	10	1.12	1.23	4.29	2.87	1.27	0.29
Hangul	110	0.56	0.62	18.87	3.59	1.59	0.03
Rhesus macaque	7	0.56	0.62	3.15	1.37	0.61	0.20
Cow	100	0.00	0.00	18.25	0.00	0.00	0.00
Serow	75	0.00	0.00	16.29	0.00	0.00	0.00

Table 4.5 Percentage frequency of occurrence (FOO), proportion of biomass consumed and number of individual consumed by leopard for different prey species in autumn season (2011-2013).

Animal	Wt. (kg)	FOO (%)	% Relative estimated bulk	Collectable Scats/ Kill	Biomass/ 100 Scats	% Biomass eaten	No. of Individuals eaten/100 Scats
Small Rodents	0.2	47.42	51.68	0.10	102.68	44.64	513.42
Langur	10	11.86	12.93	4.29	30.12	13.09	3.01
Goat	20	9.28	10.11	7.46	27.10	11.78	1.36
Sheep	20	8.76	9.55	7.46	25.59	11.12	1.28
Dog	12	7.73	8.42	5.00	20.22	8.79	1.68
Bird	0.85	2.58	2.81	0.42	5.65	2.46	6.65
Black Bear	80	1.55	1.69	16.74	8.07	3.51	0.10
Porcupine	12	1.55	1.69	5.00	4.05	1.76	0.34
Hangul	110	1.03	1.12	18.87	6.54	2.84	0.06
Cow	100	0.00	0.00	18.25	0.00	0.00	0.00
Jackal	10	0.00	0.00	4.29	0.00	0.00	0.00
Rhesus macaque	7	0.00	0.00	3.15	0.00	0.00	0.00
Serow	75	0.00	0.00	16.29	0.00	0.00	0.00

4.3.3 Prey Biomass estimation using leopard specific model

Application of leopard-specific biomass model (Chakrabarti *et al*. 2016) to the results of this study revealed higher contribution of small and medium size prey but lower contribution of large prey in their diet than was estimated using model developed by Ackerman *et al.* (1984). However it was observed that in case of small and medium sized prey difference in biomass estimation was relatively smaller than that in case of large prey (Table 4.6).

Table 4.6 Comparison between relative contribution (biomass) of prey species in leopard diet estimated using leopard-specific biomass model developed by Chakrabarti et al. (2016) and estimates obtained using biomass model developed by Ackerman et al. (1984)

	All Seasons			Winter			Spring			Summer			Autumn		
	Ac^{Bio}	Ch^{Bio}	%Diff	Ac^{Bio}	Ch^{Bio}	%Diff	Ac^{Bio}	Ch^{Bio}	%Diff	Ac^{Bio}	Ch^{Bio}	%Diff	Ac^{Bio}	Ch^{Bio}	%Diff
Small Rodents	43.71	45.03	2.94	32.52	34.04	4.47	46.55	48.22	3.46	53.77	54.42	1.19	44.64	45.10	1.02
Langur	14.97	15.88	5.74	19.28	20.78	7.23	15.02	16.02	6.25	10.83	11.28	4.04	13.09	13.62	3.88
Sheep	9.30	9.71	4.21	7.89	8.37	5.73	8.97	9.42	4.73	10.26	10.52	2.49	11.12	11.39	2.32
Goat	8.42	8.79	4.22	8.88	9.41	5.73	6.31	6.62	4.73	8.79	9.01	2.49	11.78	12.06	2.32
Dog	6.64	7.04	5.69	9.10	9.80	7.18	4.76	5.07	6.20	4.59	4.78	3.99	8.79	9.14	3.82
Hangul	5.47	3.47	-57.42	8.57	5.53	-54.94	6.50	4.15	-56.58	1.59	0.99	-60.27	2.84	1.77	-60.54
Black Bear	5.38	4.06	-32.68	6.14	4.70	-30.59	5.94	4.50	-31.97	5.23	3.87	-35.08	3.51	2.59	-35.31
Birds	1.70	1.76	3.34	2.58	2.72	4.87	1.00	1.04	3.86	1.10	1.11	1.59	2.46	2.49	1.43
Jackal	1.64	1.74	5.74	2.15	2.31	7.23	2.31	2.47	6.25	1.27	1.32	4.04	0.00	0.00	-
Porcupine	1.46	1.55	5.69	0.88	0.95	7.18	1.49	1.59	6.20	1.97	2.06	3.99	1.76	1.83	3.82
Cow	0.77	0.52	-48.96	2.02	1.38	-46.61	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-
Serow	0.43	0.34	-28.79	0.00	0.00	-	1.14	0.89	-28.10	0.00	0.00	-	0.00	0.00	-
Rhesus macaque	0.10	0.11	5.50	0.00	0.00	-	0.00	0.00	-	0.61	0.63	3.79	0.00	0.00	-

‘Ac^{Bio}’ represents ‘proportion of prey biomass consumed’ estimated using equation developed by Ackerman et al. (1984)
‘Ch^{Bio}’ represents ‘proportion of prey biomass consumed’ estimated using equation developed by Chakrabarti et al. (2016)
‘%Diff’ represents percentage difference in biomass estimation between two models for each species

Table 4.7 Levin's Standardized Niche Breadth Index of leopard based on relative frequencies of occurrence (RO) and relative biomass (RB) of prey species in its scats in different seasons

Season	B_{sta} (RO)	B_{sta} (RB)
Winter	0.274833	0.461776
Spring	0.171402	0.281214
Summer	0.141794	0.207790
Autumn	0.231560	0.368398

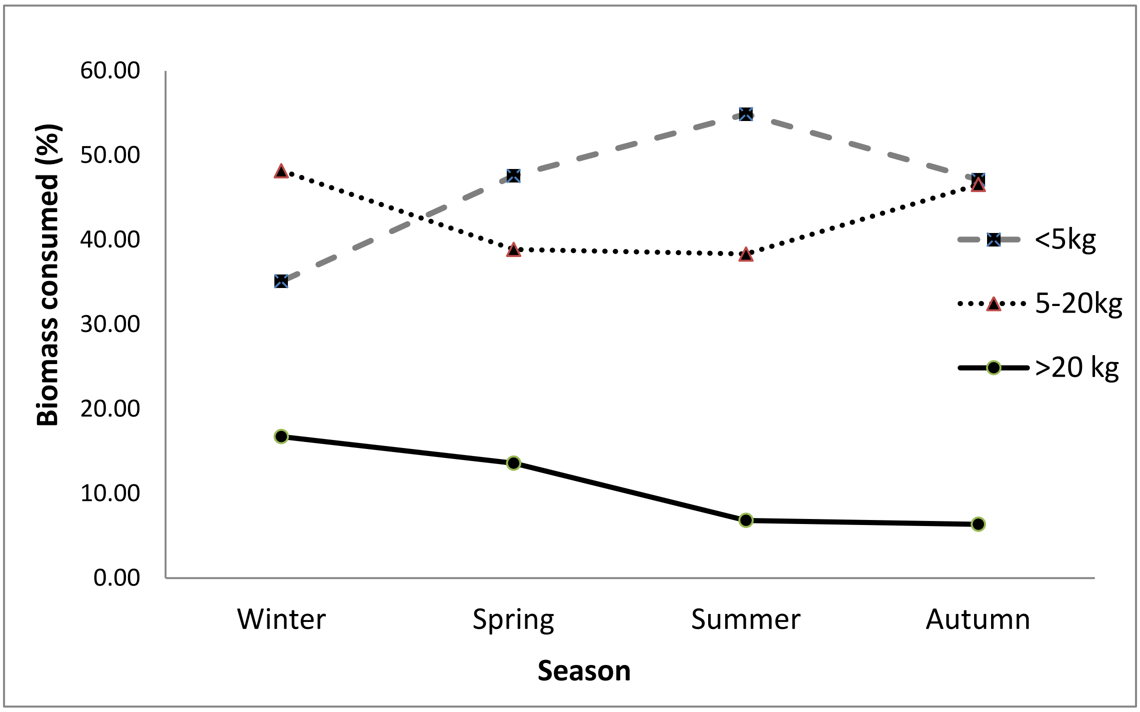

Fig. 4.4 Relative biomass consumed of different prey size classes in the diet of leopard across different seasons in Dachigam National Park

4.3.4 Prey selection

Jacobs' index was calculated from biomass availability and biomass consumption for hangul, langur and small rodents. It indicated that small rodents and langur were consumed more than their availability and hangul was consumed less than availability in all the four seasons (Table 4.8). Preference of hangul was slightly higher (-0.79) during winter season as compared to summer season (-0.90). The index of prey selection by leopard at individual species level was in the following order: rodents > langur > hangul (Fig 4.5).

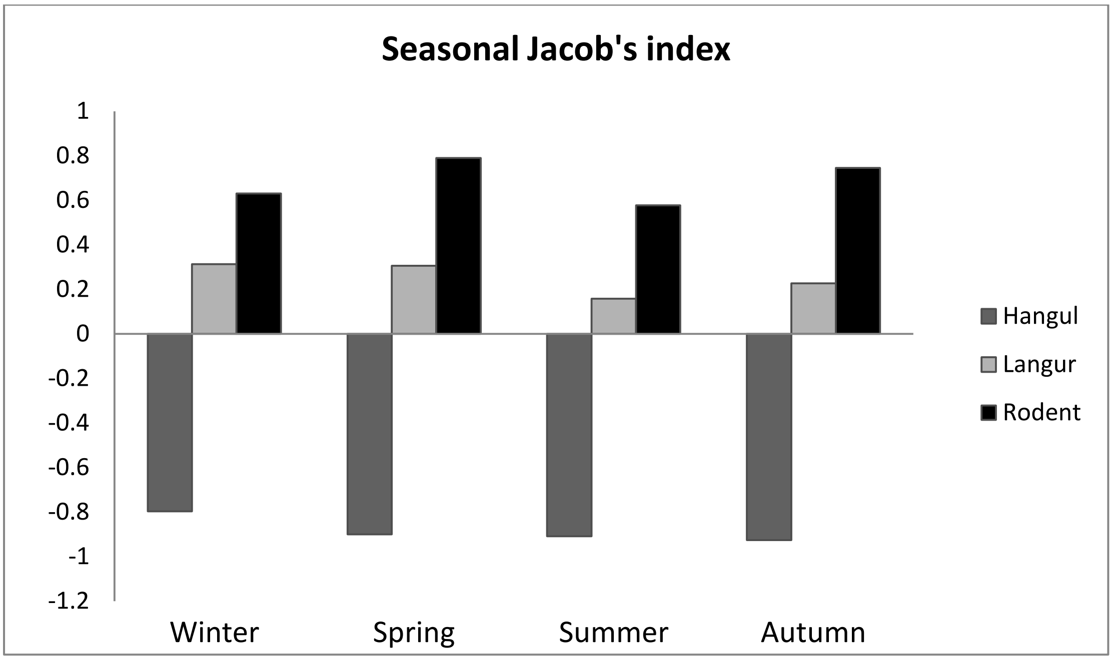

Fig. 4.5 Prey selection by leopard in the study area using Jacobs' index of selectivity based on availability of biomass and utilization as shown by scat analysis in different seasons.

Table 4.8 Prey selection by leopard in different seasons based on available biomass and consumed biomass as shown by Jacobs's selectivity index and its significance value (p).

Species	**Winter**		**Spring**		**Summer**		**Autumn**	
	Jacob's index	**p**	**Jacob's index**	**p**	**Jacob's index**	**p**	**Jacob's index**	**P**
Hangul	-0.79675	<0.001	-0.89982	<0.001	-0.90825	<0.001	-0.92618	<0.001
Langur	0.31394	0.0050	0.30660	0.0120	0.15776	0.2680	0.22710	0.0700
Rodents	0.63041	<0.001	0.78992	<0.001	0.57762	0.0001	0.74563	<0.001

p is significant at < 0.05 level

4.4 Discussion

Leopard diet has been studied in different ecosystems across its distribution range and it is found to feed on a variety of prey (Hayward *et al*. 2006a). In Africa, leopards prey mainly on medium-sized (20 – 80 kg) ungulates in savannah habitats (Bailey 1993), while they consume smaller prey (<5 kg) more often in rainforests and some mountain ecosystems (Power 2002; Schwarz and Fischer 2006). Similarly in Indian subcontinent leopard diet varies with habitat. Study in Nagarhole, India, shows that leopards prefer medium-sized prey (31 – 175 kg, Karanth and Sunquist 1995). Leopards have also been reported to take substantial small-sized prey in the 5-30 kg range (Karanth and Sunquist 1995; Ray and Sunquist 2001; Hart *et al*. 1996). Choice of prey is influenced by prey availability, abundance, vulnerability and profitability (Emmons 1987; Iriarte *et al*. 1990; Ray and Sunquist 2001). Prey scarcity has diverse effects on felids like decreasing the proportion of productive females, delaying the age of first reproduction, reducing litter size, increasing offspring and adult mortalities, expanding home ranges, intensifying movements and increasing the numbers of transients and dispersing individuals – all of which worsen facets of viability (Fuller and Sievert 2001). In general carnivores are likely to switch their diet to secondary or sub optimal prey when the primary prey species is scarce (Hamilton 1981; Seidensticker *et al*. 1990; Santiapillai and Ramono 1992; Bailey 1993).

In Dachigam NP prey availability is low, so leopards being opportunistic feeders have shifted their diet to small prey available in the form of small mammals. Rodents comprised major proportion of leopard diet in all the four seasons during the study period. Earlier Shah *et al*. (2009) have reported 15.7% rodents in the leopard diet in Dachigam NP. Sankar and Johnsingh (2002) also reported high (45.6%) contribution of rodents in leopard diet from Sariska National Park. While Selvan *et al*. (2013) reported 22.6% contribution of rodents to leopard diet in Pakke Tiger Reserve (Table 4.9). Seasonal variation in leopard diet is attributed to variation in large prey availability due to migration of prey species. In summer season availability in terms of large prey decreases as langur and hangul densities are lowest and rodent densities are highest, thus leopard consumes rodents on large scale in summer season. High occurrence of rodents in summer is in consistency with a study from Machiara National Park, Pakistan where leopards were reported to consume 22.2% small mammals in summer season and 16% in winter season (Chattha *et al*. 2015). Large carnivores can generally be expected to be energy maximizers in prey-rich habitats and nonselective number maximizers where large-bodied prey species are rare (Griffiths 1975). In some Neotropical environments, leopards have been reportedly forced to switch to smaller prey as prey populations face high human hunting pressure (Redford 1992). But in case of this study large prey population is naturally low, compelling leopards to feed on smaller prey of less than 5kg weight. Such predominance of small prey in leopard diet has been reported by a number of other studies across its distribution range, for example, Stuart and Stuart (1993) analyzed 53 scats taken from an ecotourism property in western Soutpansberg, South Africa. They found remains of 14 different species and reported about 43% of leopards diet was composed of hyrax (*Procavia capensi*) whose body weight is less than 5 kg. Power (2002), in his examination of leopard diets on three properties in the Soutpansberg mountains, two of which were game farms, found that hyrax contributed 41.3% to the leopard diet. Similarly Chase-Grey (2011) reported 30.5% occurrence of small prey in diet of leopard from the same area of South Africa.

Number of prey items found per scat showed an increasing trend from winter to summer. This is clearly due to decrease in large prey availability in summer season the leopards consume a large number of different small prey including rodents. Levin's Standardized Niche Breadth Index however indicates that niche breadth of leopard decreases from winter to summer season, this is in consistency with resources available in terms of prey. High adaptability and the behavioral resilience of leopards allow them to live close to human settlements (Daniel 1996) where they prey on a range of domestic animals (Seidensticker *et al*. 1990). Livestock is prone to predation since they lack anti-predatory behavior unlike their wild counterparts (Diamond 2002). This makes leopards vulnerable to conflict with locals and often leads to high conservation costs in terms of retaliatory killings by people. In this study domestic prey in the form of sheep, goat, dog and cow contributed 25.13% (biomass consumed) to the leopard diet. This percentage varied seasonally, highest consumption was noted in summer season when large wild prey availability is low and people let livestock out for grazing. During winter season livestock are usually stall fed and kept housed in predator-proof confinements, thus reducing the chances of leopard predation. Chattha *et al.* (2015) recently studied leopard diet in similar ecosystem of Machiara National

Park, Pakistan and reported about 23% occurrence of livestock in summer diet and 16% in winter diet of leopards. According to Census 2011 about 73 % of the population of Jammu and Kashmir lives in rural areas and are associated with agriculture and livestock rearing as main occupation. Livestock population of the state Jammu and Kashmir has been estimated as 155.867 lakhs comprising 31.185 lakhs cattle, 37.788 lakhs sheep, 7.704 lakhs Buffalo, 17.748 lakhs goat, 57.195 lakhs fowl and 5.247 lakhs duck. (Livestock census 2011). Thus livestock in the region of Jammu and Kashmir acts as a good secondary source of food to support the leopard populations when wild prey availability is scanty. But still in case of this study occurrence of livestock in leopard diet is not very high, the reason may be that study area being a National Park, livestock grazing within the park is prohibited, so the only livestock individuals available to leopards are those grazing in the peripheral areas of the park or inside the villages. Many other studies have reported dependence of leopard on livestock and other domestic animals, for example, Athreya *et al*. (2014) examined diet of leopard in a human dominated landscape in western Maharashtra and found that leopards fed on 38.5% dog, 15% cat (*Felis catus*), 11% cow and 10% goat . Similarly, Edgaonkar and Chellam (2002) reported predominance of dogs in leopard diet from Sanjay Gandhi National Park, Maharashtra.

Table 4.9 Percent frequency of occurrence of major prey species in leopard (*Panthera pardus*) diet reported in studies from Indian subcontinent.

Species	Present Study	Dachigam NP[1]	Sariska TR[2]	Sanjaya Gandhi NP[3]	Mundanthurai TR[4]	Chitwan NP[5]	Bardia NP[6]
No. of scats	714	96	125	90	111	263	103
Rodents	48.05	15.7	45.6	19.95	7.41	4.62	10.5
Primates	14.14	21	6.4	8.72	10.17	3.55	9.2
Livestock	14.75	18.3	NP	11.31	8.33	10.21	17.1
Dog	6.05	21	NP	48.70	6.48	1.46	NP
Hangul	2.05	18.4	NP	NP	NP	NP	NP
Birds	1.84	0.8	4.8	NP	NP	1.59	4
Others*	13.12	4.8	43.2	11.31	67.61	78.57	59.2

Source: [1]Shah *et al.* (2009); [2]Sankar and Johnsingh (2002); [3]Edgaonkar and Chellam (2002); [4]Ramakrishnan *et al.* (1999); [5]Thapa (2011); [6]Eliassen (2003). *Others include prey species which are either absent or found in low percentage in leopard scats in Dachigam NP.

Predation of hangul by leopard has been a point of concern for conservationists for quite a long time. Hangul being critically endangered and showing declining population trend was presumed to be predated by leopards on a large scale. But this study clearly indicates that hangul only contributes 5.47% to leopard diet in terms of the biomass consumed. This consumption also varies with season, being highest in colder months and lowest in summer months. This is in accordance with varying seasonal density of hangul in the study area. This study also indicated leopard predation on other carnivore competitors *viz* Black bear and Jackal contributed 5.38% and 1.64% respectively in terms of biomass consumed. There are numerous reports from other areas where leopards predate upon other competing carnivores (Hamilton 1976; Bailey 1993; Bothma *et al.* 1997; Stander *et al.* 1997a; Mills and Funston 2003).

4.4.1 Prey selection

When a predator kills a species more frequently than expected based on its availability it is considered as preferred prey species, while if the predator takes proportionally fewer prey than expected based on availability then it is an avoided prey species (Hayward *et al*. 2005). Apart from availability there are an array of factors affecting prey preference of a predator, which vary with area, conditions and species. Prey selection reflects not just the predator's preference but also the ease with which prey is captured (Schaller 1972). In this study leopards consumed rodents and langur more than their availability in all the four seasons and hangul was avoided in all the seasons. Langur body weight is well within the preferred weight range of leopard prey so it is quite likely that leopards consume proportionally more langurs than their availability as no other prey of similar weight range is available. Further leopard's arboreal and cryptic nature (Karanth and Sunquist 1995) helps them to predate easily upon langur. Rodents being easy to catch are seen preferred in all the four seasons as sufficient large prey is not available. This emphasizes on the leopard's opportunistic behavior and its ability to efficiently feed upon a wide range of prey including small rodents. The explanation for avoidance of hangul is that it is a large sized ungulate with an average body weight of 110 kg which is very high as compared to mean body weight of preferred prey of leopard (23 – 25 kg). Further there are various other factors also apart from prey density which affect the vulnerability of prey to a certain predator like temporal and spatial distribution, defenses and anti-predatory tactics by prey species (Sunquist and Sunquist 1997). So avoidance of a prey may also be due to predator's risk of self-injury or high energy expenditure while attacking the prey. Jacob's selectivity index of hangul varied from -0.80 to -0.90 from winter to summer which is comparable to Jacob's index of similar weighing ungulate, Nilgai (*Bos elaphus tragocamelus*) (-0.74) as reported by Hayward (2006). Preference of hangul is higher in winter than summer due to higher availability and vulnerability of hangul to predation in winter because of aggregation of hangul to a narrower belt in lower Dachigam NP. There are many other studies supporting the argument that leopards tend to select prey smaller than themselves (Johnsingh 1983; Karanth and Sunquist 1995; Rabinowitz 1989; Schaller 1972; Grassman Jr. 1999). As a solitary hunter, the leopard cannot be sustained by other conspecific members if injured; hence it preys upon species where the risk of injury is minimal (Hayward *et al*. 2006a).

