RANGING PATTERNS OF ASIATIC BLACK BEAR (*Ursus thibetanus*) WITH REFERENCE TO FOOD AVAILABILITY IN DACHIGAM NATIONAL PARK, KASHMIR

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EXECUTIVE SUMMARY

The family Ursidae is represented by eight species of bears in world of which four are present in India viz., Asiatic black bear (*Ursus thibetanus*), sloth bear (*Melursus ursinus*), Himalayan brown bear (*Ursus arctos isabellinus*), and the sun bear (*Helarctos malayanus*). In India, Asiatic black bear distribution overlaps with brown bear in north-western and western Himalayas and with sloth bear in the foot hills of north-western Himalayas and in the hill states of north-eastern India. Asiatic black bear is one of the least studied species in India and the existing studies mostly deal with their status and distribution.

Throughout their distribution range, Asiatic black bear are threatened due to poaching for gall bladder (medicine), skin (ornamental), retaliatory killings to reduce bear-human conflicts, and due to large scale habitat degradation or loss. As a result of these threats, the black bear population in India is decreasing in many areas. Asiatic black bear-human conflicts is an important management issue that needs to be addressed on priority basis as depredation of agricultural/ horticultural produce by black bears have resulted in the resentment of the local people who suffer such losses leading to retaliatory killings and animosity with the government departments in Kashmir.

For better management and mitigation of bear-human interactions, it is necessary to generate scientific information on different ecological aspects of Asiatic black bear. Thus, the present study was carried out during 2007-2011 to address the issues related to movement patterns of black bear in relation to food availability in Dachigam landscape and to understand the food and feeding habits of black bear in different seasons.

The information on the home ranges size of black bear is crucial for understanding ecology and management. Questions, such as assessing how much space or habitat is required for a species, movement behavior, and hibernation are some aspects that would be of tremendous help for bear management and in landscape level planning for conservation of bears. Information on food habits of black bear would help in understanding the reasons for crop depredation and consequent bear-human conflicts in the landscape despite high food abundance in summer within the bear habitats of Dachigam NP.

Habitat characterization and mapping were carried out to assess habitat quality and to understand the level of fragmentation and composition of Dachigam landscape. The land use/ land cover in Dachigam NP and surrounding areas was classified using the Landsat data downloaded from GLCF. Vegetation sampling was carried out for habitat characterization in Lower Dachigam area of NP. For vegetation sampling, a total of 121 permanent sampling plots were laid at an interval of 250m along the 13 transects and main Dachigam *nallah* representing all the six forest types for assessment of vegetation structure, species composition, diversity, richness and abundance.. The floristic assemblage in Dachigam was analyzed using TWINSPAN analysis and the Conical Correspondence Analysis (CCA) was used to determine the relationship of vegetation assemblage with the habitat factors which are responsible for the assemblage of plant species.

The area under forest cover in lower Dachigam was 91% and rest includes non forest areas such as rocky clefts, water bodies, human-agriculture and snow covered area. Vegetation of Lower Dachigam was represented by 34 trees, 21 shrubs, 96 herbs, 8 climbers belonging to 65 families. Based on image analysis, six forest types viz., Riverine forest, Low temperate forest, Low temperate pine mixed forest, Mid-temperate, Temperate grassland/scrubland and Oak plantation were identified in Lower Dachigam. An area of 550km^2 was calculated using GIS in the Dachigam landscape and was used for the ecological study (area of analysis) which included human habitation, crop lands, five conservation reserves and lower to middle part of Dachigam NP (falling under Central Wildlife Division). The area under forest cover was 230 km^2 (42%) and the remaining were non-forest LULC that included human settlements, croplands, rocky clefts, water bodies and snow covered area.

Using the TWINSPAN analysis six major plant communities were identified viz., 1) oak plantation community, 2) *Morus-Prunus* community, 3) *Asculuas-Rhus* community, 4) *Pinus-Ulmus* community, 5) *Parrotiopsis-Salix* community, 6) *Rosa-Rubus* community. The relationship between plant species and environmental variation was assessed using Canonical Correspondence Analysis (CCA). The first three axes of the CCA ordination had relatively high eigenvalues however, the percentage variance of plant species data explained 3.7 and 2.8, for axes 1 and 2 respectively. The cumulative percentage variances of species-environmental relation for axes of CCA (eigenvalues) are: 3.7 (0.208) and 6.5 (0.157) for axes 1 and 2 respectively. The species-environment correlation calculated for the first two axes of CCA were: 0.77 and 0.78. A Monte Carlo permutation test showed that the vegetation-environment relationship revealed by axis 1 and all axes were significant (P=0.01). The strongest correlations with the first CCA axis were significant for disturbance on plot, and had partial correlation with elevation and slope of the sites. The second CCA axis was highly correlated with species richness and slope on the plot, where as the third CCA axis was correlated with aspect, disturbance and slope on the plot.

The dispersion of both pooled and total samples of tree and shrub species was aggregated in Dachigam NP. The heterogeneity in the dispersion of tree and shrubs species was concluded to be discordant following Chi-square analysis with a probability of zero. The distribution pattern of tree and shrub species did not show significant variation and not showing independent heterogeneity. The observed species richness for tree in 121 plots was 27 and accounted for 2951 individuals. The Jackknife 1, 2 and Chao 2 estimated 27, 25, and 27 species respectively in the intensive study area. In case of shrubs the estimates of Chao 1 was again not reliable whereas, the estimation of Chao 2, and jackknife 1, 2 were 17, 17, and 17 respectively which were more realistic estimates. The occurrence of singletons was much higher than doubletons (number of species which occur only twice in a single sampling plot). The diversity index values calculated by using different indexes showed similar patterns except for evenness (e^H/S) where the value for shrub was larger than the trees. The SHE analysis for tree species depicted that the decrease in evenness was accompanied by increase in species richness. The decrease in the evenness was coherent with the analogous increase in species richness, resulting in slight to no change in H` diversity with increasing samples size. For shrub species, results showed that both H` and the cumulative Ln(N)/Ln(S) diversity were coherent and increasing by increasing the number of samples. The more or less constant H` and Ln(N)/Ln(S) with increasing number of samples indicates that the shrub species distribution in the study areas exhibits characteristics intermediate to Log normal, and log series abundance distribution.

Landscape fragmentation analysis in Dachigam landscape was based on four LULC classes: forest, non-forest vegetation, bare land, cropland, and water. The total area of forest cover was (229Km^2) which is 43.8 % of the landscape. However, the number of patches and the mean patch size are significantly different among the different types of land use and land cover types (*P*<0.005). In the landscape, the mean patch size of forest fragments was 755 m^2 and the number of forest patches was 3043. The forest patch density was 0.58 patch/ km^2 in the landscape. The mean distance among the forest patch was 53.0m. Out of total forest area in the landscape about 9.3% classified as core forest and 34.5% as edge forest. Fragmentation is represented by percentage forest coming under different classes which includes transitional class 3.1%, edge class forest 7.6 %, perforated class 15.5% and about 14.8% comes in interior forest. The Shannon-Weiner diversity index value of the landscape was 1.5394 and the Simpson index value was 0.2644.

Seven black bears (4-males and 3-females) were collared during 2009-2011 of which two were recovered as one animal died (10M) (due to natural causes while hibernating) after four months of tracking and the other animal (100M) died (due to electric shock) after seven months of tracking, and the remaining five collared animals were radio tracked till October 2011. During the two years of tracking collared bears i.e., from autumn 2009 to autumn 2011, we recorded 1880 relocations of which 497 were from ARGOS and 1383 were from VHF tracking. A total of 1219 locations were used for the home range analysis. The number of location bear black bear ranged from 86 to 247, with an average of 175 locations per black bear.

The utilization distribution based home range models were compared and amongst the parametric models the CVC_c value suggested that the bivariate normal model performed best in all of the cases except for M100 where the best model was bivariate circle. Based on the CVC_c criteria among all the models adaptive kernel and fixed kernel performed best but adaptive kernel model was best among the two kernel methods.

A total of seven software programs were compared to select most suitable home range analysis software for which the home range shape and the estimated area were compared. The mean similarly index value of the home range generated through Animal Space Use Beta 1.3 (1.87 ± 0.09) was highest, followed by HRT (1.62 ± 0.24) and it was lowest for the home range generated by Biotas (1.20 ± 0.08). The home range generated using six software programs differed significantly at 2 contours 75% and 50% (*P*<0.05; Table 5.5) but for 95% the difference was not significant at *P*<0.05. At 95% isopleths, the home range generated by HRT tool was largest among all the programs and it was 1.4 fold larger than the home range size generated by the Ad hoc and LSCV estimators of AMA extension. The GME tool performed consistently at all of 3 isopleths and the home range sizes generated were falling in the middle of all the estimated home range sizes by other programs. The home range asymptote analysis was carried out using 100% MCP and 95% Kernel density methods. By using 100% MCP method the home range of individual Id_02, 04, 06, 100 reached asymptote whereas by using 95% kernel home range stabilized for Id_02, 04 and 06 at 256, 263, 294 locations.

The home range was generated using 100%, 75% MCP and 95%, 75% and 55% Kernel method. The overall 100% MCP home range size of female with cub 04F (8.44 km^2) was smaller than home range of other two female 00F (53.84 km^2) and 06F (84.11 km^2).Whereas, 100% MCP home range for male black bear was largest for 02M (124.67 km^2), followed by 100M (23.09 km^2), 10M (9.80 km^2) and was smallest for 08M (9.62 km^2). The average 100% MCP home range of black bears at Dachigam landscape was 44.97 km^2 ± 17.08 and ranged from 8.44 km^2 to 124.67 km^2. The average 75% MCP was 22.22 km^2 ± 9.5 and ranged from 2.66 km^2 to 69.14 km^2. The 95% Kernel home range size for 04F was 9.62 km^2, and for other two females 06F, 00F, it was 76.52 km^2, 59.21 km^2 respectively. Amongst the males, 95% Kernel home range size for 02M was largest (151.92 km^2), followed by 100M (17.97 km^2), 08M (11.53 km^2) and was smallest for 10M (8.45 km^2). The average 95% kernel home range size was 47.88 Km^2 ± 20.12 and ranges from 8.45 Km^2 to 151.92 km^2. The overall 95% Kernel home ranges size estimates were larger than the 100% MCP estimates. The 75% kernel home range size for female 04F was 4.11 Km^2, for 00F and 06F was 24.04 km^2, 20.95 km^2 and for the male 02M, 08M, 10M and 100M was 80.06 km^2,4.13 km^2, 3.01 km^2,and 5.93 km^2 respectively. The average 55% Kernel home ranges of black bears at Dachigam was 10.05 Km^2 ± 5.04 and ranged from 1.13Km^2 to 38.4 Km^2.

The average annual kernel home ranges for all 3 isopleths were larges during 2010 than 2011. The annual 95% kernel home range of black bear in 2010 was 45.94 km^2 ± 20.56, whereas during 2011 it was 43.73 km^2 ± 14.1. The average 75% kernel during 2010 was 19.01 km^2 ± 7.4 and in 2011 it was 16.34 km^2 ± 6.9. The average yearly kernel home ranges of male black bears were larger than female at all 3 isopleths. The average annual 95% kernel home range for male (4 male black bears) was 52.28 km^2 ± 41.0 whereas it was 15.28 km^2 ± 4.6 for female (3 female black bears). The average annual 95% kernel home range of black bear was 35.43 km^2 ± 23.2, 75% kernel was 19.27 km^2 ± 12.7 and 50% annual kernel home range was 9.92 km^2 ± 6.8 in Dachigam landscape. The site fidelity was tested for the home range and two black bears out of four did not differ in two years (P>0.05) based on the MRPP test using BLOSSOM. The home considerable (>80%) home range overlap was observed in 3 out of 4 black bears among two years 2010 and 2011 thus suggesting site fidelity or stability.

There was significant difference among the seasonal home range sizes of black bears ($F_{2,18}$ =0.58, *P*=0.56). The average spring 95% kernel home range of black bear was 22.79 km^2 ± 8.23, summer home range was 16.64 km^2 ± 4.5, and for the autumn it was 13.56 km^2 ± 4.8. The seasonal home range did not differ significantly among the years in Dachigam landscape (P>0.05). Spring home range varied from 11.93 km^2 to 23.46 km^2, summer ranges varied from 21.15 km^2 to 21.81 km^2, and the autumn home range varied from 3.73 km^2 to 23.68 km^2. Further, no significant difference was observed among male and female black bear home ranges sizes (P>0.05). For males, the spring home range varied from 9.57 km^2 to 16.36 km^2, summer range varied form 27.42 km^2 to 38.52 km^2 and the autumn range varied from 3.69 km^2 to 16.87 km^2 whereas, for females the spring home range varied from 15.07 km^2 to 32.92 km^2, summer range varied from 23.47 km^2 to 23.66 km^2, and for autumn the home range varied from 7.47 km^2 to 38.37km^2. The varied degree of overlap was observed between the sexes of black bear.

The Mean Daily Seed ranges from 124 m/day (F06) to 450 m/day (M100) with an average of 267m/day. Among the 4 males, the MDS was highest for M100 (450m/day) and among the 3 females it was highest for F00 (266 m/day). The maximum step distance among the males was largest for M00 (10057m), and among the females it was for F06 (8794m). The number of different relocation sites was highest for F06 (0.192 new site/day), followed by M02 (0.180 new site/day) and it was lowest for M10 (0.038 new site/day). There was no evidence for consistent pattern in the distribution of turning angles among the radio-collared black bears. For all of the radio-collared black bears the majority of steps were falling between 500m to 1500m. The step length for individuals F00, M02, F06 was larger than other four individuals. The variations among the step length were high in individuals using areas within the boundary of Dachigam NP. The overall fractal dimension D was calculated to understand the path tortuosity. There was a significant difference in the fractal D values of the movement paths of radio collared black bears among the seasons (Mann-Whitney, $U = 19$, $P<0.02$). The effect of habitat variables on the movement patterns of black bear was assessed for 7 black bears at Dachigam landscape. The interaction of habitat variables varied across different scales of analysis and among the animals. The effect of different habitat variables was not similar hence analyzed separately. The results indicated that the effect was not similar for all study individuals. The results indicated that most of the bears were avoiding areas with roads and other disturbances for the movement path selection.

To understand the diet and foraging habits of black bear, 13 transects/trails covering all habitat types of the study area were systematically monitored. A significant difference in diet of black bear was observed among the seasons ($\chi^2=157.3$, df = 12, $P <0.001$). The Shannon Weiners Index (H`) value for bear diet ranged from 1.126 to 0.885 in summer and winter respectively. Scat analysis revealed that there was a considerable amount of anthropogenic food or cultivated food crop in bear diet. A shift in the diet of black bears was recorded from herbs to sugar rich food in spring and summer respectively and then to fat rich food before hibernation. Occurrence of considerable amount of anthropogenic food in bear diet can be associated with close location of these crops to the natural bear habitat.

A total of 80 hair samples were collected from the Dachigam landscape and DNA was extracted from all of these hair samples and were tried to amplify on the 20 selected microsatellite markers. Of the 20 microsatellites, 3 loci (G10H, MSUT3 and UT 23) did not amplify and 4 loci showed low success rate *i.e.* UT 29 (77.78%), MSUT 5 (72.22%), UT 31 (38.89%) and UT 3 (44.44%). Therefore, data generated from these loci was excluded and data from those microsatellites producing high success rate (>95%). These were later subjected for further analysis such as individual identification and diversity estimates.

The genetic analysis was started with 80 hair samples and 24 samples did not amplify at all since the quantity of sample was low and seven hair samples did not produce identical genotypes even after repeating thrice. In total genotype was achieved for 64 hair samples that produced identical genotypes in duplicate genotyping and 18 unique genotypes were identified in a pool of 64 genotypes. All the genotypes except ABB 5, ABB 9, ABB 16 & ABB 17 were recaptured and genotype ABB 3 was recaptured as maximum as 9 times in the genotype data of 64 samples.

The genetic variability found in black bear population of Dachigam was consistent with the variability reported in other populations of Asiatic black bear. The mean hetrozygosity was 0.67 which was higher than reported from Japan. The Model-likelihoods from program STRUCTURE indicated that all bears in the landscape most likely to belong to one panmictic population (K=1) lacking substantial genetic structuring in the population.

Using LD method, N_e estimates were found to be stable at allele frequencies 0.02 and 0.01 and the actual N_e estimates was presumed 18.1 at P_{crit} 0.01 because there were high number of alleles with low allele frequencies in our data sets. No difference in the confidence intervals was observed in N_e estimates using jackknife and parametric procedures. The estimated N_e effective population size of black bear in Dachigam suggests that the population is healthy and viable. The Ne estimates were near equal to the identified individuals (census number or individual identified for the analysis) that indicates the presence of large number of breeders in the population.

The mean relatedness value *R* for core area overlapping bears was 0.238 (90% CI 0.166-0.318), for overlapping home ranges (YO) it was 0.124 (90% CI 0.039-0.224) and for the non-overlapping home ranges (NO) it was *R*= -0.092 (90% CI -0.059-0.011). There was a negative relationship between the home range centriods distance and the genetic relatedness among the pair of individuals in Dachigam landscape. The relationship was not significant which could be attributed to the availability of food resources in Dachigam.

The Mantel test indicated a negative relationship ($P<0.05$) but not significant between the relatedness of overlapping black bears and the distance between the home range centers. The Standardized Mantel Statistic ($r = - 0.532$; $P=0.074$) indicates that the relatedness negatively influenced by the geographic distance, hence related individuals were more likely to have home ranges close together than farther apart.

By using the molecular tags, seven conflicting individual bears were tracked in the landscape demonstrating the significance of use of molecular tracking in wildlife management. There were bears which belong to Dachigam NP but they caused damage in croplands and orchards in the surrounding areas of Dachigam. It was difficult to track the movements of species such as black bear since they are active during crepuscular time. The movements of bears from Dachigam to the surrounding areas were high during spring and early summer because food availability becomes very low in Dachigam. By using the molecular tracking technique, it has been proved that during autumn bears congregate in the oak patch inside Dachigam to feed on oak acorns – a food source found only in small patches in the entire Kashmir Valley.

The investigation on the black bear food habits would enable the management of Dachigam NP to maintain optimal habitat conditions. The efforts should be made to educate the local communities to stop growing such crops in the close vicinity to the park boundary since large numbers of scats were containing anthropogenic food items. Incremental removal of horticulture crops in the surrounding areas of Dachigam NP will allow black bear for gradual transition from human food to natural food which will help in reducing conflict. Aversive conditioning of bears will be critical as bear accustomed to feed on horticulture crops will seek out alternative food resources in the area. Efforts on proper management of waste in horticulture crops and food processing industries in areas close to bear habitat will help in mitigating bear-human conflict. It is recommended that there is a need to do multi-year studies which involve monitoring of fruit availability on important food species of black bear in Dachigam landscape which will be helpful to understand the seasonal variations in food habits within years and to understand the stubborn food resources (which do not show season variability) and the alternative food resources (with seasonal changes in availability) or inadvertent (crop, orchards) food resources in the landscape. Better understanding of food and feeding habits of black bear will help in bear-human conflict mitigation in the landscape.

The forest fragmentation analysis in the present study suggested intermediate level of fragmentation and it is likely to increase because of human encroachment on the forest land. The forested fragmentation can adversely impact the movement of bear in the landscape which may lead to demographic as well as genetic isolation of species, hence leading to population fragmentation and extirpation. It is recommended to control such developments and steps should be taken to reverse the process of habitat loss by aforestation in such areas with fruit bearing plant species. The connectivity of the forest should be maintained for the term survival and genetic viability of the species.

The molecular tracking study suggested that the current practice of releasing conflicting animals inside Dachigam may not be an effective tool to reduce conflict, since bear possess strong homing tendencies. The future management practices need to protect and restore large, contiguous forested habitat for black bears in the landscape and elsewhere in the distributional range of black bears that may provide a strategy for managing bears in areas where habitats are already highly fragmented.

To ensure better management of black bear population in Dachigam landscape it is necessary to stop illegal forest encroachment and the local communities should be encouraged to grow medicinal plant of high economic value and which are avoided by black bear as cultivated food near bear habitats, and to maintain as well as restore the forest contiguity in the landscape. Ideally the incremental replacement of horticulture crops with high economic value medicinal plants in such areas of Dachigam landscape will allow black bear for gradual transition from human food to natural food which will help in reducing conflict without hampering the locals economy. There is a need to create awareness among the local communities on bear ecology and behaviour, and also about the need for co-existence of humans with the bears in the landscape through community participation, training and awareness programs.

ORGANIZATION OF THESIS

Chapter 1 Presents the general introduction of the study animal and highlights the significance of the present study; it reviews the national and international studies on the related subject and culminates with objectives of the present study.

Chapter 2 describes the study area in detail.

Chapter 3 describes the general research methodology for the overall study objectives.

Chapter 4 deals with the habitat characterization and mapping in Dachigam National Park.

Chapter 5 deals with the methodology, results, discussion and summary of Asiatic black bear home range, movement and ranging patterns in Dachigam landscape.

Chapter 6 deals with the introduction, methodology, results, discussion and summary of the food availability and feeding habits of Asiatic black bear in Dachigam National Park.

Chapter 7 deals with the introduction, methodology, results, discussion and summary of molecular tracking of black bear in Dachigam landscape.

Chapter 8 Synthesizes of the overall study outcomes and suggested management recommendations.

પ્રાક્કથન

સૌરાષ્ટ્રમાં આઝાદીના સમય પહેલાંથી કેટલાંક ઉદ્યોગો સ્થાનિક કાચા માલની પ્રાપ્તિના સ્થળે વિકસાવવા પામ્યાં હોવાનો નિર્દેશ મળે છે. આવા મોટા ભાગનાં ઉદ્યોગો ખાણ–ખનીજ સાથે સંકળાયેલ છે. આધુનિક ઔદ્યોગિકરણના યુગમાં કોઈપણ પ્રદેશની આર્થિક સદ્ધરતાનું માપ તેની ખનીજ સમૃદ્ધિને આધારે કાઢી શકાય. સૌરાષ્ટ્રમાં ધાતુમય ખનીજોને બદલે અધાતુમય ખનીજોનું પ્રમાણ વધુ જોવા મળ્યું છે. આથી આ ધાતુમય ખનીજોની વિપુલતાને કારણે અનેક ઉદ્યોગોનો વિકાસ થયો છે. તેમાં સોડા એશ, સિમેન્ટ ઉદ્યોગ, મીઠાં ઉદ્યોગ, સિરેમીક ઉદ્યોગ વગેરેનો સમાવેશ થાય છે. આ ઉપરાંત સૌરાષ્ટ્રમાં કૃષિક્ષેત્રનો વિકાસ થયેલો હોવાથી મોટાભાગની કૃષિ પેદાશો આધારીત અનેક પ્રોસેસીંગ ઉદ્યોગોનો પણ વિકાસ થવા પામ્યો છે. જેમાં કોટન, જીનીંગ, ખાંડ ઉદ્યોગ, ડેરી ઉદ્યોગનો સમાવેશ થાય છે. આ મોટા ભાગનાં ઔદ્યોગિક એકમો સ્થાનિક કાચામાલની પ્રાપ્તિના સ્થળે અથવા તો નજીકના વિસ્તારમાં વિકાસ પામે છે. સૌરાષ્ટ્રમાં વાંકાનેર, મોરબી અને થાનગઢમાં સિરેમીક ઉદ્યોગનો વિકાસ થવા પામ્યો છે. આ ઉદ્યોગ આંતરરાષ્ટ્રીય સ્તરની પ્રતિષ્ઠા ધરાવે છે. આથી સંશોધન વિષય તરીકે ''સિરેમીક ઉદ્યોગ'' ની પસંદગી કરવામાં આવી છે.

આ અભ્યાસ મારો મૌલિક હોવા છતાં મારા માર્ગદર્શક શ્રી ડૉ. બી. ડી. વાળાએ આપેલ માર્ગદર્શક અને સહકાર માટે તેમનો આભાર માનુ છું. મારા પિતાશ્રી એ. એ. પરમાર અને માતુશ્રી આર. એ. પરમારની પ્રેરણા અને સહકારથીજ આ અભ્યાસની શરૂઆત કરેલ મારી બહેન ભારતી અને ભાઈ ધર્મેન્દ્રની આભારી છું. કૌટુંબીક સભ્યોના સહકાર બદલ તેમની અંતઃકરણથી ઋણી છું.

શ્રી દોશી કોલેજ વાંકાનેરના પ્રિન્સીપાલ શ્રી ડૉ. ચુડાસમા સાહેબ અને સમગ્ર પ્રાધ્યાપક ગણનાં સહકાર બદલ આભાર વ્યકત કરું છું. મારા પ્રાધ્યાપક મિત્ર કુ. વિભાબેન વ્યાસનાં સહકાર બદલ આભારી છું. અમારી કોલેજના ગ્રંથપાલ શ્રી રાવલકાકાનો સંદર્ભગ્રંથો પૂરા પાડવા બદલ આભાર માનું છું. સૌરાષ્ટ્ર યુનિવર્સિટી અર્થશાસ્ત્ર વિભાગના અધ્યક્ષ શ્રી ડૉ. જોષી સાહેબ અને યુનિવર્સિટીના કુલપતિશ્રી અને ઉપકુલપતિશ્રીના સમયમાં જે સંશોધનાત્મક પ્રવૃતિ થાય છે તે પ્રોત્સાહનનો જ એક ભાગ છે. સૌરાષ્ટ્ર યુનિવર્સિટી ગ્રંથાલય પણ ખૂબ ઉપયોગી નિવડયું છે. ઝડપી અને સમયસર ટાઈપીંગ માટે કૌશિકભાઈ (હાલ્ડા કોમ્પ્યુટર) નો આભાર વ્યકત કરું છું. સિરેમીક એકમોના સંચાલકોનો સચોટ માહિતી આપવા બદલ આભાર માનું છું.

અર્ચના એ. પરમાર

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Chapter 8 Synthesizes of the overall study outcomes and suggested management recommendations.

CHAPTER-1: INTRODUCTION

1.1. General Introduction

The family Ursidae is represented by eight species of bears in world. Northern Hemisphere is home to seven species of bears while, the Spectacled bear (*Tremarctos ornatus*), the only South American bear inhabits the Peruvian Andes in the southern hemi-sphere. In the Northern America, the genus *Ursus* is represented by the big Grizzle bears a sub-species of the Brown bear (*Ursus arctos*) and the American Black bears (*Ursus americanus*). The polar bear (Ursus meritmus) is distributed around the artic circle while, Europe has only the brown bear, Asia is home to five species of bears Brown bear (*Ursus arctos*), Asiatic black bear (*Ursus thibetanus*), Solth bear (*Melursus ursinus*), Sun bear (*Helarctos malayanus*) and Grant panda (*Ailuropoda melanoluca*). Ursidae is a young family evolved from early canids during the late Oligocene and early Miocene about 20 – 25 million years ago. The bears are one of the most diverse groups of large mammals. They occupy extremely wide range of habitats including lowland tropical rain forest along the equator, coniferous forests, deciduous forests, prairie grasslands, desert steppe, coastal rainforest, arctic tundra and alpine talus slopes. They are opportunistic omnivores and the diet varies from plant foliage, roots, fruits, insect, to animal matter in the form of carrions, fish and other. Their dentition and digestive system has adopted and evolved to metabolize varied diet spectrum. These eight bear species are currently distributed in more than 60 countries on four continents. Unfortunately, bear numbers and range are declining in most areas of their distribution range. Some bear species have been reduced in numbers by 50% or more in the past 100 years. Many populations of bears are fragmented and getting isolated today due to habitat loss in the form of encroachment and degradation which are making the existing populations vulnerable to extinction. The time for conservation action is growing short for many species and it is likely that in the next 20 years, many isolated bear populations will go extinct forever (Servheen et al. 1999). Bears are a key indicator of ecosystem health wherever they are distributed. As such, bears can be a key focus for ecosystem conservation. Conservation of bears and the management of the habitat they need to survive will conserve habitat and space needed for many other species. Conservation of bears also conserves resources needed by local communities such as watersheds, wildlife, and the local culture that in many cases includes bears in legends and stories (Servheen et al. 1999).

Four species of bears are found in India, the sloth bear (*Melursus ursinus*), the Asiatic black bear (*Ursus thibetanus*), Himalayan brown bear (*Ursus arctos isobellinus*), and the sun bear (*Helarctos malayanus*), Asiatic black bear overlaps its distributional range with brown bear in north-western and western Himalayas and with Sloth bear in the foot hills of north-western Himalayas and in the hill states of North-Eastern India (Prater 1980; Sathyakumar 2001). The characteristics of black bear habitat is forest cover interspersed with small patches of grasslands which give high degree of edge and the early stages of forest succession.

The ability of black bear to inhabit diverse physiographic and vegetation associations is partly due to its ability to hibernate during winter when food resource is scarce in northern and north-western Himalayas (Prater 1980). In eastern Himalaya, they do not hibernate where food is available throughout the year. Hence, food availability and climate are the major determinants factors of their life history patterns and play major role in their ranging, movement and habitat utilization patterns (Hwang et al. 2002; Teruki et al. 2004; Sakamoto et al. 2009; Koike et al. 2008). The studies on habitat use reflect that the distribution of food resources governs bear movement and vegetation type utilization (Amstrup and Beecham 1976). Throughout the black bear’s distribution range, bear habitat is characterized by relatively inaccessible terrain, dense understore, and abundant food resources predominantly hard and soft mast producing plants (Pelton 1980). In Himalayas such type of large geographic areas are disappearing day by day because of human encroachment which is consequently leading the increased human-bear interactions (Charoo et al. 2011). In north western Himalaya, the land use change in the form of conversion of forested habitats into crop land or orchard has forced the bears to live in small fragmented patches and resulting in overall population decline (Sathyakumar 2001; Sathyakumar and Choudhury 2007; Charoo et al. 2011).

1.2. Historic and present distribution of Asiatic black bear in world

The fossil remains of the Asiatic black bear hasbeen found as far west as Germany and France, but in historic times the species has been mainly limited to Asia. It occupies a narrow band from southeastern Iran (Gutleb and Ziaie 1999) eastward through Afghanistan and Pakistan (Sheikh 2006), across the southern side of the greater Himalayas, to Myanmar. It occupies all countries in mainland Southeast Asia except Malaysia. It has a patchy distribution in southern China, and is absent in most of the east-central China. Another population cluster exists in northeastern China, the southern Russian Far East, and into North Korea. A small remnant population exists in South Korea. A small population of Asiatic black bear also exists in the hill of central and south Bhutan. They also live on the southern islands of Japan (*Honshu* and *Shikoku*) and Taiwan. The species now occurs very patchily through much of its former range, especially in Iran, Afghanistan, Pakistan, mainland Southeast Asia and China (Gutleb and Ziaie 1999). Its distribution in parts of China and Myanmar remains very poorly understood. The distribution of the Asiatic black bear roughly coincides with forest distribution in southern and eastern Asia (FAO 2006), except that in central and southern India this species is replaced by the sloth bear in southern India.

In Malaysia, it is replaced by the sun bear where as in north and west of the Russian Far East it is replaced by the brown bear. The distribution of black bear in Far East Russia is closely coinciding with the distribution of mixed broad-leaf and Korean pine forest (Chestin and Yudin 1999). The Asiatic black bear has been reported to be continuously distributed through southern and eastern Asia from westward through Pakistan and Afghanistan to Baluchistan Province of Iran; east to Indo-China through much of China, Korea, and Japan, with an isolated population in Taiwan (Servheen 1990; Sathyakumar 2001; Wang 1999). Schaller (1977) reported a wide distribution for Asiatic black bear from Russia and Korea to Indo-China and from the forests of the Himalayas below an altitude of 3,750 m west as far as Afghanistan and Iran (Figure 1.1).

1.3. Distribution and conservation status Asiatic black bear in India

The Himalayan region and the hills of northeast India cover *ca.* 591,800 km^2 (18% of India) and probably holds one of the largest population of black bear in Asia (Sathyakumar 2001, Sathyakumar and Choudhury 2007). In India, black bear inhabits forested habitats ranging from 70 m to ‘treeline’ and its range overlaps with that of the sloth bear below 1,200 m and the Himalayan brown bear 3,000 m (Prater 1980). In north-east India, their range overlaps with both sloth and the sun bear (Sathyakumar and Choudhray 2007). The black bear is distributed throughout the Himalayan ranges in the northwest (Jammu and Kashmir; Himachal Pradesh), west (Himachal Pradesh and Uttarakhand), central (Sikkim and northern West Bengal) and east (Arunachal Pradesh). It is also present in the hills and edge of the plains of other north-eastern states of India such as Assam, Meghalaya, Mizoram, Tripura, Nagaland and Manipur (Sathyakumar and Choudhury 2007) (Figure 1.2).

At present, the black bear are continuously distributed in north India, all along the Himalayas (1,200m to 3,300m) and the Eastern Himalayan ranges and the hills of northeast India (70m to 4,300m). Sathyakumar and Choudhury (2007) have reported that the black bear is present in 83 Protected Areas (PA) and over 98 other Forest Divisions (FDs), Reserved Forests, (RFs), and Forested Valleys (FVs). PAs include National Park (NP), Wildlife Sanctuary (WS), Conservation Reserve (CR), and Community Reserve (CMR) in India. It has been estimated that the potential black bear habitat range in India would support 5,400 to 6,750 bears (Sathyakumar 2001; Sathyakumar and Choudhury 2007).

As per Sathyakumar and Choudhury (2007), the status of black bear in the state of Jammu and Kashmir has been reported as ‘fairly common’. Black bear is reported from 16 PAs and 20 FDs, RFs, and FVs of the State. The Dachigam National Park (Dachigam NP), Kishtwar NP, City Forest NP, Overa-Aru WS, Limber WS, Lachipora WS, Gulmarg WS, Thajwas (Baltal) WS, Rajparian (Daksum) WS and 12 (CRs) *viz*., Ajas, Bran, Nishat, Dara, Khiram, Shikarkgarh, Panyar, Khangund, Khrew, Khonmoh, Naganari and Wangat have black bear populations.

In Jammu and Kashmir,black bear is also reported from over 20 other areas and some of these include FDs in Lidder (Pahalgam), Naranaga, Sindh, Wangat, Anantnag, and RFs of Gugnar, Bianoi, Pir Panjal, Zaberwan, Bandipora, and Kahai. It is also reported from Banihal CR, Sumchan Saphare WS, proposed PAs such as Pir Panjal NP, Ghambiar Mongtu WS, Dhera-ki-Gali WS, Ans River WS, and Nowshera WS. In Jammu region, black bear is reported from the FDs of Marwa, Rambandh, Batote, Doda, Badhruwa, Kistwar, Poonch, Rajouri, Nowshera, Reasa, Mahor, Udhampur, Jammu, Ramnagar and Bilwar (Sathyakumar and Choudhury 2007). Saberwal (1989) reported Asiatic black bear density estimates of 1.3–1.8 bears/km^2 in Lower Dachigam during high fruit abundance and the encounter rates ranged from 0 to 3.5 bears/ km walked. About 25 to 40 bears were estimated to use Lower Dachigam in early September and probably late June through October (times of high fruit abundance).