Top predators play a significant role in maintaining biodiversity in an ecosystem, through population dynamics and trophic cascades (Sergio *et al.* 2008; Baum *et al*. 2009). Leopard being top predator in Dachigam has an important role in maintaining ecological balance. This study lays emphasis on opportunistic behavior of leopard. It can be inferred from this study that when optimum prey is not readily available in summer season, leopards have switched their diet to suboptimum prey like small rodents to make their survival. Further hangul being critically endangered and showing declining population trend was presumed to be predated by leopards on a large scale. But this study clearly indicates that hangul is not preyed upon frequently by leopards and only contributes 5.47% to its diet in terms of the biomass consumed. In future studies, other factors responsible for decline of hangul population need to be explored.

Plate 4.1 (A) Leopard scat in field, (B) Washing of scats, (C) Hair and other undigested prey remains obtained after washing and drying. (D) Observations of hair characteristics of prey (E-H) Medullary pattern of Hangul, Rhesus macaque, Rodents, and Kashmir Gray Langur hair respectively as seen under microscope at 400X resolution.

CHAPTER 2
STUDY AREA

2.1 Background

Himalayan mountains are rich in biodiversity and provide life support system to millions of people. The phase-wise evolution of the Himalayas over 45–60 million years period has provided novel opportunities to the floral and faunal elements, arriving from all directions, to colonize the newly evolving landscapes and later diversifying into unique ecosystems (Das 1966; Singh and Singh 1987). Indian Himalaya Region (IHR) spans over twelve states of India and is distinguished as global biodiversity hotspot (Myers *et al*. 2000). The state of Jammu and Kashmir is situated at a strategic location and is important from bio-geographic, historical and economic point of view. The state possesses three distinct bio-geographic zones viz., Trans Himalaya (1A), North-west Himalaya (2A) and Semi-arid Plains (4A) (Rodgers and Panwar 1988). Ecologically this region is of huge importance due to its diverse habitats, which harbor many primitive as well as newly evolved taxa. The State covers a total area of about 2, 22,236 km^2 (Hussain 2002), (including 1, 20,849 km^2 under the occupation of Pakistan and China), the state is divided into three provinces viz. Jammu (26293 km^2), Ladakh (59146 km^2) and Kashmir Valley (15948 km^2), with each province differing markedly from one another in its climate, vegetation and culture. State is divided into three prominent floristic regions: alpine desert flora of Ladakh, subtropical flora of Jammu and predominantly temperate flora of Kashmir. The present study was carried out in Kashmir division (North West Himalayas) of state J&K, India. Dachigam National Park Srinagar was selected as the intensive study site.

2.2 Kashmir valley

Formed by the folding of Himalayan mountain chain, the valley of Kashmir is an oval-shaped basin (about 140 km long and 40 km wide) trending in the northwest to southeast direction. Literal meaning of word “*Kashmir*” is ‘desiccated land’ (from Sanskrit, *Ka* = water, *shimeera* = desiccate). It is believed that Kashmir was formerly a vast lake and this lake got drained in the form of Jhelum River (*Vyeth* in Kashmiri) by cutting through hills of Pirpanjal near Baramulla. The Kashmir valley harbors a rich floristic diversity which is of immense scientific interest. The vast areas covered by grasslands and meadowlands further add to its aesthetic splendor and resource profusion. These grasslands spread across a broad altitudinal and latitudinal gradient and are present nearly across all breadth of Kashmir valley. Kashmir Valley is broadly divided into three wildlife administrative divisions *viz* northern, central, and southern wildlife division (Fig. 2.1).

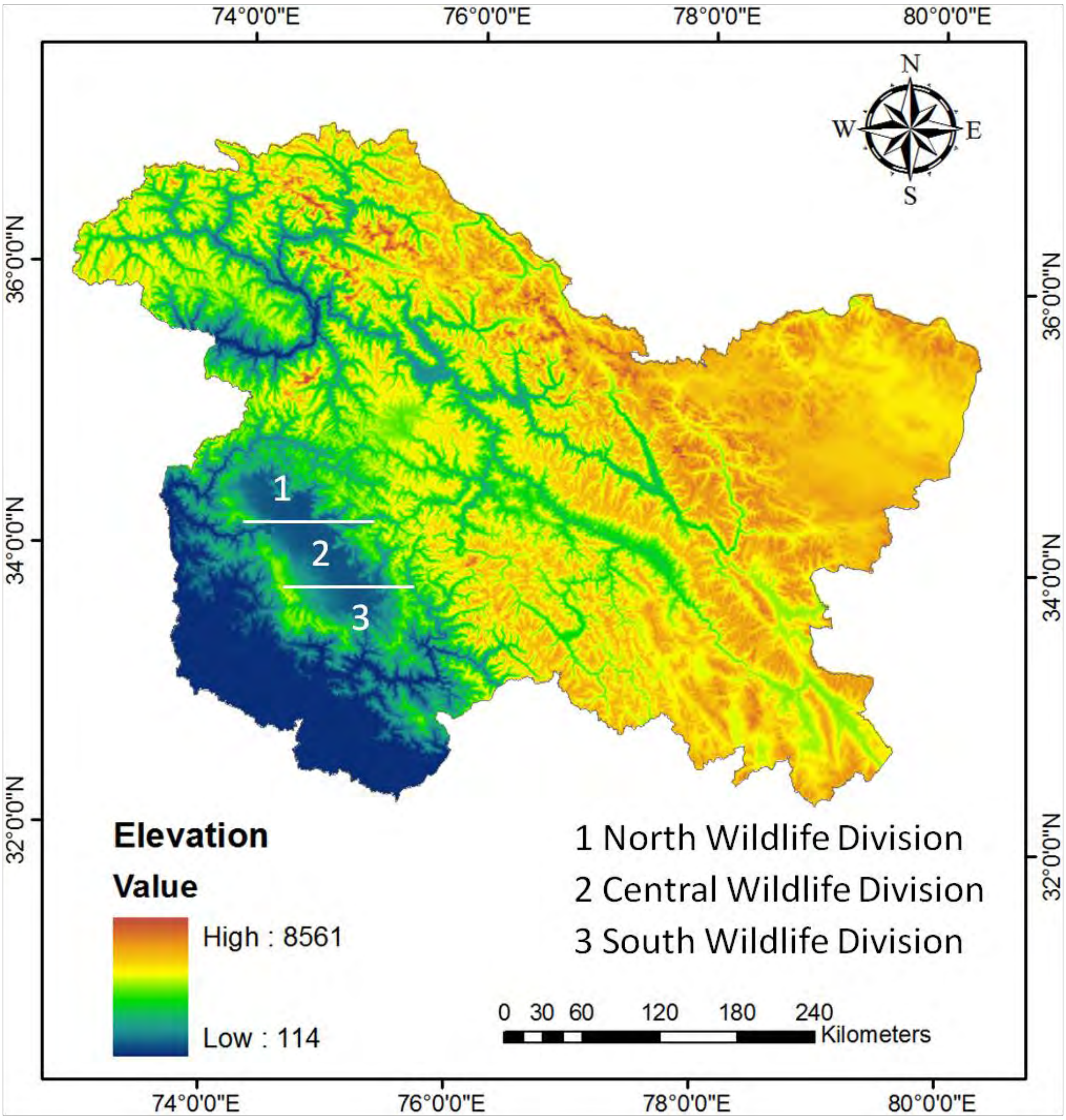

Fig. 2.1 Digital elevation map of Jammu and Kashmir

2.3 Location of the study area

Dachigam National Park lies between 34 05 N - 34 11 N and 74 54 E -75 09 E (Fig. 2.2) and the area comes under central and south wildlife divisions within the civil jurisdictions of Srinagar, Anantnag, Pulwama districts of Kashmir valley. Its area comes under 2A Bio-geographic zone and 2.38.12 (Himalayan Highlands) bio-geographical province (Rodgers and Panwar 1988). It is 21 km north-east to Srinagar the summer capital of Jammu and Kashmir state situated in Zabarwan mountain range which is a sub mountain range of Zanaskar Himalaya. Nearest Airport and railhead stand 32 and 20 km away, respectively.

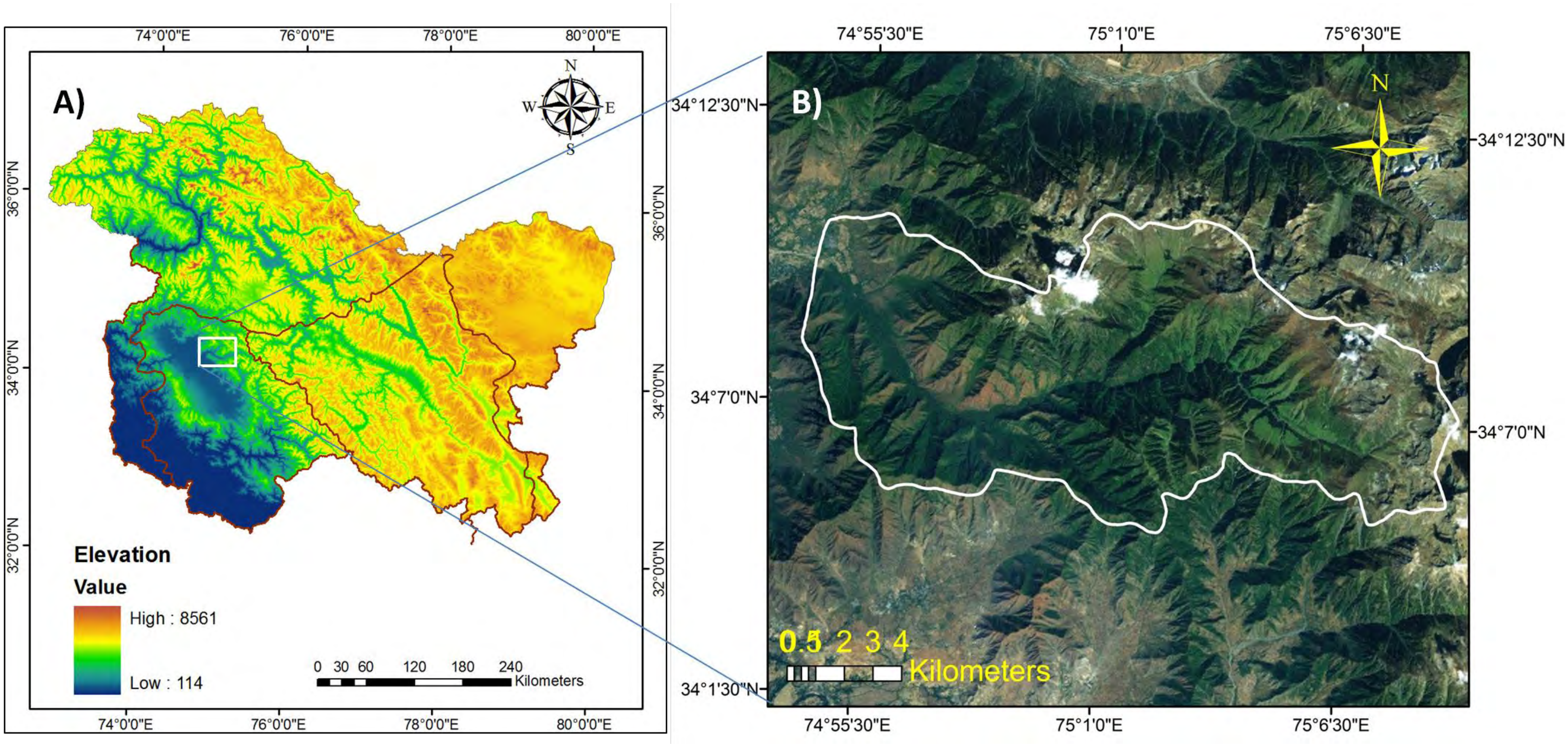

Fig. 2.2 Geographic location of Dachigam National Park in Jammu And Kashmir State. A) Jammu and Kashmir B) Dachigam NP

2.4 Geographic Information: materials and methods

Using Geographic Information System (GIS) tools, physiographic features such as elevation, aspect, slope maps were prepared for Dachigam NP. The Shuttle Radar Topographic Mission (SRTM) produced by NASA originally, has provided high quality digital elevation model (DEM). The SRTM 30m DEM file was downloaded from the CGIAR-CSI GeoPortal (Jarvis *et al*. 2008). Extract by mask feature of Arc GIS (version 9.3) was used to extract DEM for the study area from larger area. Surface option of the spatial analyst extension in Arc GIS was used to derive aspect and slope maps (Fig. 2.3 – 2.5). Normalized Difference Vegetation Index was derived from Landsat 4–5 Thematic Mapper imagery (30 m resolution) of the study area (mean of all the four seasons). NDVI is used as a measure of vegetation productivity (Pettorelli *et al*. 2009).

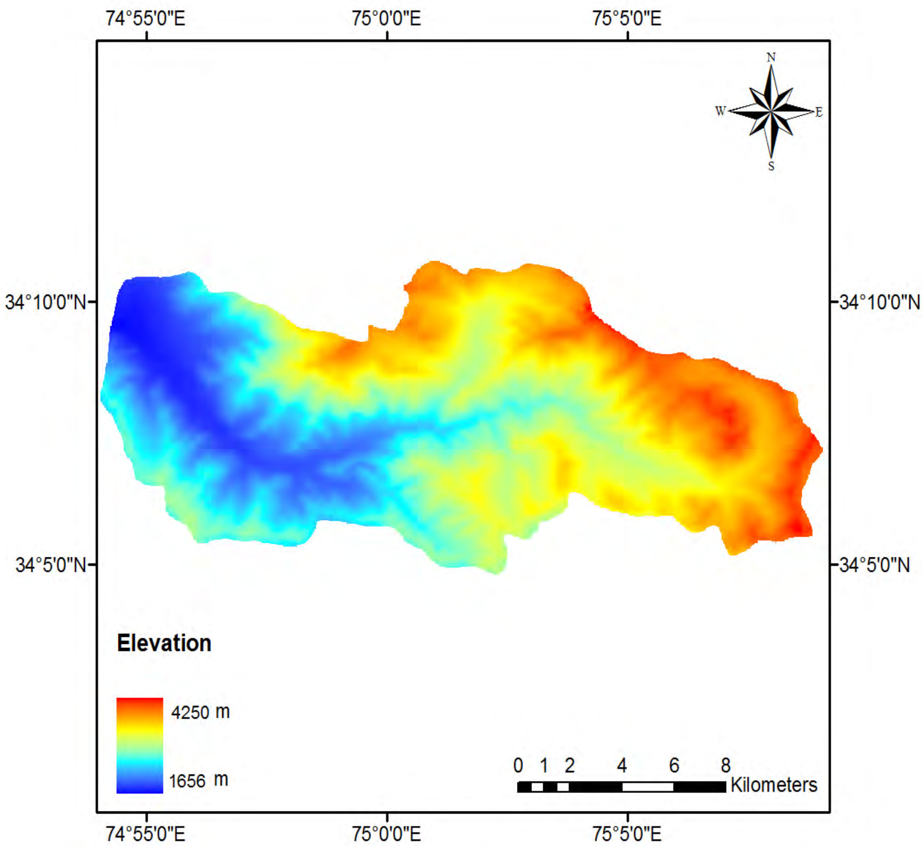

Fig. 2.3 Digital elevation map of Dachigam National park.

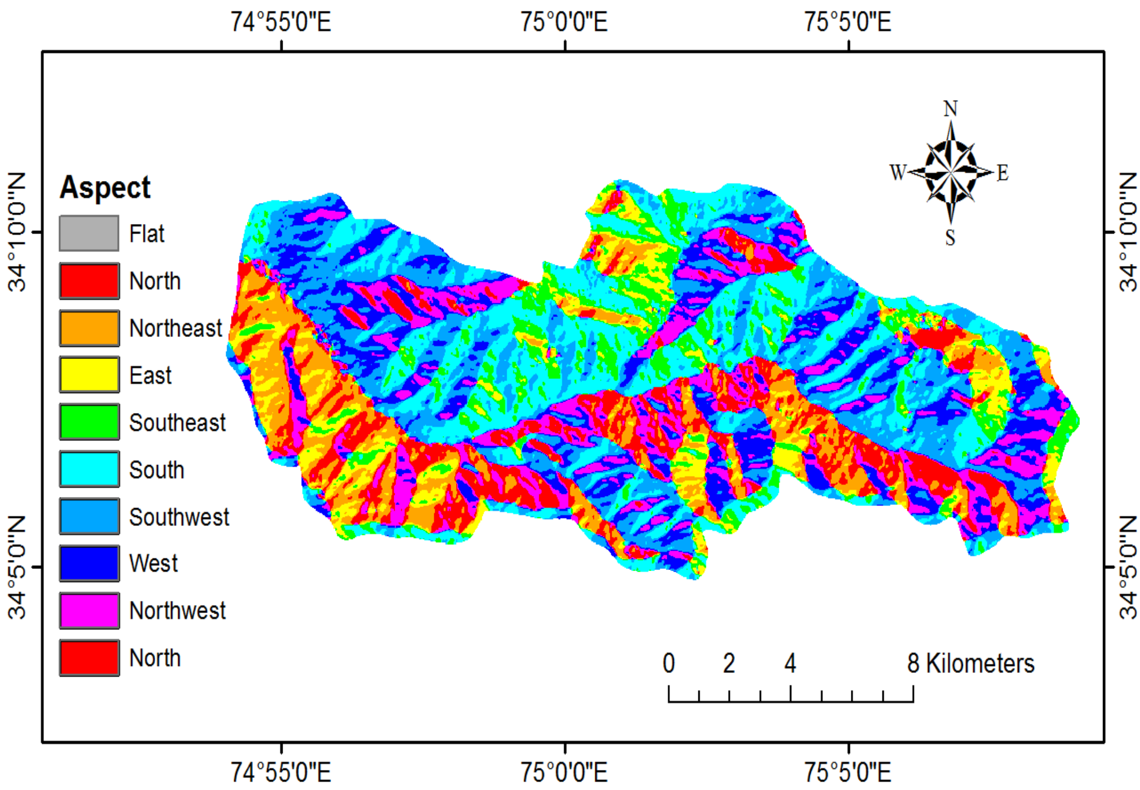

Fig. 2.4 Different aspect classes present in Dachigam National Park

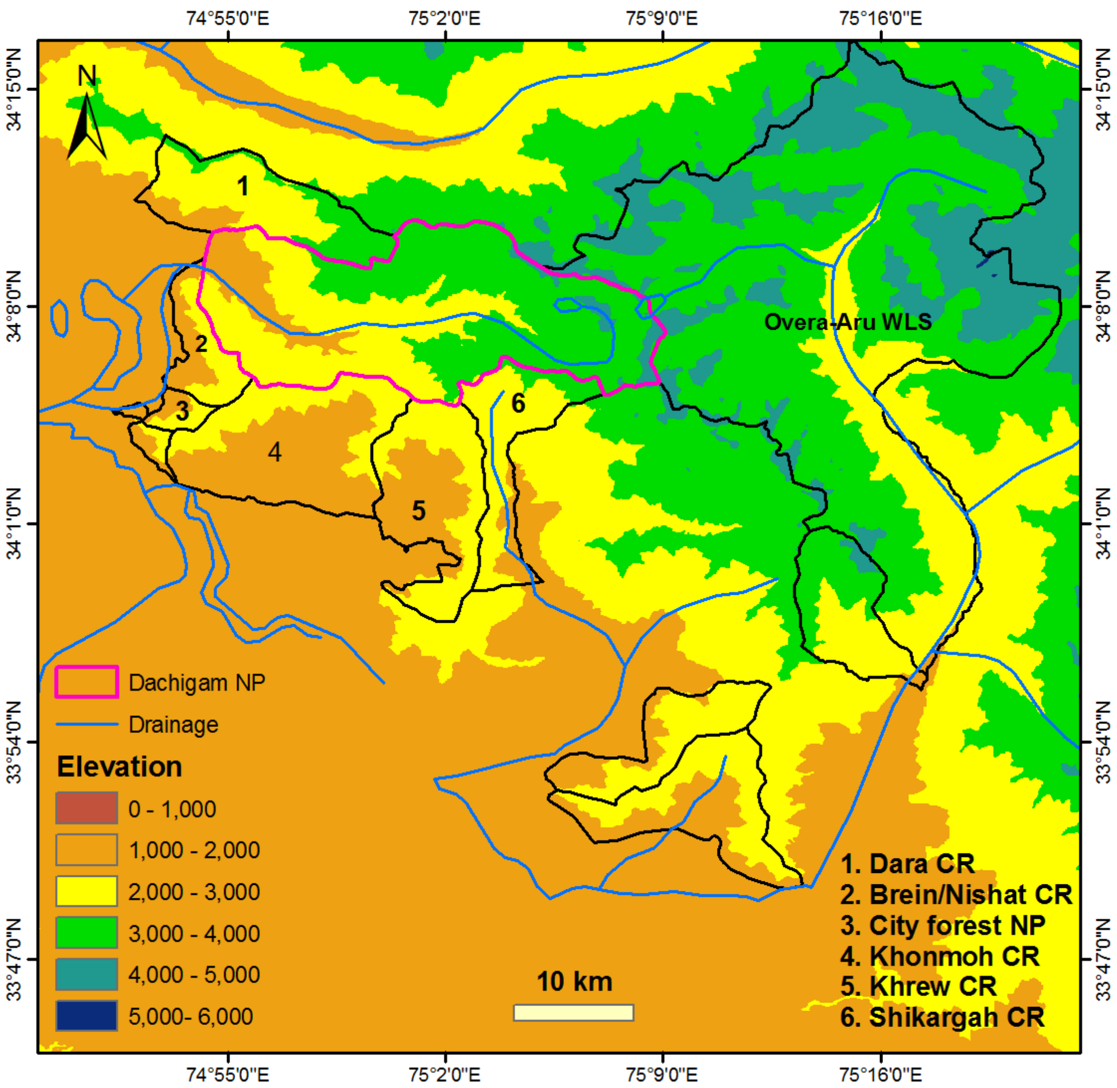

Fig. 2.5 Digital elevation map of Dachigam National park and its adjacent protected areas, showing different elevation classes (1000 m interval).

2.5 Physical features

The mountain ranges enclosing Dachigam NP are a part of the great Zanskar Range which forms the north-west branch of the central Himalayan axis, bifurcating near *Kulu* and terminating in the high twin peaks of *Nun* and *Kun*. The fold of this range is thrown into a number of undulations enclosing narrow gullies, and broader outflanked gullies locally known as *Nar*. Two steep ridges, one rising from near *Harwan* reservoir and another to the east of village *New Thir* form the natural boundaries of the National Park. The series of undulations presents a variety of slope and aspects, supporting an array of vegetation types. A number of rocky cliffs and steep slopes break the uniformity of the main slopes. The main *Dagwan* River flowing through the park originates from *Marsar* Lake and flows into *Harwan* reservoir; it is fed throughout its course by a network of streams draining through the numerous gullies.

2.6 History

The name of the park comes from the Kashmiri word *Dah* which means 10, *chi* means are and *gam* means village so "ten village". Before the existence of the park there were 10 villages which were later on translocated from the area due to the formation of a game reserve (*rakh*) by the Maharaja of Jammu and Kashmir. The name of the National Park was given in the memory of these 10 villages. Inside the park there are many areas which are named after the translocation of those villages.

2.7 Constitution

Dachigam NP remained a hunting reserve of the Maharaja of Jammu and Kashmir from its time of establishment in 1910 till 1947, after that its management was handed over to Department of Hospitality and Protocol (Fisheries Department, Directorate of game preservation) and subsequently to the Forest Department. It was managed under the Wildlife wing of Forest Department and later Dachigam was declared as a sanctuary by state order no. 276/C in 1951 (Holloway 1970; Holloway and Wani 1970). Dachigam Wildlife sanctuary was upgraded to National Park on 4 February 1981 (state order no. FST/20) by the Govt. of Jammu and Kashmir. The management of Dachigam NP was handed over to the newly formed Department of Wildlife Protection, Jammu and Kashmir 1982 after separation from Forest Department. The park is divided into two administrative units *viz* Lower and Upper Dachigam which are administered by Central and South Wildlife Division respectively. Today it is managed in IUCN category- II (National Park). Dachigam NP is surrounded by many conservation reserves which are contiguous to the boundaries (Fig. 2.5). There are many villages which are located on the periphery of Dachigam where managing wildlife have become a challenging task for the administrators.

2.8 Climate

The climate of the area can be described as Sub - Mediterranean to typically temperate with high degrees of variation in precipitation and dryness. The basic pattern of weather and climate over the Himalayas is governed by the summer and winter monsoon system of Asia (Mani 1981). In addition, the Himalayas are effected by extra tropical western system (Western disturbance), that move in winter over the north of the sub-continent from west to east. Kashmir valley has four distinct seasons in a year: spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

2.8.1 Temperature

Monitoring of air temperature in the study area for the period of three years (2011 to 2013) revealed that the monthly mean minimum temperature varied from - 3.25 ^{o}C in January 2012 to 17.77 ^{o}C in August 2012 (Fig. 2.6). While as monthly mean maximum temperature varied from 4.35 ^{o}C in January 2012 to 31.29 ^{o}C in July 2012 (Fig. 2.7).

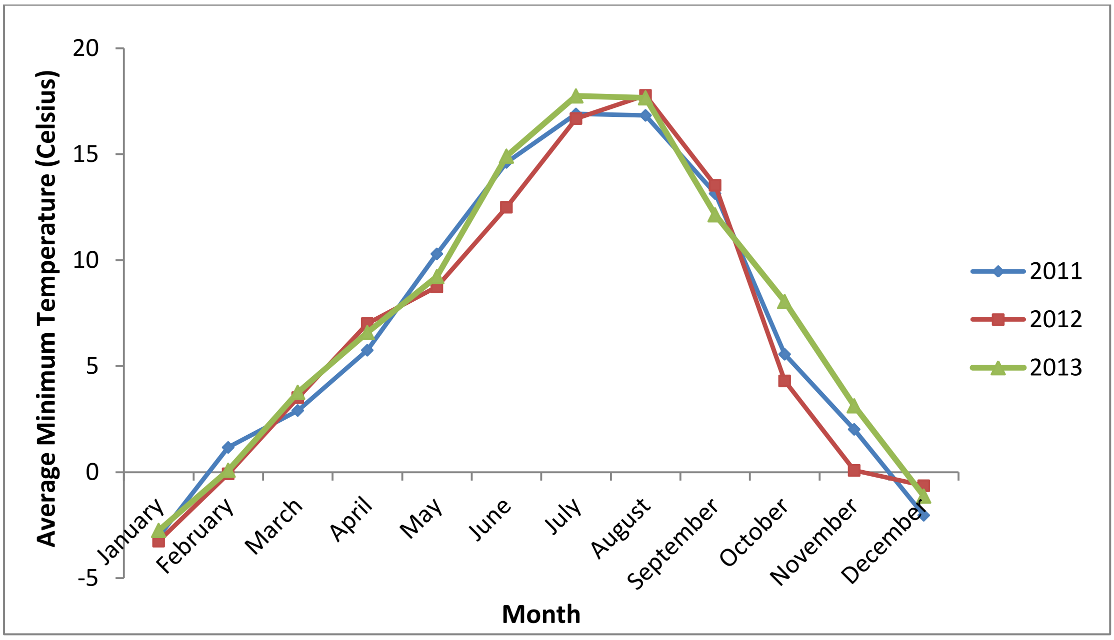

Fig. 2.6 Monthly variation in mean minimum temperature (^{o}C) in Dachigam National Park from 2011 to 2013.

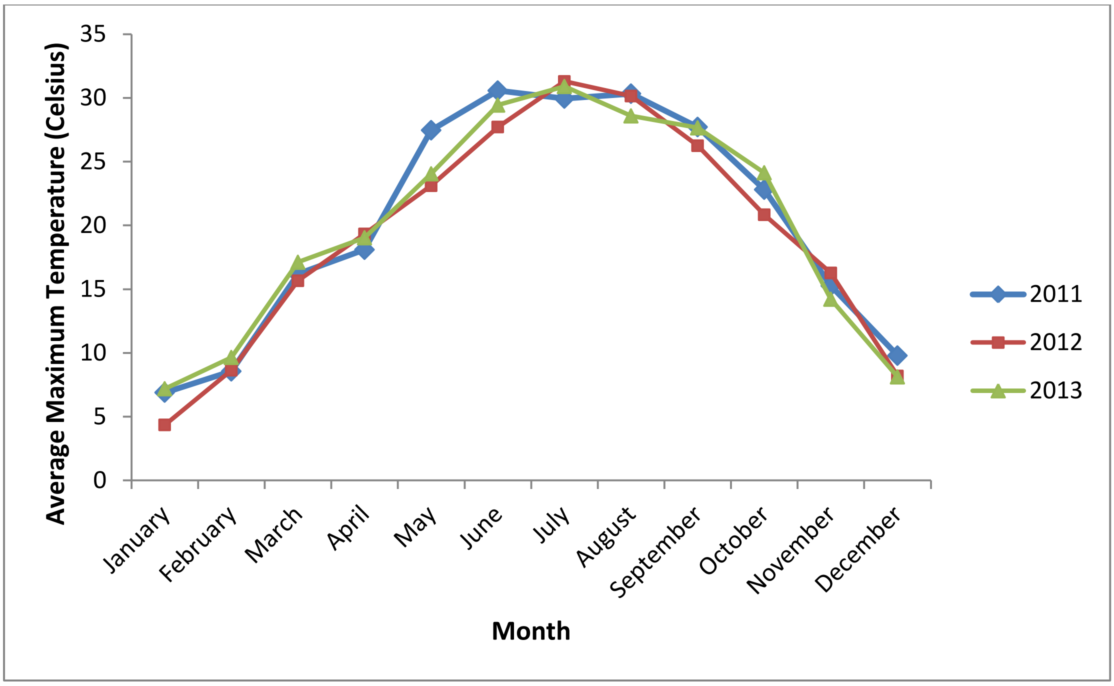

Fig. 2.7 Monthly variation in mean maximum temperature (^{o}C) in Dachigam National Park from 2011 to 2013.

2.8.2 Precipitation

The central and eastern Himalaya receives most precipitation during summer and the western Himalayan region receives most of its precipitation in winter (Chaulgain 2006). Thus most of the precipitation in Kashmir valley is received in winter and spring season. Snow is the main source of precipitation in winter and in upper parts of the park it melts till the month of June. The annual precipitation in the study area ranged between 628 mm and 932 mm during this study. Autumn season received lowest rainfall in all the three years (Fig. 2.8).

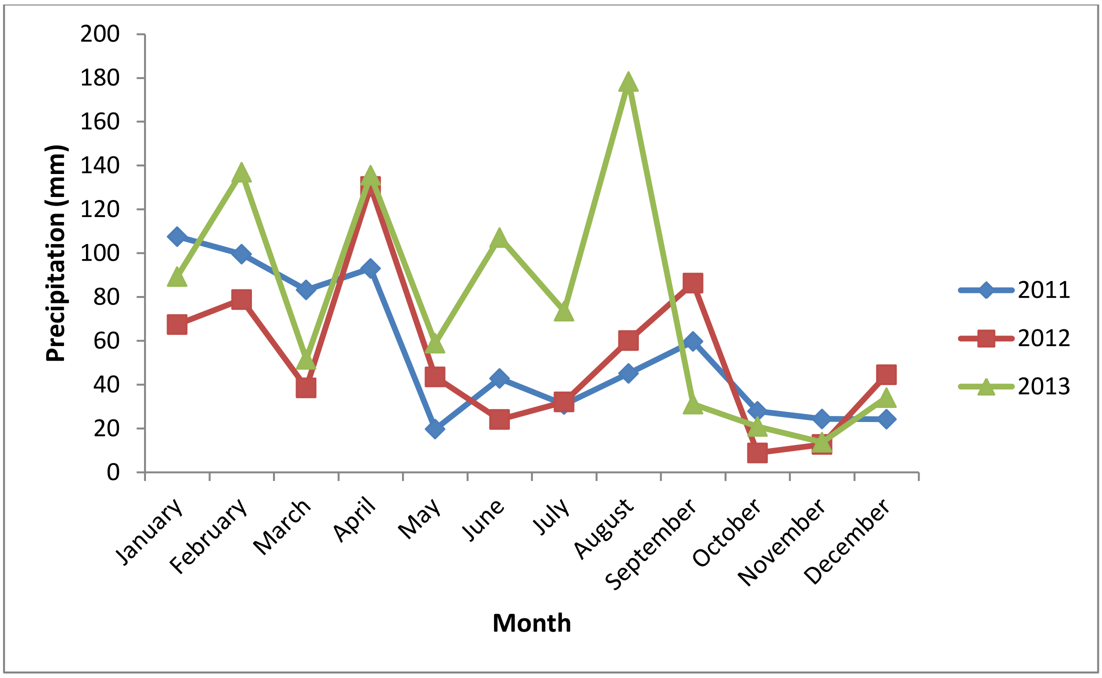

Fig. 2.8 Monthly variation in precipitation (mm) in Dachigam National Park from 2011 to 2013.

2.9 Geology

Geological studies indicate the Kashmir valley possesses a typical intermountain valley fill, comprising unconsolidated gravel sand and mud succession appearing as plateaus above the present plain of Jhelum and its tributaries. These plateau-like terraces are called *Karewas* or *Vudra* in the local language. The rock formations are varied and belong to all age groups from Achaean complexes to recent alluvium. In general, this Himalayan zone is characterized in bulk by complex crystalline rocks such as granite, gneisses and schist which form the core of the Zanskar range. This complex is partly sedimentary and consists of slates, phyllites, schists with embedded crystalline limestone (Kurt 1978). The region around Dachigam NP starting from Khrew, Khonmoh, and extending up to near Mahadeo consists of calcareous slates, shale and blue lime stone (Singh and Kachroo 1976). Most of the sediments composing these ranges have been laid from Cambrian to tertiary. The soil depth in the study area on the slope from lower to middle reaches is less than 25 cm and hence it falls under the category of very shallow soils.

2.10 Vegetation

The altitudinal range of lower Dachigam varies from 1650 m to 3500 m and thus has a complex mixture of vegetation types with broad leaved forest of maple (*Acer caesium*), mulberry (*Morus alba*), *Ulmus* spp., walnut (*Juglans regia)*, Hatab (*Parrotiopsis jacquimontiana*) and a variety of conifers such as deodar (*Cedrus deodara*), blue pine (*Pinus wallichiana*), spruce (*Picea smithiana*), and Fir (*Abies pindrow*) growing in an altitudinal sequence. Upper Dachigam altitude ranges from 2000 m to 4250 m. It comprises vegetation gradient of sub alpine community of forest followed by scrub vegetation of birch (*Betula utilis*) and rhododendron (*Rhododendron* sp.) interspersed with meadows of herb rich grass lands over 3300 m. The Normalized Difference Vegetation Index (NDVI) of the study area varies substantially along changing vegetation types and elevation above sea level (Fig. 2.9).

As per Champion and Seth (1968) the vegetation of Dachigam is typical of Himalayan moist temperate forest; sub-alpine forest and alpine forest type and can be classified into following types.

1. Moist Temperate deciduous forest

2. *Parrotiopsis* scrub forest

3. Western Himalayan low level blue pine forest

4. Western mixed coniferous forest

5. Deciduous alpine scrub

6. Western Himalayan sub-alpine birch - rhododendron forest

7. Dwarf juniper scrub

8. Dry temperate scrub

9. Alpine pastures.

A detailed vegetation study was carried out by Singh and Kachroo (1976) in Lower Dachigam. The dominant species in order of frequency constituting the flora of Dachigam NP are; *Compositae; Gramineae; Rosaceae; Labiatae; Leguminaceae; Cruciferae; Umbelliferae; Boraginaceae; Caryophyllaceae* and *Cyperaceae* (Singh and Kachroo 1976).

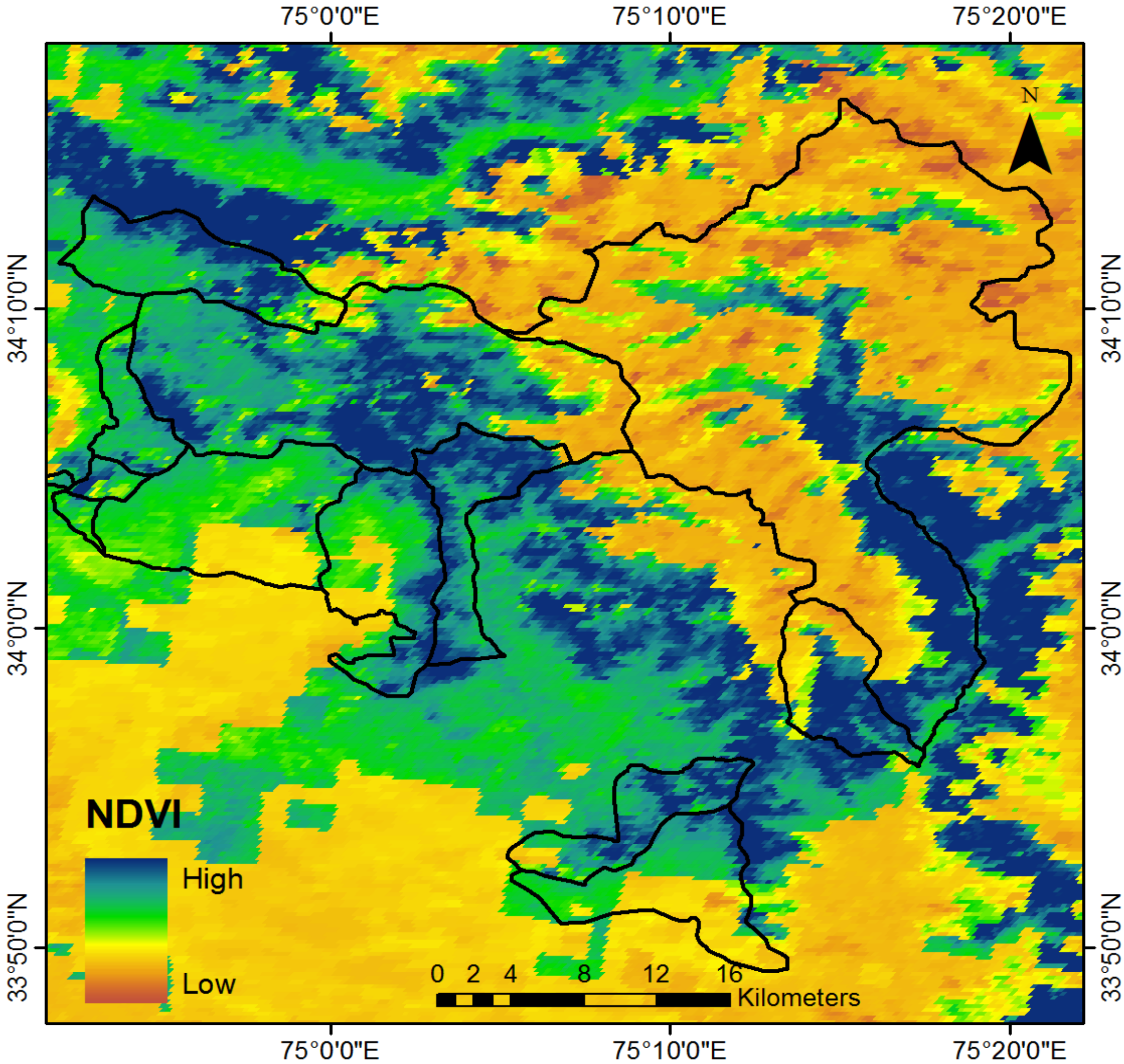

Fig. 2.9 Variation in Normalized Difference Vegetation Index (NDVI) across Dachigam National park and its adjoining protected areas. Source: Landsat 4–5 Thematic Mapper imagery (30 m resolution).

2.11 Fauna

As other Himalayan ecosystems Dachigam NP supports rich faunal diversity. Dachigam NP is represented by several mammal species having high conservation value, which include Hangul (*Cervus elaphus hanglu*), Himalayan musk deer (*Moschus chrysogaster*), serow (*Capricornis thar*) and snow leopard (*Uncia uncia*). Other species found in the Park include Asiatic black bear (*Ursus thibetanus*), leopard, Kashmir gray langur (S*emnopithecus ajax*), rhesus macaque (*Macaca mulatta*), red fox (*Vulpes vulpes*), jackal (*Canis aureus*), jungle cat (*Felis chaus*), leopard cat (*Prionailurus bengalensis*), Small Indian civet (*Viverricula indica*), long tailed marmot (*Marmota caudata*), yellow-throated marten (*Martes flavigula*), Himalayan weasel (*Mustela sibirica*) and Indian Crested Porcupine (*Hystrix indica*). Wild boar (*Sus scrofa cristatus*) was reported after 30 years during the camera trapping exercise carried out recently (Ahmad *et al*. 2013). Besides, the park inhabits a good diversity of insects, reptiles and avifauna. A list of avifauna of Dachigam NP is shown in Appendix I.

Plate 2.1 Winter season in Dachigam National Park

Plate 2.2 Spring season in Dachigam National Park

Plate 2.3 Summer Season in Dachigam National Park

Plate 2.4 Autumn Season in Dachigam National Park

CHAPTER 5
SOCIOECONOMICS, CONFLICT AND ATTITUDES

5.1 Introduction

5.1.1 Background

Alteration of earth by humans is substantial and growing at an alarming pace. While humans and predators have co-existed for millennia, the frequency of conflicts has grown in recent decades, mainly because of the exponential increase in human population and the resulting expansion of human activities (Woodroffe 2000; Conover 2002; Singh *et al*. 2015). Increasing resource use by humans at the human–wildlife interface has resulted in intensification of human–wildlife conflict (Inskip and Zimmerman 2009). Human-animal conflict is highly complex phenomenon and presents an urgent challenge worldwide as it has negative impacts on ecological, economic, management, political, and social systems (Gore *et al*. 2008). Despite decades of research and considerable financial resources invested, we still lack a fundamental understanding of which ecological and social factors drive human–wildlife conflicts (Dickman 2010). Conservation of wildlife in areas with high human-wildlife conflicts has become a challenge for conservationists and policy makers as conflict has been identified as the most important cause of carnivore mortality (Woodroffe and Ginsberg 1998). To find equitable solutions for species management in these areas, multidisciplinary socioecological approaches are required (Shivik 2006; McShane *et al*. 2011; Linnell and Boitani 2012).

Understanding of both the ecological and the human dimensions of the conflict is important for effective resolution of problem as later governs the human response to the losses caused by predators. A wide array of human dimensions—such as local people's perceptions of the value of wildlife, how they want wildlife to be managed, and how they affect or are affected by wildlife—influence wildlife management decisions (Decker *et al.* 2001). Many studies have recognized the importance of incorporating these interacting human-related factors into management plans (Manfredo and Dayer 2004; Marker *et al*. 2003). However, most of the studies have focused solely on the ecological side of human–wildlife conflict with no input from the social sciences (Treves *et al.* 2006). Anthropological data is significant as it provides an overview of cultural and socio-political context of human-wildlife conflicts and ensures that wildlife management policies are locally sensitive and effective (Knight 2000; Treves and Karanth 2003).