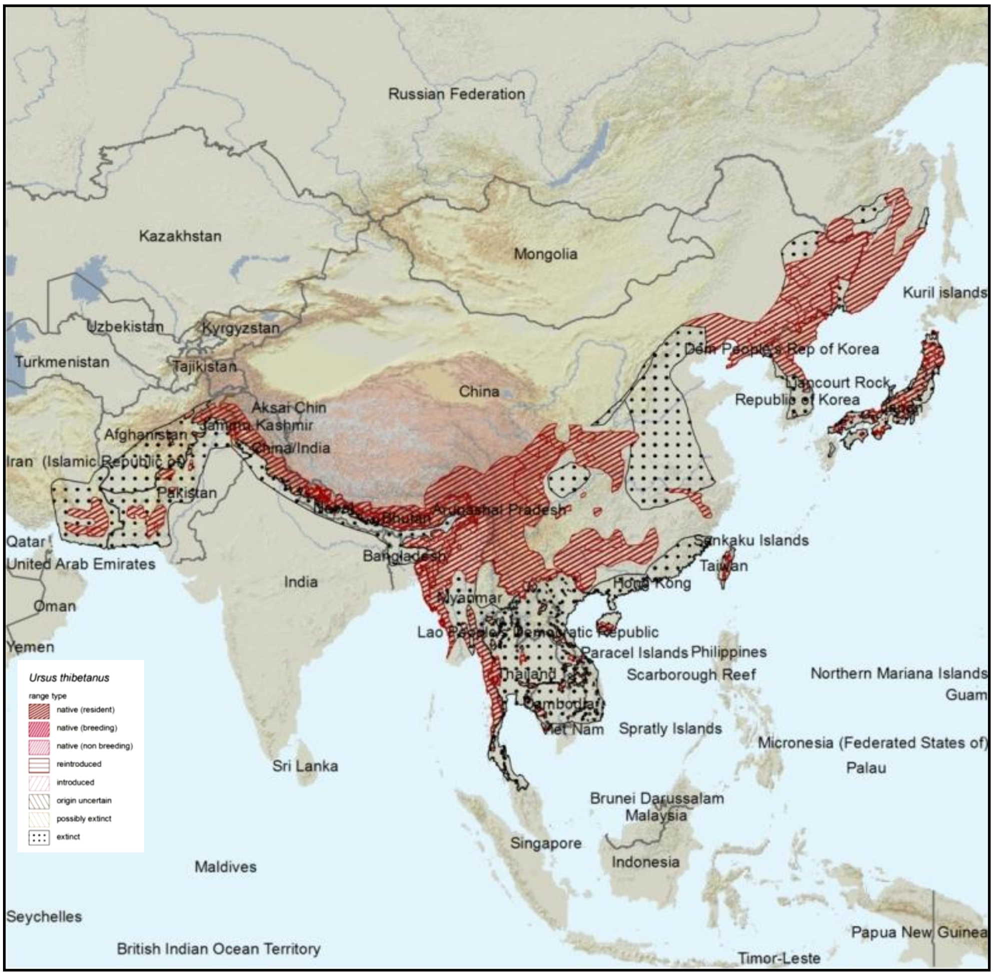


Figure 1.1. General distribution of the Asiatic black bear (*Ursus thibetanus*) as per (*Source: IUCN/SSC 2011*)

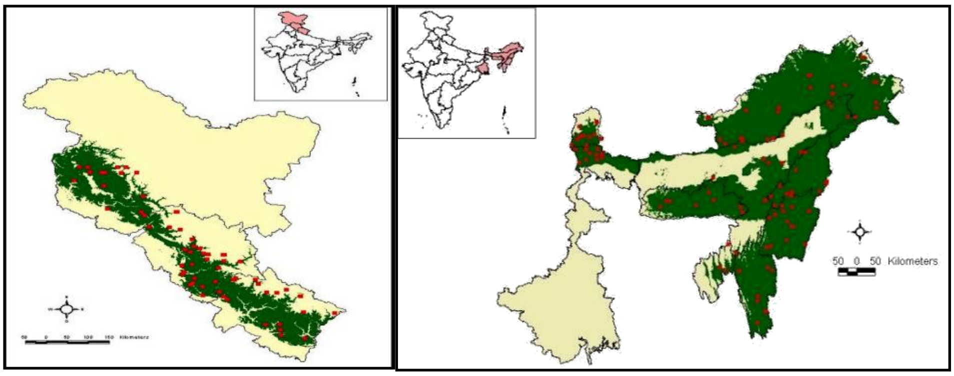


Figure 1.2. Distribution of Asiatic black bear in India (*Source: Sathyakumar and Choudhury 2007)*

1.4. Threats

Throughout the distribution range Asiatic black bear are threatened due to poaching for gall bladder (medicine), skin (ornamental), retaliatory killings to reduce bear-human conflicts, and due to large scale habitat degradation or loss (Servheen et al. 1999). As a result of these threats, the black bear population in India is decreasing in many areas. Habitat loss due to logging, expansion of human settlements, roadway networks, and hydro-power stations, combined with hunting for skins, paws and especially gall bladders are the main threats to this species (Servheen et al. 1999).

The existing information on black bear in India is either anecdotal or insufficient for effective conservation and management. A few short investigations (Schaller 1969; Manjrekar 1989; Saberwal 1989; Sathyakumar 1999, 2001, 2006; Sathyakumar and Viswanath 2003; Sathyakumar and Choudhury 2007) on black bear have been carried out so far in India. Asiatic black bear-human conflicts is a major management issue that needs to be addressed on priority basis as depredation of agricultural/ horticultural produce by black bears have resulted in the resentment of the local people who suffer such losses and consequently leading to retaliatory killings and animosity with the wildlife departments in Kashmir (Charoo et al. 2011).

1.5. Physical attributes

Asiatic black bears are similar in general appearance to brown bears, but are more lightly built and more slender limbed. The skull of Asiatic black bears is relatively small, but massive, particularly in the lower jaw. Adult males have skulls measuring 12.3–13 inches in length and 7.9–9 inches wide, while females have skulls measuring 11.5–12.4 inches long and 6.4–6.8 inches wide. Compared to other bears the projections of the skull are weakly developed; the sagittal crest is low and short, even in old specimens, and does not exceed more than 19–20% of the total length of the skull, unlike in brown bears, which have sagittal crests comprising up to 41% of the skull's length (Roberts 1977). Although mostly herbivorous, the jaw structure of Asiatic black bears is not as specialized for plant eating as that of Giant panda, Asiatic black bears have much narrower zygomatic arches, and the weight ratio of the two pterygoid muscles is also much smaller. However, the lateral slips of the temporal muscles are thicker and stronger in black bears. Asiatic black bears have powerful upper bodies for climbing trees, and relatively weak hind legs, which are shorter than in brown bears and American black bears. They are the most bipedal of all bears, and have been known to walk upright for over a quarter mile (Roberts 1977; Macdonald 2001). The heel pads on the forefeet are larger than those of most other bear species. Their claws, which are primarily used for climbing and digging, are slightly longer on fore foot (30–45 mm) than hind (18–36 mm), and are larger, more hooked than those of the American black bear. The ears are bell shaped, and are proportionately longer than those of large bears, and stick out sideways from the head. The lips and nose are larger and more mobile than those of brown bears (Roberts 1977; Nowak 1999).

Adult Asiatic black bears are slightly smaller in size than American black bears. The measurement of shoulder height is 28–40 inches and the body length ranges from 47–77 inches. They have small tail of length about 4 inches. The weight of the mature males typically ranges between 100–210kg, with an average weight of about 150kg. The body weight of female ranges for 90-140kg and it go up to 180kg in autumn season. The eyesight of Asiatic black bear is poor, their hearing power is moderate but their senses are more acute than those of brown bears (Roberts 1977; Macdonald 2001).

1.6. Evolution

The species of the bear family Ursidae, currently inhabits North America, Europe, Asia and South America. The family Ursidae is a young family evolved from early canids during the Oligocene and early Miocene period about 20-25 million years ago. The family has frequently been divided into subfamilies. Although 2 major contributors to bear taxonomy, Simpson (1945) and Erdbrink (1953), did not favor subfamily divisions as suggested by Kragavlich (1926), most systematicians divide the bear family into three (Kragavlich 1926; Kurten 1966) or four (Pilgrim 1932; Thenius 1959) subfamilies without including Ailuropodidae, the subfamily that includes the giant panda. These authors generally disagree over the inclusion of the family Hemicyoninae, or dog-like- bear (or bear-like-dog), with either the canids or ursids. After including the giant panda in a bear family Ursidae is further divided into 5 subfamilies: (1) Hemicyoninae, (2) Agriotheriinae, (3) Tremarctinae, (4) Ursinae and (5) Ailuropodidae. The family Ursidae is placed in order carnivore but, except for the large carnivorous polar bear all bears are omnivorous feeding mostly on plant materials, insects, fish and mammals. All bears are plantigrade, walking on their foot. The subfamily Ursinae has been divided into many different phylogenetic groups in the past. The modern bears comprise eight species from three families: Ailuropodinae (Giant panda), Tremarctinae (Spectacle bear) and Ursinae. Until recently, three genera, *Melursus* (Sloth bear), *Helarctos* (Sun bear), *Ursus* (Brown bear, Polar bear, Asiatic black bear and American black bear) were recognized. The evolution of Ursinae over the past 5 million years is well recorded in fossila of Europe. Early Ursinae likely evolved from *Ursavus* of the Miocene. The earliest member of the family is belived to be *Ursus minimus* which has been found in many locations in Europe (Kurten 1968). *Ursus thibetanus* radiated from *U. minimus* in early-Pleistocene and ranged into Asia and Europe during in the mid-Pleistocene with remains being found in many countries later on it was extirpated from Europe because of unknown reason. Currently *Ursus thibetanus* distribution is restricted to Asia only (Figure 1.1).

1.7. Ecology and behavior

Asiatic black bear is a forested animal inhabit in areas with dense canopy cover with limited human disturbance. Black bear is typically nocturnal, although occasionally it is active during day time. It under go hibernation during the winter in many areas throughout the distribution ranges (Schaller et al. 1989; Nowak 1991; Reid et al. 1991; Izumiyama et al. 2001). In north-western Himalaya, it undergoes hibernation during winter months (Prater 1971; Sathyakumar et al. 2012 unpublished) whereas, in eastern Himalayas, black bear tend to be active year-round (Roberts 1977). Black bear spends the hibernation period in dens, hollow tree, caves and holes dug into the ground (Sharma et al. 2011). In north-western Himalayas it may remain in their dens for 3 to 5 months (Prater 1971; Sharma et al. 2011). Adult females with young start dening first, then other females, lastly males. After the hibernation in spring, males emerge first, then females (without cubs) followed by females with cubs emerges in the last (Johnsingh 2003; Sharma et al. 2011). In the mountain ranges of Taiwan, bear's were fitted with motion-sensitive device along with radio-collar showed that bear's in Taiwan did not hibernated throughout the year (Hwang and Garshelis 2007).

As like the American black bear , Asiatic black bear breed during the summer months, usually in late June or early July and cubs are born between late December and early February, while the female is still denning (Craighead et al. 1969; Hellgren 1988; Garshelis and Hellgren 1994; Yamamoto et al. 1998). Black bears are omnivorous in their food habits, feeds largely on fruits and to some extent on leaf material, grasses, insects and other animal matter (Shaller 1969, Manjraker 1989; Hashimoto 2002, 2003; Hwang et al. 2002; Huygens et al. 2003; Sathyakumar and Viswanath 2003; Izumiyama and Shiaishi 2004; Koike 2010). The movement and ranging of the black bear is largely dependent on the quality, quantity and distribution of food which in turn is influenced by topography and climate (Reid et al. 1991; Mizoguchi et al. 1996; Oka et al. 2004; Hwang et al. 2010; Sharma et al. 2011; Nakajima et al. 2012). In Taiwan, the 100% MCP (Minimum Convex Polygon) home range sixe ranges from 24.2-70.8 km^2 for males and it was 117 km^2 for the female (Hwang et al. 2010). The home range of Asiatic black bear in Japan has been reported to be between 3 and 28 km^2, with an average size of 12.5 km^2 and a density of 0.16/km^2 (Hazumi and Maruyama 1986). Reid et al. (1991) also estimated low densities (0.1-1.3 bears/ km^2) in China. Habitat use by black bears in North America is influenced by phenological status of fruit species in the area and resulting in great variation in home range sizes (Jonkel and Cowan 1971). The ability of black bear to climb trees for feeding and use food resources efficiently, makes it to survive in relatively small home range provided one or other food species is available in the area at all times of the year. In Kashmir, during shortage of food in natural habitat black bear becomes bolder and travel more widely in search of food towards crop lands consequently leading to more frequent human encounters (Charoo et al. 2011). Warner (1987) also stated that bears that associated people with food showed levels of boldness that could lead to undesirable incidents.

Asiatic black bears occupy wide range of habitats including lowland tropical rain forest, coniferous and deciduous forests, grasslands, desert prairie and coastal rainforest. The adaptability and the plasticity in the behavior of black bear allowed adapting to a variety of habitat types. Asiatic black bear is a forested animal with relatively broad habitat preference. However, studies on habitat use showed that black bear can accommodate substantial human activity and some habitat alteration (Izumiyama and Shiraishi 2004; Hwang et al. 2010).

1.8. Rationale

Although the Asiatic black bear is continuously distributed in the forested habitats of the Himalayas and hills of north east India, scientific information on the ecology of this species is lacking. The black bear is seriously threatened throughout its distribution range due to poaching for bear parts and retaliatory killings to reduce black bear – human conflict (Servheen et al. 1999). As a consequence of these threats, black bear populations are declining in many areas. Increasing black bear – human interactions in many parts of its range poses serious management problems. For better management and to mitigation of bear-human interactions, it is necessary to generate scientific information on different ecological aspects of Asiatic black bear (Charoo et al. 2011).

The present study seeks to address the issues related to movement patterns of black bear in relation to food availability in Dachigam landscape and to understand the food and feeding habits of black bear in different seasons. Scientific information on the home ranges, movement behavior, and hibernation period of black bear will help the management in conservation action planning in the landscape. The food habit study of black bear will help in understanding the reasons for crop depredation by black bear despite high food abundance in summer within the bear habitats of Dachigam NP. In addition to the ablove, ecological questions such as diest requirements, habitat use (in different scales) and behavior are of high value in planning management for this species and in reducing Asiatic black bear-human interactions.

1.9. Aims and objectives

The present study was conducted to generate ecological information on some aspects of black bear ecology for the long term conservation and management planning in Dachigam landscape with the following objective: -

1. To charaterisze Asiatic black bear habiat in Dachigam NP.
2. To determine home range, movement and ranging patterns of Asiatic black bear in Dachigam National Park in different seasons.
3. To determine food availability and feeding habits of Asiatic black bear in Dachigam National Park in different seasons.

Plate 1.1. Asiatic black bear picture in Oak Plantation of Dachigam National Park, Jammu and Kashmir.

Plate 1.1. Asiatic black bear picture in Oak Plantation of Dachigam National Park, Jammu and Kashmir.

CHAPTER -2: THE STUDY AREA

2.1. Introduction

The present study was conducted in Dachigam landscape falling in Kashmir region of North Western Himalayas, in the state of Jammu and Kashmir, India. The Dachigam Landscape comprising of two National Park, two Wildlife Sanctuaries and eight Conservation Reserves. The Dachigam NP was selected as the intensive study area for conducting the ecological monitoring of food and feeding habits of Asiatic black bear.

The total geographic area of Dachigam NP is141 km^2. Dachigam NP is divided into two administrative units: Lower Dachigam and Upper Dachigam (Figure 2.1). The natural vegetation and the topology can also separate Dachigam into two parts as lower Dachigam is dominated by broadleaf and conifer mixed forest and it falls in the elevation gradients of 1600-4100m whereas, in Upper Dachigam the vegetation is dominated by Birch Rhododendron forest along with sub-alpine and alpine grasslands prairie.

2.2. Location

Dachigam NP lies between 34º 05'N - 34º 11'N and 74 º 54'E -75 º 09'E in the 2A Bio-geographic zone of North Western Himalayas in the State of Jammu and Kashmir (J&K) (Rodgers et al. 2000). The area of this NP comes under the civil jurisdictions of Srinagar, Anantnag and Pulwama districts of Kashmir region, J&K. Dachigam NP is located in Zabarwan mountain range of Great Himalayas, 21 km north-east to Srinagar, the summer capital of Jammu and Kashmir State (Figure 2.1).

2.3. Conservation History of Dachigam NP

The name of Dachigam NP, *Dachigam* reveals its history. '*Dachigam'* is a combination of three Kashmiri words, '*Da'* meaning 10 (ten), '*chi'* – 'are' and *gam* – 'villages'. There were 10 villagers located in the present Dachigam NP area which were translocated by the Maharaja Hari Singh (King) ruler of Kashmir State. *Dachigam* remained a game reserve (locally called '*rakh*') of the Maharaja and his guests, from 1910 up to 1947. After this, its management was handed over to the Department of Hospitality and Protocol (Fisheries Department, Directorate of game preservation, Government of Jammu and Kashmir) and subsequently to the Forest

Department of the State. It was managed under the Wildlife wing of Forest Department and later Dachigam was declared a Wildlife Sanctuary by the State of Jammu and Kashmir, in 1951 (Holloway and Wani 1970; Holloway 1971). Dachigam Wildlife Sanctuary was upgraded to a National Park in 1981 by the government of Jammu and Kashmir and handed over to the Department of Wildlife protection, Jammu and Kashmir in 1982. Today, Dachigam NP is managed as per the IUCN category-II standards by the Department of Wildlife Protection.

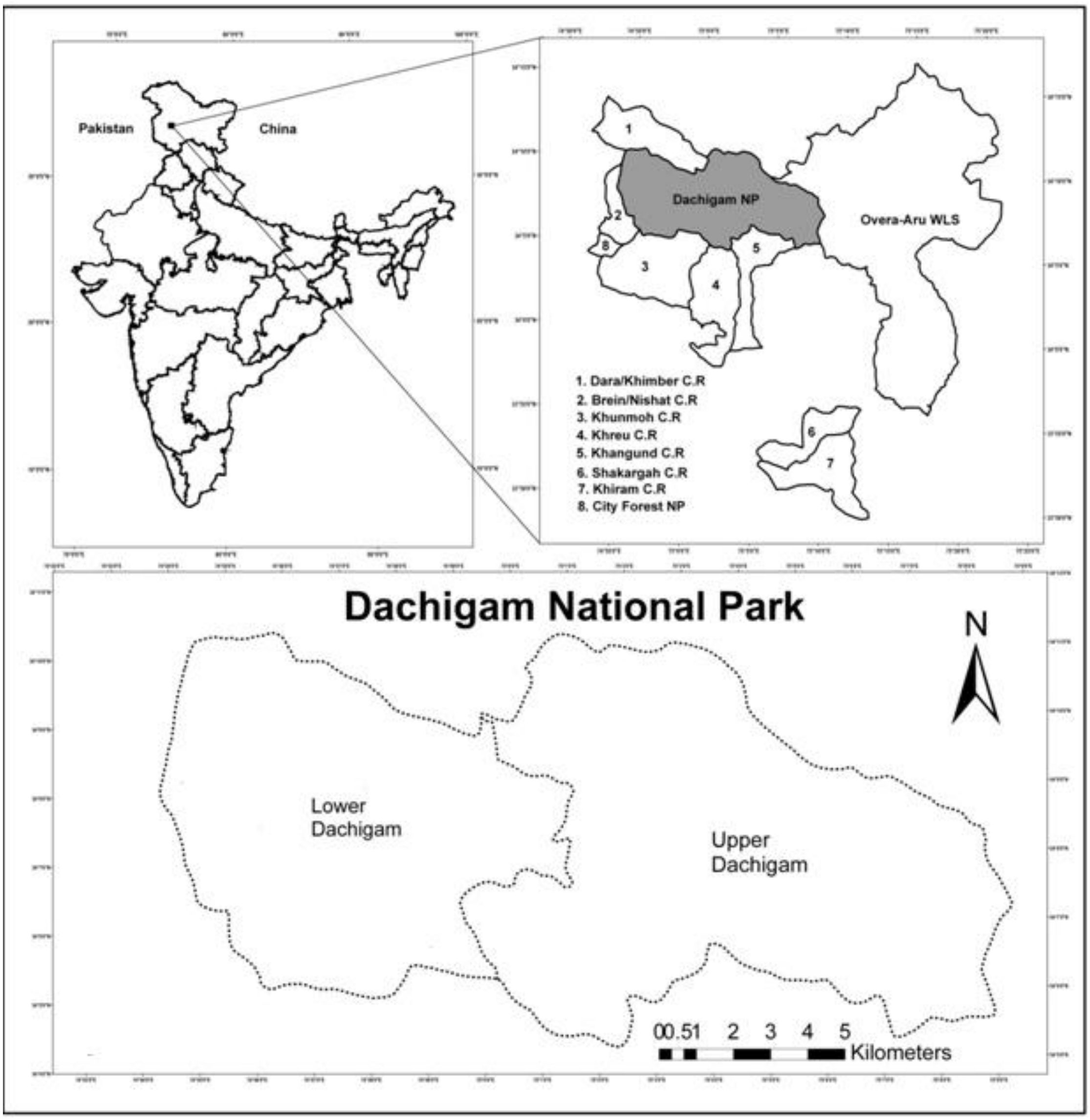


Figure 2.1. Map showing Dachigam landscape and Dachigam National Park.

2.4. Legal Boundaries, management practices and biotic interference

Dachigam NP came in existence by the government notification no. FST/ 2A dated 4 Feb 1981 which describes the boundaries of Dachigam. The natural boundaries to the park are two steep mountain ridges, one originating from Harwan water reservoir on the south west side of the park and the other originating from Dara/ Khimber side with an elevation gradient of 2,600m to 3,000m. Dachigam is bounded by Sindh valley to the north- east, Tarsar, Lidderwath, Kolhai of Lidder Valley and Overa-Aru Wildlife Sanctuary in the Far East. Tral range in the south- east and Harwan, Brain and Nishat in the west and south- west (Kurt 1978).

The prime objective of declaring the area of Dachigam as a National Park was to provide protection to the state animal Kashmir Red deer (*Cervus elaphus hanglu*) and to conserve biodiversity of the area. Today in the landscape wild animal and plants are protected under the J&K state wildlife protection Act 1987 and the Indian wildlife protection Act 1972, hunting and other activities which are identified as threats to wildlife are not allowed in Dachigam NP. The management of Dachigam NP experiences various limitations which includes the movement and activities of the employees of the other government line departments in Lower Dachigam which include: Sheep breeding farm (Sheep Husbandry Department), Trout fish form (Department of Fisheries), Draphama Guest house (Department of Hospitality and Protocol), irrigation works (Department of water supplies), Flood control working Department and Power supply Department which at times create many officious troubles in achieving the main objective of wildlife protection inside the NP.

The area which is under the human interference starts from the gate up to Draphama VIP guest house, in Lower Dachigam. In Upper Dachigam it is the grazing pressures due to migratory grazer (Naqash and Sharma 2011). The catchment of Dachigam NP requires scientific management as it is important for the maintenance of continuous water supply in Dal Lake.

2.5. Geology

The entire area of Dachigam NP is mountainous and has crystalline rocks such as granite, phyllites and schists with embedded lime stone characteristic of the core of the Zanskar range, a fold of which encloses Dachigam NP. The region from Khanmoh to Mahadeo consists of calcareous slates, shale and blue limestone (Singh and

Kachroo 1978). Most of the sediments composing these ranges have been laid from Cambrian to tertiary (Wadia 1939). The crystalline axis of the Himalayan system contains the oldest rocks and in the northern flank of these, crystalline axes are found fossiliferous sediments of marine origin (Lydekker 1876, Middlemiss 1911).The soil depth in Dachigam on the slope from lower to middle reaches is less than 25 cm and hence falls under the category of very shallow soils (Bhat 1985).

2.6. Terrain

Dachigam NP possesses Great Himalayan feature with steep mountains separated with deep gorges and valleys. The altitudinal gradients vary from1600 to 5,000 m (Figure 2.3). The series of undulations present a variety of aspects (Figure 2.4) and slope (Figure 2.5) categories are supporting an array of vegetation types. The overall terrain in Dachigam is steep and rugged on slopes and flat in the valley along the main river/ Dachigam nallah.

2.7. Climate

The Kashmir valley experiences four distinct seasons: winter (December-February), spring (March-May), summer (June-August), and autumn (September-November). The climate in Dachigam NP is sub-Mediterranean type with bixeric regime having two spells of dryness of April-June and September-November (Singh and Kachroo 1978). Dachigam NP has a temperate climate with cool summer and chilling winter. The temperature recorded in summer shows a maximum and minimum mean temperature of 27.3 and 2.0ºC (Figure 2.2).

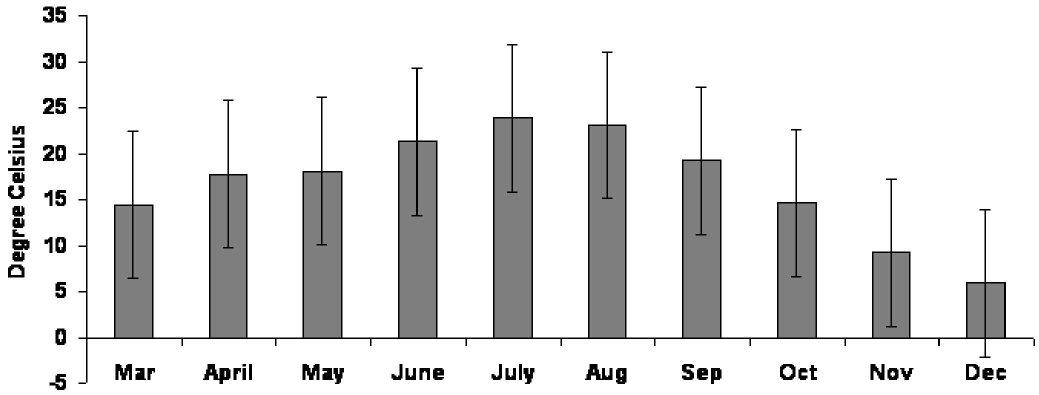


Figure 2.2. Average Temperature (^oC) recorded at Dachigam National Park, Kashmir, during 2010.

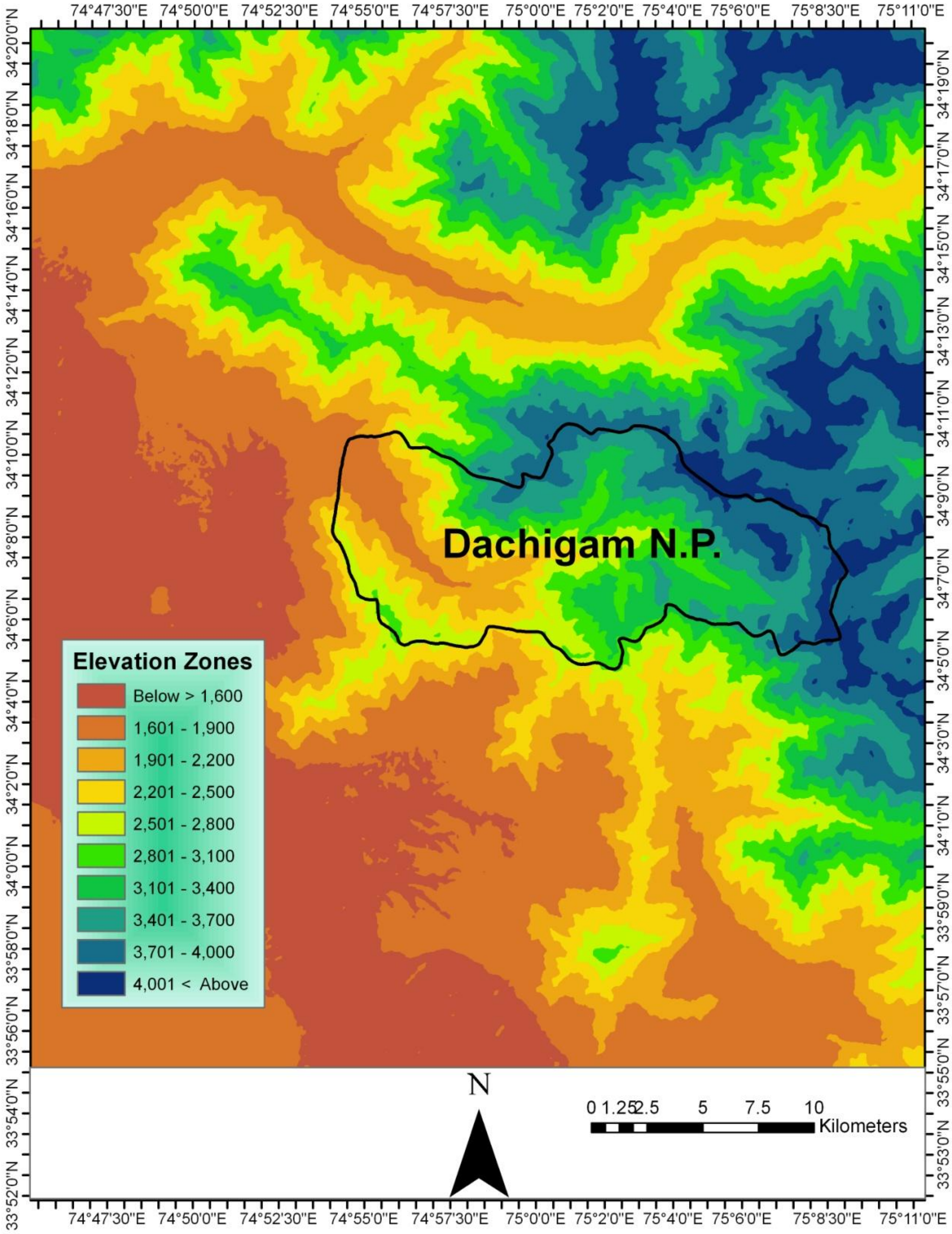


Figure 2.3. Map showing various altitudinal categories of Dachigam National Park and the surrounding areas.

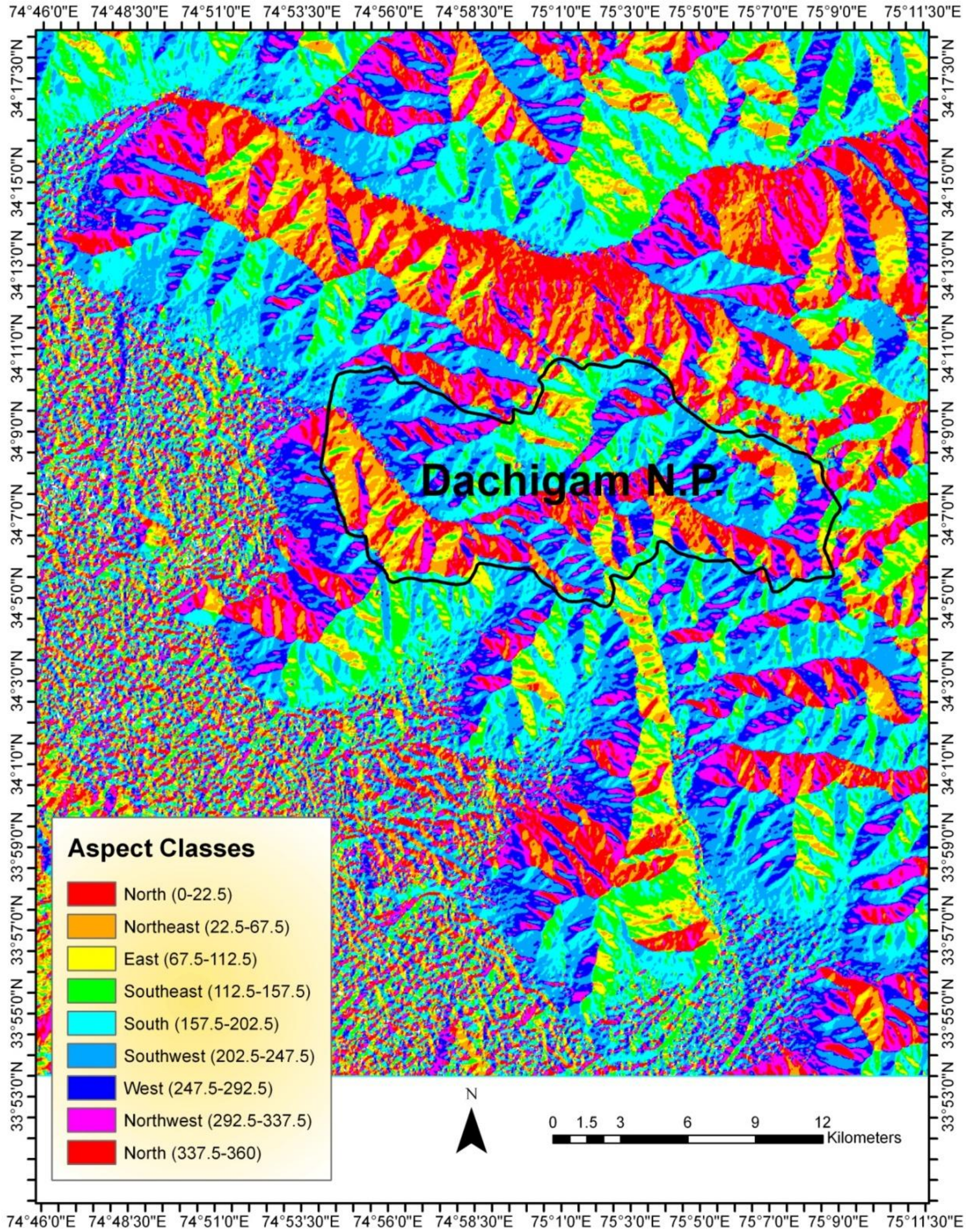


Figure 2.4. Map showing various aspect categories in Dachigam National Park and the surrounding areas.

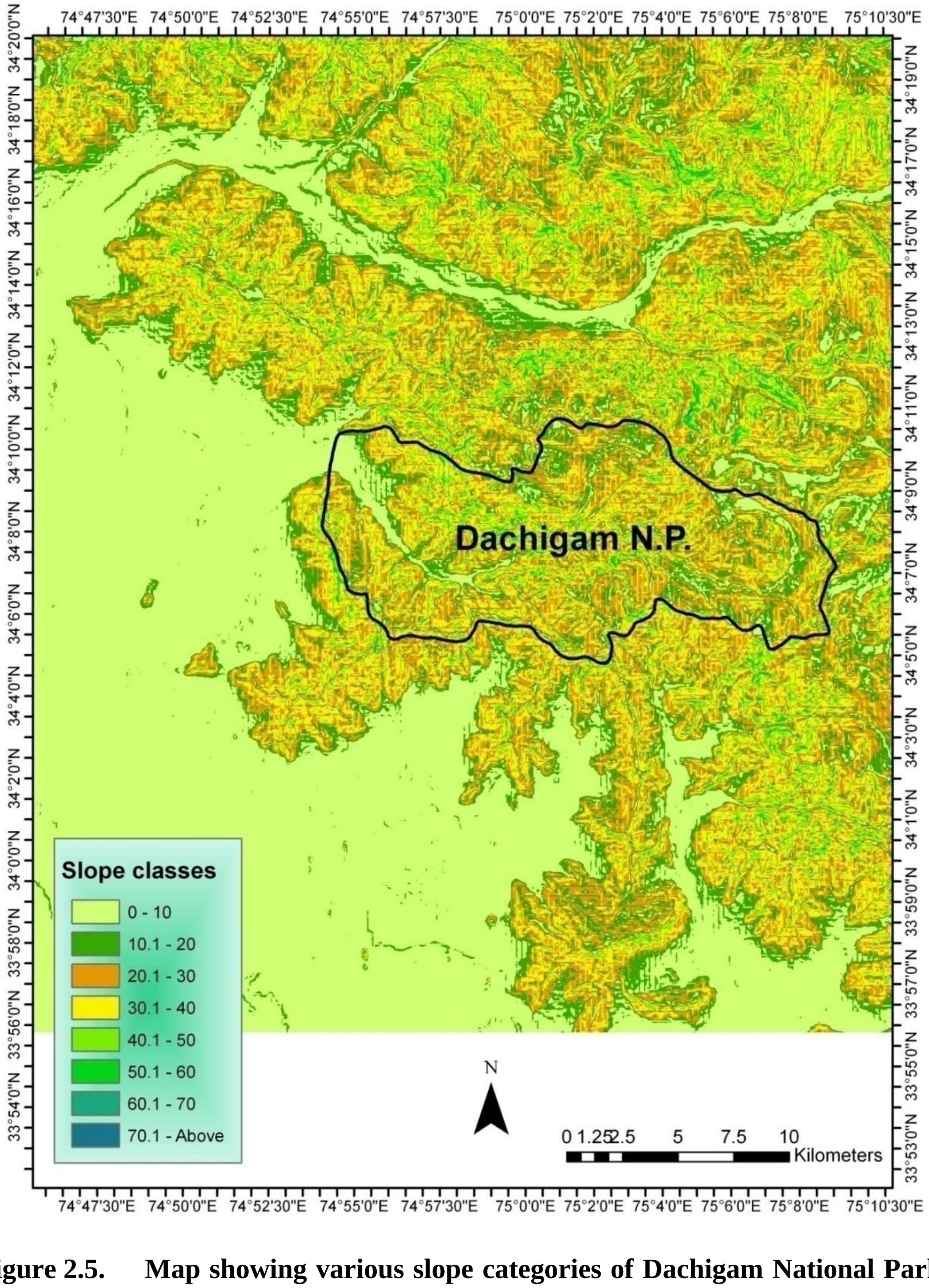


Figure 2.5. Map showing various slope categories of Dachigam National Park and the surrounding areas.

The area observes irregular weather conditions with a considerable variation in the amount of precipitation. Snow is the main source of precipitation and in some parts melts till June. The annual minimum and maximum rainfall of Dachigam NP ranges between 32 mm to 546 mm (Bhat 1985) (Figure 2.6).

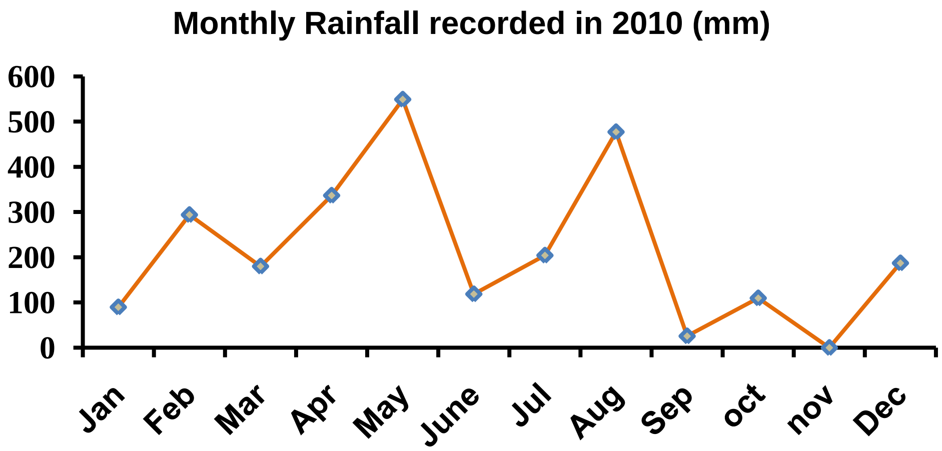


Figure 2.6. Monthly rainfall recorded in Dachigam landscape for year 2010.