Crop-raiding is a common flashpoint for human-wildlife conflict, involving ungulates, primates and other omnivores. Large bodied animals may cause huge economic losses in agriculture and forestry (Liberg *et al*.2010; Maillard *et al.* 2010; Ruusila and Kojola 2010; Hofman-Kaminsk and Kowalczyk 2012).The croplands and orchards near forest areas are unintentionally providing high quality food and space to wildlife otherwise confined to meager patches of protected natural habitats (Milton and Binney 1980; Ganzhorn and Abraham 1991). But it is unlikely for economically weak local farmers to tolerate crop damage without any retaliation. The problem of agricultural crop damage by elephants (*Elephas maximus*), nilgai (*Boselaphus tragocamelus*), blackbuck (*Antilope cervicapra*), wild pigs and sloth bears (*Melursus ursinus*) has been widely reported from different states of India (Rajpurohit 1993; Mukherjee *et al*. 1997; Rajpurohit and Chauhan 1996). Another main form of human-wildlife conflict is livestock predation by carnivores (Graham *et al*. 2005) which has been in existence since humans started domesticating wild ungulates Kruuk (2002). Chances of large predator depredation on livestock are high in the areas of low wild prey density, or where livestock are not guarded properly (Mishra 1997; Mazzolli *et al*. 2002; Bagchi and Mishra 2006). Increase in local livestock populations and overgrazing have also been documented as contributing factors responsible for escalated carnivore predation on livestock (Madhusudan and Mishra 2003; Wang and Macdonald 2006). Moreover, a host of other factors outside the control of individual farmers such as predator density, individual predator behavior and predator-prey interactions have significant role (Mishra *et al*. 2001). The problem of livestock depredation is extremely widespread and needs to be fixed on priority basis. Few examples of predators from different regions involved in livestock damage include lions (*Panthera leo)* in Africa (Bauer and de Iongh 2005), pumas (*Felis concolar)* and jaguars (*Panthera onca)* in south America (Mazzolli *et al*. 2002; Zimmermann *et al*. 2005), snow leopard (*Uncia uncia)* in the Himalaya (Mishra 1997; Hussain 2003), tigers (*Panthera tigris*) in India (Sekhar 1998; Karanth and Gopal 2005) and wolves (*Canis lupus)* and coyotes (*C. latrans*) in North America (Windberg *et al*. 1997;

Treves *et al*. 2002). In India almost all the big cats viz. lion, tiger, snow leopard and leopard have been reported to be involved in conflict with humans (Chakrabarti 1992; Chellem and Johnsingh 1993; Daniel 1996; Mishra 1997; Jhala and Sharma 1997; Jackson 1999; Rangarajan 2001; Linnell *et al*. 2002; Mishra *et al*. 2003; Atherya *et al*. 2004; Namgail *et al*. 2007; Kumar 2011; Athreya *et al*. 2011; Chandola 2012; Suryawanshi *et al*. 2013; Dhanwatey *et al*. 2013; Athreya *et al*. 2014; Harihar *et al*. 2014b; Singh *et al*. 2015). Predation may account for a small proportion of overall livestock mortalities, major cause being disease in most of the studies, but even relatively low levels of stock loss can impose intolerable costs on poor households (Stander 1997). Moreover, surplus killing, where predators kill multiple animals in one attack, can result in severe financial loss to the stock-owners concerned (Nowell and Jackson 1996). Unless addressed equitably, such conflict places the wildlife in protected areas at an increased risk of retributive killing or poaching.

To ensure that wildlife management policies are effective and sensitive to local conditions, it is important to understand anthropological factors, such as the attitudes of local people, which provide an overview of the cultural and sociopolitical context of human–wildlife conflicts. Assessing local people's attitudes can provide insight on how they will behave, for example, how they comply with wildlife protection regulations, how they respond to economic losses caused by wildlife, and the degree to which they are willing to coexist with wildlife (Fulton *et al.* 1996). Attitude surveys may make it possible to predict how people's attitudes will influence conservation policies and vice versa, allowing for more effective management and planning (Fiallo and Jacobson 1995). Attitudes toward wildlife vary because factors affecting attitudes—such as interactions with wildlife— are spatially heterogeneous (Sitati *et al.* 2003; Naughton-Treves and Treves 2005). Conflict between humans and carnivores is one of the main causes of negative attitudes towards large predators, reducing tolerance and leading to retaliatory killings (Woodroffe and Ginsberg 1998). However in India, people exhibit some tolerance for wildlife despite experiencing substantial losses to different species in terms of livestock and crop damage (Sekhar 1998; Mishra *et al*. 2003; Karanth and Nepal 2012; Karanth *et al*. 2013), although some retaliatory killings of species like snow leopard, wolf and leopard have been reported. The species involved in conflict seem to affect people's attitudes, tolerance and retaliation. For instance jaguars are frequently killed by ranchers in South

America for taking cattle (Conforti and Aze vedo 2003; Polisar *et al*. 2003) and cheetahs, lions and leopards are shot in retaliation for game and livestock predation across Africa (Woodroffe *et al*. 2007; Kissui 2008). A number of studies have been conducted on attitudes of local people toward carnivores in Asia (Bandara and Tisdell 2003; Bagchi and Mishra 2006; Allendorf 2007; Ambastha *et al.* 2007), including some studies in the Himalaya (Badola 1998; Jackson *et al.* 2003; Wang *et al.* 2006; Ogra 2009; Barthwal and Mathur 2012; Carter *et al.* 2013). However, no such systematic study has been conducted in Kashmir Division of the state of Jammu and Kashmir (Western Himalaya), where management of increasing human–wildlife conflict has become a challenge for policy-makers. In general, costs associated with conservation, such as crop damage and livestock predation by wildlife, have negative effects on local attitudes, while benefits from conservation may have positive effects. Other variables, such as race, sex, age, income, and educational level, can also influence people's attitudes toward wildlife. Usually, women, older people, people with a lower education level, people working in a natural-resource-dependent profession, or people living in a rural area within a carnivore distribution range tend to have more negative attitudes (Kellert 1994; Kellert *et al.* 1996). Negative attitudes toward wildlife often encourage people to kill wild animals (Oli *et al.* 1994; Williams *et al.* 2002; Bagchi and Mishra 2006), which takes a toll on conservation efforts.

5.1.2 Present Study

The most common conflict between humans and carnivores in the Indian subcontinent revolves around livestock and crop damage within protected areas or their buffer zones (Mishra 1997; Hussain 2003). Several species have been reported to cause crop and livestock loss from India (Karanth and Madhusudan 2002; Karanth *et al*. 2012). Kashmir being a valley has an interspersion of orchards, croplands, with human habitations and forests. Moreover land use and cropping pattern is changing rapidly near forest areas. Thus movement of carnivores for food outside these forest areas leads them to live in close proximity with humans and makes conflict inevitable. The Himalayan black bear (Ursus thibetanus) and leopard (Panthera pardus), the 2 main carnivores in the region, often come in contact with people living on the fringes of the Dachigam National Park, resulting in human–animal conflict. Study of wild prey availability in Dachigam NP (Chapter 3) shows that biomass of available wild prey is low as compared to other areas thus compelling carnivores to stray into human habitations in search of food. Researchers have noted the trend of increased depredation in areas of low wild prey availability in a variety of situations, such as with pumas in Venezuela (Polisar *et al*. 2003), lions in Kenya (Patterson *et al*. 2004) and wolves in Europe (Sidorovich *et al*. 2003). However, as compared to other regions livestock predation and crop damage by wild animals around Dachigam NP has not been adequately assessed, with only a few studies (Charoo *et al*. 2009, 2011b, Mukesh *et al.* 2015) mainly focusing on human-black bear conflict. A recent study conducted around Dachigam National Park suggested that the translocation of conflict bears from other areas to the park may be the reason for aggravated conflict in its immediate vicinity, since it causes overcrowding of bears (Mukesh *et al.* 2015). The rising human–animal conflict in the region has in turn resulted in an alarming increase in retaliatory killings of leopards and bears, threatening their survival (Singh *et al.* 2007; Mukesh *et al.* 2015). Moreover the landscape around Dachigam National Park is home to the hangul, the only red deer subspecies in India, which is critically endangered and listed in Schedule I of the Jammu and Kashmir Wildlife (Protection) Act, 1978. Its distribution range has been drastically reduced in the recent past, and poaching has been reported as one of the major reasons (Charoo *et al.* 2010). Studies have been conducted on the ecology of this endangered species, but none has highlighted local peoples' attitudes toward the species in particular or wildlife in general. It was therefore, important to assess the nature and extent of carnivore-human conflict with reference to dependence of local people on forests and their attitudes towards wildlife conservation around Dachigam NP, so that management plans are devised meeting human needs as well as mitigating conflict to tolerable levels. With this background, an attempt was made to answer following research questions during this study: 1) What is the socioeconomic status of people living around Dachigam NP? 2) What is the nature and extent of human – carnivore conflict around the National Park? 3) What are the economic benefits and losses of the National Park to local people? 4) What are the attitudes of locals towards wildlife and its conservation in the region?

5.2 Method

5.2.1 Field data collection

Semi-structured interviews (SSIs) were conducted to collect data pertaining to the human-wildlife conflict, dependency of local communities on forest resources and their attitude towards wildlife (Karanth 2007; Karanth *et al*. 2013). Semi-structured interviews enable respondents to provide more comprehensive answers than fully structured questionnaires, and are flexible enough to allow people to explain their views in their own words, which can be important in terms of truly understanding the nature of a particular situation (Hunter and Brehm 2003). Despite of some limitations, like people exaggerating their losses by predators SSIs can be used to effectively assess attitudes, and have provided valuable information regarding peoples' perceptions of large carnivores in previous studies also (Conforti and de Azevedo 2003; Marker *et al*. 2003b; Oli *et al*. 1994). The survey was designed in a way that simpler and less controversial questions were posed towards the start of the survey and more complex or sensitive issues only raised later on, when there was more chance that the confidence of the respondent had increased.

In total, 384 households from 19 villages within three ranges (administrative units) of the Central Wildlife division were interviewed between June 2011 and August 2013.These three ranges (Ganderbal, Dachigam and Khrew range) encompass the boundary of Dachigam NP in North, West and South directions (Fig. 5.1). Each household was considered a sampling unit, and interviews were restricted to one respondent per household (preferably the oldest one). Households were selected randomly, and more than 60% of households were targeted for interviews (Karanth 2007). Both men and women older than 18 years were interviewed, although the majority of respondents were men. The reason might be that the sex ratio of the study area is male biased, and women may have been a bit reluctant to answer questions due to cultural restrictions in the rural areas.

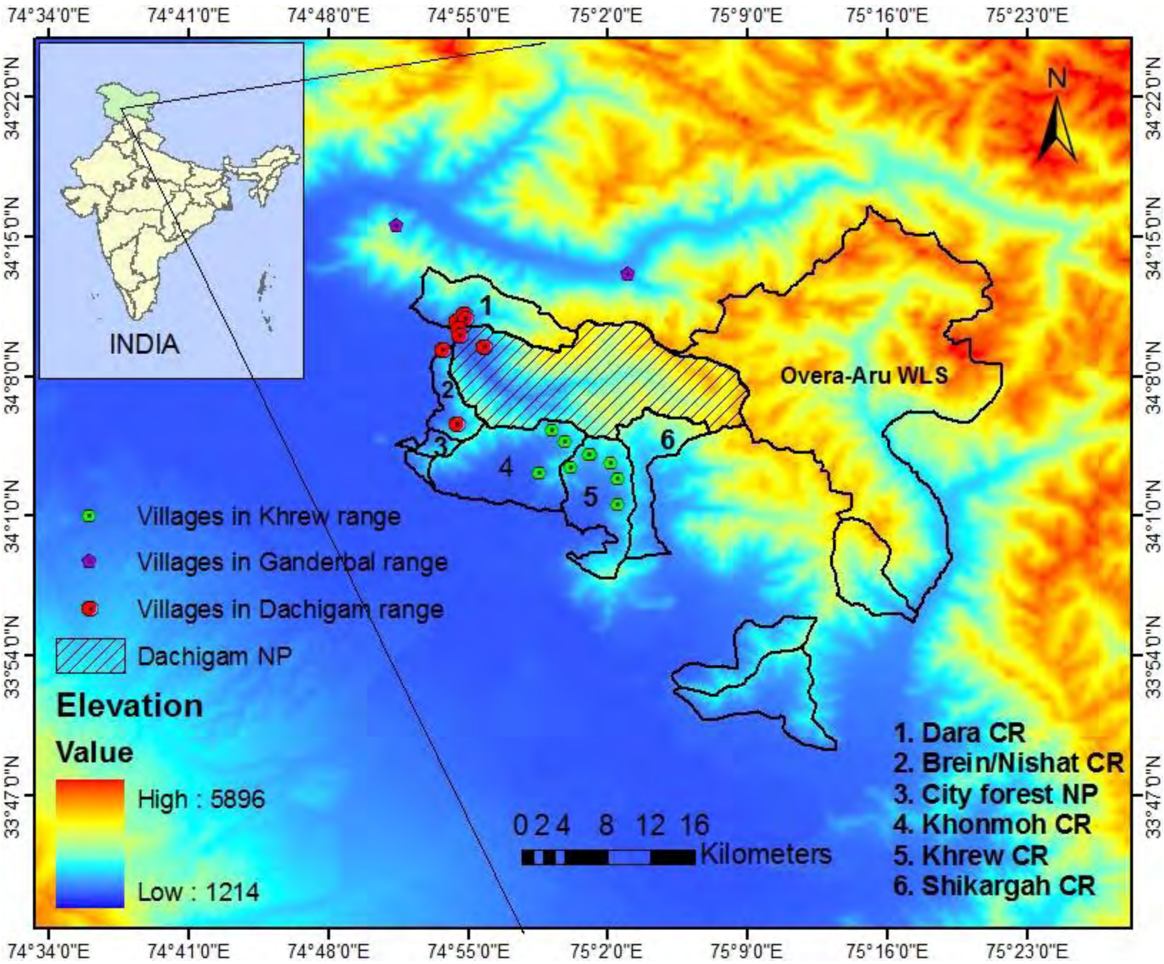

Fig. 5.1 Location of Villages around Dachigam National Park

All of the interviews were done at the households of respondents and took approximately one hour to complete one interview. The semi-structured questionnaire was designed to collect information on respondents' (1) socioeconomic and demographic characteristics (education, livestock holdings, land ownership, income sources, and economic losses), (2) experiences of crop damage and livestock predation by wild animals in 2011 and 2012, (3) attitudes toward wildlife conservation (*ie* asking whether respondents wanted wildlife to be conserved or not), (4) actions reportedly taken to protect crops and livestock and (5) details of livestock husbandry techniques and (6) dependency of people on forest products (Appendix II). Interviewees were assured that their responses would be kept confidential so as to get unbiased statements. In cases of recent predations, carcass remains were spot-checked. The predators' feeding patterns, tooth and claw marks on the victims' skin and the mode of dismembering and dispersal of the carcass parts were considered to designate the predator species involved (Brain 1980; Hill 1980; Leakey *et al*. 1994).

5.2.2 Assessment of leopard attacks on humans

In addition to the villages around Dachigam National Park 20 more villages in south and central wildlife divisions were surveyed to study patterns of leopard attacks on humans (Fig. 5.2). Overall, 31 leopard attacks on humans were recorded in these villages from 2007 to 2013. Semi-structured interviews were conducted with the victims or their next of kin who had been attacked by leopards to collect information pertaining to the attacks (Appendix III). The date and time of each incident was recorded to discover seasonality and diurnal distribution of encounters. The portion of the body attacked, age and sex of victims was recorded for analysis. Places where leopards have killed or injured humans were visited either accompanied by the family member or the companion of the leopard victim to record GPS location and other habitat characteristics.

5.2.3 Statistical analysis

Data analysis was conducted using the Statistical Package for Social Sciences (SPSS) PC version 16.0 (SPSS 2007) and program R (Software for Statistical Computing). One of the most common statistics used was the chi-squared test for independence which was employed to assess whether two categorical variables were related. Other tests used included the Kruskal-Wallis H test (the non-parametric alternative to the univariate analysis of variance) which was used to compare differences in a continuous variable between three or more groups. This test produced a Kruskal-Wallis chi-squared statistic, denoted as KW χ^2 in the results. Generalized linear modeling (GLM) was used to determine factors influencing attitudes toward wildlife and its conservation. We quantified and analyzed 12 variables that could potentially impact peoples' attitudes toward wildlife and its conservation (Table 5.1). The Akaike information criterion was used to select the most suited model, with the lowest score providing the best explanation of the most important factors (Burnham and Anderson 2004; Norusis 2005). Using AIC for model selection is preferred to simple hypothesis testing, as it provides best measure of the strength of each possible model to the overall set of models tested, thereby allowing the strongest one to be selected (Hazzah 2006; Mazzarolle 2006; Dickman 2008). This strategy was used in order to select the best model among 20 potential models using all 12 variables. Johnson and Omland (2004) have recommended a maximum of 20 candidate models based on philosophical considerations. We interpreted the effect of variables on attitudes based on the parameter estimates (β) from the selected model.

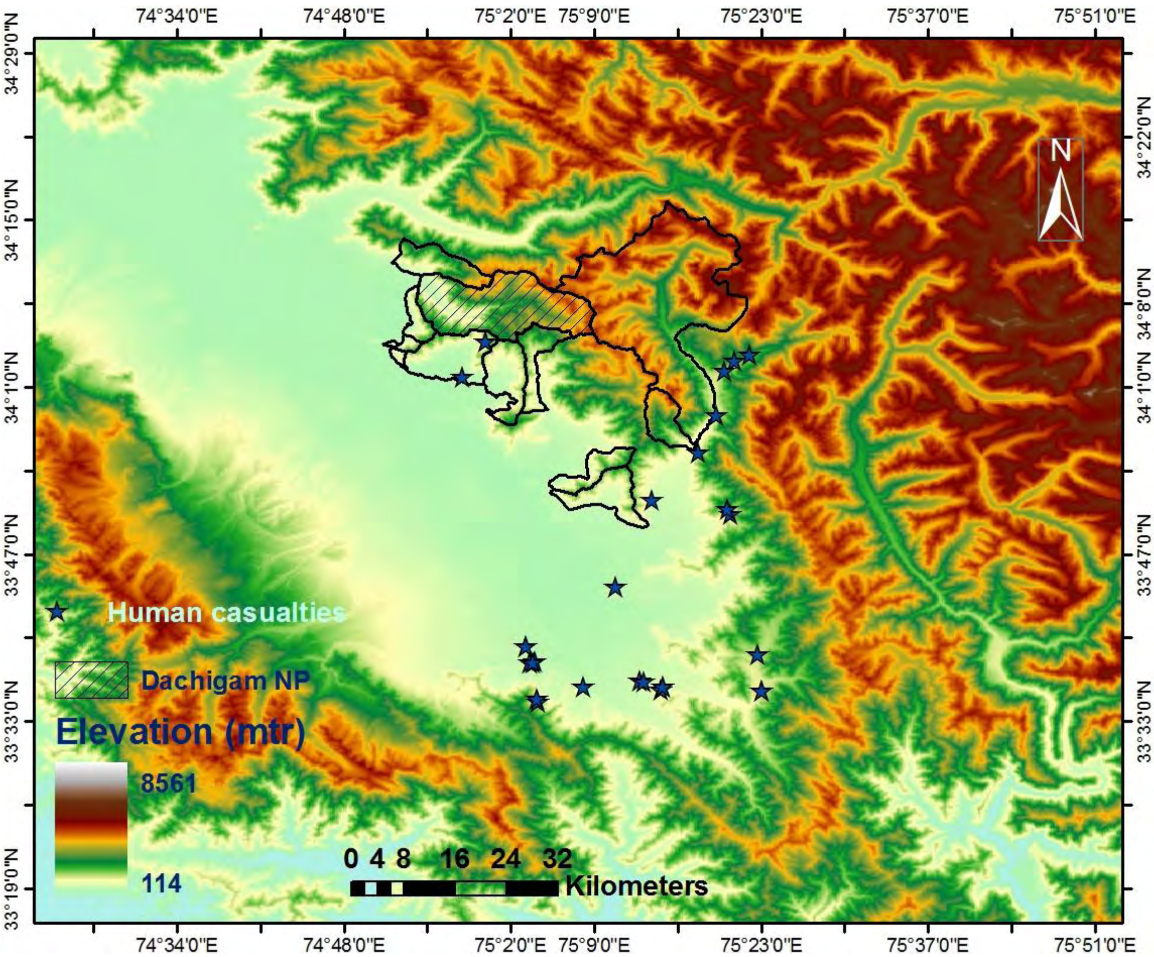

Fig. 5.2 Locations of human casualties caused by leopards reported from central and south wildlife divisions (2007-2013)

Table 5.1 Explanatory variables considered as potential predictors of attitudes of local people towards wildlife conservation

Variable	Label	Variable type	Range
Age of respondent	Age	Discrete	18-90
Gender of respondent	Gender	Categorical	Male, Female
Primary occupation of respondents	Occupation	Categorical	0-6 [(a)]
Total number of family members	Familymembers	Discrete	1-30
Number of family members who are earning	Earningmembers	Discrete	1-7
Highest education of respondents	Highesteducation	Categorical	Primary, Secondary, Tertiary
Total family income (INR)	Income	Continuous	INR 600 – 63000
Cultivable land owned by interviewee's family (acres)	Landowned	Continuous	0 -12.5 acres
Whether crop is damaged by wild animals	Cropdamage	Categorical	0 – 1
How much of crop is damaged by animals	Extentofdamage	Categorical	Low, Medium, High
Total number of livestock heads owned	Totallivestock	Discrete	1 – 558
Whether livestock depredation has occurred or not	Livestockdamage	Categorical	0 – 1

[(a)] Occupations of respondents were merged into seven broad categories.

5.3 Results

Out of 384 households interviewed, 165 were in the Dachigam range, 157 in Khrew, and the remaining 62 in Ganderbal. (Table 5.2).

Table 5.2 Survey effort for 19 villages around Dachigam NP visited during the course of the study, in Central Wildlife Division Kashmir

Range	Village name	No. of households sampled
Dachigam (n = 165)	Astan mohala, Dara	20
	Astan pur, Brain	15
	Fakeer gujri, Dara	22
	Dard khor, Dara	15
	Gandtal	20
	Harwan Shalimar	19
	Mulnar	28
	New theed harwan	26
Khrew (n = 157)	Baddalav	2
	Bajnari (bathen)	33
	Bathen	6
	Check Khonmoh	33
	Nagender	7
	Sangri Khonmoh	23
	Datri pathri (TCI)	3
	Satpokhri	34
	Zanthrak, khrew	16
Ganderbal (n = 62)	Surfraw ganderbal	56
	Gutlibagh	6
TOTAL		384

5.3.1 Demography of respondents

Among interviewed respondents, males accounted for 65.48% of the sample size and the rest were females. Age of respondents ranged from 18 to 90 years, with a median age of 35 years. There was no significant difference between different ranges in terms of mean age of respondents ($\chi^2 = 0.185$, $df = 2$, $P > 0.05$). Mean (±SE) family size was 7.16 ± 0.16 individuals per household. Lowest family size was noted for Ganderbal range (6.95 ± 0.41), while highest was noted for Khrew range 7.52 ± 0.28. No significant difference was observed in the mean family size among the ranges. The overall average female to male sex ratio was 776:1000. Sex ratio of Dachigam, Khrew and Ganderbal ranges was 910:1000, 550:1000 and 870:1000 respectively.

5.3.2 Education

67.18% surveyed families had one or more male members who had studied at least through the primary level, whereas 39.06% families had one or more female members who had studied through the same level. Mean (±SE) number of years of education for respondents was 8.36 ± 0.27 which varied with different ranges. In Dachigam, Khrew and Ganderbal ranges average years of education of respondents was 9.98 ± 0.37, 6.15 ± 0.40 and 9.62 ± 0.67, which showed no significant difference ($\chi^2 = 1.0423$, $df = 2$, $p = 0.59$).

5.3.3 Source of Income

The mean monthly income (±SE) of interviewed families in Dachigam, Khrew and Ganderbal ranges was 8686.6 ± 782.4 INR, 7461.7 ± 605.8 INR and 6451.6 ± 1015.5 INR respectively (Fig.5.3). The number of different sources of income per family ranged from 1 - 3, with a mean of 1.73 (± 0.03), with a full breakdown of reported income sources shown in (Table 5.3). In total, 91.66% (n = 352) of respondents interviewed said they owned crop land. Out of these land owners, majority (72.65% of total respondents) were practicing agriculture for income generation, whereas rest (19.01%) grew crops for subsistence purpose only. A small proportion of the households (12.76%) relied solely upon crop cultivation as the source of the revenue having no other alternate source. About 85.67% of interviewed respondents owned the livestock, and majority of respondents (60.76%) only used livestock for their subsistence. Rest of 24.91% families used livestock as an asset for income generation and only three families solely relied on livestock for their living. Apart from livestock and crops other sources of income included business, manual labor and Government or private jobs (Fig 5.4).

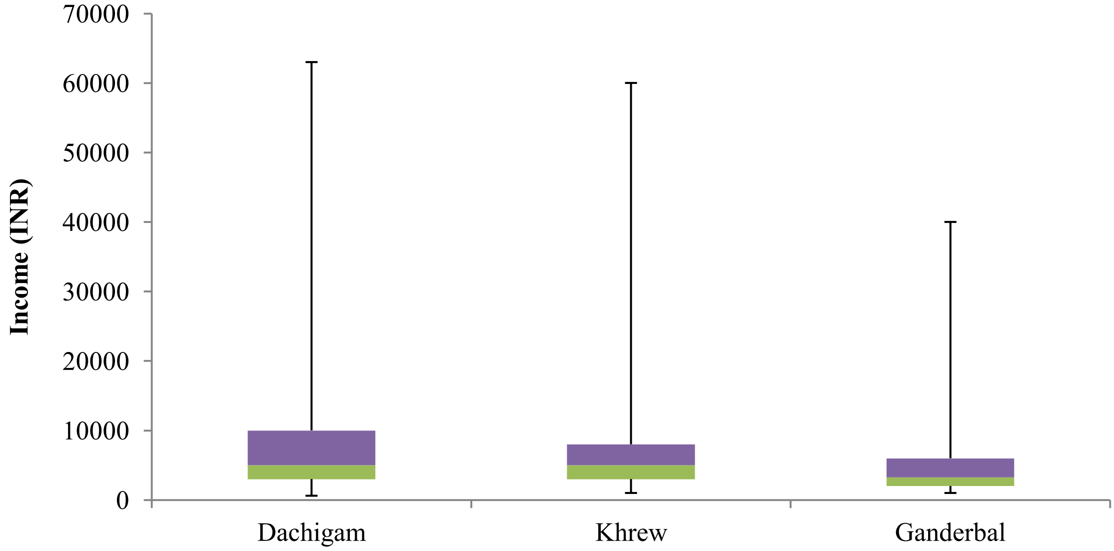

Fig. 5.3 Monthly income reported by respondents from different ranges

Table 5.3 Sources of cash income reported by interviewees, from different ranges

Income source	Dachigam		Khrew		Ganderbal		Total	
	n	%	n	%	n	%	N	%
Crop and others	53	32.12	68	43.31	34	54.84	155	40.36
Others only	52	31.52	26	16.56	8	12.90	86	22.40
Crop only	26	15.76	14	8.92	9	14.52	49	12.76
Crop, livestock and others	16	9.70	24	15.29	5	8.06	45	11.72
Crop and livestock	9	5.45	15	9.55	6	9.68	30	7.81
Livestock and others	9	5.45	7	4.46	0	0.00	16	4.17
Livestock only	0	0.00	3	1.91	0	0.00	3	0.78

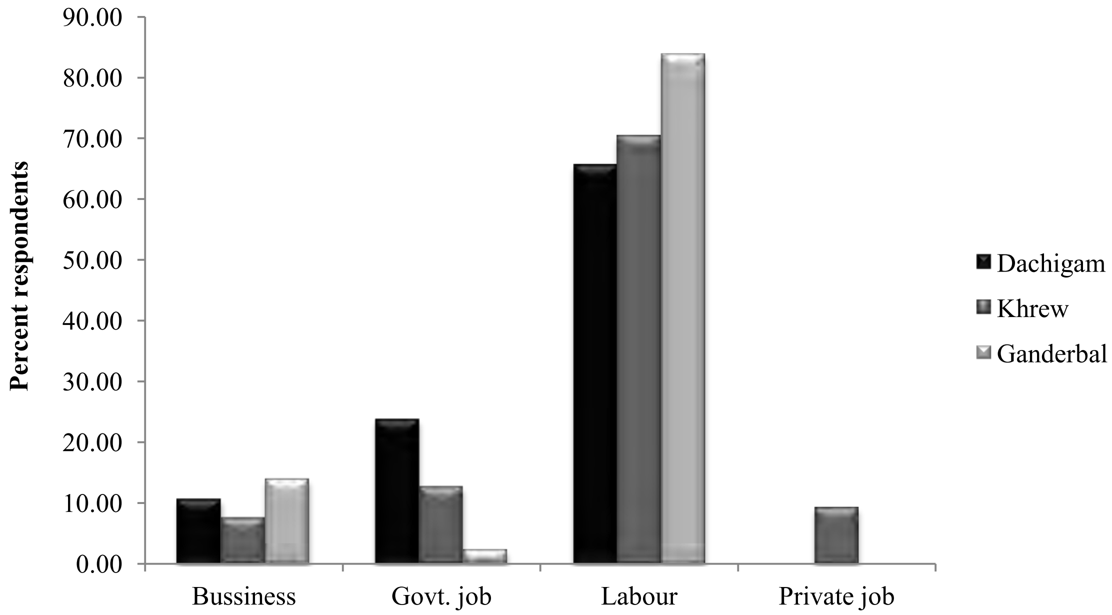

Fig. 5.4 Sources of income other then crop cultivation and livestock rearing as reported by respondents from different ranges

5.3.4 Stock ownership

Among households owning livestock, the number of livestock owned varied from 1 to 558, with a mean of 9.54 (± 1.84). Cattle (cow and buffalo) were the most common livestock type owned, being kept by 77.08% of people and accounted for 21.5% of all stock holdings. This was followed by small stock (poultry, sheep and goat) owned by 47.13% of families interviewed and comprised 77.4% stock owned while only 8.8% families kept horses that accounted for 1.1% stock owned Fig. (5.5).

Respondents from Dachigam owned the highest number of livestock overall, averaging (10.49 ± 4.31) head of stock per household, followed by Khrew (mean = 10.11 ± 1.63) and Ganderbal who owned 5.78 (± 1.19) livestock heads on average. There was no significant difference between ranges in terms of mean livestock holding (KW $\chi^2 = 2.0$, $df = 2$, $P > 0.05$). While as composition of livestock showed significant variation between different ranges. Sheep was the major livestock in Khrew (44.37%) and Ganderbal (38.67%) while as it formed only 20.87% of total livestock in Dachigam range ($\chi^2 = 8.7$, $df = 2$, $p < 0.05$) where goat contributed the maximum (42.24%) (Fig.5.5). Cost evaluation of livestock revealed that the average cost of adult cow was INR 35000, adult buffalo INR 50000, sheep INR 6000, goat INR 8000 and horse was INR 55000.

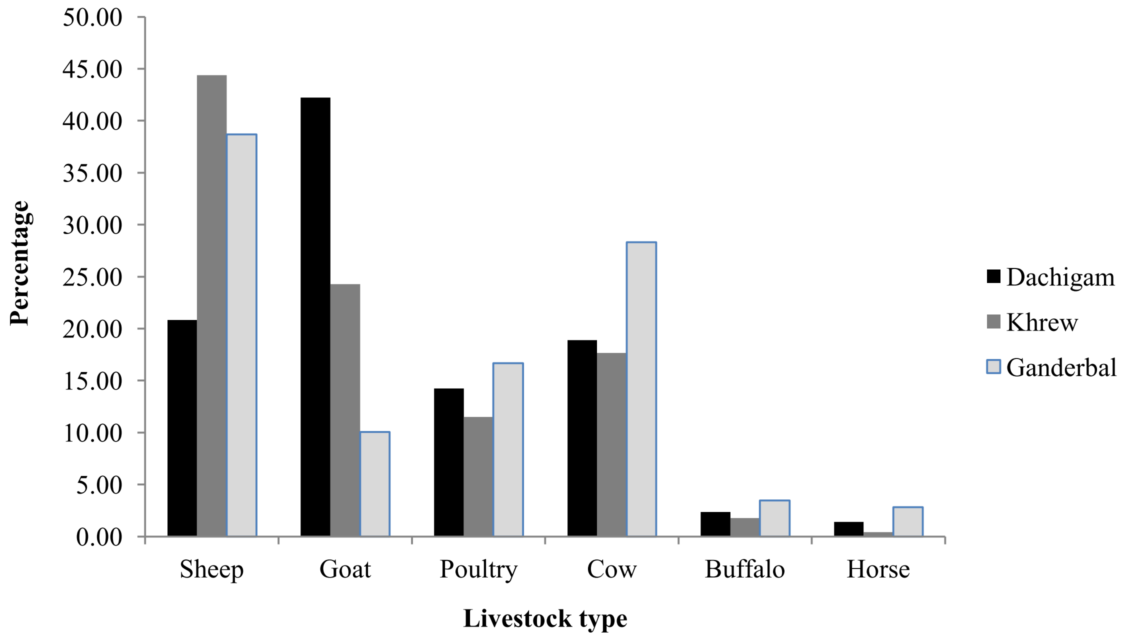

Fig. 5.5 Livestock ownership in different ranges around Dachigam National Park

5.3.5 Land Ownership

In Ganderbal range 96.77% people owned land with mean holding of 0.90 (± 0.11) acres per family and in Dachigam, the percentage of people owning land was 91.51% having a mean of 0.80 (± 0.11) acres per family. Khrew range had lowest percentage (89.80%) of people holding land, but the mean area of land held per family was highest among ranges (1.13 ± 0.09 acres). Major crop types cultivated by surveyed households included maize (*Zea mays*), cherry (*Prunus avium*), rice (*Oryza sativa*) and wheat (*Triticum aestivum*) (Fig. 5.6).

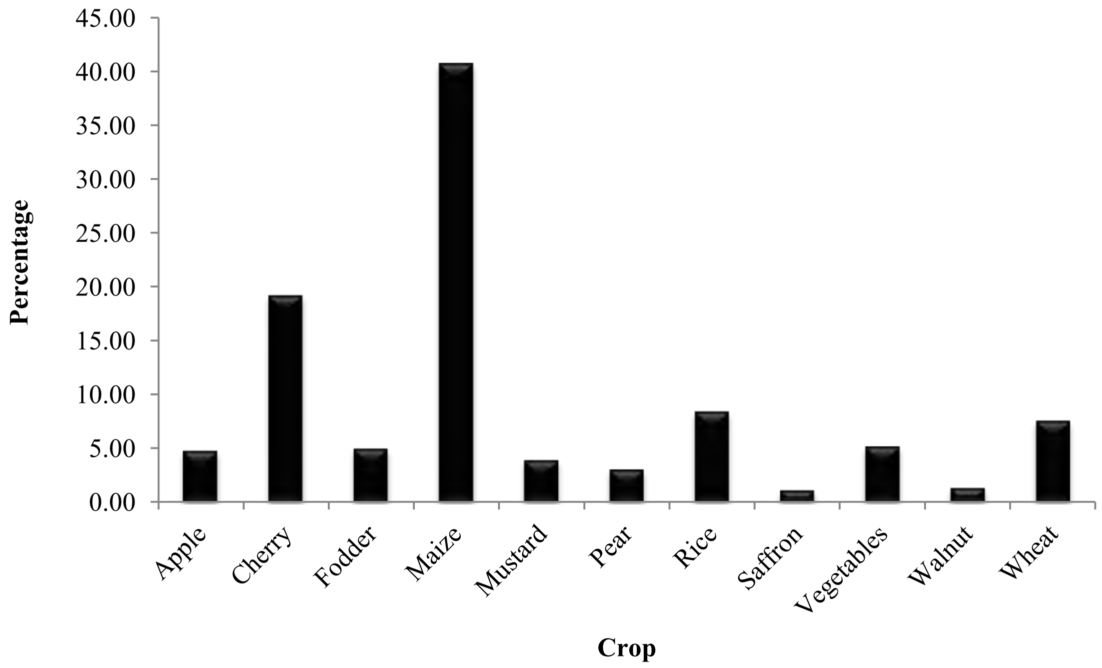

Fig. 5.6 Types of crop cultivation in villages around Dachigam National Park

Overall, 74.71% of land owning families reported crop damage by wild animals. Average amount of crop damage per household varied among different ranges but not to a significant degree. Greatest damage was observed in Khrew range (55.87 ± 2.35%) followed by Ganderbal (47.27 ± 2.57%) and Dachigam (39.36 ± 1.82%) (χ^2 = 2.8709, *df* = 2, p > 0.05). The majority of the crop damage was done by Himalayan black bears (93.15%) followed by Kashmir gray langur (5.70%) and porcupine (1.14%) which usually damaged tubers of saffron (*Crocus sativus*). Majority of the crop raiding incidents occurred in months coinciding with harvesting time of cherry (June- July) and Maize (August- September) (Table 5.4 and Fig. 5.7).

Table 5.4 Time of harvest for different crops cultivated by farmers and percent crop loss incurred by crop raiding

Cultivated Crop	Common name	Months of harvest	Percent contribution to the total crop damage
Malus domestica	Apple	July - August	12.90
Prunus avium	Cherry	June - July	21.51
Zea mays	Maize	August - Sept.	46.24
Brassica juncea	Mustard	May	5.38
Pyrus communis	Pear	July - August	2.15
Oryza sativa	Rice	July - August	3.23
Crocus sativus	Saffron	October – November	1.08
Juglans regia	Walnut	August – September	4.30
Triticum aestivum	Wheat	November	3.23

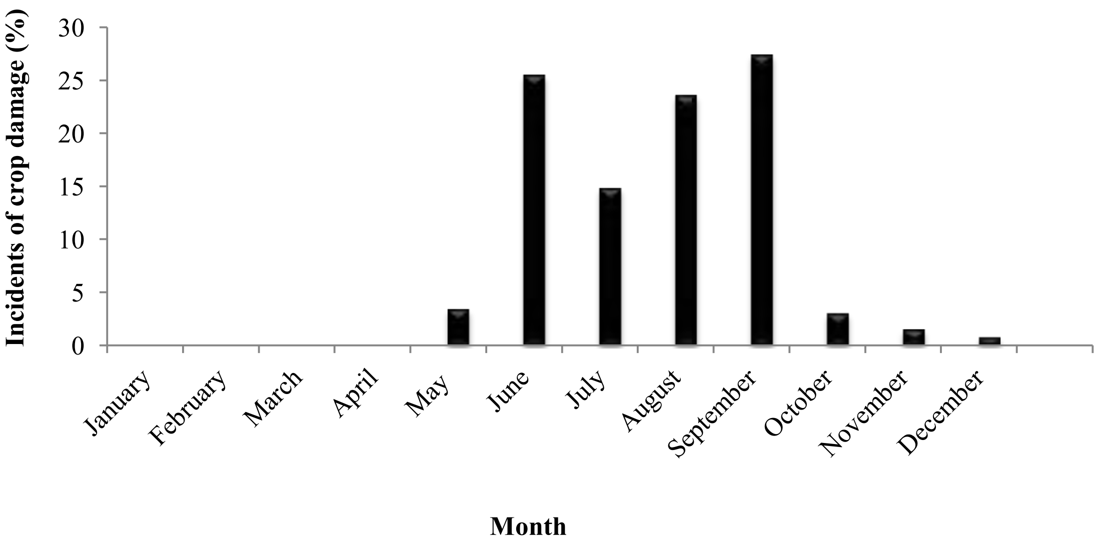

Fig. 5.7 Frequency of occurrence of crop damage incidents in different months of the year (2011-2013)

5.3.6 Livestock depredation

Among respondents, 22.90% reported livestock predation by wildlife, in particular leopards, Himalayan black bears, and jackals. A total of 88 predation incidents were reported for 2011 and 2012, resulting in the deaths of 107 head of livestock. Predation incidents by leopards (63.63%), black bears (28.40%), and jackals (7.95%) varied significantly ($\chi^2 = 48.32$, $df = 2$, $p < 0.005$). Jackals were only involved in predation of domestic fowl. Although predation occurred throughout the year, the majority (53.57%) of attacks by leopards took place in the summer and most of the bear attacks (57.55%) in autumn (Fig. 5.8). Sheep were attacked most frequently (35.23%), followed by goats (21.59%), cows (19.32%), horses (9.09%), domestic fowl (7.95%), and guard dogs (6.82%) ($\chi^2 = 35.84$, $df = 5$, $p < 0.001$) (Fig. 5.9). On average, 1.5% of livestock held by villagers was lost to predation annually.

Leopard accounted for 56 attacks on livestock in the villages surveyed during this study and killed 75 heads of livestock with an average of 1.33 (± 0.1) animals per attack. Percentage of interviewed respondents reporting livestock depredation by leopard during this study varied in different ranges, highest being Khrew (20.38%) followed by Ganderbal (17.74%) and Dachigam (7.87%) ($\chi^2 = 5.66$, $df = 2$, $p = 0.05$). Of the total livestock depredated, sheep were killed most frequently (33.9%) followed by cow (21.43%) and goat (19.64%) (Fig.5.10).

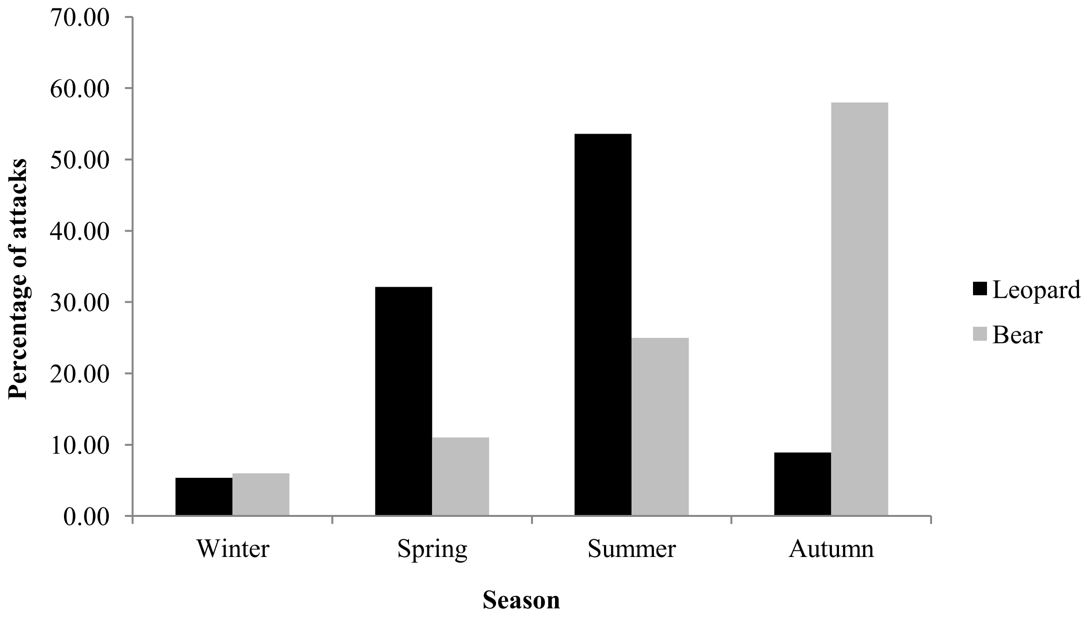

Fig. 5.8 Seasonal trend in livestock depredation by two major predators in and around Dachigam National Park (2011-2012)

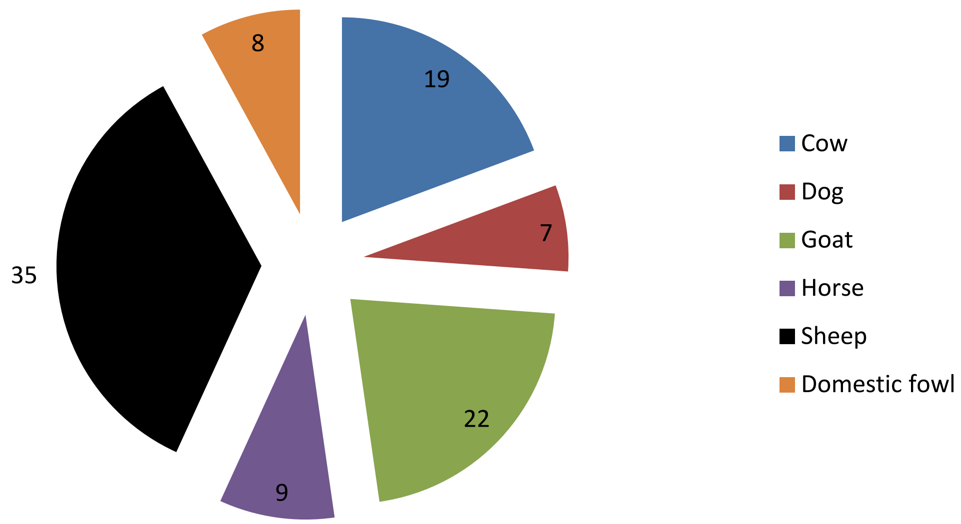

Fig. 5.9 Types of livestock depredated by carnivores in surveyed villages in and around Dachigam National Park during 2011-12

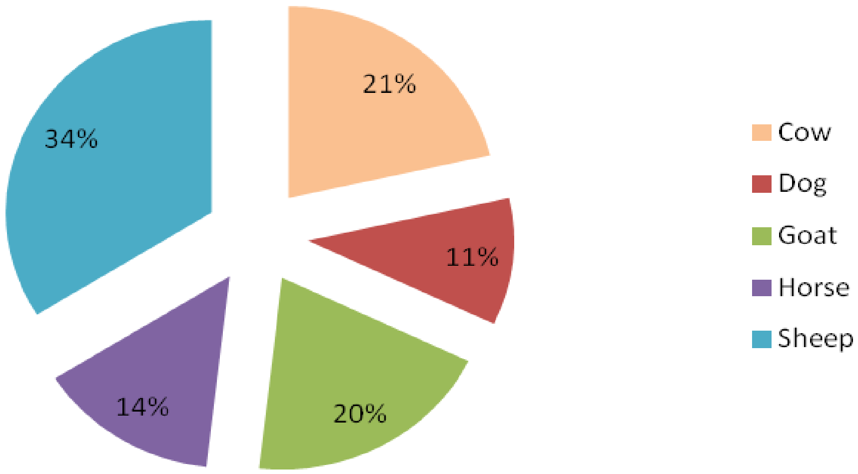

Fig. 5.10 Types of livestock depredated by leopards in surveyed villages in and around Dachigam National Park during 2011-12

5.3.7 Economics of conflict and compensation

Economic loss to predators per household was estimated using average local prices in 2013. The total loss of 107 heads of livestock over two years was valued at INR 15,56,400, of which the majority (64%, INR 4,72,000) were small stock losses (n = 69). And 17 cows lost to predation accounted for INR 5, 95,000. So annual average economic loss from livestock depredation in the study area was calculated to be INR 7,78,200. Average economic loss per household per year was estimated to be INR 7,272.89. There is no compensation scheme either from government or any non-government agency to pay for the losses caused by wild animals in the form of crop damage and livestock depredation.