The relative humidity is generally low in most part of the year. The maximum humidity is recorded during October. The mean month wise humidity recorded in the area is shown in Figure 2.7.

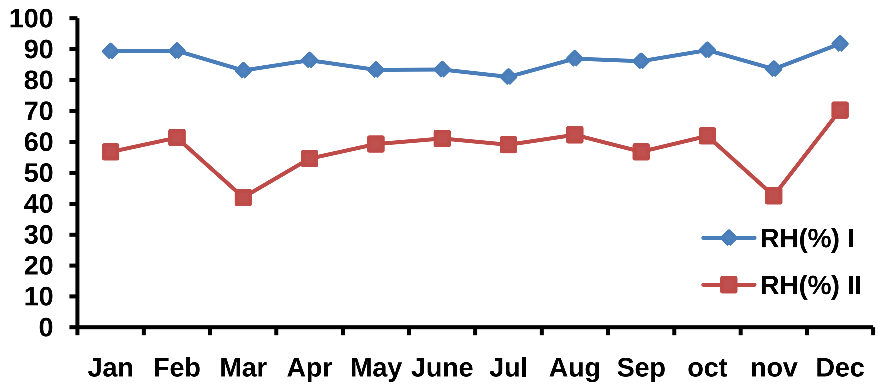


Figure 2.7. Monthly humidity recorded in Dachigam landscape during year 2010.

2.6. Water Sources

Dachigam NP has numerous perennial streams (locally called '*nallahs'*), springs, glaciers, and the main stream, *Dachigam nallah. The main nullah* receives water from a high altitude lake '*Marsar Lake'* located in Upper Dachigam which supplies water in the area throughout the year. Dachigam nallah is the main source for catchment of *Dal Lake* and the Srinagar city (Figure 2.8).

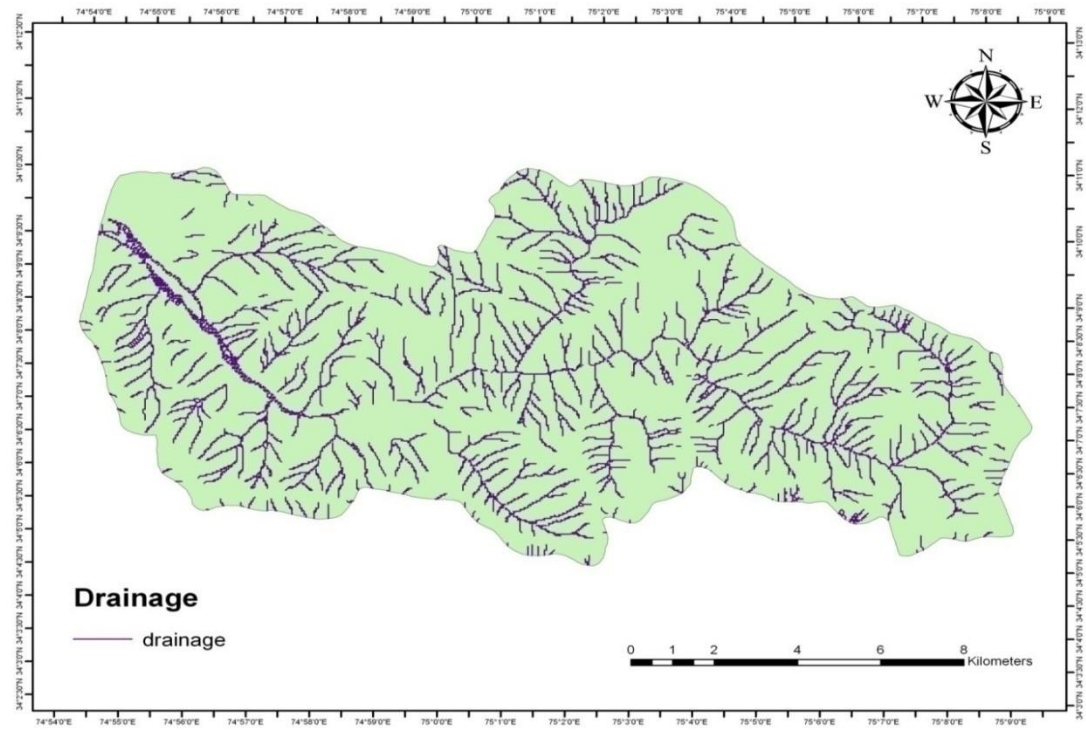


Figure 2.8. **Map showing drainage in Dachigam National Park**

2.8. Vegetation

As per revised Champion and Seth (1968) the vegetation of Dachigam NP is typically Himalayan moist temperate forest: subalpine forest and alpine forest type and can be classified into following forest types:

1. Moist temperate deciduous forest.
2. Parrotia (pohu) scrub forest
3. West Himalayan low level blue pine forest
4. Western mixed coniferous forest
5. Deciduous alpine scrub
6. West Himalayan sub-alpine birch-rhododendron forest
7. Dwarf juniper scrub
8. Dry temperate scrub

A detailed study on vegetation structure in lower Dachigam was carried out by Singh and Kachroo (1978). The vegetation of the valley is very patchy. The tree species such as *Ulmus wallichiana, Salix alba* and *Populus cilia* are found along the streams. *Prunus armeniaca* is found in open scrub areas, *Quercus robur* and *Robina pseudoacacia* in distinct pure patches which show evidence of having been planted on abandoned agricultural fields. Shrubs species are quite evenly distributed throughout the valley. Common shrub species in the lower parts of Dachigam NP are four species of *Prunus*, two species each of *Rubus*, *Berberis*, *Vibernum*, *Rosa*, *Indigofera* and *Parrotiopsis* (Ahmad 2006; Charoo et al. 2009). The vegetation on the southern aspects is characterized by grassy slopes with *Prunus armenica*, *Rosa webbiana* and *Rubus niveus*. The *nullahs* (streams) have reasonable tree cover, including species such as *Aesculus indica* and *Juglans regia*. The northern aspects have more tree and shrubs cover with species such as *Pinus griffithi, Aesculus indica, Prunus armenica* and *Parrotiopsis jacquemontiana* (Ahmad 2006).

2.9. Fauna

The faunal diversity of Dachigam NP includes mammals, birds, herpeto fauna, fishes and invertebrates. The animal diversity includes Hangul or Kashmir red deer, Asiatic black bear, Brown bear, Common leopard (*Panthera pardus*), Serow (*Capricornis thar*), Kashmir grey Langur (*Semnopithecus ajax*), Musk deer (*Moschus cupreus*), Rhesus Macaque (*Macaca mulatta*), Himalayan yellow throated martin (*Martes flavigula*), Himalayan Weasel (*Mustela* sp.), Red fox (*Vulpes vulpes*), Jackal (*Canis aureus*), Jungle cat (*Felis chaus*), Leopard cat (*Prionailurus bengalensis*), Small Indian Civet (*Viverricula indica*) and Indian Porcupine (*Hystrix indica*). Serow was reported after 20 years in Dachigam NP during the camera trapping carried out in the present study. The first record of Small Indian civet was reported from Dachigam NP in Kashmir valley of Jammu and Kashmir State was made during this study Charoo et al. (2010).

The forested habitats of Dachigam NP support high diversity of avifauna with the number of species about 150. The species include Himalayan Monal, Kokklas, Cinnamon Sparrows, Black Bulbuls, Woodpeckers, Minivets, Pygmy Owlets, Babblers, Black-and-Yellow Grosbeaks, Himalayan Griffons, Redstarts, Bearded Vultures, Red-billed Blue Magpies Choughs, Orange Bullfinch, Tits, Golden Orioles, Kashmir Flycatcher, Tytler's Leaf Warbler, Wagtails, Koklass Pheasants, Himalayan Rubythroats, Wallcreepers, and Streaked Laughing thrushs (Sharma et al. Unpublished; Naquash and Sharma 2011).

2.10. Dachigam NP and surrounding landscape

Dachigam NP is surrounded by many protected areas includes: Over-Aru Wildlife Sanctuary (WS), Thajwas WS and 10 Conservation Reserves (CR) viz., Brian-Nishat, Dara, Khonmoh, Khrew, Khiram, Shikargah, Wangat, Khangund, Panyer, Hajin, City Forest National Park some parts of Sindh Forest Division together which forms a Greater Dachigam Landscape. Administratively, these areas of Greater Dachigam Landscape fall under the Central and South Wildlife Divisions of Kashmir. There are about 40 revenue villages are also located in the surrounding areas of the Landscape.

The livelihood of the locals is dependent on agriculture, orchards, animal husbandry, poultry and dairy activities. Prior to declaration of national park, local used to be extract various NTFP form the forest and dependent on the natural resources of the area for livestock grazing, fire wood collection. The villagers within the vicinity of the park face problems such as crop depredation and loss of livestock by wild animals largely by Asiatic black bear and Common leopard. The main communities in these villages are *Kashmiris*, and *Gujars*. The *Gujar* community is the only tribal community in the area. Agriculture, horticulture is their principal activity and they rear livestock such as cows, goats, and sheep to supplement their economy. Socio-economic condition of the *Gujar* community is poor. This community is also involved in fire wood collection and herbs collection from the reserved forests.

2.11. Significance of the study area

The significance of Dachigam NP can be enumerated in several ways. The national park provides natural habitat for a number of threatened and endangered species. Dachigam NP is known world over for holding the viable population of red deer subspecies ‘Hangul’ in India. It possesses one of the best populations of Asiatic black bear in Asia (Sathyakumar 2001). Dachigam NP is one single compact catchment area in central Kashmir which has a highly unique and diverse type of fauna and flora. Dachigam NP occupies almost half of the catchment zone of the famous Dal Lake and is the main source of water for the Srinagar city.

Dachigam landscape was selected to conduct the present study with the rationale that it supports fairly good population of Asiatic black beak and today bear-human conflict management is a challenging task in the landscape (Charoo et al.

2011). The present study was designed to address the issues related to spatial ecology of black bear where the space use patterns of black bear was studied to answer the questions related to the factors governing the black bear ranging patterns on seasonal as well as annual basis.

2.12. Earlier studies in Dachigam National Park

Earlier to the present study there have been a few studies carried out in Dachigam NP and mostly focused on Hangul ecology. Gee (1965), Schaller (1969), Holloway (1970), Kurt (1978), Ahmad (2006), Charoo et al. (2010), Sharma et al. (2010), studied various aspects of Hangul ecology. Bhat (1985) studied vegetation composition of upper Dachigam. A short term study by Saberwal (1989) and Manjeraker (1989) to study the black bear distribution, abundance and food habits. Katti (1989) studied the bird community structure in Dachigam NP. Iqbal et al. (2004) analyzed prey predator relationship with reference to Hangul and Leopard. Before the present study no long term study was carried out in Dachigam on any species and management aspect. The Wildlife Institute of India initiated a long term project in Dachigam where during 2007-2011 to study the ecology of Asiatic black bear.

2.13. Management of Dachigam National Park

Dachigam NP is managed by wildlife protection department Jammu and Kashmir. In Kashmir region the wildlife department is divided into three wildlife divisions includes: North, Central and South Wildlife divisions. The area of Dachigam NP spread over two wildlife divisions central and south. The lower Dachigam falls under the jurisdiction of wildlife warden central whereas, the upper part is managed by wildlife warden south. There are two ranges in Dachigam one is Dachigam range and the upper Dachigam range. These ranges were further divided into block and beats.

2.14. Park-people interaface

There were no villages inside the boundary of Dachigam NP and the existing settilements were belonging to various government line departments. However, the NP is surrounded by 32 number of villages along with there cropland and orchards. Most of these villages were located in the surrounding areas of lower part of Dachigam since the upper Dachigam is in contiguity to Overa-Aru wildlife sanctuary.

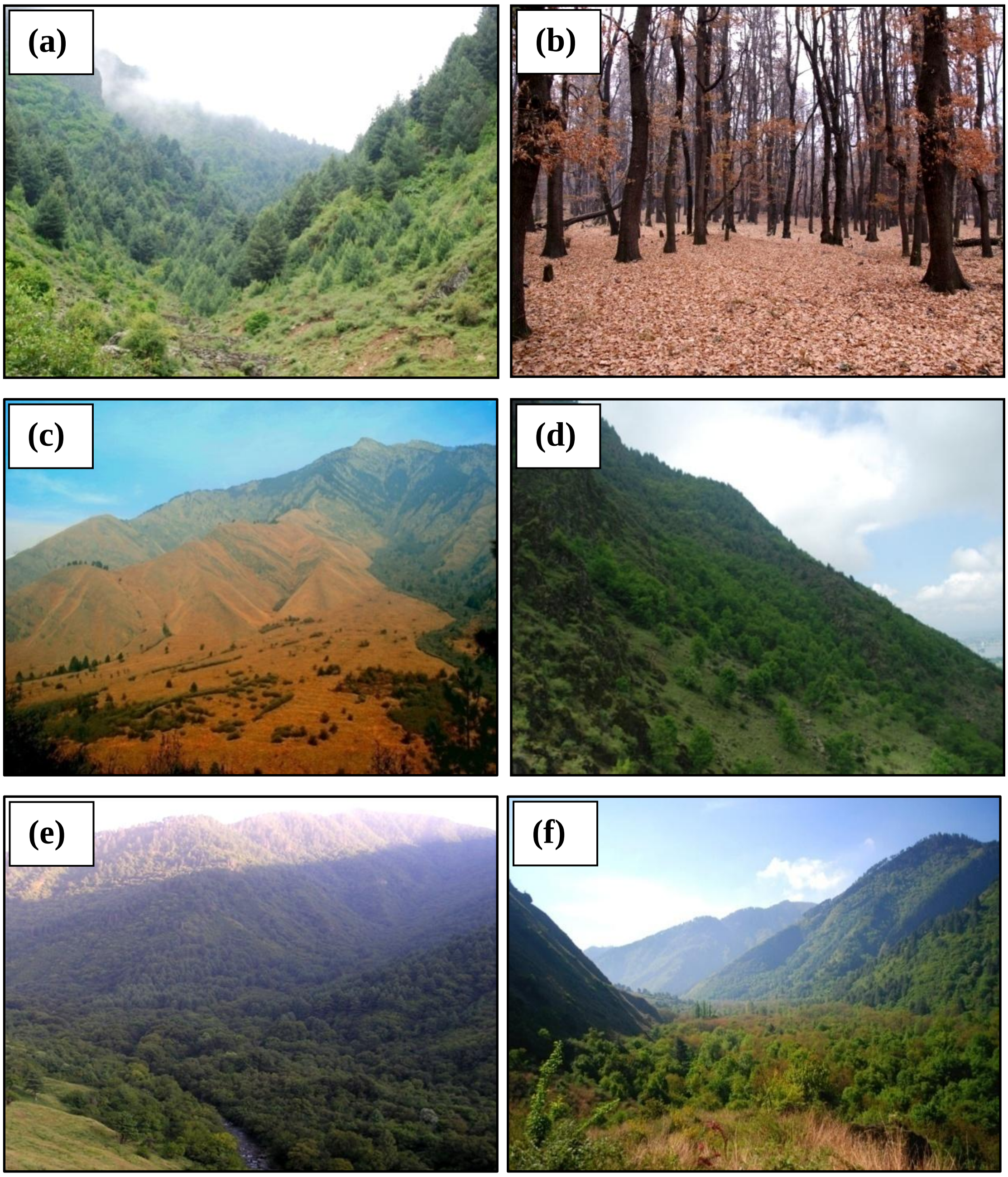


Plate 2.1. Pictures showing different habitat types of black bear: (a) Pine forest, (b) Oak plantation, (c) Temperate grassland and scrub land, (d) Mid-temperate forest, (e) Riverine forest, (f) Low temperate pine mixed forest in Dachigam National Park.

CHAPTER – 3: GENERAL METHODOLOGY

3.1. Introduction

The present study was carried out in Dachigam NP and surrounding areas from May 2007 to Dec 2011. In the beginning of the study, attempts were made to survey entire Asiatic black bear habitat in Dachigam NP. Lower Dachigam area was selected as intensive study areas to conduct field work, since lower Dachigam represent the majority of black bear habitats of Dachigam NP. The black bear habitat falling in Upper Dachigam was not assessed because of security reasons and this is the area where regular army operations were carried out. The area of the intensive study area comprises of lower Dachigam and some part of Upper Dachigam which is about 90 km^2.

The reconnaissance survey was carriedout in the intensive stusy area for identification for survey lines and sites for bear sign surveys and vegetation sampling respectively. To understand the food and feeding habits of black bear, systematic study was carriedout in lower Dachigam NP and for movement and ranging pattern analysis black bears were radio collared and tracked in Dachigam landscape (1000km^2 ca).

3.2. Vegetation characterization and habitat mapping in Dachigam National Park

The vegetation sampling was carried out for habitat characterization inside Dachigam NP. In total 13 line-transects along with 121 vegetation sampling plots covering all habitat types of the study area were marked (Figure 3.1). Of therm98 vegetation plots were marked along transects at an interval of 250m. In addition to these, 23 plots were marked along both the side of the main Dachigam *nallah* at every 500 m. At every vegetation sampling plot, tree species were quantified in circular plots of 10m radius and shrubs species in 5m circular plots. Data on diameter at breast height of trees (>25cm dbh), canopy cover, ground cover and tree height was recorded. For ground cover estimation, data on percentage of litter cover (fallen leaves etc.), bare ground, and herb/grass cover, rock cover, was quantified using four 1×1 m quadrates (Figure 3.2).

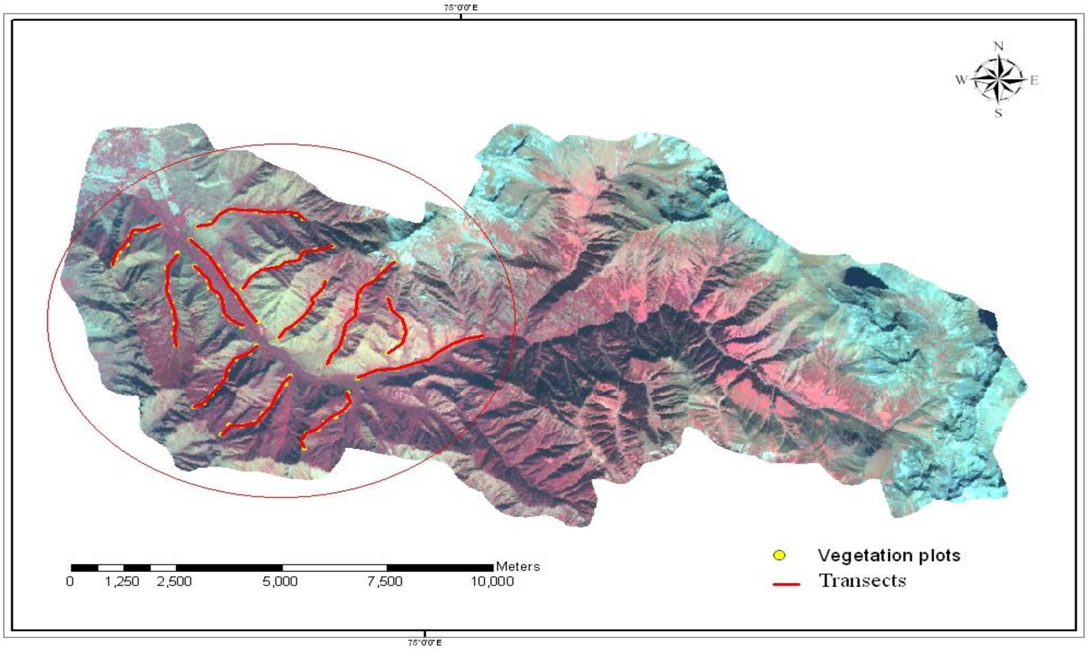


Figure 3.1. Map showing transects and vegetation sampling plots in Dachigam National Park

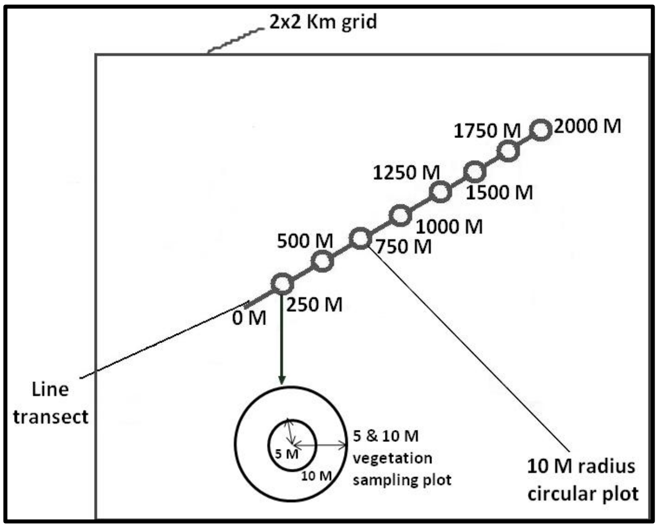


Figure 3.2. Picture showing line transect and vegetation sampling plot design used for the study

3.3. Phenological monitoring on food plant species

To understand the seasonal availability of food resources the phenological change on vegetative and reproductive parts of important food plant species (trees, shrubs, herbs) of black bear was recorded after every 15 days on permanent sampling plots (n=121). Based on the field observations, 14 important food plants (trees, shrubs) were selected for phenological and abundance quantification of vegetative and reproductive plant parts in all different habitats. Data on plant part production and basal area per hectare was recorded. The abundance of leaf buds, young leaves, mature leaves, flower bud, flowers, young fruits and mature fruits in relation to maximum crown volume was estimated (Dasilva 1994).

3.4. Fruit availability estimation

The fruit availability was estimated on important bear food plant species followed by Inman (1997) and the phenological changes in the availability of bear food items was assessed by following Rawal (1991) and Koch et al. 1995.

3.5. Food habit analysis

3.5.1. Direct feeding observation

During the study period, direct feeding observations were made opportunistically. Asiatic black bears were observed feeding on various food items. All of the feeding observations were carried out in day time staring from early morning to late in evening. The feeding observations were also made on the radio-collared bears during the study.

3.5.2. Feeding sign observation

Black bear feeding signs were observed during the systematic field work on transects, and vegetation sampling plots (Green et al. 1997). A feeding sign at one location (e.g., broken branches, fruiting bush, fallen fruits, fruiting tree, stone turning, digging, browsing sign on herbs and rake marks on trees) was considered as a single unit.

3.5.3. Post ingestion analysis (Scat analysis)

Asiatic black bear scats were collected systematically as well as opportunistically during the routine field work. The information on collected scat samples such as date, scat condition (fresh/old), habitat type, and GPS location were recorded. The scat samples were analyzed by following Graber and White (1983).

3.6. Energetic and nutritional analysis of important black bear fruit species

The total energy content of various food items was estimated by using Bomb calorimeter (Prus 1975) for understanding the importance of food item to the diet of black bear. Nutritional analysis of black bear food Item was done (Van soest et al. 1991) by collecting samples of food item.

3.7. Home range and movement pattern analysis

3.7.1. Radio telemetry based analysis

Asiatic black bears were trapped during 2009-2011 using Culvert traps (Johnson and Pelton 1980). The captured bears were chemically immobilized using Ketamine/Rompun (Ketamine hydrochloride + Xylazine hydrochloride). After sedating the bears, morphometric measurements, reproductive status, and overall condition of the animal were recorded

Black bears were radio-collared using TGW-4780H fourth generation store on board GPS subsystem which includes a GPS receiver, uGPSi controller/data logger and a VHF (Very high frequency) transmitter beacon with VHF and ARGOS frequency (151.00 – 151.10 MHz and 401.630 – 401.640 MHz) supplied by M/s TELONICS, USA. The data collected from ARGOS and the VHF tracking was used to generate home range and to understand the movement patterns of collared animals.

3.7.2. Non-invasive DNA based analysis for movement tracking of black bear

The intensive study area of about 90 Km^2 in lower Dachigam was divided into 23, 2x2 Km grids for homogenous sampling of the study area (Boulanger 1998; Boulanger et al. 2007; Mowat and Strobeck 2000). In each grid, a hair snare (made of barbed wire) was deployed along with a camera trap for the hair sample collection (Mowat and Strobeck 2000; Boulanger and McLellan 2001) and scats were collected systematically and opportunistically from the study area during regular field work. The hair samples were also collected from the conflict locations in the landscape to track the movements of bear in the landscape.

The genetic analysis was carried out by using a panel of 20-microsatellite loci primers for the amplification of isolated black bear DNA samples.

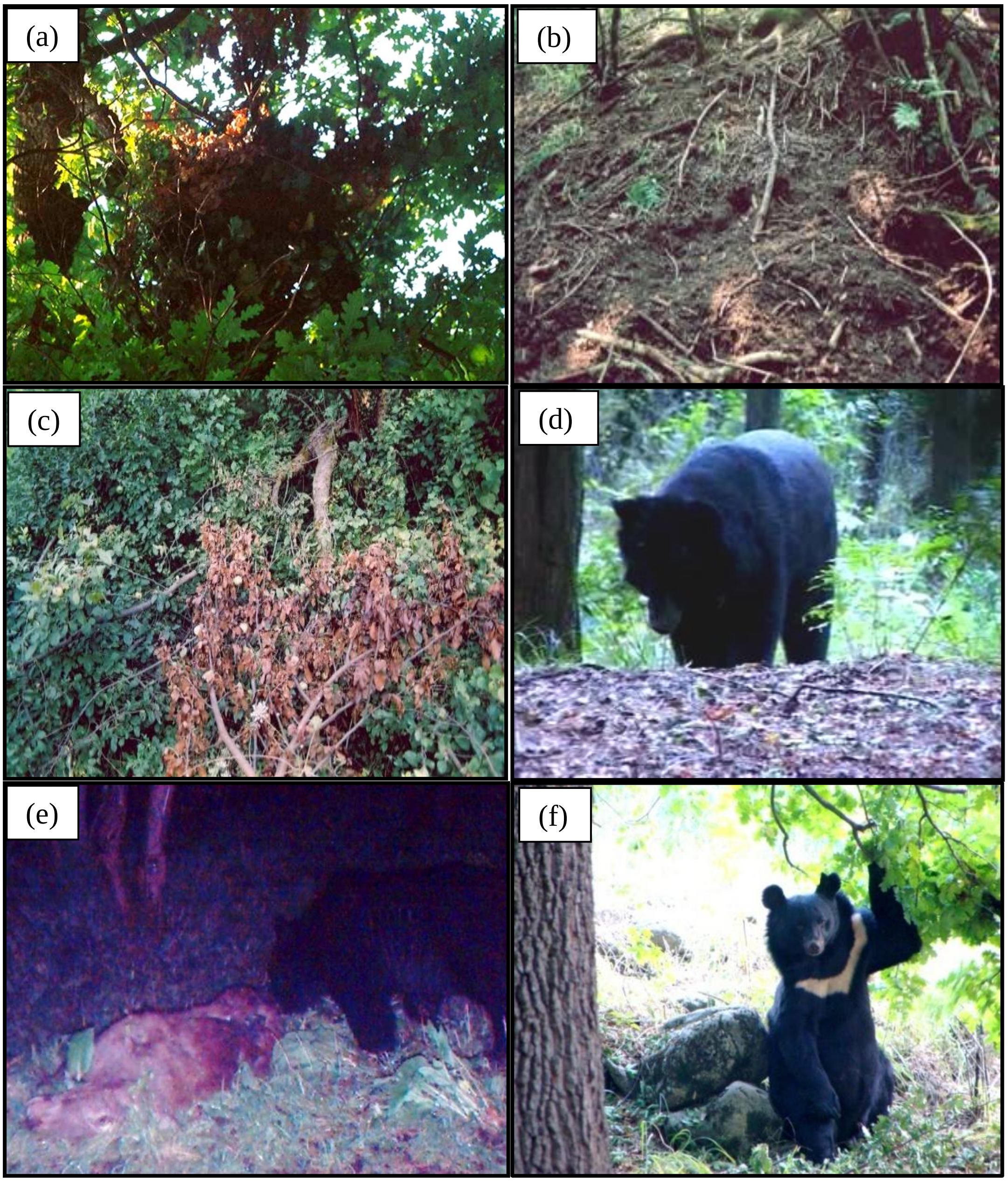


Plate 3.1. Pictures showing Asiatic black bear feeding and indirect feeding signs; (a) a black bear feeding nest on oak tree, (b) a digging for insects, (c) feeding signs on Apple tree, (d) black bear searching oak acorns on ground, (e) black bear scavenging on Hangul carcass, (f) captured while feeding on oak acorns on tree.

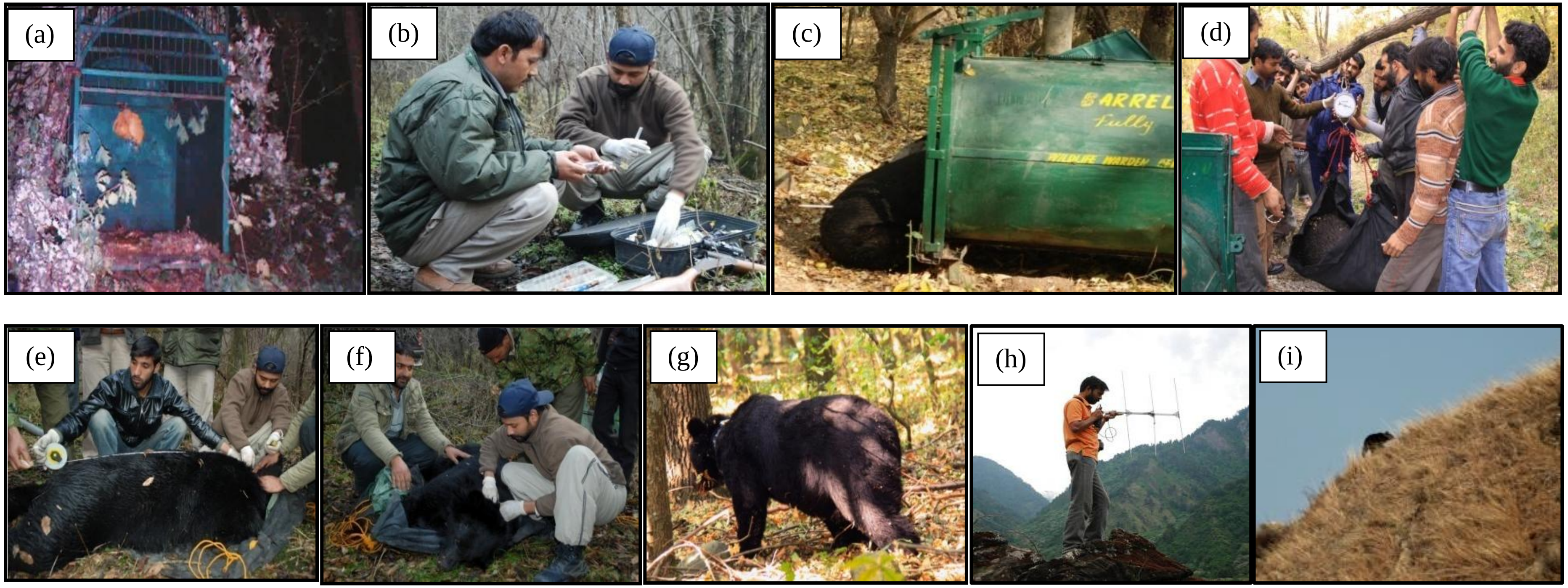


Plate 3.2. Picture showing radio collaring and tracking of black bear at Dachigam National Park: (a) trap used for capturing, (b) tranquilization drug preparation, (c) sedated black bear in trap, (d) measurement of body weight, (e) morphometric measurement recording, (f) radio collard fitted on black bear, (g) black bear released after collaring, (h) VHF tracking of collared animals, (i) radio collared black bear movement track

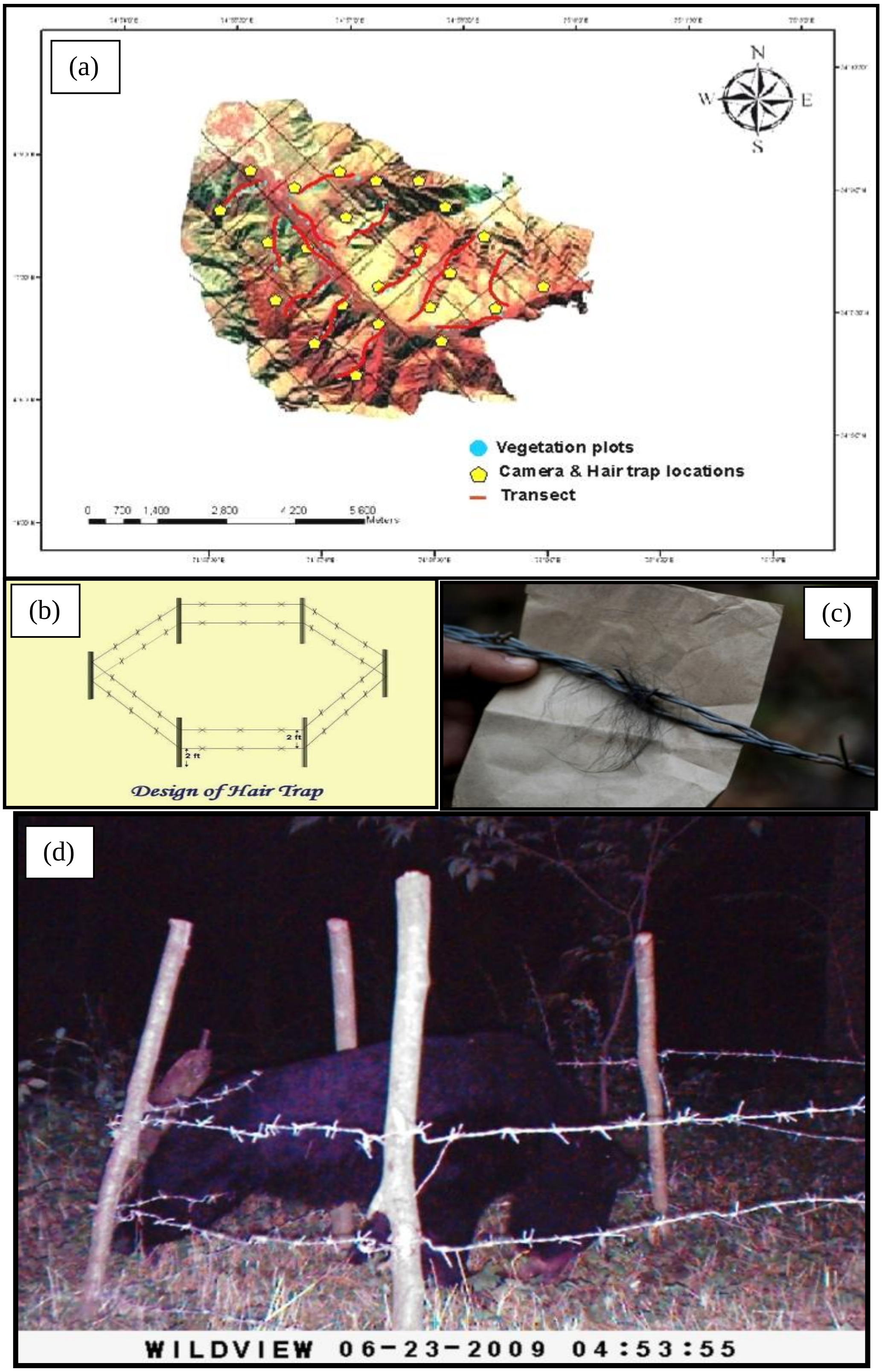


Plate 3.3. **(a) Grid map of intensice study area of Dachigam National Park showing locations of hair traps, (b) Design of hair trap, (c) tuft of hair sample collected from barded wire, and (d) photograph showing black bear inside hair trap station**

CHAPTER – 4: ASIATIC BLACK BEAR HABITAT CHARACTERIZATION AND MAPPING IN DACHIGAM LANDSCAPE

4.1. Introduction

The term habitat is defined as the place where an animal lives or, more specifically, the collection of resources and conditions necessary for its occupancy. It becomes imperative to evaluate the vegetation community structure of an area where the study species is living. In a habitat there can be many factors or site specific characters, which are necessary for the survival of a species. According to Barnes et al. (1998) habitat integrates the effect of many interacting factors, and key species which may indicate the site condition. Habitat is an umbrella comprises of biotic and abiotic factors where vegetation types are strongly controlled by macro and micro-climatic conditions. There are many studies where vegetation merits were studied and mapped (Roy et al. 1991; Nelson et al. 1999; Singh et al. 2002; Malik and Husain 2004). The commonest examples of the use of vegetation description are in the recognition and definition of different vegetation type and plant communities known as the phyto-sociology of an area for the mapping of vegetation communities and types. In a landscape forest structure, composition and the ecological processes changes over the last range of spatial and temporal scales since, they are dynamic (Andrew et al. 1997).