5.3.8 Preventive measures against conflict

About 73% of interviewed villagers used different sorts of preventive measures to avoid livestock depredation and crop raiding by conflicting animals (Fig. 5.11). Most frequently used measures were, producing noise to scare away animals by beating empty tin/metal containers (63%), use of guarding dogs (15%) and guarding of crop fields and livestock manually (9.41%).

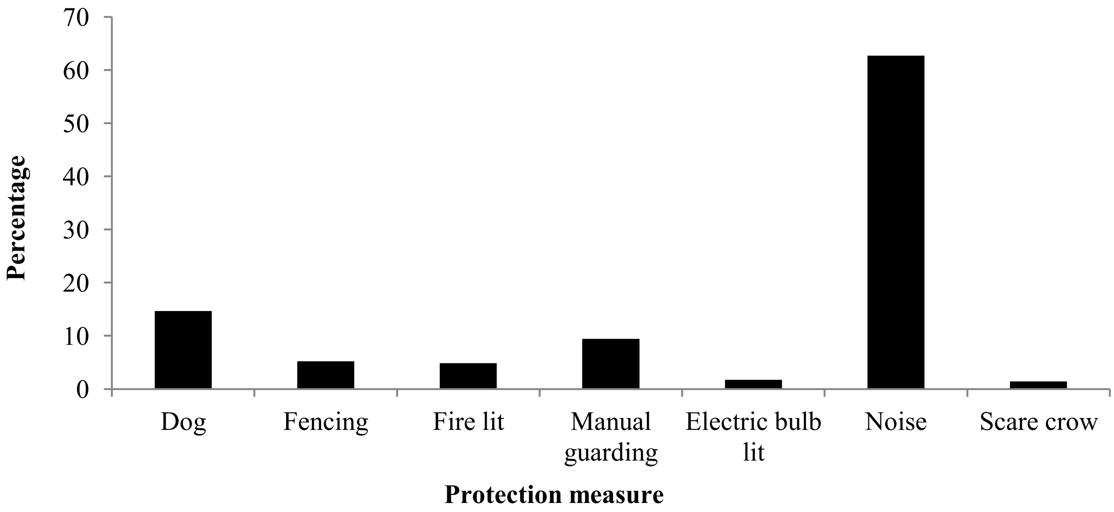

Fig. 5.11 Percentage use of different protection measures by locals to protect their crops and livestock from wild animals

5.3.9 Leopard attacks on Humans

A total of 31 leopard attack events on humans have been recorded between March 2007 and October 2013 out of which 38.70% were fatal claiming victim's lives and in 61.30% cases victims survived the attacks with major or minor injury. Maximum incidents were recorded from Qazigund range (n=11) followed by Lidder forest division (n=9), Bringi valley (n=9) and Khrew range (n=2). Majority of the victims were males (70.96%) with females constituting only 29.04% of the victims. Average age of the victims was observed to be 22.32 years (SE 3.76) with children below the age of 18 years attacked most (Fig. 5.12). Government had provided compensation of INR 1 Lac each to the family members of all the 12 victims who had lost their life as a result of leopard attacks. While as in case of victims injured in leopard attacks only 65% victims were given compensation varying from INR 1000 to INR 5000.

Fig. 5.12 Proportion of different age classes injured or killed in leopard attacks (2007-2013)

5.3.9.1 Seasonal and temporal variation in leopard attacks on humans

Leopard attacks varied across seasons with the majority of the attacks recorded in summer (35.48%) and least in winter and spring (16.13% each) ($\chi^2 = 12.79$, df = 3, $p < 0.05$) (Fig. 5.13). There was significant variation in the diurnal pattern of occurrence of leopard attacks ($\chi^2 = 27.68$, df = 2, $p < 0.01$). Majority of the leopard attacks were recorded during evening time (58.06%) followed by afternoon (22.58%) and morning (19.35%).

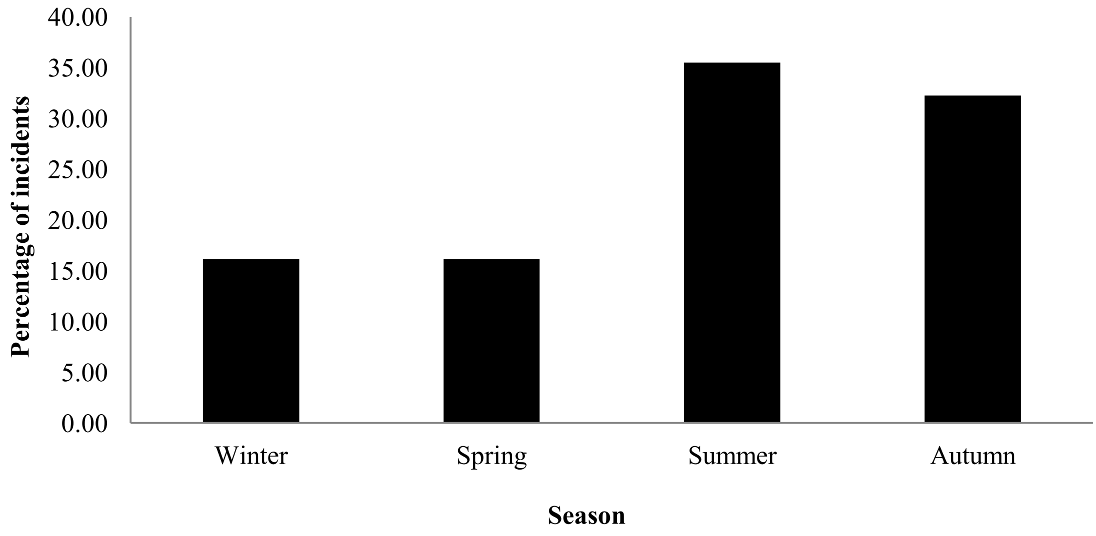

Fig. 5.13 Seasonal pattern of leopard attacks on Humans (2007-2013)

5.3.9.2 Characteristics of leopard attacks

The portion of the body attacked or injured was recorded for all the cases except in one case where body of a 7 year old victim was not recovered as leopard had taken it away. In majority of the cases neck region (55%) of the victim was attacked by the leopard followed by arm or leg (23%) (Fig. 5.14). Majority of the leopard attack incidents occurred within 100 mtrs of the nearest forest and a water source (Fig 5.15 – 5.16).

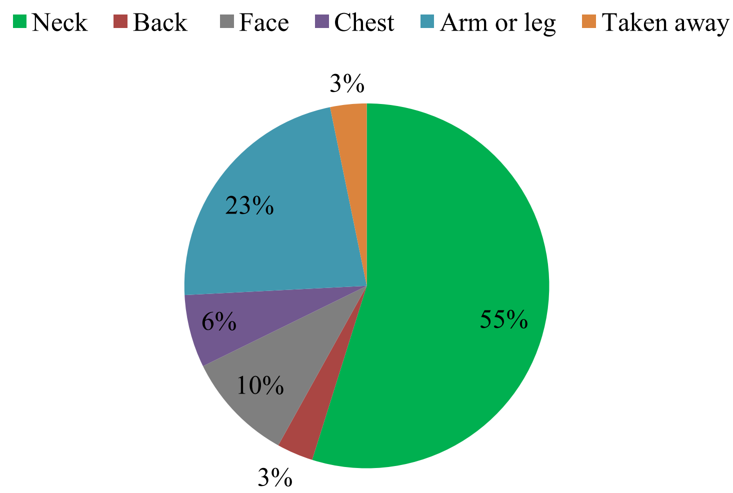

Fig. 5.14 Body part of victims attacked by leopards

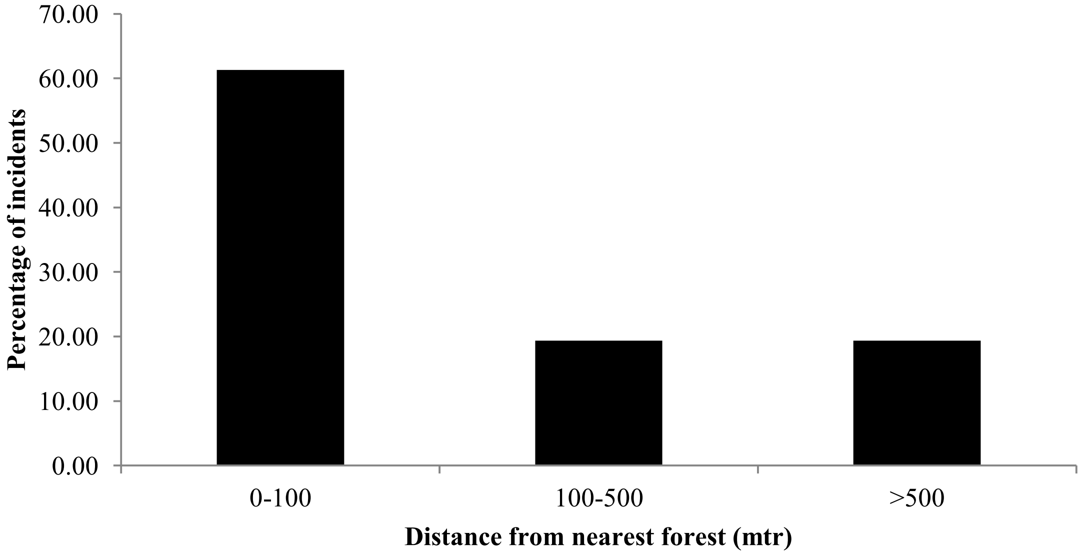

Fig. 5.15 Distance of the attack site from the nearest forest

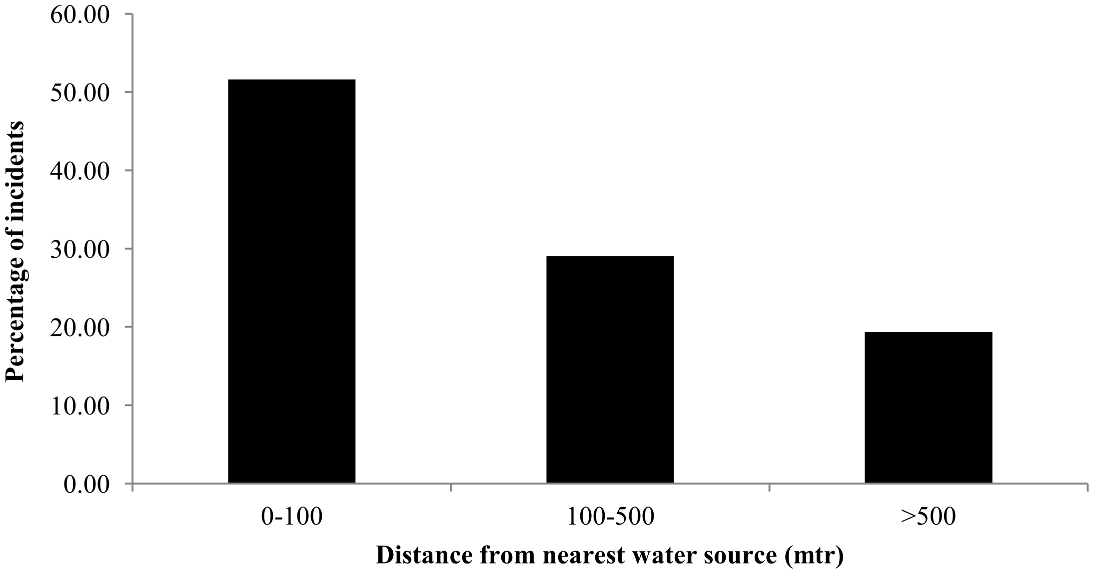

Fig. 5.16 Distance of the attack site from the nearest water source

5.3.10 People's attitude

Understanding people's perceptions of conflict is equally important as understanding actual conflict rates (Marker *et al*. 2003). About 84.18% of interviewees supported wildlife conservation, whereas 15.82% opposed it. The main reason given for the latter view was the conflict with wild animals and resulting economic losses. Support for wildlife was justified primarily for ecological reasons (57.65%), followed by aesthetic

(18.51%), social (8.19%), and economic (6.05%) reasons; 9.61% of respondents who supported wildlife conservation did not perceive any significant benefit from wildlife (Fig. 5.17).

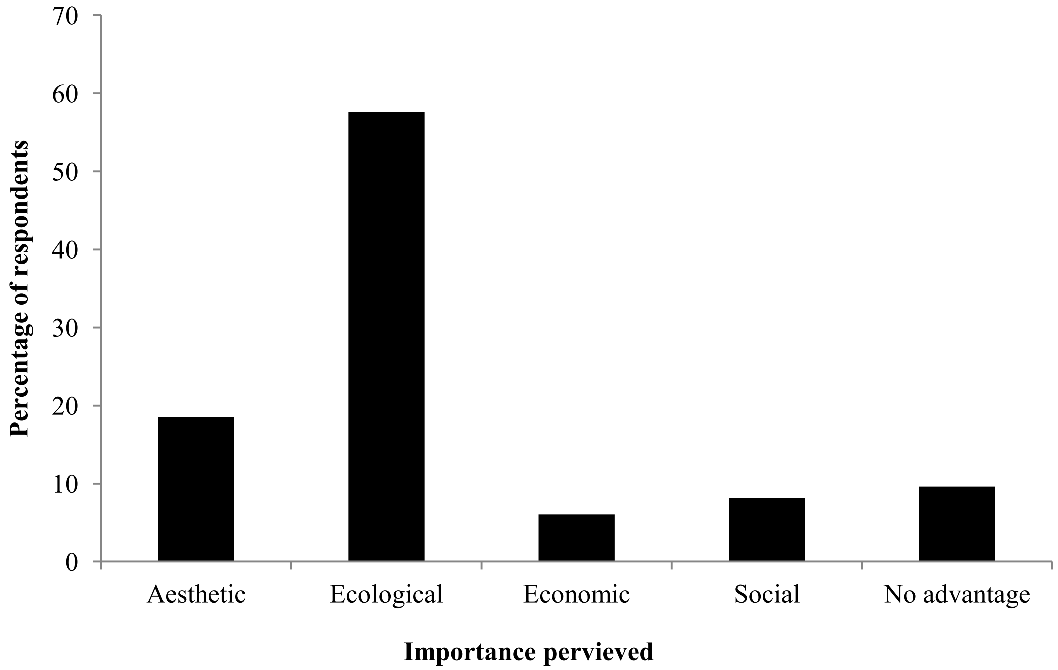

Fig. 5.17 Advantages of wildlife as perceived by respondents

When asked for cause of increase in man-animal conflict in recent past, respondents mentioned different reasons. Majority of respondents (47%) mentioned scarcity of food in forests as a major reason of animals venturing into human settlements. Some people (14%) mentioned that legal protection given to animals is the major cause of conflict as it has led to increase in population of carnivores. Anthropogenic pressure, change in land use pattern in recent past, faulty management policies by authorities were other reasons mentioned by respondents (Fig. 5.18).

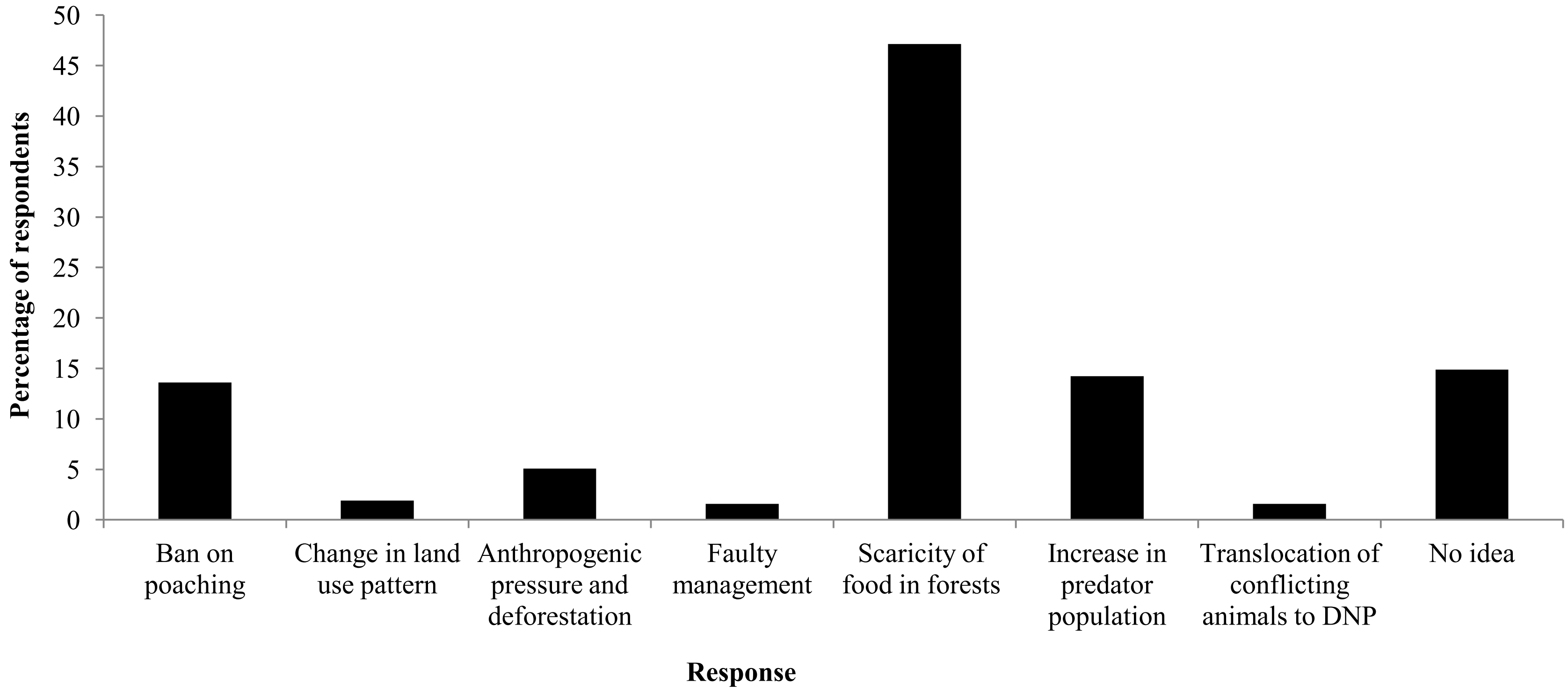

Fig. 5.18 Categories of responses (percent respondents); in response to the question "What is the main reason of increase in man-animal conflict in recent past?"

5.3.10.1 Factors influencing attitude of locals towards wildlife

Generalized linear modeling results showed that the model that best explained respondents' attitudes toward wildlife conservation included four variables: gender, crop damage, livestock predation, and total livestock holding (Table 5.5). This model was selected on the basis of lowest AIC (279.98). Positive attitudes toward wildlife conservation were significantly more common among men than among women ($P=0.018$). However, respondents who had suffered crop damage or livestock predation by wild animals had significantly high negative attitudes toward wildlife conservation. The number of livestock owned also had a significant influence on attitudes: respondents with more livestock had more negative perceptions of wildlife (Table 5.6).

Table 5.5 Structure of models used in a Generalized Linear Modeling framework with Δ AIC as model selection criterion used to identify the variables influencing attitudes of local people towards wildlife at the scale of an individual. Variables and their abbreviations are defined in table 5.1

Model	**AIC**	**Δ AIC**
Attitude ~ Gender + Cropdamage + Livestockdamage + Totallivestock	279.984	0.00
Attitude ~ Gender + Cropdamage + Livestockdamage + Income + Totallivestock	280.221	0.24
Attitude ~ Gender + Highesteducation + Cropdamage + Livestockdamage + Income + Totallivestock	280.490	0.51
Attitude ~ Gender + Cropdamage + Livestockdamage + Income + landowned + Totallivestock	282.122	2.14
Attitude ~ Gender + Cropdamage + Extentofdamage + Livestockdamage + Income + Totallivestock	282.350	2.37
Attitude ~ Gender + Cropdamage + Livestockdamage + Age + Income + Familymembers + Totallivestock	283.533	3.55
Attitude ~ Gender + Cropdamage + Livestockdamage + Age + Income + Landowned + Totallivestock	283.659	3.67
Attitude ~ Gender + Cropdamage + Livestockdamage + Age + Income	284.811	4.83
Attitude ~ Gender + Livestockdamage + Income + Landowned + Totallivestock	285.972	5.99
Attitude ~ Gender + Occupation + Highesteducation + Cropdamage + Livestockdamage + Age + Familymembers + Totallivestock	287.499	7.51
Attitude ~ Gender + Highesteducation + Livestockdamage + Age + Income	288.570	8.59
Attitude ~ Gender + Occupation + Highesteducation + Cropdamage + Livestockdamage + Age	288.860	8.88
Attitude ~ Gender + Occupation + Highesteducation + Cropdamage + Extentofdamage + Livestockdamage + Age + Familymembers + Totallivestock	289.541	9.56
Attitude ~ Gender + Occupation + Highesteducation + Livestockdamage + Age + Income + Totallivestock	290.456	10.47
Attitude ~ Gender + Occupation + Highesteducation + Cropdamage + Livestockdamage + Age + Income	290.846	10.86
Attitude ~ Occupation + Highesteducation + Cropdamage + Livestockdamage + Age + Income	292.510	12.53
Attitude ~ Gender + Occupation + Highesteducation + Cropdamage + Extentofdamage + Livestockdamage + Age + Familymembers + Earningmembers + Income + Landowned + Totallivestock	294.418	14.43
Attitude ~ Occupation + Highesteducation + Cropdamage + Livestockdamage + Age + Income + Earningmembers + landowned	296.333	16.35
Attitude ~ Gender + Highesteducation + Cropdamage + Age + Income + Familymembers + Totallivestock	304.884	24.90

Table 5.6 Influence of variables from best fit model on attitude of local people towards wildlife

Variable*	Parameter estimate (β)	Standard error	Hypothesis Test		
			Wald Chi-Square	*df*	p
(Intercept)	-0.614	0.338	3.306	1	0.000
Gender	0.741	0.314	5.554	1	0.018
Livestockdamage	-1.617	0.339	22.816	1	0.000
Totallivestock	-0.009	0.006	2.290	1	0.130
Cropdamage	-1.034	0.451	5.260	1	0.022

***Dependent Variable: Attitude**

Model: (Intercept), Gender, Livestockdamage, Totallivestock, Cropdamage

5.3.11 Dependence on forest products

Majority of the surveyed households (75.52%) depended on one or the other forest products like firewood, fodder and NTFPs. The dependence on forests was highest from Ganderbal range as 90.32% of surveyed inhabitants collected forest products followed by Khrew range (86.62%) and Dachigam range (59.39%) ($\chi^2 = 7.24$, df = 2, $p < 0.05$). In majority of the cases (84.26%) forest products were collected by women. Only in 11.17% cases men were involved in collection of forest products, while in 4.57% cases both men and women were involved. In total, 65.63% of surveyed households extracted and used firewood as a source of fuel and the proportion of people relying upon firewood varied in different ranges (Table 5.7). LPG was owned by 50.75% of households, rest 49.25% completely relied upon firewood for cooking. Inability of the people to afford other forms of fuel is the main reason for using wood as fuel. Overall average wood consumption was 11.68 kg/household/day and varied in different ranges (Table 5.8). The firewood collected was mainly burnt for cooking, water heating, space heating and sometimes for lighting purpose. People stocked firewood in autumn season for coming winters as heavy snow hampers wood collection. Fodder was another major forest product collected by villagers from forests. Overall 54.95% households collected fodder from forests to feed their livestock (Table 5.7). Average daily collection of fodder varied among different ranges from 20.69 kg to 26.65 kg (Table 5.8). It was observed that a small proportion of villagers (7.81%) collected on -timber forest products (T s) from nearby forests and the main product collected was an edible mushroom (*Morchella esculenta*) locally known as '*Guchi*'. It is a seasonal mushroom and is available in spring season only. Average monthly collection of '*Guchi'* by villagers from different ranges in spring season is given in Table 5.8.

Table 5.7 Proportion of surveyed households from different ranges dependent on various forest products

Range	Households collecting Firewood (%)	Households collecting Fodder (%)	Households collecting NTFP (%)
Dachigam	50.30	40.00	6.06
Khrew	71.97	69.43	9.55
Ganderbal	90.32	58.06	8.06
Overall	**65.63**	**54.95**	**7.81**

Table 5.8 Average quantity of different forest products extracted by locals from different ranges around DNP

Average consumption	Fuel wood (kg/household/day)	Fodder (kg/household/day)	NTFP * (kg/household/month)
Dachigam	10.49	26.65	1.91
Khrew	11.37	26.44	1.1
Ganderbal	13.17	20.69	3.35
Overall	**11.68**	**24.59**	**2.12**

*** This consumption is during the season of availability only.**

5.4 Discussion

The land use pattern of human landscape around DNP consists of small mud as well as concrete houses with agricultural fields, pastures, orchards, intertwined with the nearby natural water sources. The social and economical setup of the study villages reveals a larger mean family size (7.16), with a range of 2 to 30 family members. The female to male sex ratio of the villages (776:1000) was lower than that for India overall (940:1000) and for the rural areas of Kashmir (908:1000) (Census of India 2011). Low sex ratios have also been reported from other areas in the state, for example, from Leh (690:1000) and Kargil (810:1000) (Nazeer 2014).

Surveyed villages were primarily agro-pastoral, with most of the people (91.60%) engaged in either agriculture or horticulture. Some farmed part-time and engaged in other income generating activities, such as business, manual labor, and government and private-sector jobs. Human population growth has led to an increase in demand of agricultural products and the villages around protected areas are also facing its effects. The anticipated result of such demographic changes is that increased production pressures is placed on both the wild lands and the agricultural production systems in and around protected areas (McNeeley and Scherr 2003). Thus leading to change in land use pattern by cropland expansions and consequently having adverse effects on wildlife. When comparison was done between ranges it was found that Ganderbal has highest and Dachigam has lowest proportion of people involved in crop cultivation. Moreover mean monthly income of households from Dachigam range was highest among three ranges. Main reason is that more people from Dachigam are involved in Government jobs compared to other ranges as they also have higher literacy rate. Moreover, the percentage of people holding land as well as mean area of land held per household in Dachigam range was less than other ranges. The majority (83.85%) of surveyed households earned more than the international poverty threshold of USD 1.25 (INR 74.05) per capita per day (*i.e* INR 2221.5 per month) (Ravallion *et al.* 2009).

Livestock significantly contributes to the economy of rural people, especially dwellers of mountain areas (Pun and Mares 2000). Average livestock holding in study area was recorded as 9.5 heads per household. This is lower than the average (13 head) reported for the Kibber Wildlife Sanctuary in Himachal Pradesh (Mishra 1997). But it is close to the threshold livestock holding (10 - 15) for an average family size of 6 – 6.5 individuals below which households are unlikely to be able to sustain their pastoralist lifestyle following stock losses (Lybbert *et al*. 2004). Most common livestock held by villagers was cattle mainly for the purpose of milk production. Apart from cattle, sheep, goat and poultry were the common stocks, which were reared mostly for meat. About 9% of households owned horses and used them for tourism purpose seasonally.

Major crops cultivated in the surveyed villages include maize, cherries, rice and wheat. Maize and cherry are among preferred crops of black bear (Charoo *et al*. 2009) and consequently almost 74.71% respondents reported crop damage by wild animals. Although Kashmir gray langur and porcupine also caused crop damage, Himalayan black bear were involved in the majority of the crop damage cases (93.15%), which resembles the findings of an earlier study (Charoo *et al.* 2011b). The extent of crop damage varied in different months and can be related to the cropping pattern. Time of crop raiding coincided with harvesting time of crops (Table 5.4) as majority of incidents were observed from June to September (Fig. 5.7). It indicates that food available in the form of crops in the villages acts as an attractant for wild animals. Crop raiding and livestock predation by park wildlife can threaten people to secure sustainable livelihoods by preventing them from using cultivable land under the fear of crop loss to predators (Studsrod and Wegge 1995; Jackson and Wangchuk 2000). In addition, guarding of property and maintenance of various protective measures bear high direct as well as indirect financial costs. In rural, economically lagging communities even small losses incurred can generate negative attitudes toward wildlife conservation.

5.4.1 Livestock depredation

Livestock depredation threatens the livelihood of local communities and is often cited as the most common form of human-wildlife conflict. This loss has financial as well as psychological implications, often leading to hatred towards wildlife and consequently retaliatory killings. In the surveyed areas, more than half of the livestock predation was attributed to leopards; a number of other studies have identified leopards as the principal predators of livestock in Himalayan regions (Chauhan *et al.* 2002; Wang and Macdonald 2006; Sangay and Vernes 2008; Singh *et al*. 2008; Dar *et* *al.* 2009; Harihar *et al.* 2014b). The leopard's habit to feed upon ungulates and its ability to utilize a wide range of prey items facilitates them to predate upon livestock (Treves and Karanth 2003; Hayward *et al.* 2006a). Leopard attacks on livestock in the surveyed villages mainly occurred in the summer, which may be explained by low availability of wild prey inside the park during the summer (Habib *et al.* 2014). Moreover, due to the good availability of fodder during the summer, livestock are mostly grazed outside, in contrast to winter, when they are mostly stall fed and confined to predator-proof enclosures. This makes livestock more vulnerable to predation in the summer, especially in the absence of herders and guard dogs. However, livestock predation by black bears was mostly reported during autumn, when the bears need to feed heavily to acquire fat reserves for their upcoming hibernation. Many food crops are harvested through late autumn, and the availability of wild fruits declines by the end of autumn. This prompts black bears to venture into villages and raid livestock pens to meet their food requirements. A similar seasonal pattern of livestock predation by leopards and black bears has been reported in Bhutan (Sangay and Vernes 2008). Livestock depredation by black bear around Dachigam NP has also been reported by Charoo *et al.* (2011b). The percentage of livestock lost annually to large carnivores (1.5%) in this study is comparable to the 2.3% loss reported from Jigme Singye Wangchuck National Park in Bhutan (Wang and Macdonald 2006) and the 0.9% reported in Pakistan (Dar *et al.* 2009). Sheep (35%) and Goat (22%) composed the majority of depredated livestock. The possible reason of this high predation rate is that sheep and goat are well under the preferred weight range of leopard prey (10 - 40 kg) as reported by Hayward (2006). Jackals were only reported to be involved in poultry lifting in the study area. Khatiwada (2008) from Nepal and Kait and Sahi (2012) from Jammu and Kashmir have also reported poultry lifting by jackals.

5.4.2 Economic Values of Loss

Livestock keeping is a supplementary activity to other main occupations like crop farming in the villages around DNP. About 86% households owned one or other type of livestock (Fig. 5.5). Annual average economic loss from livestock depredation in the study area was calculated to be INR 7,78,200. Average annual monetary loss per household around DNP, is not a significant amount (INR 7,272.89), but even small losses in economically weak society has a negative impact on general perception towards wildlife conservation. It is comparable to economic loss per family reported by Mishra (1997) from Kibber Wildlife Sanctuary *viz* $128 (~ INR 7639). Large body sized livestock such as cattle are economically important not only due to their high market price but also as they are sources of manure and milk to the farmers. Therefore, the depredation on cattle and buffalo is substantial economic loss.

There is no compensation program in the state of Jammu and Kashmir to make up for the economic loss of locals due to predators. Compensation programs when implemented and executed in a proper manner have a strong impact in creating positive people-park relationships and developing a positive thinking towards wildlife conservation among locals. Compensation can be provided in terms of cash or in terms of monetary benefits like villagers living adjacent to e pal's Royal Bardia National Park were allowed to collect grass for a period of two weeks as a compensation for damage caused by wildlife. More than 70% of the respondents from that area stated this as a reason for their positive attitudes towards the Park (Sharma 1990; Studsrod and Wegge 1995). However, there are studies also across the globe arguing that compensation schemes generally have no positive effect on controlling human-wildlife conflicts (Nyhus *et al*. 2005; Lamarque *et al*. 2008; Ogra and Badola 2008). Roque de Pinho *et al.* (2014) also concluded that providing monetary incentives might not be enough to curb negative attitudes towards certain species when local perceptions of their dangerousness are deep-seated sentiments. Compensation being a short term mitigation measure should not be seen as only means of conflict management but it can be integrated in a broader mitigation strategy where other root causes of conflict are addressed with priority.

5.4.3 Resource dependency

Rural households rely highly on natural resources. Studies indicate that as much as 20–25% of rural people's income may be derived from environmental resources in developing countries (WRI 2005; Vedeld *et al*. 2007). However, contribution of forest resources to the welfare of rural households is often overlooked in poverty surveys (Cavendish 2000). Critical investigation of dependency on forest resources may help to improve macro-level poverty estimates and improve policy planning and execution.

The residents around Dachigam NP and its adjacent PAs have traditionally been using the resources from nearby forests. About 76% of households surveyed depended on one or the other forest products used for either self-sustenance or income generation. Dependence on natural resources has been attributed to a number of factors ranging from free availability of resources, traditional use and due to lack of alternatives to the resources (Chandola 2012). Dependence was highest from Ganderbal range as they had lowest average income among all the three ranges. Inability of people to buy other forms of fuel was main reason of their dependence on firewood as only 51% households owned LPG for cooking purpose. Owing to harsh winters firewood is also used to warm water and rooms in winter season in addition to cooking, thus increasing its demand manifold. Average wood consumption per household recorded in this study area (11.68 kg/household/day) was higher than reported by Kiplagat *et al*. (2008) from Kenya (5.06 kg/household/day). Fodder is another forest product extracted by a major proportion of households and its demand varies with number of livestock owned. Most of the villagers used fodder from agricultural farms also in addition to fodder extracted from forest areas. This might be the reason that average demand of fodder from forests was only 24.59 kg/household/day (average livestock held per household being 9.54) in contrast to demand of 20 kg/cattle/day as reported by Badola *et al*. (2010) from Corbett Tiger Reserve. Sheep and goat are usually sent to the high altitude alpine pastures of upper Dachigam for grazing during summers, while the other large livestock are either stall fed, or sent to nearby grasslands on daily basis. The demand of fodder, in winter months is fulfilled either from the farm residue or by stocking surplus fodder in autumn season to be used in winter. In addition to firewood and fodder a small proportion of people were observed to be involved in extraction of an edible mushroom (*Morchella esculenta*) which has high market value like other morels. It is a seasonal fungus with high nutritional value and is usually found in early spring, in forests, orchards, and sometimes in recently burned areas. Collection of morchella was mainly done by male family members because of high search effort involved irrespective of firewood and fodder collection in which females took major part.

Sustainable forest management schemes could be adopted to maintain and enhance the flow of economic benefits to the surrounding communities in the study area without damaging the natural resource system. Moreover improvement of the socioeconomic conditions of the poor and recruitment of alternative energy sources can lessen the forest dependency and deforestation problems as well. (Odihi 2003; Dayal 2006).

5.4.4 Leopard attacks on Humans

Most of the large felids have been reported to have tendency of attacking humans. In India, leopards and tigers are the felids mostly involved in attacks on humans (Goyal 2001, Athreya *et al*. 2007, 2011). In the state of Uttaranchal only around 140 human casualties have been reported between 1988 and 2000 (Chauhan *et al*. 2000). In our study 31 leopard attacks were reported to have happened in around 6 years. Children being easy to attack comprised majority of the victims. Seasonality of attacks again showed that most of the attacks on humans took place in the summer season when natural prey availability in leopard range is low. Diurnal pattern of attacks showed that most attacks took place in evening time coinciding with peak activity period of leopards. In majority of the incidents neck/throat region (55%) of the victim was attacked by the leopard followed by arm or leg (23%). Predominant use of throat bite for prey killing by leopards has been reported earlier also (Bailey 1993).

5.4.5 Attitudes

Many study respondents expressed the view that conservationists and the government are more concerned about wildlife than about human well-being, as has also been reported for Amboseli National Park in Kenya (Roque de Pinho 2009). However, the majority of our respondents expressed a positive view of wildlife and its conservation, which is in agreement with an earlier study on attitudes of teachers toward wildlife in the Ladakh region of Jammu and Kashmir (Barthwal and Mathur 2012). Livestock losses, together with crop damage, are considered major causes of negative attitudes toward wildlife and conservation policy around protected areas (Wang *et al.* 2006). Negative perception of carnivores has also been reported due to inflated perceptions of risk that often outweighs economic damage and drive retaliatory behavior (Knight 2000; Naughton-Treves *et al*. 2003). Although only a small proportion of respondents had negative attitudes toward wildlife conservation, this proportion is significant because the small number of people who oppose conservation can substantially hamper conservation initiatives by getting involved in illegal activities against threatened wildlife species.

Among participants in our study, gender, crop damage, livestock damage, and total livestock owned were the main factors that shaped attitudes toward wildlife conservation. Other factors—including occupation and age, number of family members, number of earning members, income, and amount of land owned—did not play a significant role in predicting attitudes. People who experienced crop or livestock damage had mostly negative attitudes towards wildlife and its conservation. Szinovatz (1997) from Norway also reported that negative attitudes were more pronounced in the residents of high bear damage areas. Awareness of local communities about defense measures and support for their implementation can help to prevent crop and livestock damage which may in turn improve their perception towards wildlife. The number of livestock owned by respondents affected their attitudes, as those who owned more livestock were more likely to depend on income from livestock and thus perceive potential predators as a threat. A study in Spiti, Himachal Pradesh (Suryawanshi *et al.* 2013), also concluded that villages with higher holdings of economically important livestock (yaks and horses) perceived the snow leopard to be a greater threat.

Gender played an important role in respondents' perceptions of wildlife in general and of particular species. Women participating in our study showed significantly more negative attitudes toward wildlife than men. This could be attributed to a greater apprehension about dangerous carnivores (Roskaft *et al.* 2003; Kaltenborn *et al.* 2010; Prokop and Tunnicliffe 2010), possibly as a consequence of having less exposure to them than men, who frequently confront them in defense of their families and livestock (Roskaft *et al.* 2003; Goldman *et al.* 2010).

Formal education did not play a significant role in predicting attitudes toward wildlife conservation around Dachigam National Park, a finding that is consistent with Gadd (2005) and Groom and Harris (2008). Newhouse (1990) has also argued that attitudes toward the environment may be developed on the basis of life experiences rather than education. However, education on wildlife conservation can build a knowledge base to reinforce or rationalize attitudes (Kellert 1994; Kellert *et al.* 1996; Woodroffe *et al.* 2005b) and may be an important tool for improving understanding and motivating local communities to cooperate on conservation and sustainable resource use initiatives (Cerovsky 1969). Thus, educating people about the needs and benefits of conserving wildlife is crucial for gaining support for conservation endeavors and to gain the public's participation in the conservation initiatives.

The perception of respondents that conservationists and the government cares more about wildlife than about human well-being needs to be challenged by displays of goodwill from park management, which could help build trust and improve relationships between the park and local people. Previous studies indicate that education can improve tolerance for carnivores (Woodroffe *et al.* 2005). Yet, it can be challenging to educate people with a negative attitude about large carnivores due to their lack of enthusiasm for learning about them (Bath and Majic 2001; Kaczensky 2003). Direct positive experiences, such as safely viewing animals inside the park, can help reduce fear and encourage positive perceptions of wildlife (de Pinho *et al.* 2014). Programs have been started in Tanzania to promote protected-area visitation by local residents (Wildlife Connection 2013). Similar programs should be arranged in this study area, and women should be encouraged to participate.

Plate 5.1 Leopard involved in the conflict in a residential area near Dachigam NP (Source: Internet)

Plate 5.2 Interviewing locals in one of the surveyed villages around Dachigam NP

Plate 5.3 Leopard involved in conflict in South Kashmir, Anantnag. (Leopard was later on shot dead) (Source: Internet)

Plate 5.4 News paper carrying story of leopard venturing into the nearby tourist areas of Dachigam National Park

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CITY

Leopards on prowl in tourist hub

Wildlife department sets cages, captures two wild animals; hunt on for others

ARIF SHAFI WANI

Real picture of Leopard sitting atop a roof in Gagribal area. (Citizen Journalist Shazia Arif)

Wildlife in VIP domains

In June last year a bear was captured from the Fair View villa of top leaders of state's main opposition Peoples Democratic Party (PDP) – Mufti Muhammad Sayeed and Mehbooba Mufti. A year before that leopard was spotted near Chief Minister Omer Abdullah's Gupkar residence.

Last evening I was driving through a lane near the Masjid when I suddenly spotted four leopards there. They stood unmoved even as I flashed headlights and continuously blew horn. Finally I rushed out of the area driving my car in reverse."

Dr Karan Singh endorses revive Nallah Mar voices

Renzu calls on former Yuvraj

GK NEWS NETWORK

Dr Singh also said that this historical and mesmerizing Nallah Mar canal having panoramic background view of Koh-e-Maran was abode of high literature, classical music as documented by world renowned travelers like Young Husband, Lawrence, Azam Dedmari, Moorcraft and others."