The spatial heterogeneity of the landscape influences the distribution, abundance and population dynamic of a species (Barnes et al. 1998). Information on vegetation types in such heterogeneous landscape can be helpful in solving ecological problem for the conservation as well as management of a species. Study on vegetation composition of an area can be useful tool for the environmental impact assessment and to monitor management practices and can provide basis for future changes (Kent and Coker 1992). As physical features are important for the habitat selection, the vegetation structures are critical for a species which provide food, cover and security of a habitat.

Vegetation patterns are an integrated reflections of the physical and chemical factors that shape the environment of a given land area (Whittaker 1965). They also are determinants for overall biological diversity patterns (Noss 1990; Franklin 1993), and they can be used as a currency for habitat types in conservation assessment of the landscape (Specht 1975; Austin 1991). As such, dominant vegetation types need to be recognized over their entire ranges of distribution (Bourgeron et al. 1994) for beta scale analysis (Whittaker 1960; 1977). These patterns cannot be acceptably mapped from any single source of remotely sensed imagery (Stenback and Congalton 1990; Turner and Gardner 1991; San Miguel-Ayanz and Biging 1997; Hill 1999). Here in the present study it was attempted to map these patterns at a 1:50,000 scale using combinations of remotely sensed data (satellite imagery) along with field data. The physiognomic or structure is a visibly outstanding feature of vegetation. For example, in a typical forest ecosystem, we can use the component strata as a general structural definition. These strata consist of tree layer, shrub layer and the ground layer or the ground stratum. The central concept is the physiognomic and floristic characteristics of vegetation (in the absence of vegetation other physical structures.) across the land surface can be used to define biologically meaningful biogeographic patterns in a landscape.

Ecologists use a variety of terms to describe the spatial pattern of habitat, such as *patch, connected, fragmented, edge,* and *edge effects.* For the purposes of this exercise, habitat refers to sites having appropriate levels of the biotic (e.g., prey items, food species, mutualists) and abiotic (e.g., moisture, temperature, light, nutrients) features required for the survival of a species (McGargial and Marks 1995). In raster land cover maps, patches are usually identified as clusters of contiguous map cells of the same cover type. When the habitat exists in the landscape as a few large patches, the habitat is said to be highly connected. Habitat is considered to be fragmented when the habitat occurs in a large number of small patches. Land cover change that results in habitat loss often causes habitat fragmentation by breaking up the few large patches into an increased number of small patches.

The boundary between two habitat types is called an edge. Within a patch, factors such as temperature, moisture, food resources, and the abundance of predators may be different near the edges of a patch as compared to the interior part (Matlack 1993). Changes in the ecological factors near the patch boundaries are termed edge effects. Because smaller habitat patches have a greater edge-to-interior ratio, edge effects tend to be more prevalent in small patches. Thus, habitat fragmentation, by creating small patches can increase the amount of edges and edge effects throughout a landscape.

Landscape fragmentation and its potential impact upon the problems such as global change, biogeochemical cycles, land use dynamics, and biodiversity have become central issues in Earth System Science (National Research Council, 1998). As a consequence, new ecological theories (Wilson 1988), modern methods to study spatial dynamics (Turner et al. 1995) and new applications to natural resources-planning and monitoring have taken place (Goodland et al. 1993). Perhaps the most important ongoing process of natural landscape fragmentation is the deforestation in the forested habitats of Himalayas and elsewhere (Batistella et al. 2000). In Dachigam landscape before this study no investigation was carryout to understand the land use/land cover assessment in the landscape. The present research combines Land Use and Land Cover (LULC) analysis through the processing of geo-referenced data, particularly satellite imagery, with landscape ecology theory and methods. In the present study the overall perspective was to contribute to a better understanding of patterns of landscape fragmentation in recently human colonized areas by way of forest encroachment and degradation.

The heterogeneity of landscapes – as a parameter of landscape structure – is described as the “quality or quantity of dissimilar elements occurring in a landscape”. It is the “opposite of homogeneity, in which elements are the same” (Turner et al. 2003). The process of fragmentation of landscapes, in the sense of the piece-meal conversion of a formerly contiguous habitat, usually primarily affects animals with relatively large territories – e.g., birds or large mammals. On the other hand, animals with limited mobility are separated into isolated populations more rapidly because of such elements as roads or urban structures (Swenson and Franklin 2000). However, in science there is no consistent understanding of the term landscape fragmentation (Jaeger 2000). Today, the term is increasingly used internationally as synonymous for all anthropogenic invasions of landscapes and habitats which are resulted due to human encroachment and exploitation of natural resources in an area.

4.2. Objective

This chapter deals with the following objectives:-

1) Vegetation characterization and mapping of black bear habitat types in Dachigam NP.
2) Vegetation community composition, distribution, richness, evenness, diversity and specific association among different plant species in Dachigam NP.
3) Landscape structure analysis to understand the composition of the landscape.

4.3. Methods

The methods used for vegetation quantification and habitat mapping of black bear in Dachigam NP followed the standard methods adopted by various workers in the Western Himalayas (Singh et al. 2002). The sampling strategy included three stages: 1) field reconnaissance survey, 2) unsupervised classification of Landsat LISS III images followed by supervised classification, and 3) seasonal vegetation sampling on permanently marked vegetation plots along the transects.

After the reconnaissance survey Lower Dachigam was selected as intensive study area representing black bear habitat based on the elevation and forest type with an area of 90 Km^2 form the total area of 141 Km^2 of Dachigam NP.

4.3.1. Mapping of forest cover in Dachigam national Park and surrounding area in Dachigam landscape

The forest cover in Dachigam NP and surrounding areas was classified using the Landsat data downloaded from GLCF. The information was provided in four spectral bands in the visible and infra-red regions with spatial resolution of 23.5 meters. The preprocessing of the image was carried out by following the standard methodology (Singh et al. 2002) which includes geometric and radiometric correction followed by geo-referencing of the scene at 1:50,000 scale using ancillary data and GPS locations. The image obtained through unsupervised classification and was processed with the vegetation data for the supervised classification using the signature file containing the plant community data. The field knowledge was subsequently incorporated to improve the accuracy of the classification. Hybrid classification was carried out which has the advantage of both the procedure (unsupervised and supervised) and the field information generated during surveys (Singh et al. 2002). The vegetation classes were delineated on the basis of spectral value of FCC. The spectral bands 3, 2, 1 (RBG) of landsat data were also important for the vegetation class separation with different spectral (DN) values of different vegetation classes, though infrared (NIR) band was most important for the vegetation classification.

In the present study the topographic maps of Survey of India (SOI) with 1:50,000 scale and the landsat data (LISS III) of 27th September 2009 downloaded from GLCF, were used. The study area was covered in two scenes (Figure 4.2).

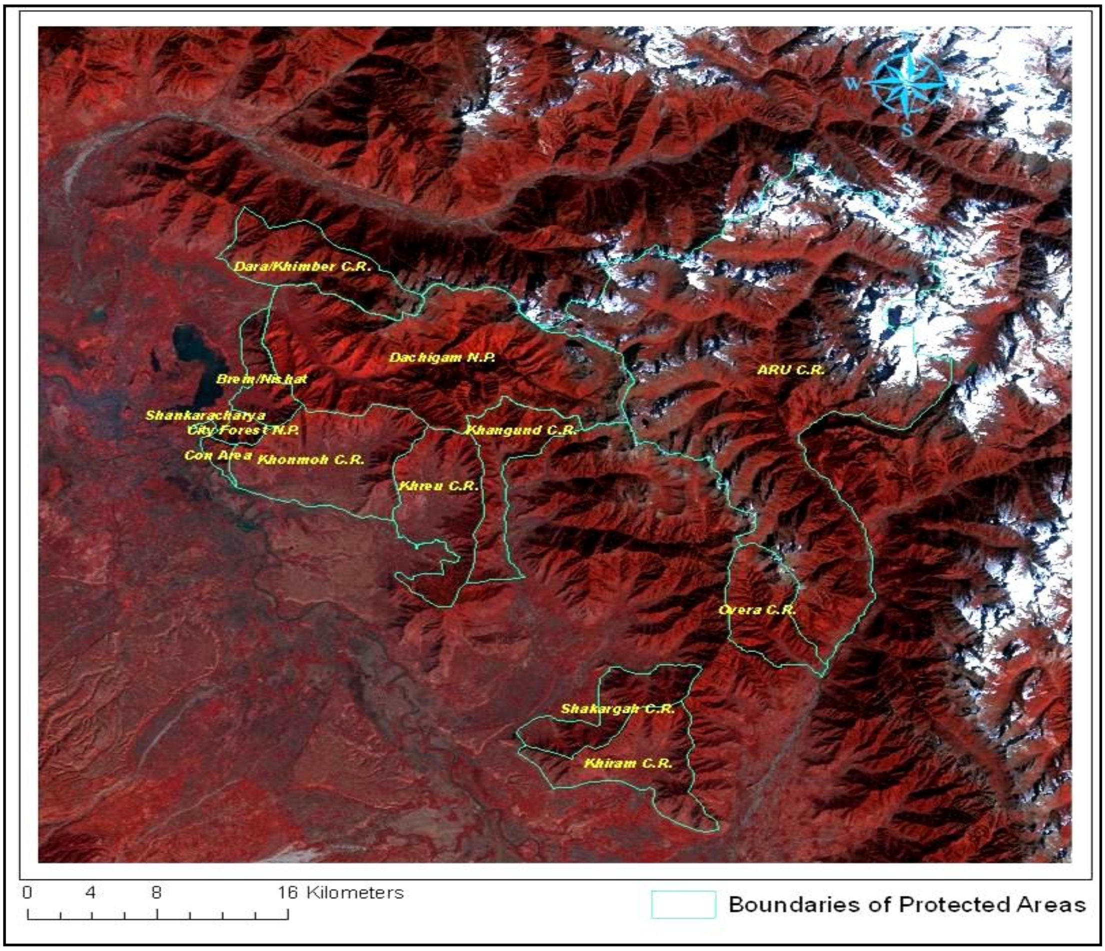


Figure 4.1. The satellite imagery used for the land cover classification along with boundaries of protected areas in Dachigam Landscape.

The satellite data was processed by using ERDAS-Image 8.4 and the ArcInfo 9.3 software. The two scenes covering the study area were mosaiced to delineate the study area. The satellite images covering the study area were geo-rectified with the help of topographic maps and the geo-rectified data was having root mean square (RMS) error of 2.58%.

4.3.2. Vegetation sampling and plant community analysis

The vegetation sampling was carryout out for habitat characterization inside Lower Dachigam NP. Random stratified sampling approach was followed. For the vegetation sampling 121 permanent sampling plots were used marked along the 13 transects and main Dachigam nallah. Of these, 98 plots were marked along the transects at an interval of 250 m and remaining 23 plots were marked along the banks of main Dachigam nallah at every 500m interval. The sampling plots were marked in all six forest types with respect to the area for vegetation quantification. For tree species, circular plots of 10 m radius were marked for total enumeration of tree species, their number, GBH, canopy cover in percentage (using densitometer) and tree height was recorded. For shrubs circular plots of 5 m radius were marked inside the 10 m radius plot used for the tree cover to record shrub species, number of individuals, shrub cover and their individual height. For quantifying herbs and grasses 1 x 1 m quadrates were laid inside the 5 m circular plots to record herbs and grass species and to estimate percentage ground cover of herbs, grasses, litter, bare rock and other parameters using 'line intercept' method in four different direction. At each sampling plot other habitat variables such as elevation using altimeter or GPS, slope using ocular estimation, aspect using compass, distance to water using range finder or ocular estimation, disturbance (presence/absence of human use signs/sightings) distance to human used trail, distance to road and GPS location were recorded.

4.3.3. Analytical methods for plant composition, species diversity estimation

For the vegetation structure and composition analysis, species diversity, richness and abundance etc were calculated by using BioDiversity Professional software (A biodiversity parameter computation software) package developed by the Natural History Museum and the Scottish Association for Marine Science was used. The vegetation data was analysed by following Mueller-Dumbois and Ellenberg (1974). The plant Species richness estimation was carried out using observed and estimated richness in the study area to justify the sample size adequacy for representing species from the study area. The species richness analysis randomly pooled the samples and examined for specific indicators accumulate as the samples are pooled. Species distribution was analyzed by using chi-squared tests to understand whether the plant species are distributed randomly through the samples or aggregated or uniformly distributed. SHE analysis (Buzas and Hayek 1996, Hayek and Bauzas

1997) was carried out to estimate the relationship between S (species richness), H (diversity as measured by estimated Shannon-wiener index) and E (evenness) in the samples.

In SHE analysis, the relative contributors of species richness and evenness to H` diversity are partitioned using the decomposition formula: H= In(S) + In (E). Assumptions for this are (1) maximum H` diversity occurs when all species are equally distributed [$H`_{Max}$ = In(s)], and (2) E is related to H` by equation E = $e^{H`}$/S. SHE analysis partitions H` diversity into richness and evenness components which allows independent evaluation of their contribution to H`. SHE analysis is being considered as one of the most effective methods for testing of 'goodness-of-fit' to these stochastic models (Tokeshi 1990).

The plant community type is an assemblage of plant species interact at the same time, place and have defined species composition and physiognomy, regardless of serial stage; usually named by, the name of the species which dominate in the stand. The floristic assemblage in Dachigam was analyzed using TWINSPAN (Hill 1979) two way indicator species analysis for the numerical and hierarchical classification of plant communities in Dachigam NP.

The differential species are used to make a division or a dichotomy and thus to separate one group of plots from another, with one set of differential species characterizing one group and another set the other. However, the idea behind differential species is based on presence/absence, rather than abundance, and is thus a qualitative rather than a quantitative concept. Hill et al. (1979) devised the pseudospecies concept as a way of adapting abundance data to a qualitative equivalent which can then be used in the presence of marking a division. Thus any species abundance scale is partitioned into a species of pseudospecies, each of which then be used in the process of making a dichotomy.

The input parameters for TWINSPAN analysis were decided after testing the data at various cut levels for abundance and later on kept defaults because of the best possible results. The changes in TWINSPAN outputs resulted from varied parameters and by increasing number of plot starting from 75 vegetation plots carefully. The input parameters opted for the final analyses were 0, 1-2%, 3-5%, 6-10% and 11-20%. The maximum numbers of indicators were kept at five.

At the first stage of the analysis the data was converted into pseudospecies. The distribution of pseudospecies in each of the two groups was examined, and found that some pseudospecies were found to be only present on one side of the division, while others were on another side. Such pseudospecies, which occur exclusively on either side of the dichotomy, were considered as indicator species of the group. A pseudospecies in a community is quantitative and equivalent of a differential species (one with a clear ecological preference) for e.g species such as *Pinus wallichiana*, pseudospecies *Pinus wallichiana2* means *Pinus wallichiana* with 1-2% abundance. However, the presence of differential species can be used to identify particular environmental conditions (Figure 4.2).

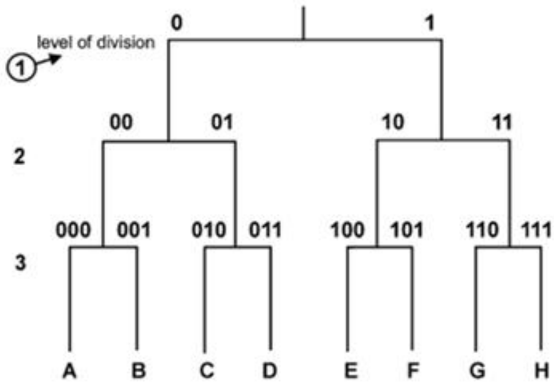


Figure 4.2. Figure showing the division steps

A weightage of 2 was given for the highest pseudospecies cut level and weightage 1 was given to all the other cut levels. The level of division was decided to bring species into consideration of high abundance and which help in identifying the associations with dominance of such species in the community. Further divisions were made exactly in the same way, so that each of the two groups resulted from the first division were later divided into four groups and so on. The TWINSPAN analysis was performed using the software package PC-ORD 4.0 (Mccune and Mefford 1999). These plant communities grouping were subsequently compared with the groups identified using DCA method. The DCA diagram provided a visual summary of the species composition data from the vegetation sampling plots. The TWINSPAN classes were drawn in by hand with the DCA diagram.

The Conical Correspondence Analysis (CCA) (Ter Braak 1986) was used to determine the relationship of vegetation assemblage with the habitat factors which are responsible for the assemblage of plant species. Canonical correspondence analysis (Ter Braak, 1986) is a multivariate direct gradient analysis method that has become very widely used in ecology. This method is derived from correspondence analysis, but has been modified to allow environmental data to be incorporated into the analysis. It is calculated using the reciprocal averaging form of correspondence analysis. However, at each cycle of the averaging process, a multiple regression is performed of the sample scores on the environmental variables. New site scores are calculated based on this regression, and then the process is repeated, continuing until the scores stabilize. The result is that the axes of the final ordination, rather than simply reflecting the dimensions of the greatest variability in the species data, are restricted to be linear combinations of the environmental variables and the plant species data. This method has been used for the vegetation data ordination by many researchers in past (Jiang 1994; Vogiatzaki and Mannion 2003; Tavili and Jafari 2009). In this way two sets of data are then directly related (e.g. vegetation data and environmental data). The results of CCA can be presented in a diagram containing the environmental variables plotted as arrows emanating from the center of the graph, along with points for the samples and taxa. The relationships between the samples and species are as in CA; each sample point lies at the centroid of the points for species that occur in those samples. The arrows representing the environmental variables indicate the direction of maximum change of that variable across the diagram. The CCA analysis was carried out using Multivariate Statistical Package MNVP 3.21(Kovach Computing services).

4.3.4. Landscape structure and fragmentation analysis

The landscape satellite image was classified using the method mentioned in section 4.3.1 of this chapter to identify the different land use/ land cover types in the landscape. To understand the landscape structure, landscape indices were calculated using Fragstats 3.4 (McGarigal and Marks 1995) and ATtILA (Analytical Tools Interface for Landscape Assessments) (Ebert and Wade 2004) extension program of ArcView 3.4 software program. The Index selection was based on their usefulness to address landscape fragmentation (Haines-Young and Chopping 1996; Dale and Person 1997). There were some indices are particularly useful to test the hypothesis about landscape fragmentation processes in Dachigam landscape. Among them, area indices and number of patches are of special interest. The edge, shape, and core area indices were calculated because of their relations with architecture and configuration of the landscape. Mean nearest neighbor index defines the average distance to the nearest patch of same patch type. Interspersion/juxtaposition indices may be useful to compare landscape configurations. The Shannon’s diversity indices were also calculated to understand the richness and diversity in the landscape. The maps of the forest class, landscape fragmentation, diversity index, patch density and patch density richness were developed using the ArcView3.4 and ArcGis 9.3 software program.

4.4. Results

4.4.1. Land cover/Land use mapping

4.4.1.1. Land cover/Land use (LULC) in Dachigam National Park

The total area of Dachigam NP was 141 km^2 calculated using GIS (Figure 4.3). The Dachigam NP is administratively divided into two: Lower and Upper Dachigam. Lower Dachigam NP was selected as our intensive study area with an area of approx. 90 Km^2. The area under forest cover in lower Dachigam was 91% and rest 9% includes non forest areas which are rocky clefts, water bodies, human-agriculture and snow covered area. The spatial distribution of different land cover types was generated after hybrid classification method. The vegetation of Lower Dachigam is represented by 34 numbers of tree species, 21 shrubs, 96 herbs, 8 climbers belonging to 65 families.

A. ***<u>Forest cover</u>***

Following are the forest types in Dachigam National Park: -

I. Riverine forest

Riverine forest mainly confined along the main Dachigam *nallah*. It is basically a succession vegetation type which is mainly dictated by the local eudopho-climatic conditions. The plant community of this forest type was represented by following broad leaved tree species *Morus alba, Morus nigra, Salix babylonica, Populus alba, Acer caesium, Juglans regia, Ulmas lavigata, Rhus sp., Corylus sp,*. The dominant shrub species in this forest type are *Rosa brunonii, Roubinia sp, Indigofera heterantha, Vibernum sp, Berberis sp.* The under growth comprises of *Arenaria serpylliofolia, Viola odorate, Geranium sp., Solenanthus cereinatus, Climatis grate, Vitis vinifera*. This forest type lies in the elevation gradients of 1600m to 1900m and it comprises almost 30% of the total area of intensive study area (Figure 4.3).

II. Low Temperate Pine mixed forest

Pine forest found and grows on the slopes along the north and north east aspects between Harwan water reservoir and Phalipora. This land use/ land cover type contributes to 48 % of total intensive study area. *Pinus wallichiana* is the dominant conifer that sometimes reaches up to the open scrubs and forms patches. In the lower zones the *Pinus wallichiana* has very little undergrowth and has the following shrub species such as *Lonicera quinquelocularis, Vibernum continifolium, Berberis lycium, Rosa webbiana, Stipa sibirica, Artemesia vestita, Polygonum auplexicaule, Geranium wallichiana, Origanum normal* and others. In many places, pine trees found to be in association with other shrubs such as *Rosa brunonii, Rhus succedanea, Parrotiopsis jacquementiana, Rosa webbiana, Prunus cerasifera, Creteagus monogyua, Berberis lycium*. Pine forest is distributed mainly at the elevation range of 1,800m to 3,400m throughout the Dachigam in small patches (Figure 4.3).

III. Low Temperate forest

The low temperate forest is distributed in the elevation zone of 1,700m to 2,100m. This forest type is composed of various tree species and the dominant tree species were *Pinus wallichiana*, *Aesculus indica*, *Rhus* spp., *Lonicera quinquelocularis* the dominant shrub species were *Rosa webbiana*, *Rosa brunonii*, and *Berberis lycium.* This forest type shares large number of species with riverine and mid- temperate forest and is distributed between riverine and the mid-temperate forests, covering the north facing slopes starting from the Rajnar area in Dachigam block up to the Gratner in Pahalipora block. Low temperate forest type comprises 15% of the total forest area of Lower Dachigam (Figure 4.3).

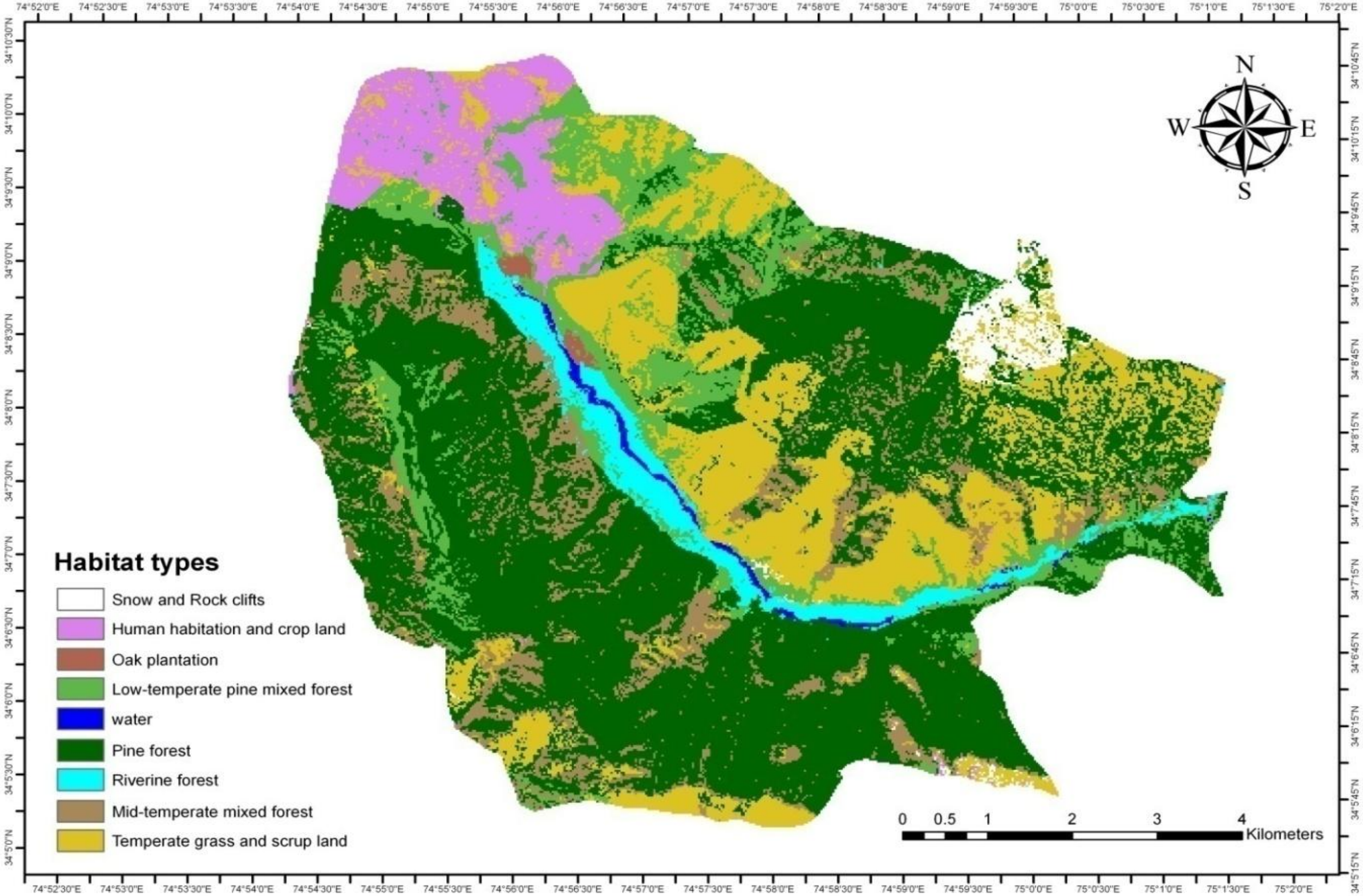


Figure 4.3. Map showing different forest/habitat types of black bear in intensive study area (lower) of Dachigam National Park.

IV. Mid- Temperate forest

Mid temperate mixed forest is distributed at the elevation gradient of 1,800m to 2,400m. In this forest type the dominant tree species were *Juglans regia, Aesculus indica, Rhus sp. Populus ciliata, Corylus colurna, Padus cornuta, Fraxinus sp., Taxus wallichiana*. The dominant shrub species in this forest type are *Prunus sp., Berberis sp., Vibernum sp., Rosa webbiana,* etc. This forest type is very much important for Black bear and Hangul throughout the year. It comprises almost 20% of the total area of Lower Dachigam (Figure 4.3).

V. Temperate grassland/scrubland

These are vast starches of open lands particularly on slopes facing South – west between 1,800m to 2,700m. These open stretches are sparsely covered by thickets of broad leaved deciduous scrub comprising, *Parrotiopsis jacquemontiana,* and *Prunus armeniaca.* This vegetation type has large number of xerophytic species which makes scrubland patched. These species include *Indiofera heterantha, Rosa brunonii, Rosa webbiana, Lonicera quinqelocularis, Geranium nepalensis, Dipsacus mitis, Dactylis gloerate, Colochicum luteum, Stipa sibirica, Zizypus anathera, Fragaria verca, Kocleuria cristata*. This vegetation type is very much important for Hangul. The temperate grass and scrubland habitat forms 30% of the total intensive study area.

VI. Oak Plantation

Oak plantation is a plantation of white or English oak (*Quercus robur*) planted by Maharaja of Kashmir in early 60's. White oak is an exotic species, now it has become one of the most important habitats for species such as Asiatic black bear, Hangul. Oak plantation is a small patch in riverine forest with around 18 hectare area. Oak acorn is the most important food of black bear in autumn season (Manjrekar 1989). Asiatic black bear use to feed extensively in this patch before going into hibernation or winter sleep. The other tree species in this patch are *Aesculus indica*, and *Morus alba*.

B. *Non-forest*

Forest areas include barren rocky clefts, and water bodies.

I. Snow and Barren/ Rock cliffs

The area of barren/ rock cliffs in Dachigam NP is negligible in both intensive area and totals Dachigam areas and contributes 2% (1.2Km^2). This land use type shown in the map represents rock cliffs and areas which are covered by snow in most of the months of the year. Most of the areas in this land use type is devoid of plantation and support very few species of plants.

II. Water bodies

In Dachigam NP there are many perennial streams and lakes. The area covered in this class is small but they are well distributed in Dachigam and which are fulfilling the water needs of the wildlife. The image which was used for the analysis could only represent perennial and lakes and but did not include seasonal streams and other water sources. This class of LULC represents 0.5% (0.38Km^2) of intensive study area.

4.4.1.2. Land use/land cover types in greater Dachigam Landscape.

An area of 550km^2 calculated using GIS in Greater Dachigam landscape was used for the ecological study (area of analysis) (Figure 4.4). This area of analysis selected for the study comprises of human habitation, crop lands, five conservation reserves and Lower to middle part of Dachigam NP which is administratively falling under Central Wildlife Division. The total area under forest cover was (230 km^2) which was 42 % of the total area. The non-forest LULC includes human settlements, croplands, rocky clefts, water bodies and snow covered area. The spatial distribution of different land cover types was assessed after hybrid classification method. The crop lands in the landscape represent horticulture and agriculture crops (Figure 4.4).

A. Forest areas

The forested area was classified into three major classes which includes Conifer forest, Broadleaf mixed forest, and temperate grassland and scrubland.

1. **Conifer forest type (Pine dominated forest).** The pine forest is located mostly in the middle and upper elevation ranges in the landscape. The area covered by Pine forest was highest and largely falling in Protected Areas (PA) and this forest type was mostly devoid of disturbance. *Pinus Wallichiana* was the dominant tree

species in this forest type and the other conifer tree species were *Abies pindrow*, and *Taxus wallichiana*. The total area under pine forest cover was 168 km^2 and comprises 30.4 % of the total area in the landscape (Figure 4.4).

2. **Broadleaf mixed forest type.** The mixed forest type is the second type forest cover in the landscape after pine forest and it is located in the middle to lower elevation zones of the landscape. The mixed forest represented by the large number of species which includes *Aesculus indica*, *Juglans regia*, *Populus* spp, *Salix* spp and others. This forest type comprises of 10% of the total area and the total area was 58Km^2. The mixed forest occupying areas between conifer forest and other LULC in the landscape.
3. **Riverine forest.** The Riverine forest type is located only in Dachigam NP. This forest type holds highest diversity in the form of large number of plant species (tree, shrub etc) and it is the most important type of LULC for large number of wild animals species such as Hangul, black bear, leopard and etc. The riverine forest comprises 0.5 % of the total areas in the landscape. Riverine forest type runs all along the main Dachigam nallah (Figure 4.4).
4. **Temperate grassland and scrubland**. The grassland and scrubland areas are located in the open areas mostly on the west facing slopes in the landscape. The grassland and scrublands in Dachigam NP provides important habitat for the species such as Hangul and black bear. This land use type occupies areas in the middle elevation zones and was in the form of patches in the landscape. The Temperate grassland and scrubland forest comprises 8.8% (48.8Km^2) of the total areas in the landscape.

B. Non-Forest areas

The non-forest areas cover degraded / barren areas, snow, human settlement, and croplands.

1. **Degraded/barren areas.** The degraded area are mostly located in Dara/Khimber conservation reserve towards North-East of the Dachigam NP and this land use type cover large amount of area in Khunmoh and Khrew conservation reserve. The total area of degraded forest type land use was 45.4 km^2 and forms 8.1% of total areas in the landscape (Figure 4.4).

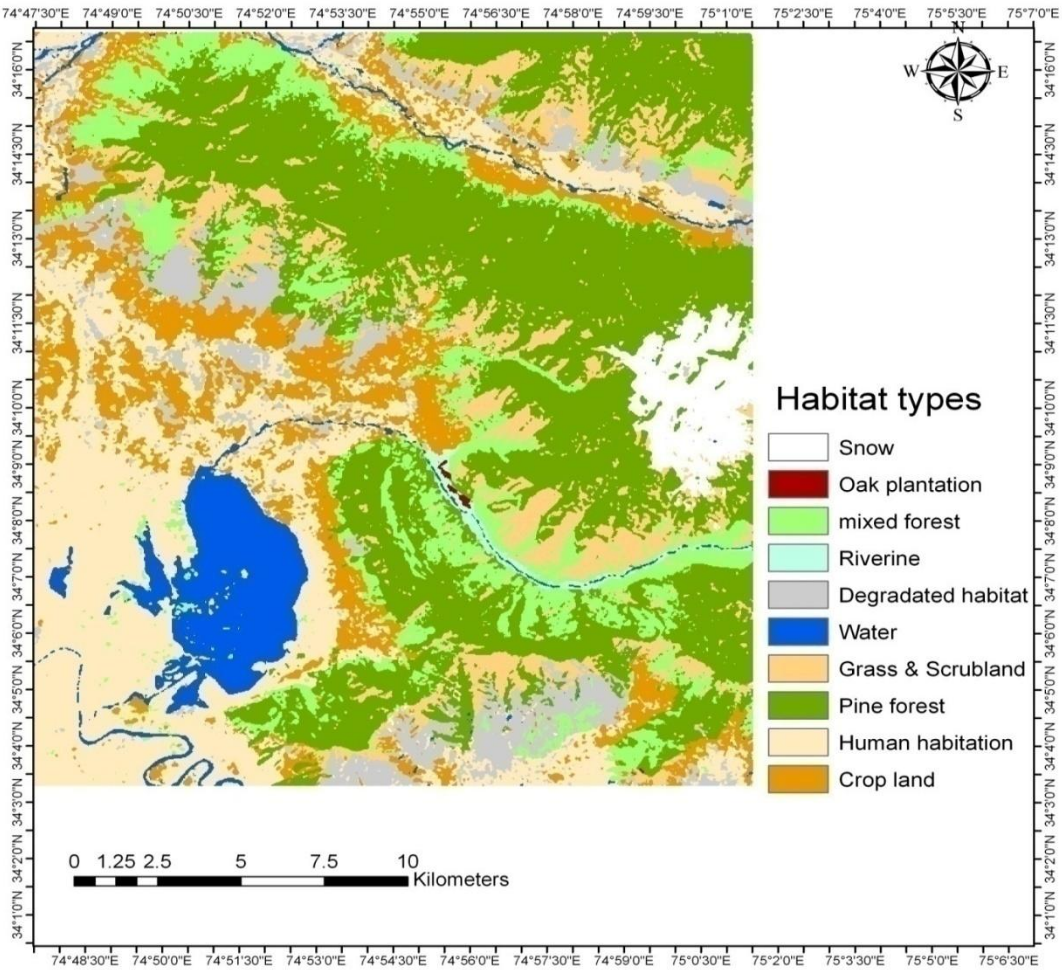


Figure 4.4. Map showing Land cover/ land use types in Dachigam landscape (areas of analysis).

2. **Human settlements.** The human settlements were mostly located towards Dal lake on the North-Western side in the landscape. The total area covered by this land use type was 118 km^2 and about 21.3% of the total area.
3. **Crop lands.** In Dachigam landscape this land cover type is located in the fringe areas of the protected area and in the other forested habitats. This land cover type comprises about 66.2% of the total areas in the landscape and is one of the major land use type in the landscape. The cropland cover composed of horticulture crops and the agriculture crops.
4. **Snow and rocky clefts.** The area of barren/ rock cliffs was negligible in the landscape and contributes 2.9% (16Km^2). This land use type shown in the map represents rock cliffs and areas which are covered by snow in most of the months of the year. This land use type support very few species of plants and mostly barren (Figure 4.4).

5. **Water.** Dachigam landscape is the catchment area of Dal Lake and covers 5.2% of the total area of the landscape.

4.4.2. Vegetation community assemblage in Dachigam National Park.

The TWINSPAN analysis and the cluster analysis were used for the vegetation structure analysis in Lower Dachigam NP. PC-ORD 4.0 software program was used for the analysis of plant community. The dendogram generated based on the eigen values for the ordination of indicators species, was interpreted for two cut levels. The resulted dendogram is the hierarchical representation of species (Figure 4.5). This dichotomy classification of vegetation in Lower Dachigam divides the species into two major vegetation groups and these two groups were further classified into six minor groups. The plant communities were named according to the dominant species type.

Community 1 was called Oak plantation as oak was the most dominant tree species recorded in this community. The other species were *Aesculus indica*, *Salix wallichiana* and *Morus alba* in very few number. The oak plantation has been considered as separated community because of management history and the plantation however, it is a small patch of 17.7 hectare in Numbal beat of Dachigam block. The density of *Aesculus indica* was highest (47.8 tree/hectare) followed by *Salix wallichiana* (31.8 tree/ hectare), oak tree (5.78 tree/hectare) respectively. The oak (*Quercus robur)* plantation is located in the riverine forest type of the study area. Oak trees were not recorded in any other plot during the vegetation survey in the study area. The TWINSPAN dendogram showed that this single species forming a separate group and only recorded from plot no. 14, 15 (Table 4.1).

Community 2 was called as *Morus-Prunus* community located in the riverine forest due to highest density of *Morus alba* (81.6 ± 13.6), *Morus nigra* (14.5 ± 7.4), *Prunus armeniaca* (97.6 ± 12.3), *Prunus cerasifera* (38.5 ± 10.2) and *Prunus Prostata* (156.2 ± 50.4). This community is composed of maximum number of tree (25) and shrub species (11) among all plant communities. The dominant shrub species were *Rubus fruticosus* (123 ± 80.7), *Prunus tromomtosa* (213.7 ± 80.7) and *Prunus prostata* (156.2 ± 50.4). The Shannon's diversity index and the richness values were 0.8929 and 0.8946. In this community, 10 fruit bearing species were recorded with relatively high densities. *Morus-Prunus* community was located in the valley region of Dachigam starting from gate of the park up to bran nar nallah running along the main Dachigam nallah.

Community 3 was named as *Aesculus -Rhus* community due to the highest density of *Aesculus indica* (78.9 ± 24.5) and *Rhus succidiana* (37.9 ± 14.3) species. This community is located in the mid-temperate habitat. The other tree species which makes this community were *Celtis australis* (78.7 ± 11.4), *Parrotiopsis jacquimontiana* (48.5 ± 17.5), *Lonicera quinquelocularis* (20.2 ± 7.7). The shrub species were *Prunus tomentosa* (242.6 ± 88.7), *Rosa webiana* (139.5 ± 78.1), *Crataegus songarica* (133.5 ± 55.9), *Acer caesium* (86.4 ± 24.6) and *Vibernum cotinifolium* (412 ± 106). The Shannon's diversity value and richness for this community were 0.8280 and 0.8839. This plant association is located in the middle elevation zones of Mahadev, Chandernar, Zahil, Kaw nar, Breen nar, Yachi gachi *nallah.*

Community 4 was called as *Pinus-Ulmus* community because of highest density of *Pinus* and *Ulmus* species. The *Pinus-Ulmus* community is occupies middle to upper elevation zones of Dachigam NP and distributed in Pine forest. The other species which constitute this community were *Platanus orientalis* (27.3 ± 15.2), *Prunus cerasifera* (67.5 ± 29.3), *Ulmus wallichiana* (43.2 ± 22.5), *Celtis australis* (14.6 ± 9.3), *Ulmus lavigata* (79.6 ± 16.8). This community occupies largest area of Dachigam NP. The Shannon's diversity and richness were 0.8020 and 0.8946. The largest patch of this community was present in Chandarnar and Yachi-gachi nallah.

Community 5 was called as *Parrotiopsis-Salix* community lies in the Low temperate mixed habitat in the middle of riverine and mid-temperate habitat and the community was named due to the occurrence of *Parrotiopsis jacquimontiana* and *Salix* species in highest density among all other communities. The density of *Parrotiopsis jacquimontiana*, *Salix alba* were 139 ± 27.3, 79 ± 20.3 respectively (Table 4.1). The other species present in this community were *Salix babyloniea* (10.27 ± 6.8), *Salix wallichiana* (5.44 ± 2.7), *Populus alba* (27.3 ± 7.2), *Populus caspica* (13.98 ± 8.76) and *Pyrus communis* (11.65 ± 5.86). *Berberis lycium* (257.9 ± 68.4), *Rubus fruticosus* (123.7 ± 68.4), *Rosa webiana* (93.2 ± 43.1) and *Prunus prostata* (307.6 ± 69.2) (Table 4.2). The Shannon's diversity index and the richness values were 0.8233 and 0.8843. This plant community was located in middle elevation zone of Bradin nar, Murkha, Mahadev nar, Pan nar and Pachadov area.

Community 6 was called as *Rosa-Rubus* community due to the presence of highest density of *Rosa webiana* (520 ± 152), *Rosa burnonii* (361 ± 152), *Indigofera heterantha* (360 ± 146), *Rubus antennifer* (234 ± 151), *Themada anathera* (148.6 ± 81.2) and *Rubus fruticosus* (425 ± 115) (Table 4.2). The dominant tress species recorded were *Parrotiopsis jacquimontiana* (63.3 ± 19.4), *Robinia pseudoacacia* (58.4 ± 17.4), and *Rhus succidiana (*13.27 ± 9.1) (Table 4.1). The Shannon's index and the richness value were 0.7490 and 0.9104. This community is mostly located in open areas of Drog, Menu, Reshwodery and Bran nar *nallah* (Figure 4.5).

4.4.2.1. Vegetation-environment relationship

The relationship between plant species variation and environmental variation was assessed using Canonical Correspondence Analysis (CCA). The canonical co-efficient and the intersect correlations indicate the relative importance of each environmental factor in predicting the species composition along the ordination axes. Species scores and the environmental vectors from CCA, were used to create an ordination diagram to describe - the relationship between the plant communities and the site variables. For simplicity, the ordination is presented as two separate diagrams, one displaying the site locations (Figure 4.6) and another displays the species location (Figure 4.7). Arrows that paralleled axis 1, explained the most variation in species composition and site data. This axis was positively correlated with disturbance on the site as determined by four point scale and negatively correlated with landform, elevation, slope and aspect. The second axis represents other variables, such as-distance of plot from nearest trail and distance from water stream or drainage. The species richness at this axis was positively correlated with distance to trail and drainage but negatively correlated with species richness on the sampling plot. The placement of different plant species on the CCA axis revealed that how these species was distinct from each other and in what way the environmental variable is associated with the distribution of plant species in the community. The first three axes of the CCA ordination had relatively high eigenvalues (Table 4.5). However, the percentage variance of plant species data explained 3.7 and 2.8, for axes 1 and 2 respectively. The cumulative percentage variances of species-environmental relation for axes of CCA (and their eigenvalues) are: 3.7 (0.208) and 6.5 (0.157) for axes 1 and 2 respectively. All of the three axes had similar explanatory power. The species-environment correlation calculated for the first two axes of CCA were: 0.77 and 0.78

(Table 4.8). A Monte Carlo permutation test (Table 4.8) showed that the vegetation-environment relationship revealed by axis 1 and all axes were significant (P=0.01). The correlation between the first three CCA axes and environmental factors were determined. The strongest correlations with the first CCA axis were significant for disturbance on plot, and had partial correlation with elevation and slope of the sites. The second CCA axis was highly correlated with species richness and slope on the plot, where as the third CCA axis was correlated with aspect, disturbance and slope on the plot. The temperate pine mixed forest and mid-temperate forest which occurs on higher elevations with steeper slopes and were devoid of disturbance, are located at the top of the second axis, and the riverine forest including oak plantation were located in to the valley regions where moderate to high level of disturbance exists. The low-temperate habitat was having low to moderate level of disturbance and were having moderate to high level of species richness. The Temperate grass and scrubland habitat plots were mostly situated on the bottom of the second axis and showing high richness because of large number of shrub species were distributed in this habitat and having inverse relation with disturbance indicate that the species in this habitat occurs in low and undisturbed areas (Figure 4.6). The riverine habitat was positively associated with the disturbance and inversely related to elevation slope and occurs in flat to moderately elevated areas (Figure 4.7). The temperate pine mixed and mid-temperate habitat was positively associated with elevation, slope, aspect, and negatively associated with disturbance (Figure 4.7). However conclusions about the habitat and associated plant community were less reliable, given the limited number of environmental variables. These plant communities have different environmental conditions and were showing relationship with disturbance (Figure 4.8). The plant species which occurs with different community associations in the present study support the previous studies conducted elsewhere and showed similar type of plant community associations (King et al. 2004; Mohtashamina et al. 2007; Shikui et al. 2011; Vogiatzakis et al. 2003).

Table 4.1. Mean density (per hectare) of tree species in different habitat types of Dachigam National Park, during 2009-11

Habitat/ Species	Low temp mixed		Mid temp		Oak plantation		Riverine		Temp pine		Temp grass	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Celtis australis	33.5	12.3	78.7	11.4	0	0	28.1	9.4	14.6	9.3	7.96	7.9
Ulmus wallichiana	19.42	7.61	7.58	5.3	0	0	14.3	6.9	43.2	22.5	0	0
Morus alba	68.8	16.2	12.13	6.7	0	0	81.6	13.6	14.4	6.8	0	0
Morus nigra	10.3	6.2					14.5	7.4				
Parrotiopsis jacquementiana	139	27.3	48.5	17.5	31.8	31.8	96.6	26	93.3	33.3	63.3	19.4
Rhus succidiana	25.63	8.6	37.9	14.3	0	0	28.8	10.8	9.1	7.0	13.27	9.1
Populus cileata	13.98	8.7	0	0	0	0	5.14	3.6	11.37	7.1	0	0
Acasia sp.	1.55	1.5	0	0	0	0	3.08	3.08	0	0	0	0
Juglans regia	27.96	9.5	13.6	10.7	0	0	82.1	14.3	6.83	3.6	0	0
Qurecus robur	0	0	0	0	5.78		0	0	0	0	0	0
Populus alba	27.3	7.20	0	0	31.8	31.8	5.14	5.1	27.3	17	0	0
Rubinia psedoacacia	9.1	4.20	0	0	0	0	5.14	3.6	0	0	58.4	17.9
Prunus ceracifera	79.5	31.5	84.9	11.1	0	0	38.5	10.2	67.5	29.3	13.3	13.3
Aesculus indica	55.9	20.9	78.9	24.5	47.8	47.8	71.9	17.3	34.1	18.4	0	0
Pinus wallichiana	17.5	9.0	66.8	27.4	0	0	29.4	11.2	16.8	5.9	18.6	13.8
Prunus armeniaca	50.5	12.6	68.2	22.2	0	0	97.6	12.3	38.7	20.1	0	0

Habitat/ Species	Low temp mixed		Mid temp		Oak plantation		Riverine		Temp pine		Temp grass	
Pyrus malus	17.09	9.2	12.13	9.45	0	0	8.22	5.52	2.28	2.2	0	0
Ulmus lavigata	16.31	6.2	33.4	17.8	0	0	24.66	9.3	79.6	16.8	23.9	16.2
Lonicera quinquelocularis	0	0	20.2	7.7	0	0	0	0	0	0	0	0
Acer caesium	4.66	2.3	86.4	24.6	0	0	23.63	8.0	4.55	4.5	18.6	12.7
Salix alba	79	20.3	0	0	0	0	4.11	4.1	0	0	0	0
Populus caspica	13.98	8.7	0	0	0	0	10.3	10.3	11.4	11.4	0	0
Platanus orientalis	4.66	3.9	12.13	9.19	15.9	15.9	14.38	5.4	27.3	15.2	29.2	19.4
Salix wallichiana	5.44	2.7	0	0	31.8	31.8	12.33	7.9	40.9	20.4	0	0
Salix babylonica	10.27	6.8	0	0	0	0	3.8	3.8	0	0	0	0
Pyrus communis	11.65	5.8	19.7	16.8	0	0	3.08	3.0	0	0	31.8	21.8
Prunus cerasifera	9.32	3.3	30.3	13.6	0	0	38.5	10.2	67.5	29.3	42.5	31

Table 4.2. Mean density (per hectare) of major shrub species in different habitat types of Dachigam National Park, during 2009-11.

Habitat/ Species	Low temp mixed		Mid temp		Oak plantation		Riverine		Temp pine		Temp grass	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Vitis vinisera	71.5	37.8	18.2	18.2	0	0	49.3	25.5	0	0	0	0
Rubus sp.	28	15.7	12.1	12.1	0	0	28.8	18.4	63.7	63.7	0	0
Indigofera heterantha	435	90	103.1	51.7	0	0	106.8	55.8	18.2	18.2	360	146
Rosa webiana	93.2	43.1	139.5	78.1	0	0	86.3	51.3	36.4	36.4	520	152
Rubus antennifer	77.7	36.7	0	0	0	0	0	0	0	0	234	151
Rosa brunonii	0	0	0	0	0	0	0	0	63.7	43.8	361	152
Rubus fruticocus	123.7	68.4	63.8	20.6	0	0	123.3	56.2	0	0	425	115
Prunus tromontosa	108.7	48	242.6	88.7	0	0	213.7	80.7	291	124	16.8	7.1
Isodon plectranthus	59	25.6	84.9	34.4	0	0	135.6	50.5	155	105	31.8	22.9
Prunus prostata	307.6	69.2	334	106	701	191	156.2	50.4	373	123	95.5	68.6
Spiraea canescens	40.4	24.1	0	0	191	191	16.44	9.7	63.7	63.7	21.2	21.2
Cratagus songarica	118.1	44.8	133.5	55.9	0	0	197.2	65.2	237	137	63.7	36.8
Themada anathera	0	0	0	0	0	0	84.11	44.1	0	0	148.6	81.2
Vibernum cotinifolium	111.9	39.3	412	106	0	0	135.6	45.7	45.5	31.6	117	117
Crategus oxycantus	40.4	16.3	54.6	14.1	0	0	32.9	13.2	0	0	42.5	28.6
Berberis lycium	257.9	68.4	72.8	36.8	1656	510	316	116	409	173	0	0

Table 4.3. Mean tree and shrub densities (#/hectare) in different habitats of Dachigam National Park, 2009-11.

	Habitat type	Number of sampling plots	Mean density/ha	S.E
Tree	Riverine	14	87.6	8.68
	Low temp mixed	41	56.6	1.15
	Mid-temp	21	34.0	3.92
	Temp-Pine	31	47.7	2.71
	Temp-grass and scrubland	12	9.30	4.32
	Oak plantation	2	565.0	119
Shrub	Riverine	14	141.6	30.9
	Low temp mixed	41	55.2	5.09
	Mid-temp	21	108.3	13.8
	Temp-Pine	31	66.0	7.82
	Temp-grass and scrubland	12	213.0	34.5
	Oak plantation	2	1338	191

Table 4.4. Diversity indices of tree and shrub species in different habitat types of Dachigam National Park.

Habitat	Number of sampling plots	Shannon's method index Log base 10	Evenness
Riverine	14	0.8929	0.8849
Low temp mixed	41	0.8233	0.8843
Mid-temp	21	0.8280	0.8839
Temp-Pine	31	0.8020	0.8946
Temp-grass and scrubland	12	0.7490	0.9104
Oak plantation	2	0.8480	0.8685

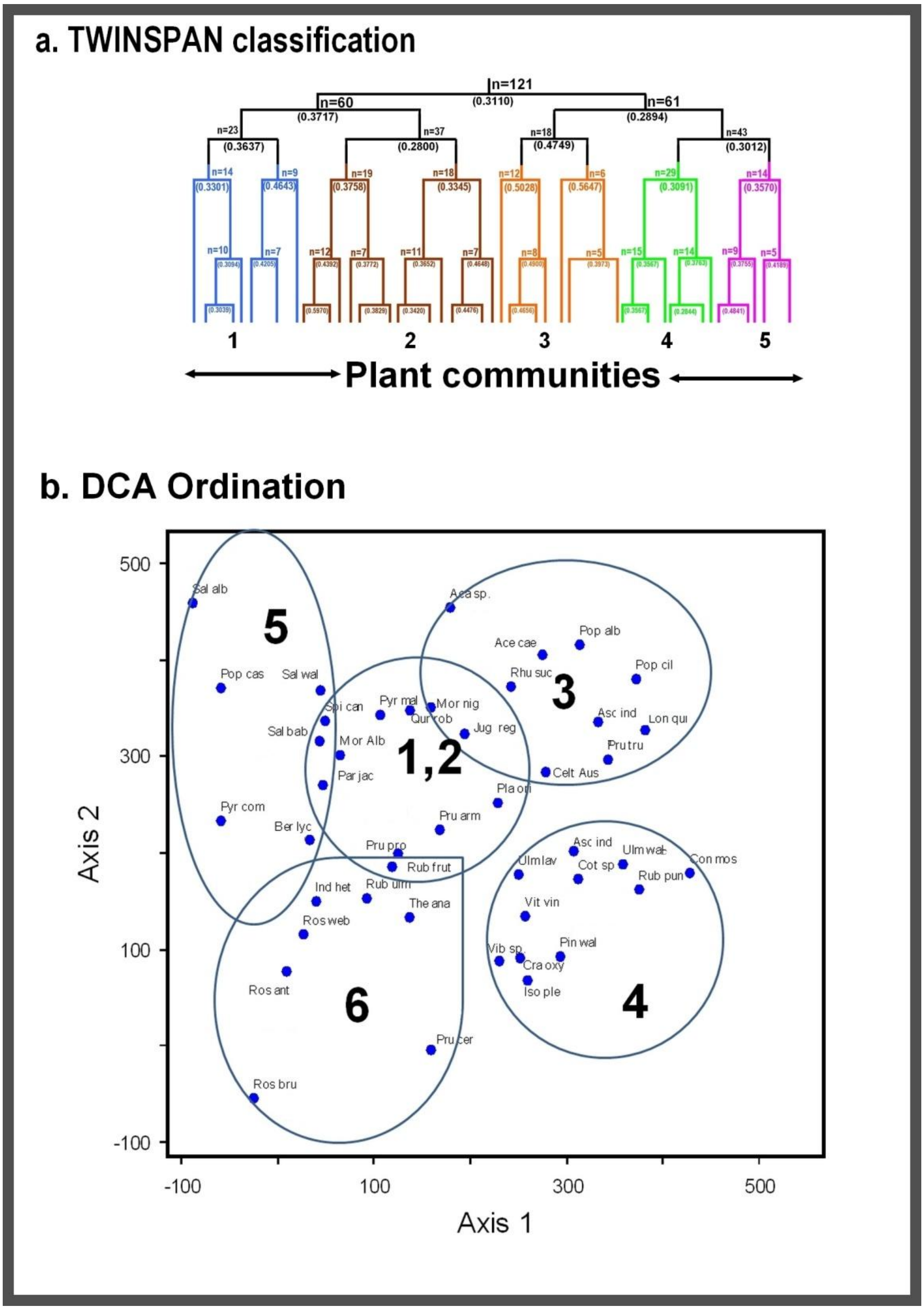


Figure 4.5. Figure showing the relationship between the five plant communities obtained using TWINSPAN (a) and DCA (b) methods in Dachigam National Park. (1. *Morus-Prunus*, 2 *Aesculus indica; 3 Pinus-Ulmus; 4) Parrotiopsis-Salix;5) Rosa-Rhnus) (Oak* community was considered in *Morus-Prunus* community since there was only two plots which were having Oak trees and it was a plantation in riveriene habitat)

Table 4.5. Eigenvalues and species-environment correlations of the first three CCA axes in Dachigam NP.

	Axis 1	**Axis 2**	**Axis 3**
Eigen value	0.208	0.157	0.117
Variance in species data % of variance explained	3.7	2.8	2.1
Cumulative % explained	3.7	6.5	8.6
Pearson Correlation, Spp-Ent*	0.771	0.777	0.638
Kendall (Rank) Corr., Spp-Envt	0.543	0.602	0.437

Table 4.6. Monte Carlo permutation test (99 permutations)

Monte Carlo Test Results- Eigenvalues					
		Randomized data			
	Real data	Monte Carlo test, 99 runs			
Axis	Eigenvalue	Mean	Minimum	Maximum	P
1	0.208	0.091	0.067	0.123	0.0100
2	0.157	0.073	0.053	0.114	
3	0.117	0.060	0.047	0.079	

Table 4.7. Standardized canonical coefficients, biplot and inter-set correlations of environmental factors with the first three CCA axes in Dachigam National Park.

	Standardized canonical coefficients			Biplot Scores			Inter-set correlation		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Distance to drainage	0.053	0.005	-0.149	0.007	0.014	-0.083	0.014	0.029	-0.164
Distance to trails	0.014	-0.016	0.155	0.017	-0.004	0.147	0.031	-0.009	0.291
Aspect	0.166	-0.041	-0.287	0.076	-0.056	-0.205	0.144	-0.119	-0.406
Elevation	-0.021	0.040	0.213	-0.287	0.098	-0.008	-0.545	0.209	-0.017
Slope	-0.089	0.113	-0.143	-0.232	0.116	-0.059	-0.441	0.248	-0.116
Ground cover	0.057	-0.072	-0.086	0.066	-0.048	-0.041	0.126	-0.103	-0.082
Species Richness	-0.095	-0.395	0.054	-0.082	-0.341	0.012	-0.015	-0.729	0.024
Disturbance	0.418	0.036	0.156	0.373	-0.021	0.082	0.710	-0.044	0.163

Table 4.8. Monte Carlo permutation test (99 permutations) for species-environment correlation in Dachigam National Park

Monte Carlo test results for species-environment correlations					
	Real data	Randomized data			
		Monte Carlo test, 99 runs			
Axis	Spp-Envt Corr.	Mean	Minimum	Maximum	P
1	0.771	0.596	0.521	0.688	0.0100
2	0.777	0.564	0.469	0.653	
3	0.638	0.541	0.467	0.627	

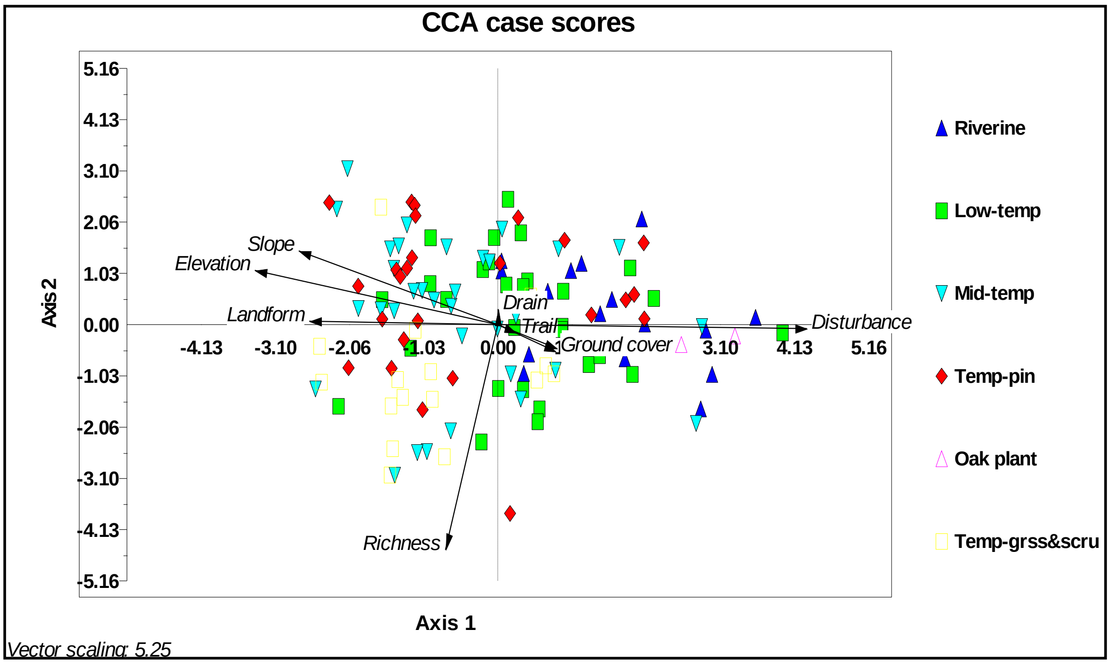


Figure 4.6. Ordination diagram produced by canonical correspondence analysis of sites with respect to five significant environmental variables. Arrow indicates magnitude and direction of environmental gradients relative to two axes of greater change.

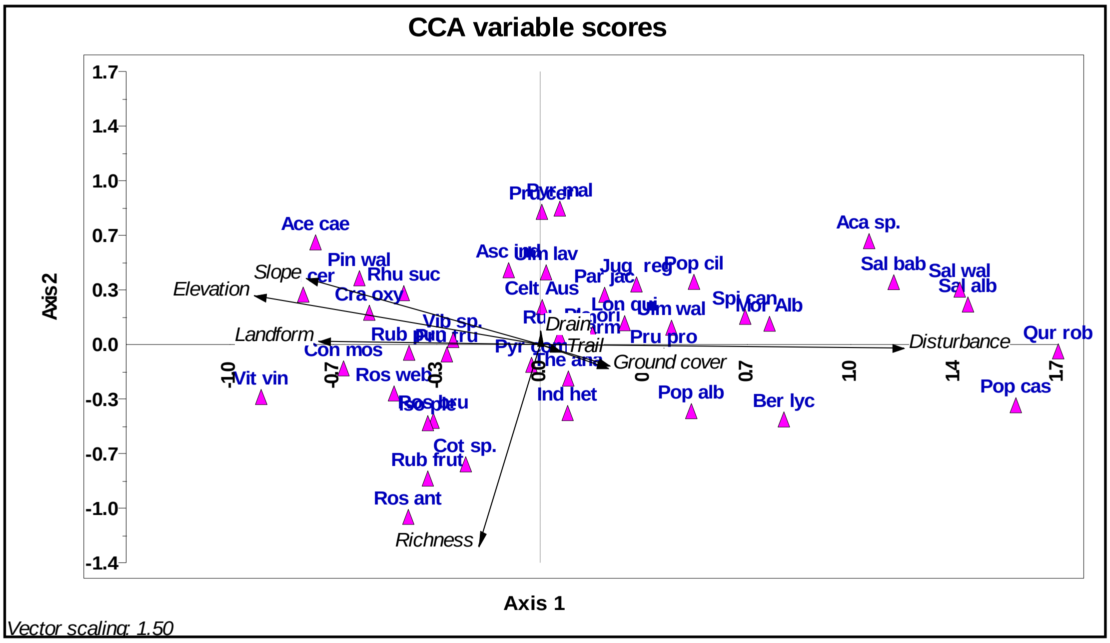


Figure 4.7. Ordination diagram of species with respect to environmental variables crated by canonical correspondence analysis. Arrows indicate magnitude and direction of environmental gradients relative to two axes of greater change.

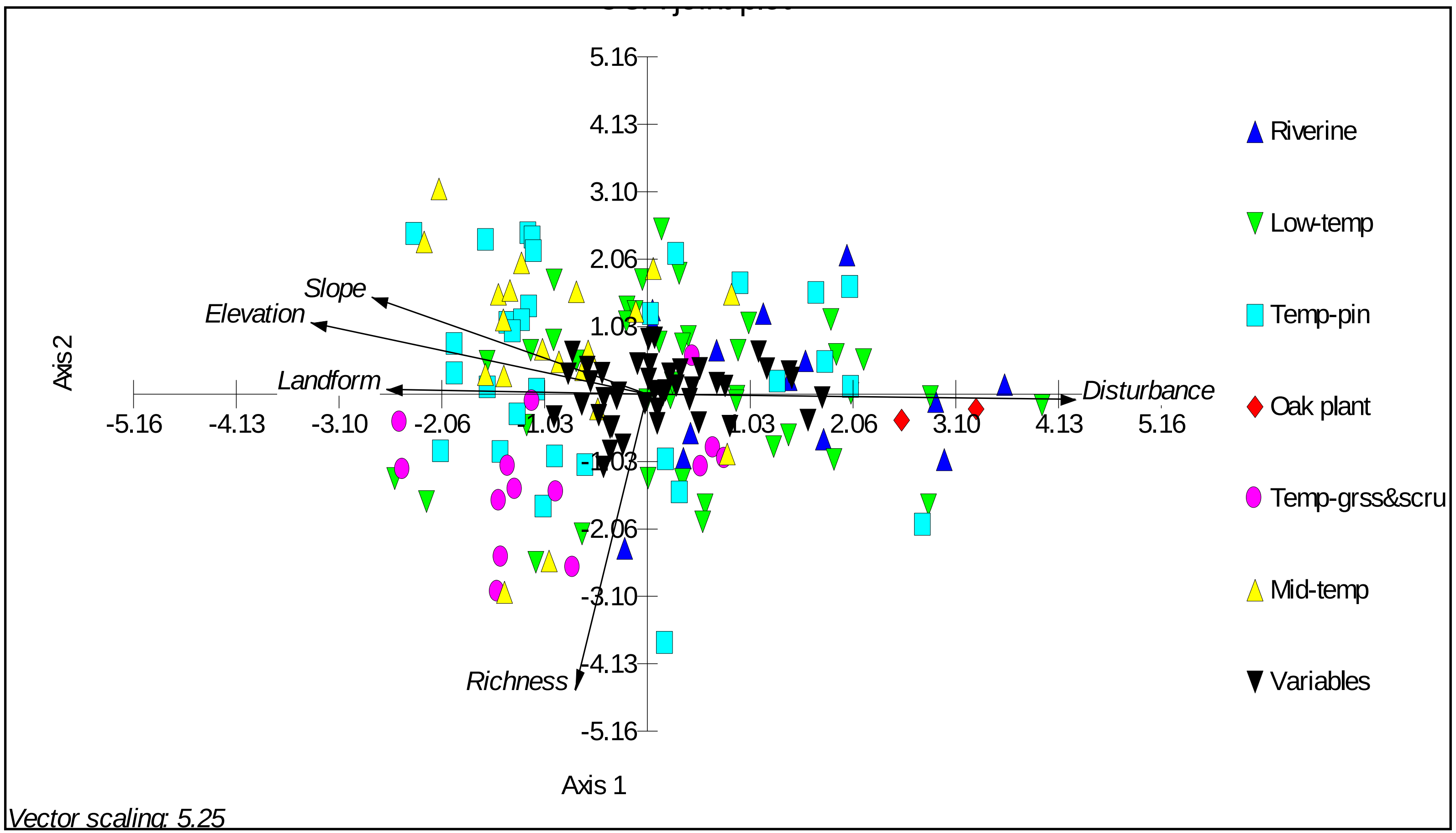


Figure 4.8. CCA ordination diagram with plant species (black triangle), sampling plots (different color triangle representing different habitats) and environmental variables (arrows) on the basis of species abundance; first axis is horizontal, second axis is vertical.

4.4.3. Pattern of vegetation composition in Dachigam National Park

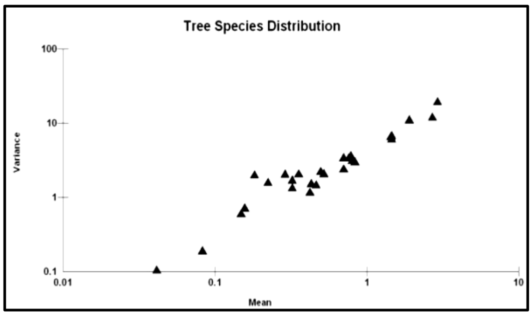
The flora of Dachigam NP is represented by large number of families includes 34 (27 in intensive study area (ISA)) species of trees, 21 species of shrubs (17 in ISA) , 87 species of herbs, 9 species of grasses, 8 species of climbers belonging to 65 families.

4.4.3.1. Distribution

The distribution patterns of plant species in Dachigam NP was evaluated at both community and species level (Figure 4.10). The dispersion of both pooled and total samples of tree and shrub species showed aggregated dispersion in Dachigam NP (Table 4.9). The dispersion was aggregated both in total samples and with respect to each other. The heterogeneity in the dispersion of tree and shrubs species was concluded to be discordant following Chi-square analysis with an probability of zero (Table 4.9). The distribution pattern of tree and shrub species did not show significant variation and not showing independent heterogeneity.

Table 4.9. Distribution of tree and shrub species at community level in Lower Dachigam National Park, 2007-11

	Chi - Square Value	D.F.	Probability	Dispersion
Tree species				
Total	15602.1	3267	0	Aggregated
Pooled	664.01	120	0	Aggregated
Heterogeneity	14938.1	3147	0	Discordant
Shrub Species				
Total	11837.64	2057	0	Aggregated
Pooled	791.66	120	0	Aggregated
Heterogeneity	11045.97	1937	0	Discordant



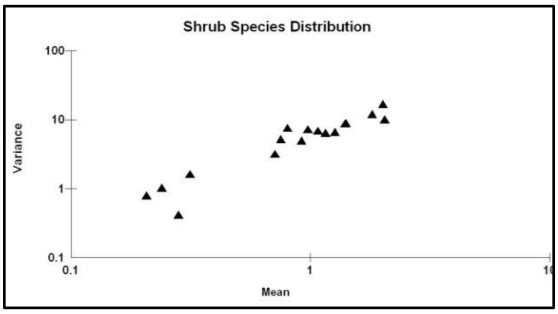


Figure 4.9. Species distribution patterns in Dachigam National Park (a) Tree and (b) Shrub species.2007-11.

4.4.3.2. Richness

The observed species richness for tree in 121 plots was 27 and accounted for 2951 individuals. The Jackknife 1, 2 and Chao 2 estimated 27, 25, and 27 species respectively in the intensive study area (Table. 4.10). The species richness estimated with Chao 1 was very high and not reliable, because the area of lower part of the Dachigam was inhibited by 10 villages historically and in many parts of the area large number of plantation was carried out during colonial rule in India by the maharaja of Kashmir. In case of shrubs the estimates of Chao 1 was again not reliable whereas the estimation of Chao 2, and jackknife 1, 2 were 17, 17, and 17 respectively which were more realistic estimates. The estimates of all species richness estimators were same except Chao 1, as its limitation and sensitivity to singletons (number of species which occur only once in a single sampling plot). The occurrence of singletons was much then doubletons (number of species which occur only twice in a single sampling plot).

Table 4.10. Estimated and observed species richness for tree and shrub species in Dachigam National Park, 2007-11.

Category	Tree species	Shrub Species
Sample size	121	121
Observed Species richness	27	17
Observed individual richness	2951	2099
Estimator: Chao 2	27	17
Estimator: Jackknife 1	27	17
Estimator: Jackknife 2	25	17
Estimator: Bootstrap	27	17

4.4.3.3. Diversity and evenness

The diversity index values calculated by using different indexes shown similar patterns except the evenness (e^H/S) where the value for shrub was larger than the tress (Figure 4.10). The number of shrub species was less than the tree species (Table 4.10). The SHE analysis is used to independently and simultaneous evaluation of relative contributions of species richness and evenness to community diversity in the study area. In SHE analysis, the relative contribution of richness and evenness to H\` diversity were partitioned using the disintegration for formula: H\`= In (S) + In (E).

The SHE analysis in the present study was used by following Hayek and Buzas (1997, 1998) to understand the species abundance distribution. The species abundance distributions are used to explain of community organization.

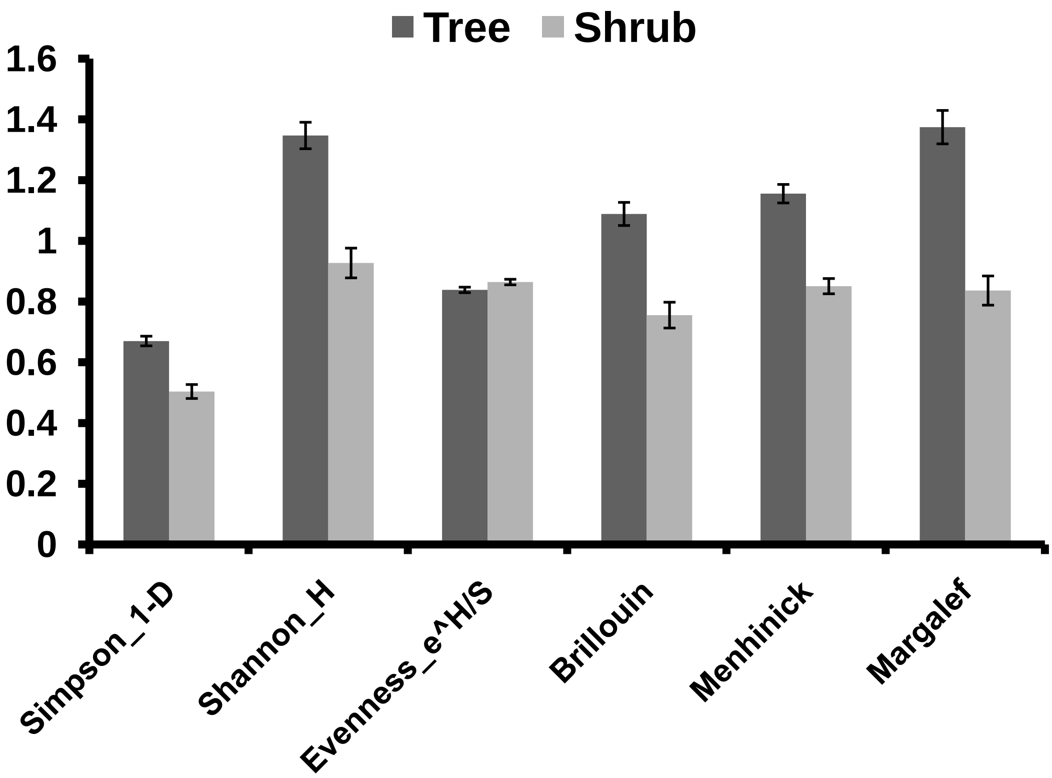


Figure 4.10. Figure showing different diversity index values for tree and shrub species at Dachigam National Park.