Gale hits Dal lake

CHAPTER 6
CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The complexity of prey-predator interactions needs to be taken into account during the decision-making process for management and conservation. The lack of robust information pertaining to distribution, abundance and ecology of many species often hampers the conservation process significantly. Reliable data on population and biomass estimation of major prey species are still non-existent for most of the protected areas of Kashmir valley. The purpose of the present study was to collect basic information on feeding ecology of leopard with reference to potential prey availability in Dachigam National Park. Dachigam holds last viable population of the critically endangered hangul deer whose population has been showing a declining trend. One of the main purposes of this study was to investigate the extent of leopard dependence on critically endangered hangul. The study focused on estimating seasonal density and distribution of leopard prey and investigating seasonal diet of leopards in Dachigam NP. The study also looked into human-wildlife conflict and attitude of locals towards wildlife conservation around Dachigam NP.

6.1 Significance and contributions

The results presented in chapter three give an account of seasonal prey abundance and spatial-distribution using Density Surface Modeling (DSM) approach in Dachigam NP. It also presents the estimates of rodent population density on seasonal basis. Overall density (±SE) of langur was estimated to be 16.32 ± 1.87/km² and that of hangul was estimated as 5.11 ± 0.51/km² in the study area. Both the species showed seasonal variation in the density with higher density in colder months and lower density in hotter months. Rodent density also showed seasonal variation and highest density was found in summer season (2014 ± 830.71/km²) and the lowest in winter (1172.6 ± 442.74/km²). DSM results indicated elevation, mean of NDVI and CV of NDVI were the factors significantly effecting hangul and langur densities in both wet and dry season. The models estimated that the highest densities of hangul as well as langur in wet season (winter and spring) occurred in lower elevations ranging from 1800-2200 m. In dry season (summer and autumn) it was observed that the densities of both the species in the study area got decreased and both species were distributed to a wider area and higher elevation. Density distribution map prepared as an outcome of DSM analysis identified the thrust areas to which conservation efforts need to be focused in different seasons. Biomass estimation showed that study area supports a low prey biomass as compared to other protected areas. The present study provided information on the demographic structure of potential prey species of large carnivores on the basis of which regular monitoring of prey – predators must be carried out on long – term basis.

Chapter 4 describes food habits and prey selection by leopards. Analysis of 714 scats collected in different seasons during 2011- 2013 revealed that the prey spectrum of leopards varied with season according to availability of prey. 17 different prey items were identified from leopard scats. Small rodents were dominant in leopard diet in all the four seasons with varying percentage of occurrence. Leopards depended most on rodents in summer season, when large prey availability was low, indicating their flexibility to adapt their foraging behavior according to the situation and making it evident that leopard has ability to sustain on smaller prey species. In winter season when large prey density in the study area increases leopard’s dependence on rodents reduces. The presumption that leopards are involved in large scale hangul predation and are responsible for their population decline was proved to be wrong as hangul contributed less than 5% to the leopard diet in all the seasons. Overall this study strongly emphasizes on opportunistic behavior of leopards as they switch to sub-optimal prey in absence of large prey.

In Chapter 5 an attempt has been made to present the socioeconomic status of locals and the nature and extent of human – wildlife conflict faced by them around Dachigam NP. This chapter also presents an evaluation of attitudes of locals towards wildlife and its conservation in the region. Results indicated that majority of the respondents from the study area were involved in agriculture and livestock rearing. 74.71% respondents reported crop damage and 22.90% respondents reported livestock predation by wild animals. In south and central wildlife divisions 31 human casualty cases caused by leopard attacks from 2007 to 2013 were also investigated. Majority of the victims comprised of male children and most of the attacks took place in the evening hours. Most common response by forest officials to the human-carnivore conflict was translocation of the problem animal to a protected area. Translocation being a debatable mitigation measure has been opposed by most of the studies (Linnell *et al.* 1997, Swanpoel 2008, Athreya 2012). High densities of leopards and humans coexist in Akole, Maharashtra without much damage to each other only because there are no inappropriate human interventions (Athreya 2012). In contrast to it around 50 leopard attacks on humans were reported from croplands of Junnar from 2001 to 2003 following a large scale capture and translocation program of leopards (Athreya *et al*. 2011). Thus it can be concluded that it is better to implement effective preventive measures to reduce the conflict rather than to rely on translocation as a mitigation measure.

Attitude study revealed that majority of the respondents in our study supported wildlife conservation while only 15.82% respondents opposed it. Generalized linear modeling results showed that the model that best explained respondents' attitudes toward wildlife conservation included four variables: gender, crop damage, livestock predation, and total livestock holding. Although only a small proportion of respondents had negative attitudes toward wildlife conservation, this proportion is significant because the small number of people who oppose conservation can substantially hamper conservation initiatives by getting involved in illegal activities against threatened wildlife species. Unless such negative attitudes are changed, conflict will always be present that impacts survival of wildlife negatively.

This study has provided new insights on several ecologically important aspects of leopard population in Dachigam NP. It provides crucial information on resource availability and resource selection by leopards and here they appear to cope with temporal and spatial variation in food resources. Availability of food resources in space and time can have significant impact on various ecological facets like diet selection, ranging patterns, habitat use and size and growth rates of population. In this study the shift of leopard diet towards small rodents and the high frequency of human-wildlife conflict can be attributed to low large wild prey availability. There are numerous studies concluding that low wild prey availability is the major driver of human-wildlife conflict (Bagchi and Mishra 2006). Appropriate strategies need to be used for augmenting available wild prey populations in the region. The threats faced by hangul and langur populations need to be mitigated at an earliest. Progressive decline in wild prey population may otherwise lead to further increase in the conflict menace in future. The study also highlighted the fact that leopards are not responsible for declining hangul population which was perceived earlier. This opens a different aspect to look at factors which are responsible for declining hangul population in Dachigam NP.

6.2 Recommendations

Here are some recommendations which need to be considered and necessary interventions made accordingly.

- The critical linkages of Dachigam NP with other protected areas around it are fragmented by the presence of human settlements. Management interventions are needed to demarcate and safeguard the corridors used by leopard as well as its prey for seasonal migration between different protected areas to reduce the natural mortality and the conflict during movement.
- Hangul was historically distributed to a wide range of mountains across the state. The current range and habitat of hangul needs to be expanded by reintroducing hangul in some of its past ranges. Prior to reintroduction these areas need to be surveyed to collect baseline information about present habitat conditions and potential biotic threats present there. In the disturbed, fragmented and degraded forest areas, habitat improvement through protection, plantation and reduction of biotic pressures need to be carried out to make it suitable for hangul survival.
- Since leopard predation is not responsible for the decline in hangul population, there is a need of detailed evaluation to understand the factors responsible for the decline in population of this critically endangered ungulate.
- The presence of several government departments inside the park was recognized as the main outstanding problem which needs to be solved only by their removal from the park as soon as possible.
- Tourism in Dachigam NP has to be sustainable and regulated. There should be a more strict regulatory mechanism in place which can limit tourism pressure up to sustainable levels.
- Livestock losses and crop damage were the major factors responsible for negative attitudes toward wildlife conservation policy around the park, so

reducing crop and livestock damage to socially acceptable levels could have a strong positive effect. Public information efforts are needed to educate landowners on the best ways to prevent livestock predation and crop raiding—such as providing proper nocturnal management of livestock, using guard dogs, properly fencing crop fields wherever possible, and ensuring that domestic animals are accompanied by humans when grazing. Moreover, farmers should be encouraged to properly dispose of agricultural and horticultural wastes to avoid attracting wild animals.

- State of 'absolute no livestock-loss' may never be achieved in a multiple-use landscape within carnivore range. Hence, government and nongovernmental organizations should introduce compensation and livestock insurance schemes to make up for losses caused by wildlife; no such schemes currently exist.
- Local people need to be sensitized about the various complex environmental issues. And awareness campaigns need to be organized for locals and forest frontline staff regarding the handling of human- wildlife conflict situations.

6.3 Challenges and limitations

Owing to the shy or elusive nature of hangul a lot of sampling effort was required to obtain minimum number sightings for robust seasonal population estimates. Despite of such huge effort some less abundant prey species in the area like wild boar and musk deer were sighted only a few times during the study. Security scenario of the area was another major challenge which presented a lot of limitations during our study. This study was largely able to overcome all the hurdles and complete all the proposed objectives.

6.4 Future work

This study provided valuable insights into abundance, food habits as well as human wildlife conflict issue that need to be addressed in order to conserve leopard and its prey species in and around Dachigam NP. Efforts should now be enhanced and expedited to know the status and study various ecological aspects of leopards in other protected and non protected areas of the state. This study covered Central and South wildlife divisions for studying human leopard conflicts. Similar study needs to be conducted in Northern wildlife division of the state where human leopard conflict is on rise. In Dachigam NP there is a strong need for in depth studies on hangul migration to ascertain the summer grounds of hangul. That will also put light on threats faced by hangul in its summer range outside Dachigam NP as well as along the migratory routes. It is also recommended that a regulated long term scientific study of hangul and langur be carried out particularly laying emphasis on less studied aspects like reproductive ecology, behavior, pathology and genetics. Carter *et al.* (2013) studied attitudes toward tigers (*Panthera tigris*) and concluded that concentrating mitigation and conservation efforts at a specific location where wildlife-related impacts occur will likely reduce negative attitudes toward wildlife within a larger surrounding area. Similar studies need to be undertaken around Dachigam NP to examine spatial distribution of attitudes toward wildlife and human-wildlife conflict so that mitigation efforts are focused accordingly.

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Appendix I: Bird species recorded in Dachigam National Park.

Family	Common name	Scientific name	Status
Family- Accipitridae			
1	Black Kite	*Milvus migrans*	R
2	Sparrow Hawk	*Hiereatus nisus nisosimilis*	RM
3	Booted Eagle	*Hiereatus pennatus*	RM
4	Golden Eagle	*Aquila chrysaetos*	R
5	Eurasian Griffon	*Gyps fulvus*	RM
6	White-Rumped Vulture	*Gyps bengalensis*	R
7	Bearded Vulture Or Lammergier	*Gypaetus barbatus*	R
Family- Falconidae			
8	Common Kestrel	*Falco tinnunculus*	RM
Family- Phasianidae			
9	Snow Partridge	*Lerwa lerwa*	R
10	Himalayan Snowcock	*Tetraogallus himalayensis*	R
11	Chukar	*Alectoris chukar*	R
12	Western Tragopan	*Tragopan melanocephalus*	R
13	Himalayan Monal	*Lophophorus impejanus*	R
15	Koklass Pheasant	*Pucrasia macrolopha*	R
Family- Columbidae			
16	Snow Pigeon	*Columba leuconota*	R
17	Rock Pigeon	*Columba livia*	R
18	Oriental Turtle Dove	*Streptopelia orientalis*	RM
19	Eurasian Collared Dove	*Streptopelia decaocto*	R
20	Red Collared Dove	*Streptopelia tranquebarica*	R
21	Spotted Dove	*Streptopelia chinensis*	R
Family- Psittacidae			
22	Rose-Ringed Parakeet	*Psittacula krameri*	R
23	Slaty-Headed Parakeet	*Psittacula himalayana*	R
24	Indian Cuckoo	*Cuculus micropterus*	RM
25	Eurasian Cuckoo	*Cuculus canorus*	RM

Family- Strigidae			
26	Eurasian Eagle Owl	*Bubo bubo*	R
27	Little Owl	*Athene noctua*	R
28	Long-Eared Owl	*Asio otus*	RM
Family- Aodidae			
29	Himalayan Swiftlet	*Collocalia brevirostris*	R
30	Alpine Swift	*Tachymarptis melba*	RM
31	Common Swift	*Apus apus*	M
32	House Swift	*Apus affinis*	RM
Family- Alcedinidae			
33	Pied Kingfisher	*Ceryle rudis*	R
34	Common Kingfisher	*Alceodo atthis*	RM
35	White-Throated Kingfisher	*Halcyon smyrnensis*	R
Family- Coraciidae			
36	European Roller	*Coracias garrulus*	RM
Family- Upupidae			
37	Common Hoopoe	*Upupa epops*	RM
Family- Picidae			
38	Eurasian Wryneck	*Jynx torquilla*	M
39	Scaly-Bellied Woodpecker	*Picus squamatus*	R
40	Grey-Headed Woodpecker	*Picus canus*	R
41	Himalayan Woodpecker	*Dendrocopos himalayensis*	R
Family- Alaudidae			
42	Crested Lark	*Melanocorypha bimaculata*	R
Family- Hirundinidae			
43	Dusky Crag Martin	*Hirundo concolor*	R
44	Barn Swallow	*Hirundo rustica*	RM
45	Striated Or Redrumped Swallow	*Hirundo daurica*	R
Family- Oriolidae			
46	Eurasian Golden Oriole	*Oriolus oriolus*	RM
Family- Surnidae			
47	Common Starling	*Sturnus vulgaris*	RM
48	Common Myna	*Acridotheres tristis*	R
49	Jungle Myna	*Acridotheres fuscus*	
Family- Corvidae			
50	Yellow-Billed	*Urocissa*	R

	Blue Magpie	*flavirostris*	
51	Rufous Treepie	*Dendrocitta vagabunda*	R
52	House Crow	*Corvus splendens*	R
53	Large-Billed Crow	*Corvus macrorhynchos*	R
54	Nutcracker	*Nuctifraga caryocatactes*	
55	Yellow-Billed Or Alpine Chough	*Pyrrhocorax graculus*	
56	Eurasian Jackdaw	*Corvus monedula*	
57	Raven	*Corvus corax*	
58	Jungle Crow	*Corvus macrorphynchos*	
Family-Pycnonotidae			
59	White-Cheeked Bulbul	*Pycnonotus leucogenys*	
60	Black Bulbul	*Hypsipetes madagascariensis*	R
Family-Muscicapidae			
Sub. Family-Timalinae			
61	Jungle Babbler	*Turdoides striatus*	
62	Striated Laughing Thrush	*Garrulax striatus*	
63	Variegated Laughing Thrush	*Garrulax ariegatus*	
64	Streaked Laughing Thrush	*Garrulax lineatus*	
Sub. Family- Muscicapinae			
65	Kashmir Redbreasted Flycatcher	*Muscicapa subrubra*	
66	Little-Pied Flycatcher	*Muscicapa westermannt*	
67	White-Browed Blue Flycatcher	*Muscicapa supercillaris*	
68	Slaty Blue Flycatcher	*Muscicapa leucomelanura*	
69	Verditer Flycatcher	*Muscicapa thalassina*	
70	Grey-Headed Flycatcher	*Culicicapa ceylonensis*	
71	Paradise Flycatcher	*Terpsiphone paradist*	RM
Sub. Family- Sylvinae			
72	Plain Leaf Warbler	*Phylloscopus neglectus*	R

73	Tytler's Leaf Warbler	*Phylloscopus tytleri*	R
74	Tickell's Leaf Warbler	*Phylloscopus affinis*	R
75	Sulphur-Bellied Warbler	*Phylloscopus griseolus*	RM
76	Yellow-Browed Warbler	*Phylloscopus inornatus*	R
77	Lemon-Rumped Warbler	*Phylloscopus chloronotus*	R
78	Blyth's Leaf Warbler	*Phylloscopus reguloides*	RM
79	Gold Crest	*Regulus regulus*	
Sub. Family- Turdinae			
80	Orange-Flanked Bush Robin	*Tarsiger cyanurus*	
81	Blue-Capped Redstart	*Phoenicurus caeruleocephala*	R
82	Black Redstart	*Phoenicurus ochruros*	R
83	White-Winged Redstart	*Phoenicurus erythrogastrus*	
84	Plumbeous Water Redstart	*Rhyacornisfuliginos us*	R
85	Little Forktail	*Enicurus scouleri*	M
86	Spotted Forktail	*Enicurus maculates*	
87	White-Capped Water Redstart	*Chaimarrornis leucocephalus*	R
88	Blue Rock Thrush	*Monticola solitarius*	R
89	Blue Whistling Thrush	*Myophonus caeruleus*	R
90	Grey-Winged Blackbird	*Turdus boulboul*	
91	Chestnus Thrush	*Turdus rubrocanus*	
Family- Troglodytidae			
92	Winter Wren	*Troglodytes troglodytes*	
Family- Cinclidae			
93	White-Throated Dipper	*Cinclus cinclus*	
94	Brown Dipper	*Cinclus pallasii*	
Family- Prunillidae			
95	Alpine Accentor	*Prunella collaris*	
96	Altai Accentor	*Prunella hamalayana*	
Family- Paridae			
97	Grey Tit	*Parus major*	
98	Green-Backed Tit	*Parus moniticolus*	
99	Crested Black Tit	*Parus melanolophus*	

100	Black Tit	*Parus rufonuchalis*	
101	Yellow-Cheeked Tit	*Parus xanthogenys*	
102	Fire-Capped Tit	*Cephalopyrus flammiceps*	
103	White-Throated Tit	*Aegithalos niveogularis*	
Family- Sittidae			
104	European Nuthatch	*Sitta europaea nagansis*	
105	White-Cheeked Nuthatch	*Sitta leucopsis*	
Family- Certhidae			
106	Tree Creeper	*Certhia familiaris*	
107	Himalayan Tree Creeper	*Certhia himalayana*	
Family- Motacillidae			
108	Yellow Wagtail	*Motacilla flava*	
109	Grey Wagtail	*Moctacilla cinerea*	
110	Pied Or White Wagtail	*Motacilla alba*	
111	Large Pied Wagtail	*Motacilla maderaspatensis*	
Family- Zosteropidae			
112	White Eye	*Zosterops palpebrosa*	
Subfamily- Passerinae			
113	House Sparrow	*Passer domesticus*	
114	Russet Sparrow	*Passer rutilans*	
115	Eurasian Tree Sparrow	*Passer montanus*	
Family- Campephagidae			
116	Scarlet Minivet	*Pericrocotus flammeus*	
117	Long-Tailed Minivet	*Pericrocotus ethologus*	
118	Small Minivet	*Pericrocotus cinnamomeus*	
Family- Emberizidae			
119	Pine Bunting	*Emberza leucocephalos*	
120	White-Capped Bunting	*Emberiza stewarti*	
121	Grey-Necked Bunting	*Emberiza bunchanani*	
122	Rock Bunting	*Emberiza cia*	

Appendix II: Questionnaire for the assessment of Socioeconomics status and Attitude of locals toward wildlife conservation

Date Place S. No.

1. Family head (M/F); Name ____________________________ age _________
2. Economic status of family

   M ____ F _____Children _____ Dependents ______ earning members ____

   Highest education; M ____________________ F _________________________

   Total family income (annual); salary ______ agriculture ______other________
3. Agricultural status

   Own land _________ (kanals); Fertilizers used? Y/N ___________

   crop (a) ________________ sown in ___________ av. prod _____________

   (b) ________________ sown in ___________ av. prod _____________

   (c) ________________ sown in ___________ av. prod _____________

   Crop damage; Y/N _______ Year________How much? _________________
4. Resource dependency on forest; Y/N __________ LPG; Y/N ____________

	Requirement	Collection from forest	Collected by	Collected where
	Daily (kg)	Daily (kg)		
Fire wood				
Fodder				
NTFP				

5. Livestock

	Current Number	Mortality (in the past 12 months)	
		Disease	Depredation by Leopard/B. Bear
Sheep			
Goat			
Cow/Buffalo			
Horse			
Poultry			

6. Livestock depredation ; Y/N _______ Year ___________
7. Attack on Human; Y/N ______________

Injury/Death __________ Compensation (amount) _______________

8. Preventive measures used to avoid man-animal conflict:_________________

9. Prime advantage of Dachigam to you:

10. Major problems in raising livestock:

    Disease ☐ Predation ☐ Shortage of pastures ☐

    Should we conserve wildlife or not? _____________

    Why? (advantages as per respondent (economic, ecological, aesthetic etc)____________________

11. Cause of increase in conflict: _________________________________

12. Solution of conflict:____

13. Any suggestions about changes you want to make in area and management of National park for coexistence of man and wildlife?

Appendix III: Questionnaire for the Assessment of Leopard human Conflict

Date: ______________ Observer: _________________________ S. no.: _________

Village: _______________ Lat. ____________ Long. _____________ Elev. _______

District: ______________ Range _______________Division _________________

General Information

Name of respondent **(Optional)**: ____

Relation to affectee: ____ _______

Age: ______ Sex: _____ Occupation: ____________ Income: Rs._______/month.

Highest Education / Literacy: ____

No. of family members of affectee: _______________________________________

Approx. no. of total livestock of all kinds owned: _________________________

Cows______ Buffaloes______ Sheep______ Goats_____ Horses _____Poultry ___

Avg. loss of livestock per year because of diseases: ___________________________

Dogs owned. If yes, number: ____

Loss of poultry: (1) Due to disease __________ (2) Due to predator_______________

Number of years the person is staying or coming to this area: ___________________

Which animal do you think is attacked the most by Leopard: ___________________

Did severity of attacks co-inside with maximum sightings? ____________________

Reasons why the problem has increased? __________________________________

Approx. time, which the livestock spend around villages or in pasture lands: _______

Stall ________________ Pastures ____

Victim; Human/Livestock/Other: ____________________________________

Attacked by: Leopard / Black bear/Wolf/others: ______________________________

Killed or Injured: ____

Location/Habitat: ____

Date and time of attack: ____

Age and sex of victim/animal: ____

Body part attacked and eaten: ____

Activity of victim/animal when attacked: ___________________________________

Was leopard sighted in vicinity? Yes/No. If yes, since how many days? _____________

Alone or in a group: ____

Herder's presence: _______________ or watched by dogs? _____________________

Compensation received: ___________If yes, How much? ______________________

Habitat Analysis of attack site:

GPS reading of attack & hiding site (if possible): __________________Elev. _____

GPS reading of site where dragged to (if possible): ______________Elev. _______

Terrain: Steep/Gradual/Undulating/Flat/Valley ______ Slope: _____Aspect: ______

Type of vegetation: ____

Nearest forest from attack site: 0-100m, 100-500m, 500-1000m, >1Km

Any significant landmark such as stream or riverbed: __________________________

Distance from; water source: ____________ ridge/cliff: ________________________

Distance from house(s) around:

Pakka ________________________ Kachcha __________________________

Attack done in open or in corral: ________ corral secured or open: _______________