Tree species

The SHE analysis depicted that the decrease in evenness was accompanied by increase in species richness. The decrease in the evenness was coherent with the analogous increase in species richness, resulting in slight to no change in H` diversity with increasing samples size. This decreasing evenness suggests that added species tend to be relatively uncommon or rare, while cumulative Ln(E)/Ln(S) remained relatively constant in each sample indicating that each sample community will be best fit by log, normal species abundance distribution (Figure 4.11).

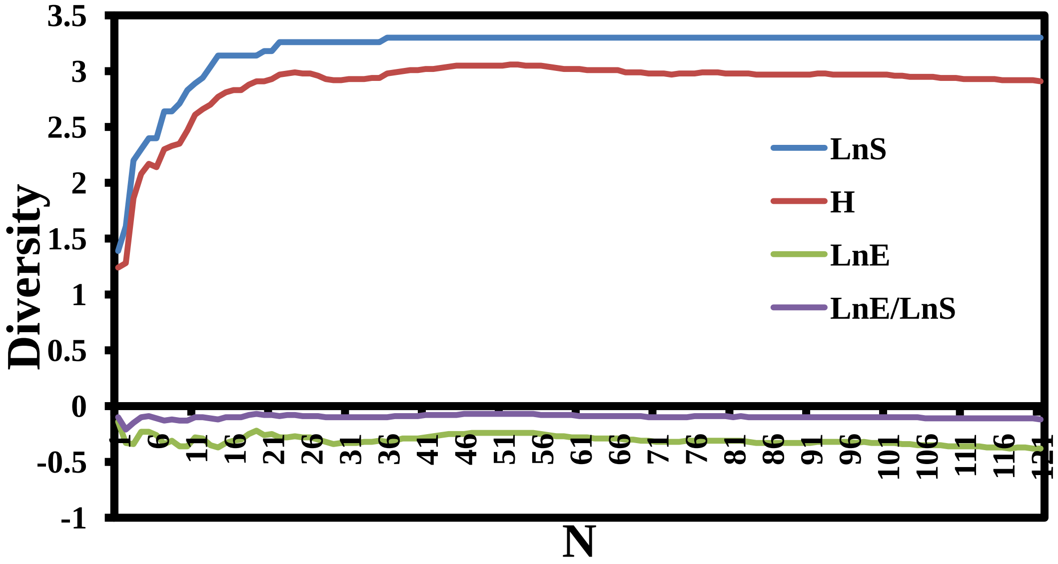


Figure 4.11. Figure showing relationship between diversity, richness and evenness recorded in sampling plots among the tree species using SHE analysis at Dachigam National Park, 2009-11

Shrub species

The shrub species plot data showed that both H` and the cumulative Ln(N)/Ln(S) diversity were coherent and increasing by increasing the number of samples. While Ln(N)/Ln(S) suggests that shrub distribution is sensitive to prediction. This constant evenness suggests that added species tend to be relatively common, and the constant evenness with comparison to increased H` value, predicts the distribution of shrub species expected to be more heterogeneous in distribution by addition of some species. The more or less constant H` and Ln(N)/Ln(S) with increasing number of samples indicates that the shrub species distribution in the study areas exhibits characteristics intermediate to Log normal, and log series abundance distribution which is also explained by Magurran (2004) that for the communities with small number of abundant samples (Figure 4.12).

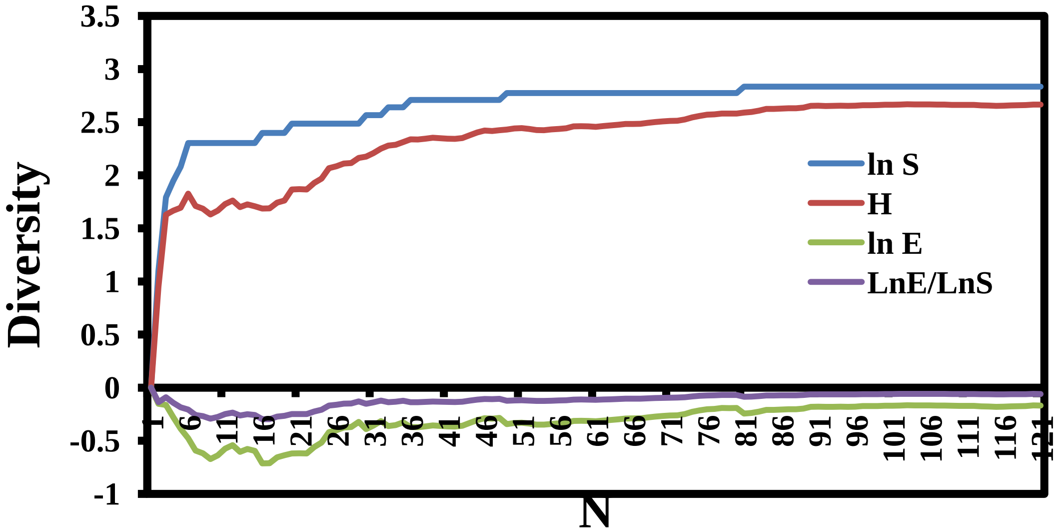


Figure 4.12. Figure showing relationship between diversity, richness and evenness recorded in sampling plots among the shrub species using SHE analysis at Dachigam National Park, 2007-11.

4.4.4. Landscape structure

Landscape fragmentation analysis in Dachigam landscape was based on four LULC classes: forest, non-forest vegetation, bare land, cropland, and water (Figure 4.4). Table 4.11 shows selected landscape indices used to understand the landscape structure. In the present analysis the results for forest cover type were used to infer forest fragmentation. The total area of forest cover was (229Km^2) which is 43.8 % of the landscape. However, the number of patches and the mean patch size are significantly different among the different types of land use and land cover types (*P*<0.005). In the landscape, the mean patch size of forest fragments was 755 m^2 and the number of forest patches was 3043 (Figure 4.13 and 4.14). The forest patch density was 0.58 patch/ km^2 in the landscape (Figure 4.15). The largest patch index does not depict these differences among the different types of forest types. Although there are large patches of forest, their number and size differ with respect to the landscapes. Certainly, human settlements configuration affects these results, since large forest patches were protected in the landscape. The mean distance among the forest patch was 53.0m. Higher patch density and core area density for forests also suggest a higher fragmentation and a better conservation of forest remnants in the landscape in the form of protected areas. Out of total forest area in the landscape about 9.3% classified as core forest and 34.5% as edge forest (Table 4.11). The fragmentation is represented by percentage forest coming under different classes which includes transitional class 3.1%, edge class forest 7.6 %, perforated class 15.5% and about 14.8% comes in interior forest (Figure 4.14). It is imperative to consider that forest fragmentation in the landscape, since in the present landscape large amount of area was indexed by edge area followed by core area which may affect the propagation of disturbances in the landscapes positively, thus indicating fragmentation in the primery forest of the landscape. The Shannon-Weiner diversity index value of the landscape was 1.5394 and the Simpson index value was 0.2644 (Figure 4.16).

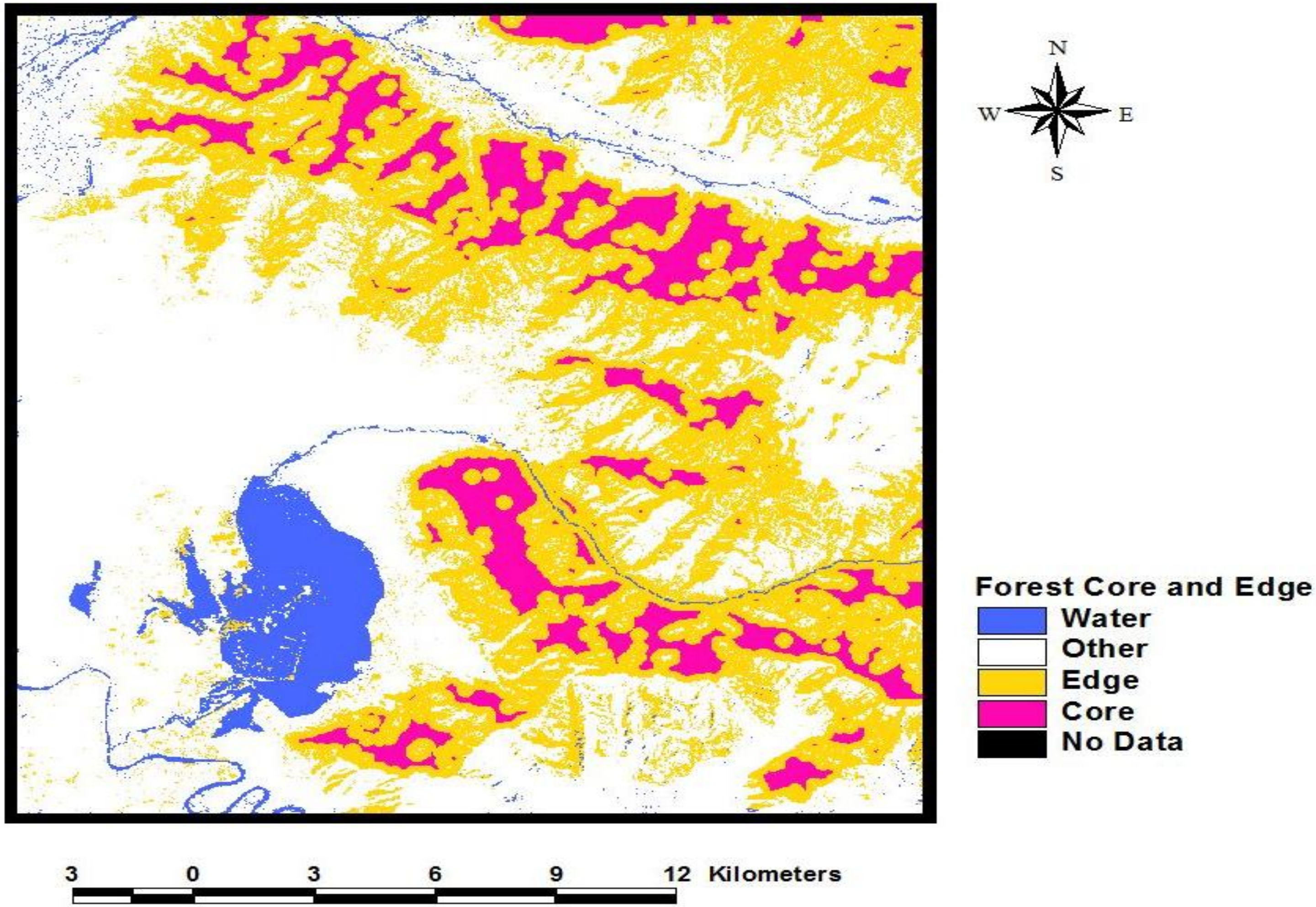


Figure 4.13. Map showing core forest areas, edge forest areas in Dachigam Landscape.

Table 4.11. List of landscape structure parameters that were used to characterize Dachigam Landscape.

ID	Unit	Details
AREA	556716154.5	Total area of the area of analysis (Dachigam Landscape)
LANDAREA	523912500	Total terrestrial area in the landscape
LC_OVERLAP	99.3	% overlap between reporting unit and land cover themes
N_INDEX	61.7	% of reporting unit that is all natural land use
N_INDEX_A	323901900	Area under natural land use
PFOR	43.8	Percentage landscape that is forest
PFOR_A	229780800	Total area of forest in the landscape
PSHRB	9.30	Percentage area under scrub land and grassland
PSHRB_A	48787200	Total area of scrubland and grassland
PNBAR	8.6	Percentage area barren or degraded forest
PNBAR_A	45333900	Total area of barren or degraded forest
U_INDEX	44.5	Percentage area under human land use
U_INDEX_A	233465400	Total area under human land use
PURB	35.2	Percentage area under urban land use
PURB_A	184678200	Total area of urban land use
PAGT	21.9	Percentage area under agriculture
PAGT_A	115111800	Total area of agriculture land
FNUMBER	3043	Number of forest patches in the landscape
FDENSITY	5.8	Forest patch density within the landscape
FLARGEST	191754000	Size of the largest forest patch in the landscape
FAVGSIZE	75500.3	Average size of forest patch in the landscape
F_PLGP	83.4	Proportion of largest forest patch to total forest area
F_MDCP	53.0	Mean distance among the forest patches
F_PWN	3043	Number of forest patches with neighboring forest in search radius
FEDGE210	34.5	Percentage of forest edge in the landscape
FCORE210	9.3	Percentage of forest as core forest
F_E2A210	78.7	Total ratio of forest edge to total area of landscape
PFF9	85.9	Average forest connectivity within the landscape
PFFPTCH9	2.6	Percentage of forest class patch in the landscape
PFFTRAN9	3.1	Percentage of landscape that is transitional forest
PFFEDGE9	7.6	Percentage of landscape that is edge forest class
PFFPERF9	15.5	Percentage of landscape that is perforated forest
PFFINTR9	14.8	Percentage of landscape that is interior forest
H	1.5394	Shannon-Weiner diversity
H_PRIME	0.8592	Standardized Shannon-Weiner diversity
C	0.2644	Simpson index

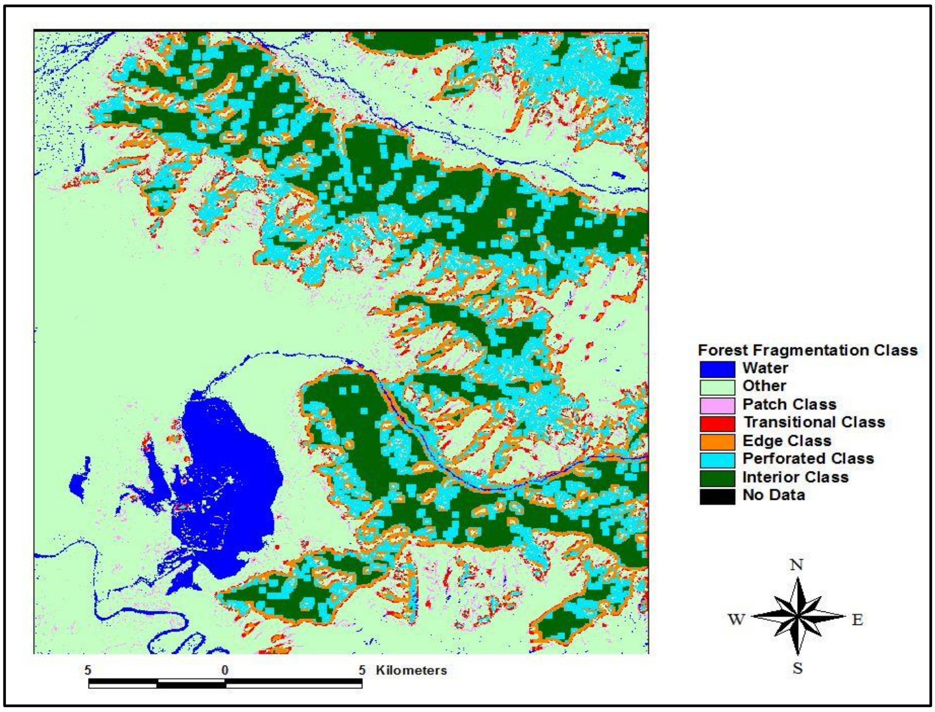


Figure 4.14. Map showing the forest fragmentation classes in Dachigam landscape, 2007-11.

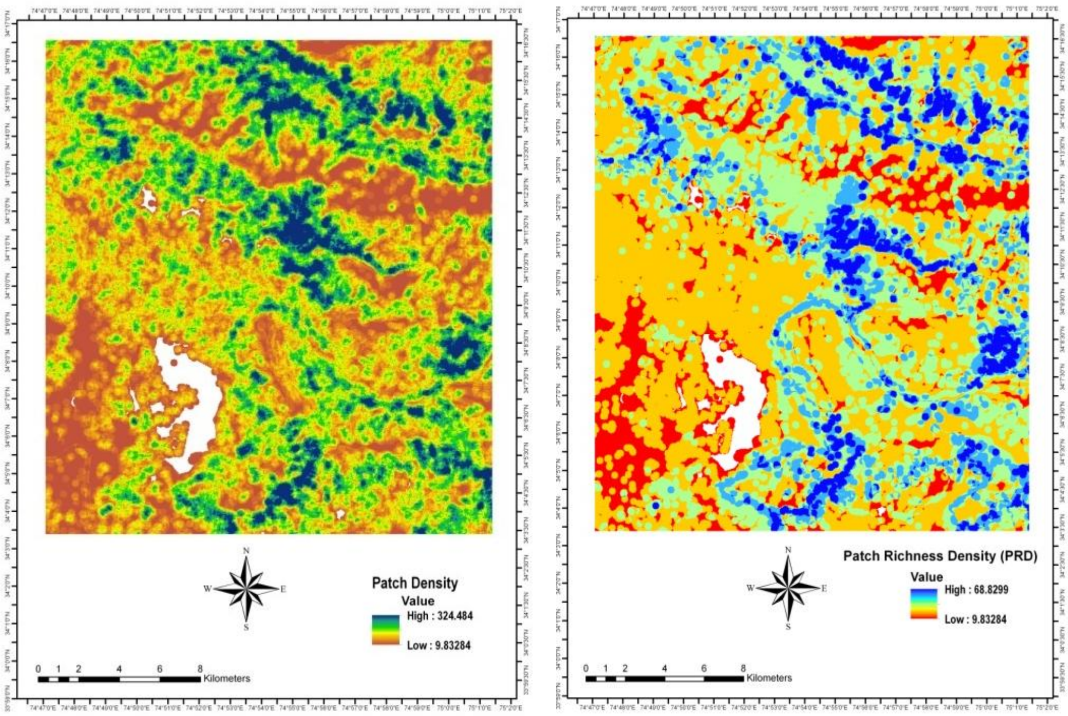


Figure 4.15. Maps showing the patch density (a) and the patch richness density (b) of different land cover types in Dachigam landscape, 2007-11.

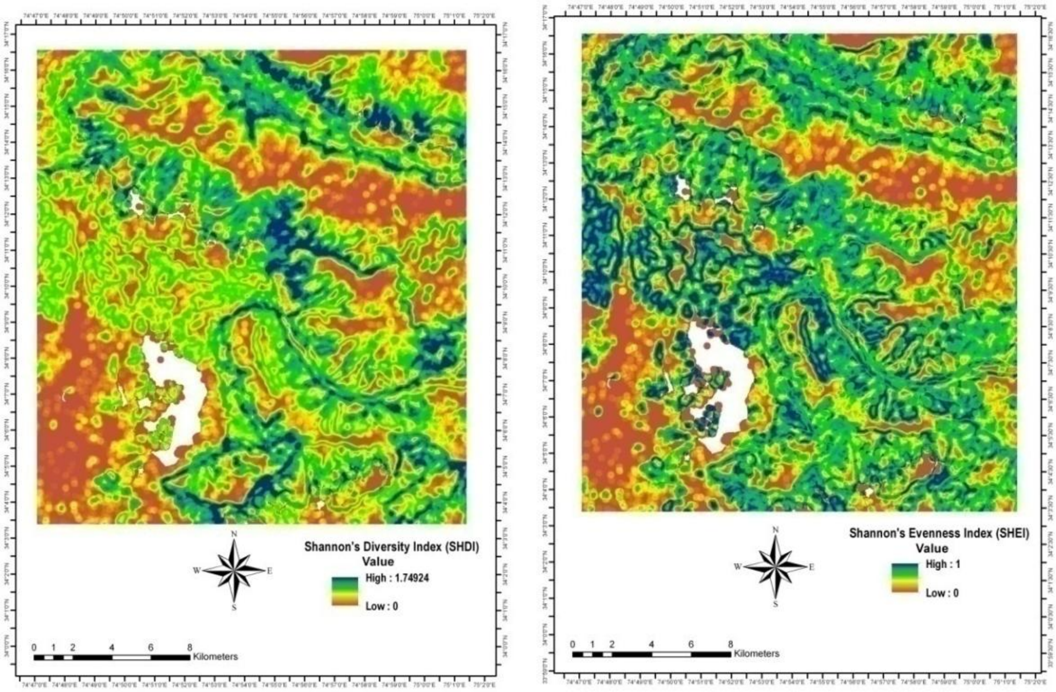


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Figure 4.16. Map showing Shannon's diversity index (a) and the Shannon's evenness index (b) in Dachigam Landscape, 2007-11.

4.5. Discussion

4.5.1. Land cover/ land use mapping

The mapping of land cover is done by adopting or developing a land cover classification system by delineating the areas of relative homogeneity after labeling those areas using categories defined by the classification system. The land cover characteristics in Dachigam landscape has changed in several primary forest and which consequently leading to fragmented land cover types. Land cover / land use types were identified and mapped in the intensive study area and showed significant variation in their floristic composition (Figure 4.4). The present study is the first attempt to classify the land use types in the lower Dachigam NP and no study is available to compare change in the landscape. However, the results can be compared with other similar study elsewhere on general architecture of the landscape. The spectral and spatial resolution of Landsat image allowed a detailed discrimination of land use/ land cover classes, even after considering the large thematic complexity of the study area. The hierarchical classification methods were found to be effective in classifying vegetation of many other areas (Singh et al. 2002).

The present study was the first study were landuse classification was carried out in this landscape and there were no LULC map was available for the comparison. However, the land use change deduction analysis will be helpful for the assessment of changes in the landscape composition.

4.5.2. Vegetation community structure in Dachigam National Park.

Dachigam NP is important as it holds the last viable population of Hangul and supports one of the largest populations of Asiatic black bear (Sathyakumar 2001). A total of 34 species of trees and 21 species of shrubs were recorded in the study area. The distribution of the woody vegetation was patchy in the landscape and was quantified along the environmental gradient. Whittaker (1956) and Smith and Huston (1989) stated that the distribution of vegetation is correlated with resources availability in the landscape. The TWINSPAN analysis was applied for general classification of tree and shrub species which divided into two major groups, which were further divided into six minor groups. Out of the six major plant communities identified in the study area the *Morus-Salix* community is mainly distributed close to water and was dominated by large number of fruit bearing woody plants and their widespread distribution can be related to seed dispersion by species such as black bear and langur. The *Ulmus-Rhus* community was named because of the highest density of *Ulmus* and *Rhus* species which were mostly distributed in flat and less steeper slopes or over the semi mountainous areas with individuals of *Aesculus indica*. Oak community was named due to the dominance of Oak tree and these trees were not reported from any other sampling plot in the landscape and were confined to a small patch which was planted in riverine habitat. The Pine community was wide spread because of its adaptability with different environmental conditions. Pine community was distributed on the south-east facing slopes in the valley. The community straucture analysis results indicated that the deleniation of community based on the sepecies occurance was difficult since the there were large number of species which were common among the coominities. The difference was marginal and thus not forming very distinct clusters (Figure 4.5). The vegetation in Dachigam has undergone several management interventions in the past, since it was inhabited by human population becore getting notified as the protected areas.

4.5.3. Land cover/ land use in Dachigam landscape and Vegetation composition

The land cover types classification was done primarily to understand the utilization patterns and selection by Asiatic black bear in the landscape. The classification keys used in the analysis were developed based on the community structure of woody plant species cover. The vegetation groups identified from the classification of the remotely sensed data resembles with the communities or vegetation classes derived from TWINSPAN analysis, agglomerative clustering and ordination analysis. In general, using multivariate and remote sensing techniques, for the classification of different vegetation groups of ecological importance is possible, although some results have showed the lower classification accuracies (Figure 4.4).

The Riverine forest is the largest forest type in the intensive study area which is dominated by tree species such as *Morus alba, Morus nigra, Salix babylonica Populus alba, Acer caesium, Juglans regia, Ulmas lavigata, Rhus sp., Corylus sp.* This forest is a succession vegetation type which is manly dictated by local climatic conditions. The riverine forest type runes all along the main Dachigam nallah and the high densities of fruiting species makes it very important for the species such as Asiatic black bear, Langur, and Hangul (Sharma et al. 2010). The density of fruiting tree and shrub species such as *Morus* spp., *Juglans regia*, *Rosa brunonii, Berberis* sp., *Roubinia* sp, was highest in riverine forest.

The low temperate pine mixed forest is distributed in the middle elevations of northern and north eastern slopes of the study area and *Pinus wallichiana* is the dominant tree species which sometimes reaches up to the open scrubs and forms patches. This forest type also support shrub species as *Vibernum continifolium, Berberis lycium, Rosa webbiana,* which were important food plant species of black bear in the landscape. The low temperate pine mixed forest is important to black bear since there were large number of den sights was located in this forest type.

The low temperate forest is composed of various tree species such as *Pinus wallichiana, Aesculus indica, Rhus* spp., *Lonicera quinquelocularis* the dominant shrub species were *Rosa webbiana, Rosa brunonii,* and *Berberis lycium.* This forest type is distributed between riverine and the mid-temperate forests and covering the north facing slopes starting from the Rajnar area in Dachigam block up to the Gratner in Phalipora block. This forest type supports many fruit bearing shrub species which were important food species and bears use this forest types largely dring late autumn and early winter to feed on Rosa species.

The Mid temperate mixed forest is distributed in mid altitude and is a mixed forest of woody plant species such as *Juglans regia, Aesculus indica, Rhus sp. Populus ciliata, Corylus colurna, Padus cornuta, Fraxinus sp., Taxus wallichiana*. This forest type is also rich in food plant species which support Asiatic black bear, Langur and Hangul.

Temperate grassland/scrubland are the vast starches of open lands particularly on slopes facing South – west between the elevation gradients of 1,800m to 2,700m. These open stretches are sparsely covered by thickets of broad leaved deciduous scrub comprising, *Parrotiopsis jacquemontiana, Prunus armeniaca, Celtis australis,* and *Ulmus sp.* This vegetation type has large number of zerophytic species as its undergrowth. These include *Indiofera heterantha, Rosa brunonii, Rosa webbiana, Lonicera quinqelocularis, Geranium nepalensis, Dipsacus mitis, Dactylis gloerate, Colochicum luteum, Stipa sibirica, Zizypus anathera, Fragaria verca, Kocleuria cristata*. The temperate grasslands were most preferred forest type of Hangul (Ahmad 2006).

Oak plantation is a plantation of white oak planted by Maharaja of Kashmir in early 60's. White oak is an exotic species now it has become one of the most important habitats for species such as Asiatic black bear, Hangul. Oak plantation is a small patch in riverine forest with around 18 hectare area. During field investigation, fairly large numbers of black bears were sighted in this patch foraging of oak acorns. The Oak plantation in Dachigam is the single one plantation of Oak tree in Kashmir valley except two-three trees in some areas far from Dachigam. Our radio-collaing study revealed that Dachigam bears feed exensively on oak acorns and congregated in large groups during autumn (see chapter no.6).

In Dachigam the non-forest area is composed of rocky clefts and water bodies and was distributed in isolated patches homogenously in the entire intensive area. The rocky clefts were important for many animal species as they provide refuge in the form of den sights or resting sights for black bear and leopards (Sharma et al. 2011). Inside Dachigam there were large number of water bodies which comprises of main Dachigam Nallah followed by many perennial water streams and there were many small annual water streams which are covered by dense forest cover on both the sides and were not mapped since it was difficult to distinguishing as the image used for the analysis was of 23.5m resolution.

4.5.4. Diversity patterns of plant species in Dachigam National Park

Out of 65 families that represented the flora of Dachigam NP the most of the species belongs to Rosaceae, Ranunculaceae, Salicaceae, Asteraceae families. The high abundance of species belonging to Rosaceae families which are important for the survival of black bear as they are mostly fruit bearing plant species. Large number of bear food plants species belong to the Rosaceae and Ranunculaceae relecting the species composition of the area. High species diversity will help the species for the survival in adverse conditions or during low productivity years. Studies stated that the climate change is affecting the phenological patterns of species in Himalayas (Rawal et al. 1991). The change in phenological availability of food items can adversely affects the behavior of bear and most likely it can lead to the changes in the physiological needs of bear during the different life history phases. The analysis of the estimated species richness for the plant diversity support the fact that there would be some unrecorded species exists in the area (Table 4.10). Therefore it is advisable to carryout intensive sampling on both temporal and spatial scale which may result in better understanding of the plant community and diversity patterns in the area.

4.5.4.1. Distribution

The distribution of the plant species in the present study was evaluated at both the community and species level. Since complete community analysis assess whether individual species distribution was random with respect to each other, or aggregated together or the dispersion of species was aggregated in different samples (Magurran 2004). In the present study the distribution of tree and shrub species at individual level have showed good fit to lognormal distribution. The results of the analysis showed that the distribution of total sample and with respect to each other was found to be aggregated. The large number of studies on the plant assemblages exhibited log normal distribution patterns of species abundance (May 1975, Longino et al. 2002) and many of such log normal distributions can be described as canonical. As the log normal distribution is a consequence of the central limiting theorem, which states that when a large number of factors act to determine the amount of a variable, random variation in those factors will result in the variable being normally distributed (May, 1975). Here the variable is the number of individuals per species (log transformed) and the determining factors are all the processes that govern community ecology (Figure 4.9).

The heterogeneity in the species dispersion concluded to be discordant following Chi-square analysis (Sokal and Roulf 1981) (Table 4.9). In the present study Chi-square tests were used to measure patchiness in species populations or in entire communities (i.e. the distribution of organism through the samples was random, aggregated or uniformly distributed). The abundance patterns in communities can be examined by number of individuals per species to create a frequency distribution and such patterns of species in communities have some predictability. As most of the species (common) in a community tend to have intermediate abundance levels where as few species have high abundance (extremely common) and low abundance level (few or rare). The samples of this distribution fit the predicted patterns with an increased number of sample collections the distribution of abundance can be described by a lognormal curve (Preston 1948). The distribution of plants is affected by a wide variety of environmental and biotic factors. However the ultimate deterministic pattern of vegetation distributions according to Brown (1994) is related with the variation in the physical environment.

4.5.4.2. Richness

The observed species richness for tree species in 121 plots was 27 and accounted for 2951 individuals. The Jackknife 1, 2 and Chao 2 estimated were same in the intensive study area (Table 4.10). The species richness estimated of Chao 1 was very high and were not reliable, because the area of lower part of the Dachigam was inhibited by 10 villages historically and in many parts of the area large number of plantation was carried out during colonial rule in India by the maharaja of Kashmir. The flora of Kashmir valley and the upper part of Dachigam NP is very rich in plant biodiversity and was comparatively less disturbed in comparison to lower part of Dachigam NP. As Chao 1 estimate is considered to be very sensitive to random and patchy distribution, here the estimates of Chao 1 should not be used for the prediction on tree species richness in disturbed area (Magurran 2004). The estimates of jackknife 1 were close to observed richness. In case of shrubs the estimates of Chao 1 were again not reliable 21 species whereas, the estimate of Chao 2, and jackknife 1, 2 were reliable as the estimate was 17 species which was same for all estimators (Table.4.10). The results of all species richness estimators were same except Chao 1 as its limitation and sensitivity to singletons (number of species which occur only once in a single sampling plot). The occurrence of singletons was much then doubletons (number of species which occur only twice in a single sampling plot). Considering the effectiveness and the reliability the Chao 2 estimates were considered to assess the species richness in Dachigam NP.

4.5.4.3. Diversity and Evenness

The Beta diversity used here is used to compare responsiveness of different groups of flora to landscape and environmental changes in a sample (Greigh-Smith 1983; Mc Cune and Antos1981). The results of the analysis for the beta diversity in the present study showed that the overall species composition differed between sampling plots. This difference may be due to variations in the site conditions associated with topographic aspects. The SHE analysis for the tree species showed that evenness was negative correlated with species richness whereas, the cumulative Ln(E)/Ln(S) remained relatively constant in each sample, indicating that each sample community will be best fit by log normal species abundance distribution (Figure 4.11 and 4.12). The assemblage of tree species indicates no to very less disturbance in the habitats as it may depart from the log normal distribution at community level in the presence of disturbance (Magurran 2004). The sample size is a critical consideration in the assessment of richness, evenness, and diversity patterns for spatially and temporally variable communities such as herbaceous forest understories (Small and McCarthy 2002). The diversity and the cumulative diversity for shrub species were found to be increasing with increasing the sample size whereas, the evenness was constant (Figure 4.12). The combatively increased H` value indicated the distribution of shrub species was expected to be more heterogeneous in distribution by addition of some more species. This pattern indicates that the shrub species distribution exhibits characteristics intermediate to Log normal and log series abundance distribution and the present findings has corroborated the view of Magurran (2004) since the distribution of species possess characteristics intermediate to log normal and log series abundance for the communities with small number of species abundant samples.

4.5.5. Dachigam landscape structure and fragmentation analysis

The Dachigam landscape was represented by large number of patch which indicates fragmentation. Higher patch density and core area density for forests also suggest a higher fragmentation and a better conservation of forest remnants in the landscape in the form of protected areas (Table 4.11). The total edge and the edge density were high because edges were longer for all classes, except for water (Figure 4.13). Depending on the LULC class adjacent to the forest patches, different effects may be observed in terms of ecological processes. For example, if the forest patch borders degraded forest/ barren land, this fragment may become more susceptible to disturbances in its structure and composition. Conversely, if the forest is adjacent to a cropland/ orchard (non-forest vegetation), secondary succession may be accelerated. Studies based on field data collection and further analyses are being carried out to address these relationships in both colonization areas. The relative importance of edge lengths and area of patch types is given by the landscape shape index. The results also highlight the complexity of Dachigam landscape, marked by large elongated patches (Figure 4.14). The Mean nearest neighbor distances between the forest patches was 5.8m, suggesting important similarities between the settlements in terms of the isolation of forest fragments (Table 4.11). In this case, the use of a more detailed classification may also change the neighborhood relationships. The interpretation of these findings will contribute to the evaluation of different models of rural settlement in the Dachigam landscape, assisting in the landscape planning for the conservation of large ranging animals such as black bear and leopard in the landscape. In this sense, this part of the chapter represents a preliminary scheme based on the use of integrative analytic methods. Studies on vegetation structure and composition, LULC history and institutional arrangements may also bring important elements for the better landscape planning in the Dachigam landscape and such type of study can help in the landscape planning in the areas of Kashmir valley which are of conservation importance.

The results of the landscape structure analysis indicated that the fragmentation was not very high in Dachigam landscape. The changing land use in the landscape was a major threat for the wildlife populations. It is suggestive that future change deduction analysis of the landscape will help in better understanding of the landscape fragmentation. Previous researchers have demonstrated that there are thresholds of fragmentation with respect to the tolerance of a species (Jaeger and Holderegger

2005). The simulation model used in other studies has suggested that the population's chances of survival depend on the number of roads and other developmental activities in the landscape. In the present landscape unorganized development of roads and other human settlements in the landscape will affect the population of black bear in the landscape (Hellgren and Maehr 1992). The effects of the road and other human developments of the movement patterns of black bear were discussed in chapter no.5.

4.6. Summary of major findings

1). About 42% of the total area of analysis was covered by forest that comprised of four major forest types viz., conifer forest, broadleaf mixed forest, riverine forest and temperate grassland/scrubland.

2). Using TWINSPAN analysis, six plant communities were identified viz., *Morus-Prunus, Pinus-Ulmus, Parrotiopsis-Salix, Aesculus-Rhus*, Oak plantation and the *Posa-Rubus* communities.

3). The vegetation environment relationship was assessed using CCA and the results depicted that disturbance and topological variables were the major environmental factors behind the ordination of the species.

4). The vegetation of lower Dachigam is represented by 34 (27 in intensive study area) species of tree, 21 shrub, 96 herbs and eight climber species and their distribution was aggregate both in total samples and with respect to each other. The distribution pattern of tree and shrub species did not varied significantly and no independent heterogeneity was observed.

5). The SHE analysis for tree species depicted that the decrease in evenness was accompanied by increase in richness with slight to no changes in diversity with increasing sample size. However, in case of shrubs, diversity and the cumulative diversity were found to be increasing in relation to the number of samples and the distribution of species exhibits characteristics intermediate to log normal and log series abundance distribution.

6). Large number of forest patches suggested fragmentation in forest and the configuration of human settlements in the landscape certainly affected the architecture of the study area. Dachigam landscape still holds good amount of forest connectivity in the form of interior forest and perforation class.

7) The detailed classification of high resolution imagery will help in better understanding of the landscape fragmentation and the change deduction analysis will bring the clear picture of land use changes in the landscape. The results of the study would help in better landscape planning and prioritization.

CHAPTER - 5: ASIATIC BLACK BEAR HOME RANGE, MOVEMENT AND RANGING PATTERNS IN DACHIGAM LANDSCAPE

5.1. Introduction

The information of the ecology of black bear is scanty in India (Servheen 1990). Even basic information such as presence- absence does not exist for many areas in the distributional range (Sathyakumar 2001). The Kashmir valley has an interspersion of forests, orchards, croplands and human habitations, making it a region that is vulnerable to black bear-human interactions. Such interactions have been reported to be increasing in the recent past and making wildlife management a challenging task (Charoo et al. 2011). In order to understand and mitigate black bear-human interactions in this landscape, it is necessary to have an understanding of resource utilization patterns by the black bear. Due to black bear's shaggy black coat, cryptic behavior, and ability to cover large distances for foraging, makes it difficult to monitor individuals that are not individually identifiable or marked. Therefore, radio telemetry is an extremely important tool for gathering scientific information on animal behavior, movement and ranging patterns (Fancy et al. 1988).

The home range of the animals was analyzed since the earliest of hunting cultures where the hunters first started to track animals for the hunting interest (Laver 2005a). But today, the understanding of the home range size of an animal have become central for the conservation and management of the species in consideration and which is resulting in the improvement and more sophistication of the home range analysis technique as well as methods.

Burt (1943) defined home range as the area traversed by an animal in its normal activities of food gathering, mating, and caring for young ones. Estimating home range of an animal gives insights into animal behavior and ecology, and it is necessary to quantify home range and the core area of activity of the target species. However, we must keep in mind that the home range boundaries and the area are imprecise, at least in part, because the boundaries are probably imprecise to the animals themselves. Knowledge about the home ranges contributes both management and ecological questions, such as assessing how much space or habitat is required for a species, ecological information on mortality, reproduction behavior, dispersal, and hibernation period of a species such as the Asiatic black bear.

Today, the home ranges are also used to delineate the protected area boundary which is important for the protection of the imperil species which is very commonly used practice (e.g., it is a legal mandate for the protected area management in USA). Hence, understanding of the spatial requirement of a species is important for the protection and also in the management of species involved in conflict (Laver 2005).

5.1.1. Selection of home range method and the software program to estimate home range size of black bear.

The animal space utilization pattern by an animal in a given area represents the home range of animal used for survival (Fuller et al. 2005). The home range analysis of an animal is necessary for the several reasons among which the space utilization pattern is central which provide the basic information of the animal relation to heterogeneous spatial landscape. Studies on American black bear and other proved the importance of home range analysis (Jonkel and Cowan 1971; Smith and Pelton 1990). For studying the home range of an animal, many methods have been developed with the advancement of computer science and human capability of interpretation of ecological information, using the mathematical formula and statistical hypothesis (Harris et al. 1990; Lawson and Rodgers 1997; Powell 2000; Laver and Kelly 2008). The minimum convex polygon (MCP) (Mohr 1947) is the most commonly used method in home range analysis followed by Kernel density analysis methods (Worton 1989). The MCP methods do not consider the varied use of space by an animal in the minimum convex polygon but it forms the polygon, by joining the outer most location travelled by an animal, that is the another reason makes the MCP most popular method among the researchers. The MCP method is highly sensitive to the number of locations and the outliers (Harris et al. 1990; Samuel and Fuller 1996; Barg et al. 2005; Horne and Garton 2006a).Where as the kernel method consider the utilization patterns of the habitat enclosed in the home range by using the probability utilization function with varied level of preference or concentrated use by animal. Today, the development of most sophisticated approaches for the home range analysis methods encourage the researchers to select a method that best explains the behavior and ecology of an animal. These methods included two types: a) parametric or hypothesis-driven: uni- and multi-modal techniques, circular normal, bivariate normal or exponential power functions (Horne and Garton 2006a), and the non-parametric methods include two types of kernel density analysis: fixed and adaptive kernel which consider the grid cell overlap or the probability kernels that indicate the likelihood of a location being used by an animal (Worton 1989; Horne and Garton 2006a).

The home range method can greatly affect the home range size of an animal so selecting an appropriate home range analysis method is critical for precise estimation of home range and utilization distribution of an animal. Horne and Garton (2006b) suggested using likelihood-based method evaluation based on information-theoretic criteria such as Akaike's information criterion (AIC) and the likelihood Cross-validation criterion (CVC). While selection of the model one should consider the behavioral aspect and the observed space used by an animal (Wang et al. 2012). For the selection of the best model for the home range analysis sixe models were compared out of which four were parametric and two were non-parametric. The model with lowest AIC and CVC values was considered the best model for home range size estimation of black bear in Dachigam landscape.

Home range analysis of an animal is remains' central in the conservation and management planning. With the advancement of computer science and human understanding of animal behavior, encouraged the researchers for the development of new and advance methods of home range analysis. Researchers studied the movement and ranging patterns of animal by radio-tracking or other means, where they obtain a series of estimated geographic locations of animal movement then they desire to estimate one or more parameters related to the home ranges to answer the question where and the animal travels (Burt 1943). The spatial patterns of movement are fundamental to the ecology of animal populations, influencing their social organization, mating system, demography, and the spatial distribution of prey and competitors. However, our ability to understand the ecology of an animal and to generate information on parameters related to the animal space use has been limited by the descriptive nature of the statistical models, used to analyze them. As a need to analyze and understand the spatial patterns which an animal or a population of a species possess, various researchers have developed statistical methods and software programs. Due to the advancement of computer science and mathematical simulation ability of human is leading to the development of new models and software programs. A variety of techniques and software programs are available to understand the home range of an animal and the determine patterns of use within the home range (Harris et al. 1990; White and Garrot 1990). In the present study, some of the most recent home range analysis software programs were reviewed which will help researchers in selection the most appropriate home range program to estimate the most robust home range and other parameters related to the home range size of an animal. Previously Larken and Hakin (1994) summarized the functionality, user interfaces and other characteristics of 11 software programs that were available during their review time. Olfenbuttel (2005) compared the three add-in programs such as Animal Movement Extension (AMA) developed by Hooge et al. (1999), Home Range Extension (HRE) developed by Rodgers and Car (1998) and ABODE developed by Laver (2005), which were designed to work in either ArcView 3.2 and ArcGIS 8x or higher. However, few studies have addressed the possibility of home range size difference estimates based on the software programs, some users of these program suspect that they are unlikely to produce similar and comparable results, even if the values of the parameters where kept same for all of the programs (Lawson and Rodgers 1997). Lawson and Rodgers (1997) addressed the differences in home range size computed by 4 software programs (CALHOME, RANGES IV, RANGES V, and TRACKER). They found large differences in the reported home range sizes using several home range estimators computed by the differing software programs, and concluded that comparisons of home range size and habitat use of a particular species among research studies could be misleading because of software program used. Since then no detailed review is available where researcher have compared the home range (Kernel) estimates.

The information generated using software programs such as home range size, habitat selection were used for the conservation and management planning. By understanding relationship between black bears and their habits, limiting factors and effective decisions can be made regarding habitat protection and management on the landscape basis. So it is vital to estimate the home range of black bear more precisely and for which it is imperative that we should use methods that are biologically appropriate and most accurately quantify an animal’s space utilization pattern. In the present study the radio-telemetry locations of Asiatic black bear were used to examine how closely home ranges estimates corresponds between several programs of home range analysis. It was not clear that which method or software is best for the home range analysis of black bear. Thus, the study was designed to evaluate software program such as Biotas 2.0, AMA, HRE, ABODE, Animal Space Use 1.3beta, HOMERANGE, GME (Geospatial Modeling Environment) which were programmed to work on Microsoft Operating Systems and were having easy user-friendly interface. Though we were aware of other packages that were not tested in the present study since, most of them do not passes the criteria and functions which were used for comparison and the analysis for example: - CALHOME, Kernel HR 4.27, Hawth's tool and adehabitat package for R-software.

5.1.2. Home range and ranging patterns analysis of black bear in Dachigam landscape

Many studies on American black bear described the home range size, space use type and most importantly the factor's associated with the space use of black bear (Elowe 1984; Garshelis and Pelton 1981; Horner and Powell 1990; Smith and Pelton 1990; Powell et al. 1997). There can be many factors which play role in the delineation of the home range size of a species. One of the most important factors affecting the animal space use is the tendency for most animals to confine their activities to a particular area of home range (Burt 1943). Within a home range, many animals prefer certain habitat and avoid other habitat which is attributed by the habitat composition, availability of food resources, vegetation structure and the topology of the terrain (Morrison et al. 1998; Horne et al. 2008). Earlier studies documented the effect of factors such food availability, distribution (Jonkel and Cowan 1971; Amstrup and Beecham 1976; Rogers 1977; Young and Ruff 1982; Powell 1987; Hellgren 1988; Smith and Pelton 1990), sex, age (Reynolds and Beecham 1980; Garshelis and Pelton 1981; Hellgren 1988) kinship (Jonkel and Cowan 1971; Lindzey and Meslow 1977; Garshelis and Pelton 1981), social behavior (Jonkel and Cowan 1971; Lindzey and Meslow 1977), and reproductive status (Hellgren 1988) of black bear on the home range size, movement, and territorial behavior. Smith and Pelton (1990) suggested home range size and the degree of territoriality is an indicator of habitat quality. Further, Amstrup and Beecham (1976) suggested the regional variation in home range size may be explained by the quantity, quality and distribution of food as influenced by climate and topography. Studies on home range overlap of black bear suggests that the extensive home range overlap in black bear was observed in areas where food availability is high (Garshelis and Pelton 1981; Garner 1986; Powell 1987; Hellgren

1988; Smith and Pelton 1990) and minimal overlap was observed in areas where food availability was low (Jonkel and Cowan 1971; Rogers 1976; Young and Ruff 1982; Powell 1987). The degree of home range overlap is quite variable among and between sexes of black bears in North America. Many studies reported extensive home range overlap among male bears and between male and female bears, but the degree of home range overlap among female bears is variable. Reynolds and Beecham (1980) attributed home range overlap in Idaho to patchy and unpredictable distribution of food.

The home range sizes of adult male American black bears (*Ursus americanus*) are usually much larger than those of adult females (Jonkel and Cowan 1971; Reynolds and Beecham 1980; Young and Roof 1982). Amstrup and Beecham (1976) argued that adult males can increase their reproductive potential by using areas that encompass the home ranges of several breeding adult females, which leads to the use of large areas that cannot be defended as territories.

Prior to the present study home range size of Asiatic black bear was studies in China (Reid et al. 1991; Trent 2010), Japan (Ohsako 1995) and Taiwan (Hwang et al. 2010). This is first study in India where movement and ranging pattern of Asiatic black bear was evaluated. Radio-collars were fitted on seven black bears to understand the aspects of spatial ecology in heterogeneous landscape of Dachigam in central Kashmir.

5.1.3. Movement patterns of black bear in Dachigam landscape.

The movement pattern of is a critically important phenomenon of an animal and survival strategy, which promotes habitat selection, gene flow, population abundance and describes the distribution boundary of a species (Weber 1987; Turnchin 1998; Franke et al. 2004; Epps et al. 2005; Fahrig and Rytwinski 2009). The movement path selected by an animal can explains the spatial response and how an animal interacts with its environment (Dickson et al. 2005; Whittington et al. 2005). Therefore, studying movement patterns of a species allows us to quantify how spatial environmental patterns affect organism behaviors. Large numbers of studies are available where researchers have studied the movement patterns of American black bear (Glenn and miller 1980; Young and Ruff 1982; Rogers et al. 1987; Maehr et al. 1988; Stratman et al. 2001) and there were very few studies where researchers have studied the movement patterns of Asiatic black bear (Sakamoto et al. 2009). Studies linking fine-scale movement behavior to habitat quality have generally measured movement behavior either in terms of path complexity or the permeability of non black bear habitats (Young and Ruff 1982; Brody and Pelton 1988; Roever et al. 2010). The movement path selection of an animal is influenced by many factors which include foraging behavior, habitat quality, habitat complexity, disturbance factors and the various life history stages (Weins et al. 1995; Crist et al. 1992; Etzenhouser et al. 1998; Schultz 1998; Schultz and Crone 2001; Roever et al. 2010). Number of studies are available where researchers have studied the permeability of forest gaps, impact of roads on the movement of American black bear and Grizzly bear and suggested that forest gaps in the forms of island human habitation, crop lands, roads, etc. impede the movement patterns of an species (McLellan and Shackleton 1988; Spellerberg 1998; Dyer et al. 2001; Gibeau 2000; Waller and Servheen 2005; Roever et al. 2010). The most recent advancement in habitat selection studies is studying the step selection function (SSF) of an species which allow us to study the factors which can impede the movement and there relative impact on the step selection function (Fortin et al. 2005; Coulon et al. 2008; Roever et al. 2010). The landscape in Dachigam is mountainous and is a mosaic of protected areas and human habitation where black bear are depredating on horticulture crops and livestock. In this landscape local peoples and animals were sharing landscape which is leading to large number of black bear – human interactions (Charoo et al. 2011). The black bear in the landscape were negotiating the island human habitations in forest areas and such forest gaps can highly effect the movements of black bear between the forest patches and such kind of effects were also documented by large number of studies on bear species and other large carnivores (Brody and Pelton 1988; Clevenger and Waltho 2000; Hood and Parker 2001; Gibeau. 2000; Nielsen et al. 2004; Dickson et al. 2005). In the present study the effect of various habitat factors on movement path selection of black bear was assessed at different spatial scales.

5.2. Methods

5.2.1. Trapping and radio collaring of Asiatic black bear

Asiatic black bears were trapped during 2009-2010 using Culvert traps (Johnson and Pelton 1980). The captured bears were chemically immobilized using Ketamine/Rompun (Ketamine hydrochloride + Xylazine hydrochloride). After sedating the bears, morphometric measurements, reproductive status, and overall condition of the animal were recorded. Blood and hair samples were collected from each bear and preserved for the genetic analysis. The zygomatric arch of the sedated bears was measured and the collars fitted accordingly to minimize collar drop offs (D. Garshelis, *pers. comm.* 2009). The radio collars were fitted to allow the natural growth of animal. The collared animals were also ear tagged using standard plastic color coded ear tags for identification. The collared animals were released in wild after natural reflexes and behavior returned. Black bears were radio-collared using TGW-4780H fourth generation store on board GPS subsystem which includes a GPS receiver, uGPSi controller/data logger and a VHF (Very high frequency) transmitter beacon with VHF and Argos frequency (151.00–151.10 MHz, and 401.630 – 401.640 MHz) supplied by M/s TELONICS, USA (Plate 3.2).

5.2.2. Radio-tracking of collared animals:-Ground and satellite radio tracking

Initially the GPS collars were programmed to store GPS fix after every five hours (on a roll over basis) but later few collar were reprogrammed to record GPS location within a interval of one hour and disseminate of these GPS locations to satellite data after a period of 7 days at 1300UTC. The satellite collars determine GPS location using Doppler shift methods through Argos satellite systems and were using Argos system to disseminate GPS locations and the collar were equipped with on board systems memory to store data with the option of remote transmission to hand held data logger. The satellite overpass was

The results of the camera trap data indicated that the bears were more active during the crepuscular time and coincide with the satellite overpass on the study area. The longest duration of satellite overpass on the study area matches with the activity period of black bear i.e., 1300 UTC in the evening at this time black bear were most active (Sharma et al. 2011). The expected average time to fix for data dissemination was kept at 90 sec initially and later on 80 sec to satellite at different uplinking times to get high through output. The transmission power of the used collars was 800mW.

The radio-collared black bears were tracked with the help of hand held directional S-element H- or Yagi directional antennae as per convenience and TR-4 receivers (TELONICS, USA). Telemetry was conducted during day-light hours only. An attempt was made to locate all radio collared bear 2 to 3 times a week. The ground telemetry locations were supplemented with satellite locations. The satellite collars have not performed as per the expectation and resulted with 10-15% of the total number of GPS locations expected as per the programming. Initially the ground telemetry locations were estimated by triangulation from 2 to 3 fixed points along roads/trail and from the vantage points in the study area but later on homing (White and Garrot 1990) of the animals was performed at most of the time triangulation was not possible in Dachigam landscape (signal bounce was the problem in valley areas of Dachigam). For the triangulation the Andrew's maximum likelihood estimator for 3 or more bearing (Lenth 1981; White and Garrot 1990) was followed. The locations calculated visually in this manner contain certain marginal error (Springer 1979; White and Garrot 1990) and it was necessary to calculate the error in locations because the location error affects the LSCV (Least Square Cross Validation) estimates in kernel home range analysis. The location accuracy was tested before and after deployment of collars on animals and location error was calculated by comparing the GPS locations of collar with the placed at known points in the study area (den sites , fruiting patch). The average error for ground telemetry was 190m and the locations which were having high error were not used in the analysis. The data collected from Argos and the VHF tracking was used to generate home range and to understand the movement patterns of collared animals.

5.2.3. Selection of best Utilization distribution based home range analysis model

To select the best home range analysis method data of seven radio-collar black bear in Dachigam landscape during 2009-11. The radio collar data analyzed using the program Animal Space Use 1.3 Beta (Horne and Garton 2006a). The home range was calculated using six home range models: bivariate normal, two-mode bivariate circular normal, two-mode bivariate, bivariate exponential power, adaptive kernel and fixed kernel; the first four models were parametric and the last two were non-parametric method. The parameters for parametric models were estimated by using maximum likelihood the simplex algorithm (Horne and Garton 2006a). For the kernel models smoothing parameter were decided as per the Horne and Garton (2006a). To evaluate the relative performance of all the six models an information-theoretic approach was used. In case of parametric models we calculated the second order Akaike's information criterion (AIC_c; Akaike 1973; Burnham and Anderson 1998), where the relative support for model *j* is determined by the differences (Δ AIC_j) in

AIC_c between model *j* and the model with the lowest AIC_c. Apart from AIC_c all models were also compared using the likelihood cross-validation method, which hold backs the one sample each time, constructs the model with the remaining data and then evaluates the fit of the model at the hold back location. Similar to AIC, the relative support for model *j* is determined by the difference ($\Delta\ CVC_j$) in CVC between models *j* and the model with the lowest CVC. The AIC_c can only be applied to parametric model but the CVC criteria can be used in both of the cases parametric and non-parametric models (Horne and Garton 2006b).

5.2.4. Comparison of different home range analysis software program and selection of best home range estimation software for the home range analysis of black bear in Dachigam landscape.

For the comparison of different software the best utilization distribution based model of home range analysis based on the present study and which is available in all of the software programs selected for comparison. The published studies advocated the use of fixed kernel method over adaptive kernel because the *h* value is remain same in the entire home range where the adaptive *h* value varies which over estimates the home range size (Seaman and Powell 1996). The 95%, 75% and the 50% contour were generated as these three levels were commonly used in the home range analysis studies (literature review) and so the finding will have greater applicability. The smoothing parameters for the kernel analysis were *ad hoc* LSCV and LSCV while using AMA program, in case of Home range extension (HRE) BCV was used as the smoothing parameter, where as in ABODE, Biotos2.0, HOMERANGE, Animal Space Use 1.3beta, GME software program LSCV as smoothing parameter for the home range analysis of black bear. In addition to kernel analysis Minimum Convex Polygon (MCP) was also used though it tends to be sensitive to sample size and the outliers (extreme) data point (Samuel and Fuller 1996). The software programs used for the comparison were: Biotas 2.0, AMA (Animal Movement Analysis in ArcView 3.2), HRE (Home Range Extension of ArcGIS 9.X), ABODE (ArcGIS 9. X), Animal Space Use 1.3beta, HOMERANGE, GME (Exe run standalone but uses the R-software modules and ArcGIS 10.X environment for the execution of commands). For the comparison of the home range estimates produced by different software program one-way ANOVA in excel was used to test the difference in the home range size among the estimators. A part from the home range size the effect of programs was also used to evaluate the mean shape index of home range generated by these software's for all the seven black bears in the landscape (McGarigal and Marks 1995). The shape index was calculated as the home range perimeter divided by the square root of its area adjusted for circular standard and the analysis was done by using the Patch Analyst extension (Rempel et al. 2008) in ArcGIS 9.x software.

5.2.5. Movement patterns analysis of black bear

The movement pattern analysis was carried out by radio-collar as well as genetic data. This chapter deals with the radio-collar data whereas, the DNA based movement patterns were presented in separate chapter 7 where genetic tracking analysis was presented.

5.2.5.1. Radio telemetry based analysis

Seven GPS collared bears were monitored in Dachigam landscape to study their daily, seasonal and annual movements following methods suggested by Armstrup et al. (2001), Blanchard (1987) and Fancy et al. (1988). The daily and seasonal movement patterns of black bears in relation to food availability was studied at and around the Dachigam NP by adopting techniques, suggested by (Aebischer et al. 1993; Alt et al. 1980a; Amstrup and Beecham 1976; Garshelis and Pelton 1981). The average movement speed of individual black bear was calculated using Euclidian distance between successive locations.

5.2.5.2. Effect of habitat variables on the movement pattern of black bear in Dachigam landscape

The movement path selection by black bear may be influenced by habitat quality, food resources and the varied level of human disturbance. To assess the effects of habitat variables and the linear features of the movement path, the habitat characteristics of black bear actual paths and random paths were compared by using multiple logistic regression (Figure 5.1) (Manly et al. 1993).

For the analysis, the black bear paths were converted into a series of points which were separated by 100m and defined bias direction at the end point of each path. The 100m step length was selected to balance the negative autocorrelation which was inherent with shorter step lengths. For the valid comparison between the black bear actual path recorded using the radio-tracking of black bear with the random generated path, the shape of the path should be similar except for their responses to liner features. Number of studies tested this approach (Serrouya 1999; Dyer et al. 2001; Rondinini and Doncaster 2002) and failed to test for similarity in shape of the actual and random paths. In the present analysis to generate the random path correlated + biased random walk suggested by Trunchin (1998), Schultz and Crone (2001) was used for the random path comparison with the actual path, as the correlated + biased random models the influence of both directional persistence and directional bias on an organism's movement. This model predicts a weighted average of previous and bias directions. The generated random paths were converted into points which were separated with the same distance taken for the actual path. The values for all the points generated from actual and random paths were extracted using the ArcGIS 9.x software and Line/Road density analysis, Nearest Feature v.3.8b (Jenness 2004) add in for program ArcView 3.2a. The covariates used for the analysis are listed in Table 5.1 and Figure 5.1. For the analysis, the median or variance of these habitat types was measured at 100m intervals. Predictor variables for the analysis were variation in ruggedness (TRI; Riley et al.1999) using SAGA (Conrad 2006), and the Euclidian distance to natural food paths (DNF), cultivated crop field (DCF), distance to stream (DS) from the actual path and the random path, trail (DT) and road density (DR) (trail and road measured within radii of 1 km around the point). Variables were tested for non-linearity. For the analysis black bear paths segments were randomly selected from the movement path generated by plotting the GPS locations of VHF and ARGOS tracking for individual black bear. The spatial autocorrelation between the successive path segments of black bear was minimized by dividing the path length *L* into 2*L* and then randomly selected one segment from within each partition. The partial autocorrelation coefficients in the linear model were low between 0.04 to 0.16 for 0.5, 1 and 2 km path segments and which fulfills the assumption of independence between the path segments (Swihart and Slade 1986). The effect of habitat variables, topography and the linear features on the movement pattern of black bear in the landscape was tested by using the Logistic regression in gme packages of R-Program the logit model is similar to RSF and SSF used by Manly et al. (2002), Boyce et al. (2003). The model is assumed to take the exponential form:

$$\boldsymbol{w(\mathrm{x}) = \exp(\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_p X_p)}$$

Where w(x) is the relative probability of movement path selection, the w(x) was estimated by comparing observed black bear movement paths to a random possible movement path. X_1 to X_p were the habitat factors and β_0 to β_p were respective coefficients estimated using the logistic regression. For the present analysis the exponential forma of the model is:

$$\boldsymbol{w(\mathrm{x}) = \exp(\beta_1 TRI + \beta_2 DNF + \beta_3 DS + \beta_4 DCF + \beta_5 RD + \beta_6 TD)}$$

The response of black bear to each covariate (i.e., habitat variable used for the analysis) was evaluated based on the β- coefficient values. Where these β- coefficient values indicate selection or avoidance of a habitat variable by individual black bear.

Table 5.1 Predictor variables used for the black bear movement patterns analysis.

Variable	Description
Habitat and topographic predictors	
Ruggedness	Topographic Ruggedness Index (TRI)
Distance to streams	Metres
Distance to natural food	Metres
Distance to cultivated food	Metres
Human use predictors	
Trail density	Km/km2; radius of 0.5, 1.0, 1.5km
Road density	Km/km2; radius of 0.5, 1.0, 1.5km

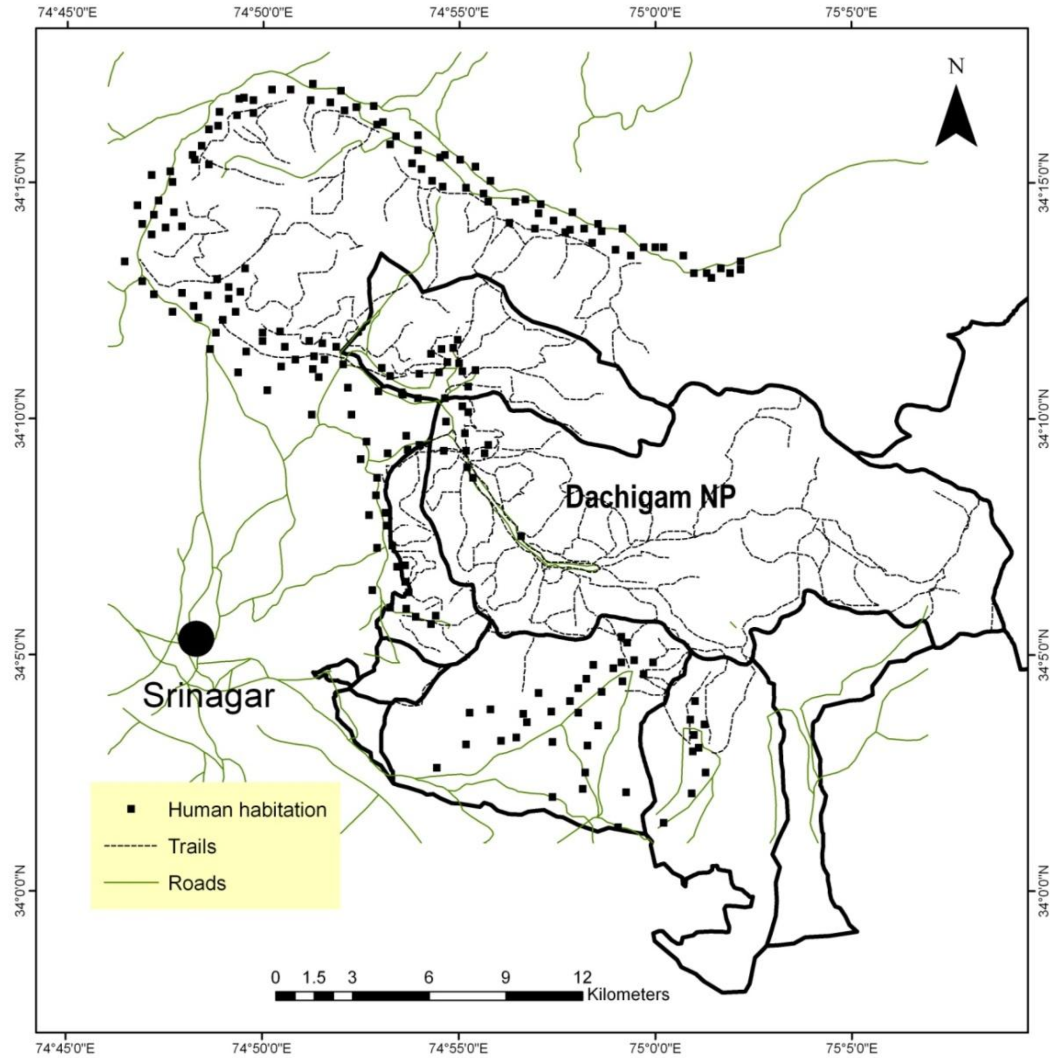

Figure 5.1. Map showing human habitation and linear features in Dachigam landscape

5.3. Results

Seven black bears (4-males and 3-females) were collared during 2009-2011. Out of which two collars were recovered as one animal died (10M) (during hibernation natural death) after four months of tracking and the other animal (100M) died (electric shock) after seven months of tracking, and the remaining five collared animals were radio tracked till October 2011. During the one year tracking period of collared bears i.e., from autumn 2009 to autumn 2011, we recorded 1880 relocations out of which 497 were from ARGOS and 1383 were from VHF tracking (Table. 5.1).

Table 5.2. Details of the radio-collaring period date of collaring and the number of GPS location recorded at Dachigam National Park, Kashmir, during 2009-11.

Bear ID	Tracking period (mm/yyyy)	Sex	(Tracking period)	Telemetry methods		Total
				Argos locations	Ground Tracking	
F00	12/2009 -10/2011	Female	22 months	85	273	358
F04	11/2009- 10/2011	Female	23 months	94	312	406
F06	10/2009-10/2011	Female	24 months	128	374	502
M02	12/2009 – 10/2011	Male	24 months	113	157	270
M08	12/2010 – 07/2011	Male	8 months (died)	36	106	142
M10	12/2009 – 03/2010	Male	4 months (died)	24	92	116
M100	03/2011-09/2011	Male	6 months	17	69	86

5.3.1. Performance of different kernel home range analysis models

Based on the AIC_c, the bivariate exponential power model was ranked lowest among the four parametric models for all the black bears (Table 5.3), whereas the model with highest support was bivariate normal with 11 variables for all bears except M08 bear. The best model in the case of M08 was bivariate normal with 6 variables with lowest AIC_c value (1891.7). The bivariate circle was the second best supporting model AIC_c in three cases (M100, M10 and F06). While using CVC criteria the best supporting model was Adaptive kernel in case of four individuals (M100, M10, F06, F04) but for the remaining three individuals F08, F00 and M02 the best supporting model was fixed kernel with lowest CVC_c value of 1846.7, 6772.6 and 7131.5 respectively. The bivariate exponential power model has the lowest support among all parametric models with highest AIC_c value. The CVC value was also highest in all of the cases except M10, M02 bear with lowest support among all the four parametric and two non-parametric models. Among the parametric models the CVC_c value suggest that bivariate normal model performed best in all of the cases except M100 individual where the best model was bivariate circle. Based on the CVC_c criteria among all the models adaptive kernel and fixed kernel performed best but adaptive kernel model is best among the two kernel methods.

Table 5.3. Relative performance of six models for estimating home-ranges of black bear in Dachigam landscape, Kashmir, 2009-11. The evaluation is based on the second-order Akaike's information criterion (AICc) and likelihood cross-validation criterion (CVC). For each black bear, a = the best supported (best) model, b = the second best supported model (ΔAICc or ΔCVC < |2|), and c = the least supported (worst) model.

			Bi-modal			**Kernel**	
		Exponential Power Model	Bivariate Normal (6)	Bivariate Circle (7)	Bivariate Normal (11)	Fixed Kernel Density	Adaptive Kernel Density
100	**AICc**	2490.4[c]	2404.2	2352.2	2346.5[a]	NA	NA
10		2425.3[c]	2418.8	2358.5	2352.7[a]	NA	NA
8		1898.3[c]	1891.7[a]	1896.0	1894.2	NA	NA
6		7517.1[c]	7349.3	7276.7	7271.7[a]	NA	NA
4		6098.6[c]	5926.2	5808.0	5726.1[a]	NA	NA
2		7566.7[c]	7386.7	7366.4	7315.9[a]	NA	NA
0		6928.8[c]	6884.8	6889.0	6833.8[a]	NA	NA
		Exponential Power Model	Mode Bivariate Normal (6)	Bivariate Circle (7)	Bivariate Normal (11)	Fixed Kernel Density	Adaptive Kernel Density
100	**CVC_c**	2489.7[c]	2405.1	2351.2	2354.5	2309.9	2302.7[a]
10		2424.7	2427.4[c]	2361.7	2359.4	2355.5	2333.0[a]
8		1896.8[c]	1892.3	1887.8	1877.0	1846.7[a]	1859.8
6		7455.1[c]	7349.7	7290.0	7270.6	7091.4	7059.1[a]
4		6086.0[c]	5924.6	5800.3	5726.9	5695.7	5682.4[a]
2		7567.6	7384.6[c]	7379.4	7309.6	7131.5[a]	7143.5
0		6925.4[c]	6884.4	6912.7	6830.7	6772.6[a]	6785.0

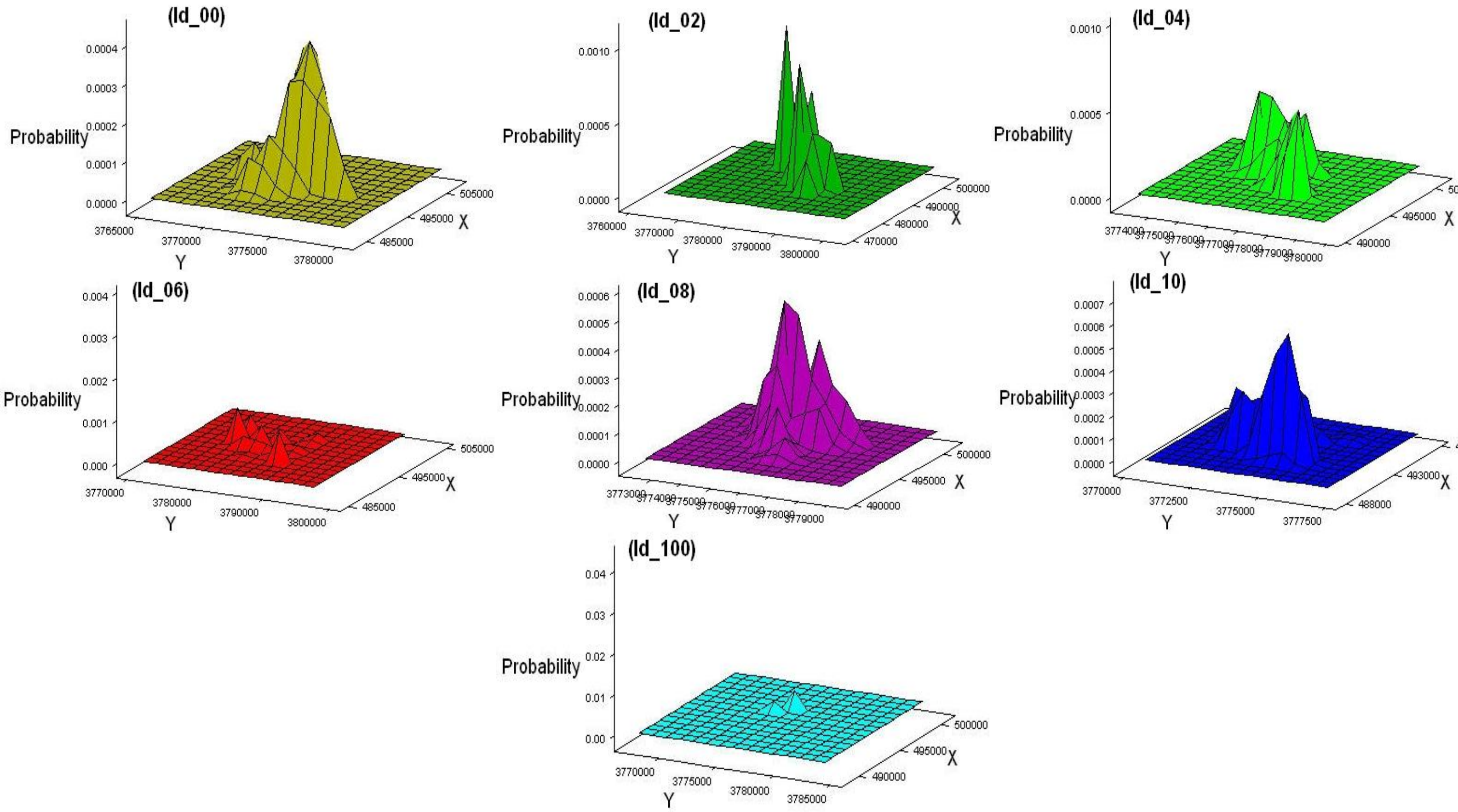

Figure 5.2. Probability utilization distribution of use by radio collared animals in kernel home ranges at Dachigam landscape during 2009-11.

5.3.2. Comparison of home range estimates of different home range analysis software programs

A total of 1219 locations were used for the home range analysis of black bear at Dachigam landscape. The number of location bear black bear ranged from 86 to 247, with an average of 175 locations per black bear.

The mean similarly index value of the home range generated through Animal Space Use Beta 1.3 (1.87 ± 0.09) was highest, followed by HRT (1.62 ± 0.24) and it was lowest for the home range generated by Biotas (1.20 ± 0.08) (Table 5.4).

The home range generated using 6 software programs differed significantly at two contours 75% and 50% (P<0.05; Table 5.5) but for 95% the difference was not significant at P <0.05.At 95% isopleths the home range generated by HRT tool was largest among all the programs and it was 1.4 fold larger than the home range size generated by the Ad hoc and LSCV estimators of AMA extension. At 95% isopleths the home range sizes generated through AMA, ABODE, and Biotas were similar but the home range size generated through Animal Space Use Beta 1.3 and HOME RANGE programs were smallest among all programs 23.36± 9.28 and 30.94± 12.2 respectively. The home range generated by HRT was largest among all at 95% and 75% isopleths but at 50% the largest home ranges were generated by Biotas software. The home ranges generated by both of the 2-smoothing estimators for AMA extension were similar in size at all the three isopleths (95%, 75%, and 50%). At 75% isopleths the home range size generated through Biotas was smallest among all the programs. The GME tool performed consistently at all of 3 isopleths and the home range sizes generated were falling in the middle of all the estimated home range sizes by other programs. The examples of home ranges polygons created by the 6 home range estimation programs can be seen in Figure 5.3.

Table 5.4. Comparison of mean shape index of the home ranges generated by different software programs for all the seven black bears at Dachigam landscape, Kashmir, during 2009-2011.

Home range program	Mean Shape index and S.E
AMA	1.44 ± 0.20
HRT	1.62 ± 0.24
ABODE	1.35 ± 0.11
Animal Space Use Beta 1.3	1.87 ± 0.09
GME	1.52 ± 0.32
Biotas	1.20 ± 0.08
HOME RANGE	1.41 ± 0.10

There was no consistency in the home range size estimation among the programs used for the home range analysis. The GME program was selected for the further home range analysis, since the estimates of GME were ranging between the largest and the smallest and it has performed consistently at all of the three isopleths of the analysis. The GME program is unique as the user can customized the analysis by giving all of the parameters which are required for the Kernel home range analysis.

Table 5.5. Comparisons of overall home ranges size (Km2; S.E) of Asiatic black bear using six home range estimation software programs and three estimators at Dachigam National Park, Kashmir, during 2009-2011.

Program	Estimator	N	95%	75%	50%
AMA[1]	Ad hoc	7	48.89	20.85	8.56
			(20.56)	(10.77)	(4.19)
	LSCV	7	47.89	20.31	8.19
			(17.31)	(10.43)	(3.99)
HRT[2]	LSCV	7	69.33	35.96	10.14
			(29.53)	(16.10)	(5.16)
ABODE	LSCV	7	43.06	22.55	12.62
			(17.31)	(10.48)	(5.85)
HOME RANGE	LSCV	7	30.94	16.21	18.01
			(12.28)	(6.69)	(8.67)
Biotas	LSCV	7	48.34	10.85	19.67
			(14.60)	(5.78)	(11.36)

Program	Estimator	N	95%	75%	50%
GME[3]	LSCV	7	36.43	19.27	9.93
			(23.25)	(12.70)	(6.81)
Animal Space Use Beta 1.3	LSCV	7	23.36	-	3.22
			(9.28)		(1.31)
	MCP	7	37.98	22.22	-
			(14.39)	(9.5)	
			$F_{8,54}$= 1.97; *P*=0.07	**$F_{7,48}$= 2.38; *P*=0.03**	**$F_{7,48}$= 2.79; *P*=0.01**

[1]AMA: Animal Movement Extension of ArcView

[2]HRT: Home Range Extension of ArcGis

[3]GME: Geospatial Modeling Environment

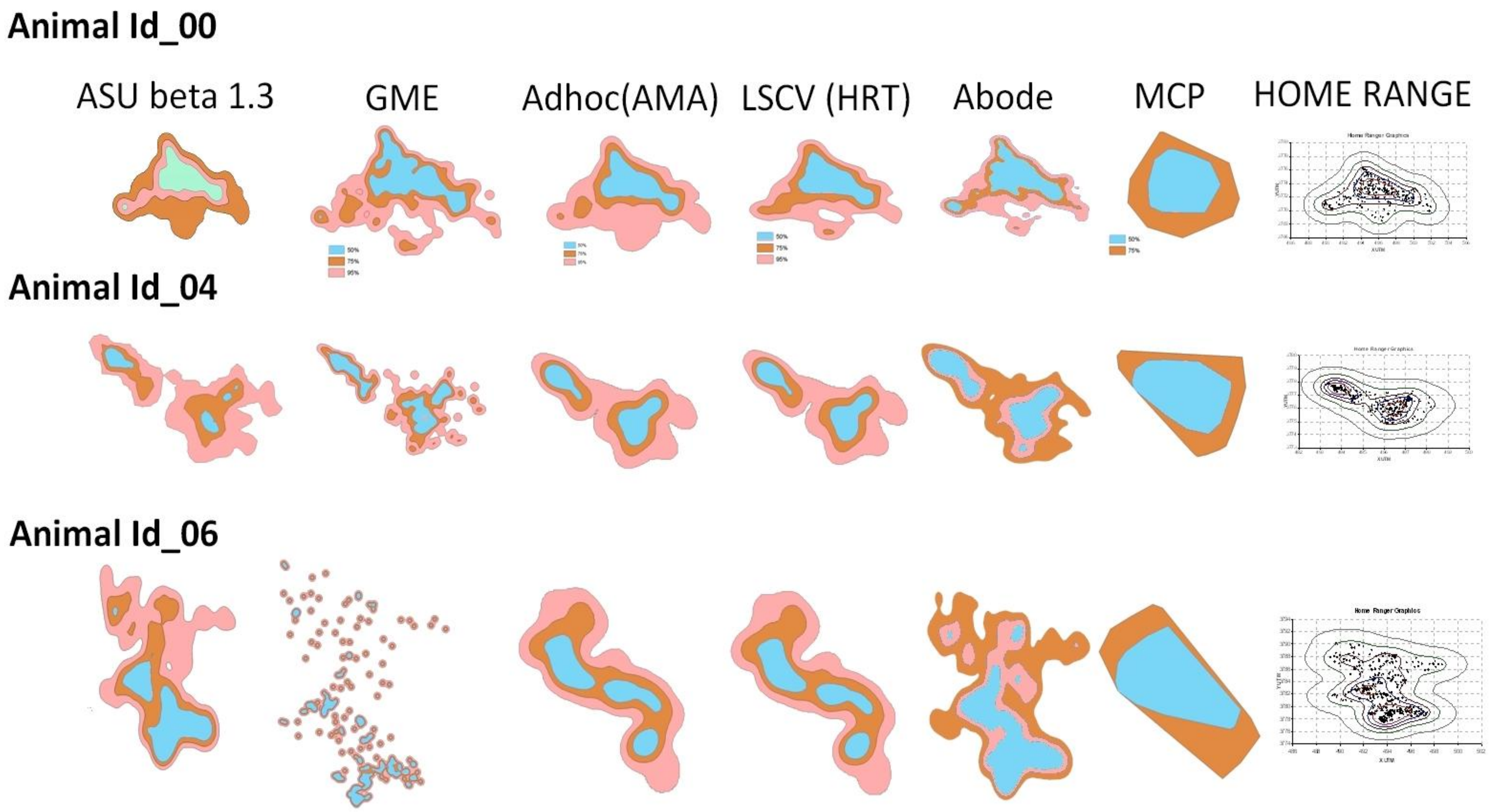

Figure 5.3. Comparisons of home range shapes of Asiatic black bear generated using different home range estimation software programs in Dachigam landscape, during 2009-2011.

5.3.3. Home range analysis of black bear in Dachigam landscape.

5.3.3.1. Home range asymptote analysis

The home range asymptote analysis was carried out using 100% MCP and 95% Kernel density methods. By using 100% MCP method the home range of individual Id_02, 04, 06, 100 reached asymptote and the individuals with Id_00, 08, 10 do not reached to asymptote during the study period (Figure 5.4). For the animal with Id_02, 04, 06 and 100 the number of locations required to reach asymptote were 244, 256, 276, and 372 locations respectively. By using 95% kernel density the home range reached asymptote for only three individuals Id_02, 04 and 06 and for the remaining four the asymptote was not achieved (Figure 5.5). The home range got asymptote for Id_02, 04 and 06 at 256, 263, 294 locations respectively during the study period.

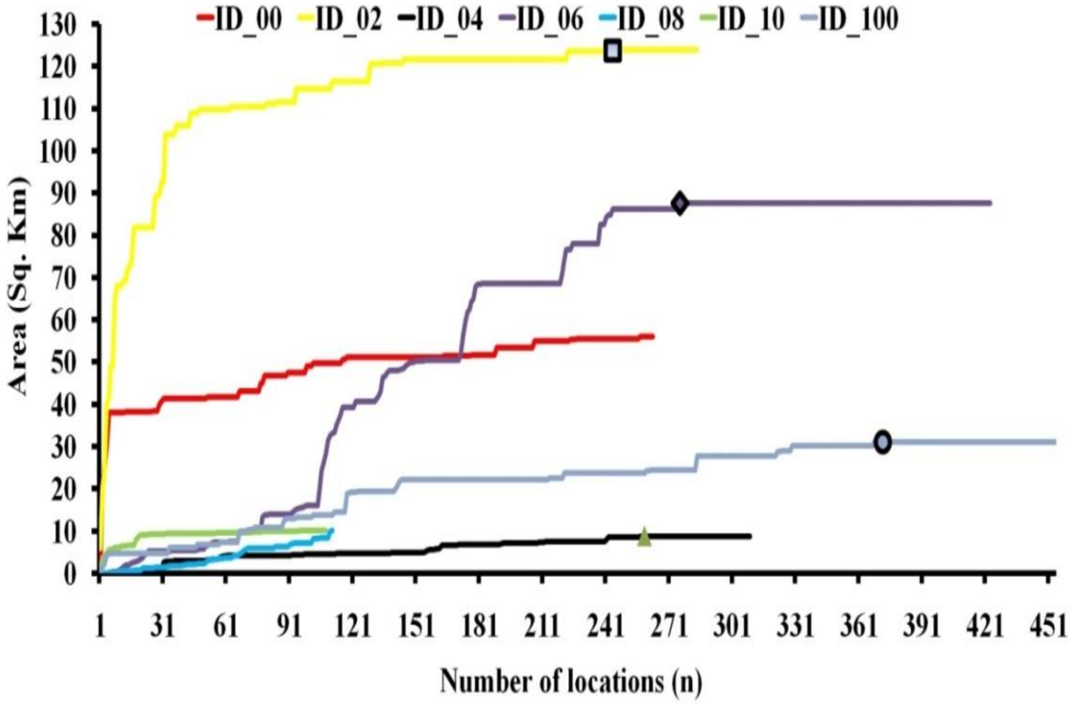

Figure 5.4. Asymptote analyses for all collared black bears using consecutively added locations to the MCP for the home range size estimation at Dachigam landscape during 2009-2011.

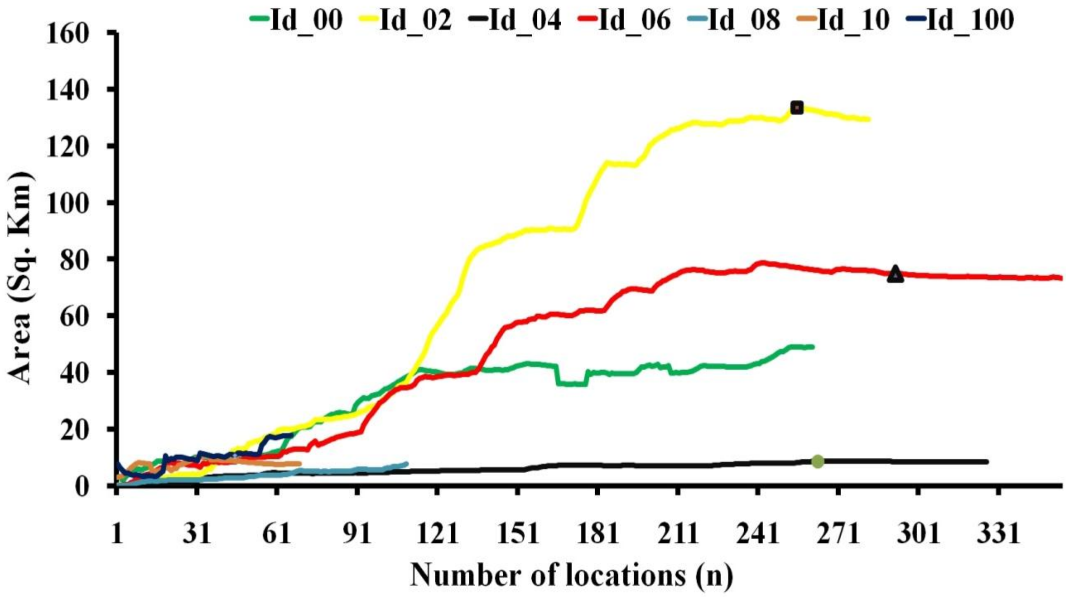

Figure 5.5. Asymptote analyses for all collared black bears using consecutively added locations to the 95% Fixed kernel for the home range size estimation at Dachigam landscape during 2009-2011.

5.3.3.2. Over all home range size

The home range was generated using 100%, 75% MCP and 95%, 75% and 55% Kernel method. The overall 100% MCP home range size of female with cub 04F (8.44 km^2) was smaller than home range of other two female 00F (53.84 km^2) and 06F (84.11 km^2) (Figure 5.6; Table 5.6).Whereas, 100% MCP home range for male black bear was largest for 02M (124.67 km^2), followed by 100M (23.09 km^2), 10M (9.80 km^2) and was smallest for 08M (9.62 km^2) (Figure 5.7; Table 5.6). The average 100% MCP home range of black bears at Dachigam landscape was 44.97 km^2 ± 17.08 and ranges from 8.44 km^2 to 124.67 km^2. The average 75% MCP was 22.22 km^2 ± 9.5 and ranges from 2.66 km^2 to 69.14 km^2 (Table 5.6). The 95% Kernel home range size for 04F was 9.62 km^2, and for other two female 06F, 00F, were 76.52 km^2, 59.21 km^2 respectively (Figure 5.8; Table5.6). While among the male black bear the 95% Kernel home range size for 02M was largest (151.92 km^2), followed by 100M (17.97 km^2), 08M (11.53 km^2) and was smallest for 10M (8.45 km^2) (Figure5.9; Table 5.6). The average 95% kernel home range size was 47.88 Km^2 ± 20.12 and ranges from 8.45 Km^2 to 151.92 km^2. The overall 95% Kernel home ranges size estimates were larger than the 100% MCP estimates. The 75% kernel home range size for female 04F was 4.11 Km^2, for 00F and 06F was 24.04 km^2, 20.95 km^2 (Figure 5.8; Table 5.6) and for the male 02M, 08M, 10M and 100M was 80.06 km^2,4.13 km^2, 3.01 km^2,and 5.93 km^2 respectively (Figure 5.9;Table 5.6). The average 55% Kernel home ranges of black bears at Dachigam was 10.05 Km^2 ± 5.04 and ranges from 1.13Km^2 to 38.4 Km^2(Table 5.6).

Among the females 04F and males 08M has restricted their movements within the natural habitat inside Dachigam NP, where as other female (00F, 06F) and the male (02M, 10M, 100M) have used area outside the Dachigam NP substantially (Figure 5.8 and 5.9).

5.3.3.3. Yearly home ranges of black bear and home range stability

The annual home ranges were estimated for black bears which were tracked year round. The annual home range size of black bear estimated for four black bears out of seven black bears. The average annual kernel home ranges were larger during 2010 for all three isopleths were larges during 2010 than 2011 (Figure 5.10 and 5.11; Table 5.7). The annual 95% kernel home range of black bear in 2010 was 45.94 km^2 ± 20.56, average 75% kernel during 2010 was 19.01 km^2 ± 7.4 and the 50% kernel was 7.32 km^2 ± 2.5 in 2010 (Table 5.7). The average annual 95% MCP were also larger during 2010 (39.24 km^2 ± 21.5).

The average yearly kernel home ranges of male black bears were larger than female at all three isopleths (Table 5.7; Figure 5.10). The average annual 95% kernel home range for male (four male black bears) was 52.28 km^2 ± 41.0 whereas it was 15.28 km^2 ± 4.6 for female (three female black bears). The annual 75% and 50% kernel home range for male were 27.89 km^2 ± 22.4 and 14.55 km^2 ± 12.0 respectively. The average annual 95% kernel home range of black bear was 33.78 km^2 ± 22.8, 75% kernel was 17.83 km^2 ± 12.4 and 50% annual kernel home range was 9.25 km^2 ± 6.5 in Dachigam landscape (Table 5.7).

Site fidelity: - The home range site fidelity was tested for only four black bears which were monitored two consecutive years 2010 and 2011 out of seven radio-collared black bears at Dachigam landscape. The home range of two black bear out of four did not differ in two years (P>0.05) based on the MRPP test using BLOSSOM (Table 5.8). The home considerable (>80%) home range overlap was observed in three out of four black bear among two year 2010 and 2011 thus suggested site fidelity or stability.

Table 5.6. Estimated home ranges of radio-collared black bears in Dachigam landscape. (100% minimum convex polygon (MCP), 95% MCP, 95% Fixed kernel, seassonal 95% kernel and number of locations (n) used in analysis. Area calculated were in km^2, during 2009-2011.

ID	Total 100% MCP	Total 75% MCP	Total 95% kernel	Total 75% kernel	Total 55% kernel	Mean 95% Kernel Spring		Mean 95% Kernel summer		Mean 95% kernel autumn	
	Area	Area	Area	Area	Area	n	Area	n	Area	n	Area
00F	53.84	29.32	59.21	24.04	13.84	49	10.65	42	16.52	99	13.61
02M	124.67	69.14	151.92	80.06	38.40	60	61.93	64	36.09	53	34.16
04F	8.44	4.314	9.61	4.11	2.23	58	9.9	58	4	65	4.74
06F	84.11	39.13	76.52	20.95	9.54	62	45.56	73	24.45	63	28.26
08M	9.62	4.19	11.53	4.13	1.86	30	8.62	17	12.51	10	2.46
10M	9.80	2.66	8.45	3.01	1.13	27	7.77	37	1.73	19	0.98
100M	23.09	6.81	17.97	5.93	3.37	42	15.12	19	21.18	21	10.75

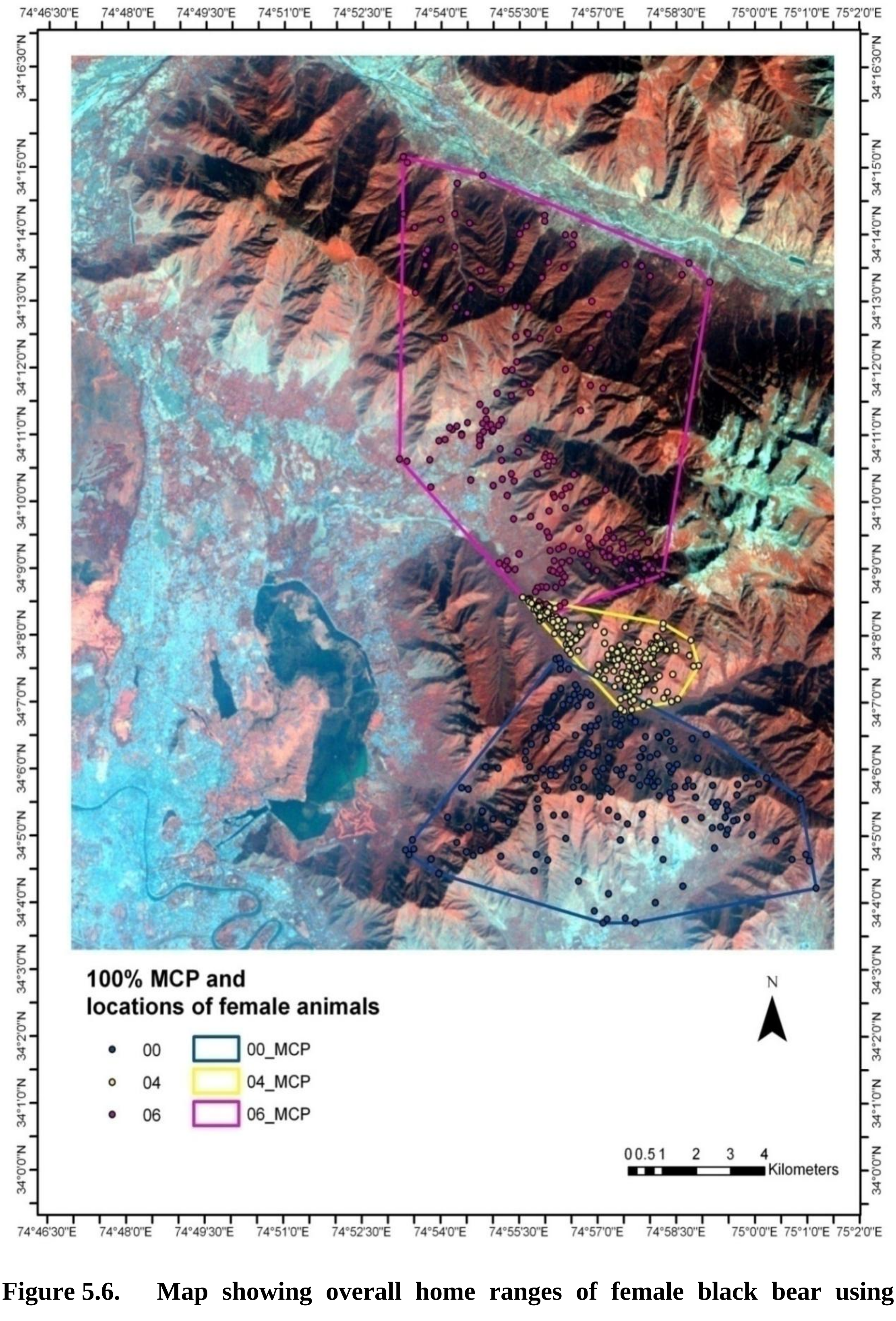

Figure 5.6. Map showing overall home ranges of female black bear using 100% minimum convex polygon method in Dachigam landscape, Kashmir, during 2009-2011.

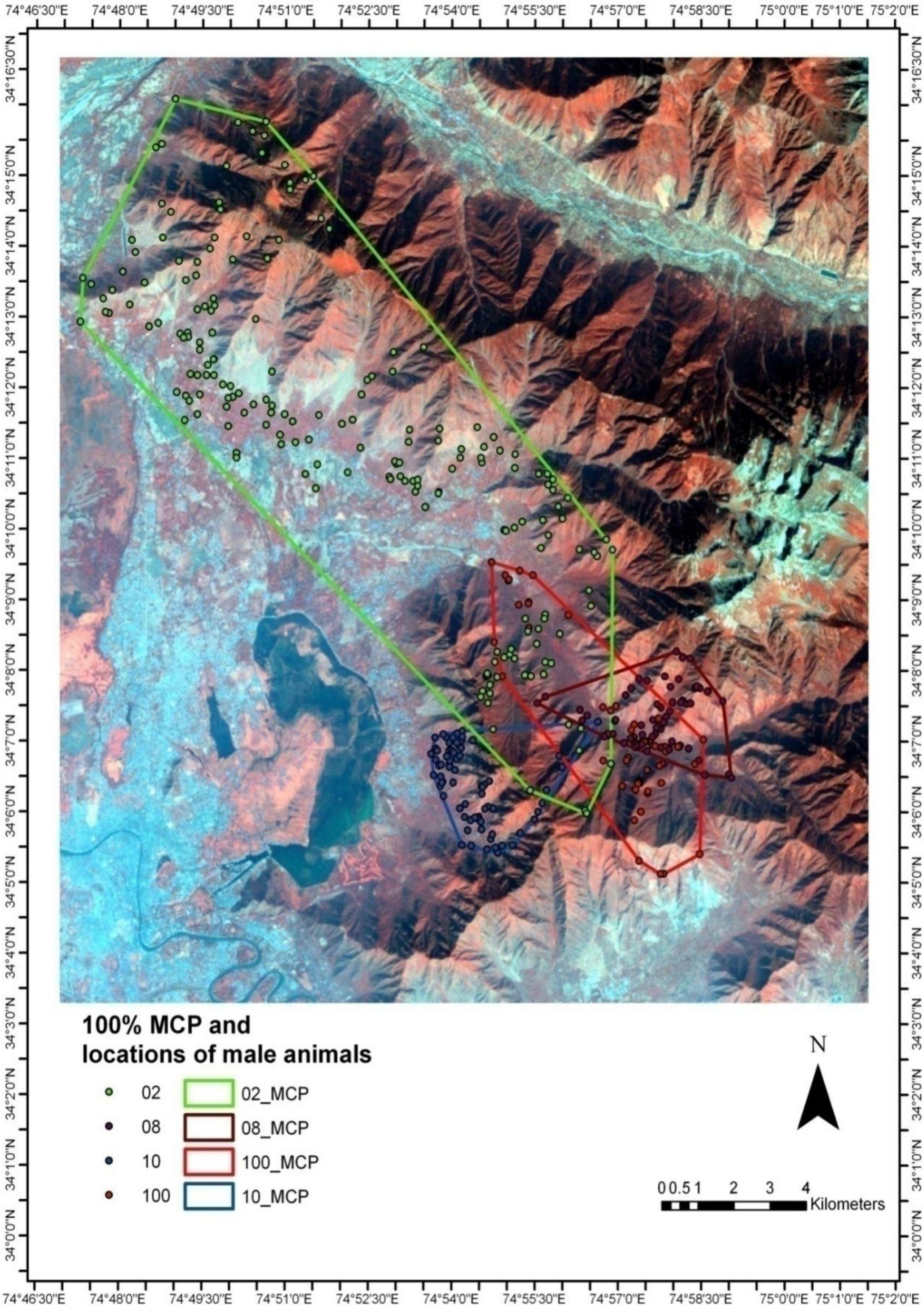

Figure 5.7. Map showing overall home ranges of male black bears using 100% minimum convex polygon method in Dachigam landscape, Kashmir, during 2009-2011.

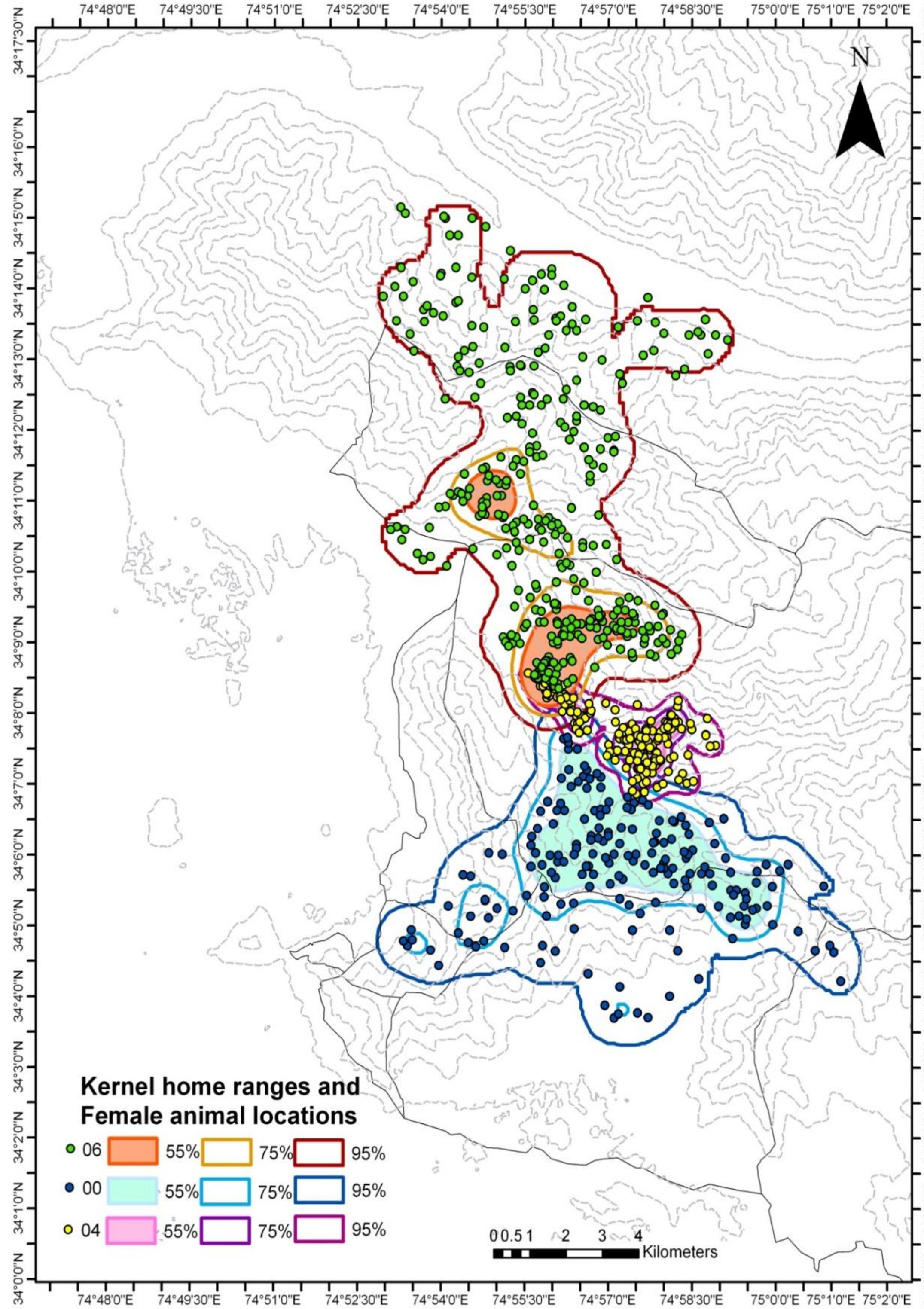

Figure 5.8. Overall home ranges of female black bears using fixed-kernel method (55%, 75%, 95%) in Dachigam landscape, during 2009-2011.

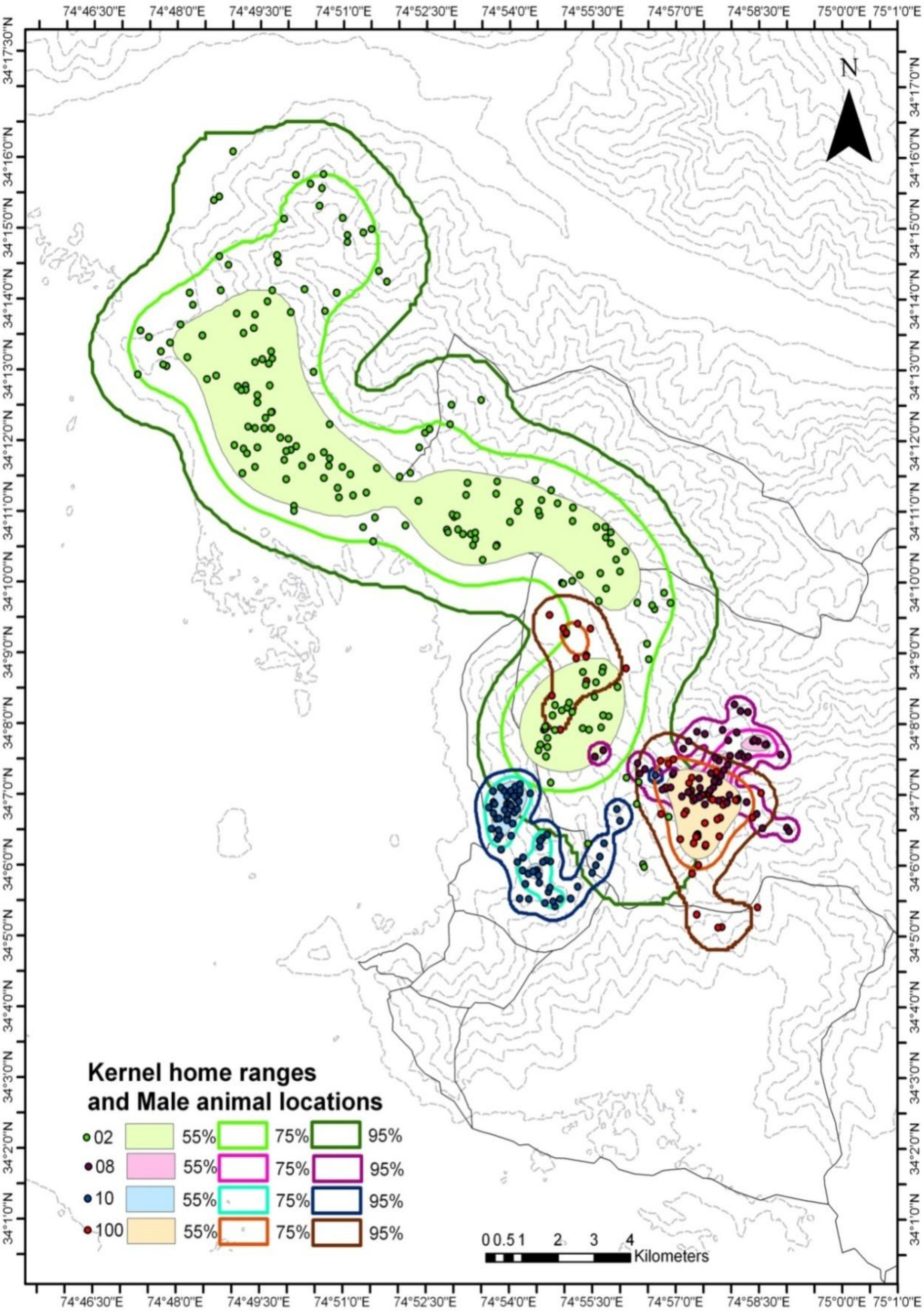

Figure 5.9. Overall home ranges of male black bears using fixed-kernel method (55%, 75%, 95%) in Dachigam landscape, Kashmir, during 2009-2011.

Figure 5.10. Comparison of yearly kernel home ranges of male black bears in Dachigam landscape during 2009-11.

Figure 5.11. Comparison of yearly kernel home ranges of female black bears in Dachigam landscape during 2009-11.

Table 5.7. Annual home range sizes for Asiatic black bear in Dachigam landscape, Kashmir, during, 2009-11. The average annual home range size of black bear estimated using the fixed-kernel analysis 95%, 75%) and the 95% minimum convex polygon (MCP). Average home range size (± SE) is presented by year (2010-2011), for male and female. N is the number of individuals used in the annual home range estimates. "Locations" is the average number of locations (± SE) used to estimate home ranges. Mean annual home range size (Km ^{2}; SE) of adult male and female black bears in Dachigam Landscape, Kashmir during 2009-2011.

Sex	**N**	**Locations**	**Mean HR Size (Km^2)**			
			Fixed-Kernel			**MCP**
Year			95%	75%	50%	95%
2010	4	794 (199)	45.94 (20.56)	19.01 (7.4)	7.32 (2.5)	39.24 (21.50)
2011	4	743(185)	43.73 (14.1)	16.34 (6.9)	4.80 (1.9)	34. 19 (17.25)
Sex						
Male	4	307 (76)	52.28 (41.0)	27.89 (22.4)	14.55 (12.0)	43.71 (36.93)
Female	3	633(211)	15.28 (4.6)	7.78 (2.4)	3.76 (1.1)	11.82 (2.39)
Combined	7		33.78 (22.8)	17.83 (12.4)	9.2 (6.5)	27.76 (19.66)

Table 5.8. Home range stability and degree of overlap between the home ranges of black bears in 2010 and 2011 in Dachigam landscape, Kashmir. The home range stability was tested using the MRPP at P<0.05 significance level.

Home range overlap[@]				**MRPP**			
Id_year	Overlap (%)	Area overlap (km^2)	Id-year	No. of locations	Test Statistic	Average within group distance*	P-value
00_2010 and 00_2011	68.1	25.54	00_2010	99	-3.4	1.3	0.02
00_2011 and 00_2010	64.3		00_2011	65		1.5	
02_2010 and 02_2011	49.4	56.45	02_2010	108	0.3	1.7	0.24
02_2011 and 02_2010	91.5		02_2011	69		1.2	
04_2010 and 04_2011	86.2	5.78	04_2010	101	-1.6	1.6	0.48
04_2011 and 04_2010	80.5		04_2011	63		1.4	
06_2010 and 06_2011	88.0	54.88	06_2010	98	-2.4	1.1	0.03
06_2011 and 06_2010	78.0		06-2011	81		1.6	

[@] : Estimate of site home range stability based on the percentage overlap of individual black bear in two different years.

*: Within group average pair wise distance measures between locations (km).

5.3.3.4. Seasonal home ranges of black bear

There was significant difference among the seasonal home range sizes of black bears ($F_{2,18}$ =0.58, P=0.56), The average spring 95% kernel home range of black bear was 22.79 km^2 ± 8.23, summer home range was 16.64 km^2 ± 4.5, and for the autumn season it was 13.56 km^2 ± 4.8 (Figure 5.12 and 5.13; Table 5.9). The home range of black bear 02M was largest in all seasons among all of the seven black bears whereas the smallest home range was of 10M id black bear in all seasons. The bear with id 04F was having second smallest home range in seasons among all the animals (Table ?)

Among year effects: - No significant difference was detected in seasonal home range of size of black bear among the years in Dachigam landscape (P>0.05; Table 5.9). Spring home range varied from 11.93 km^2 to 23.46 km^2, summer ranges varied from 21.15 km^2 to 21.81 km^2, and the autumn home range varied from 3.73 km^2 to 23.68 km^2 (Table 5.9). There was no significant difference was observed among male and female black bear (P>0.05; Table 5.9). For male the spring home range varied from 9.57 km^2 to 16.36 km^2, summer range varied form 27.42 km^2 to 38.52 km^2 and the autumn range varied from 3.69 km^2 to 16.87 km^2. Whereas, for females the spring home range varied from 15.07 km^2 to 32.92 km^2, summer range varied from 23.47 km^2 to 23.66 km^2, and for autumn the home range varied from 7.47 km^2 to 38.37km^2 (Table5.9).

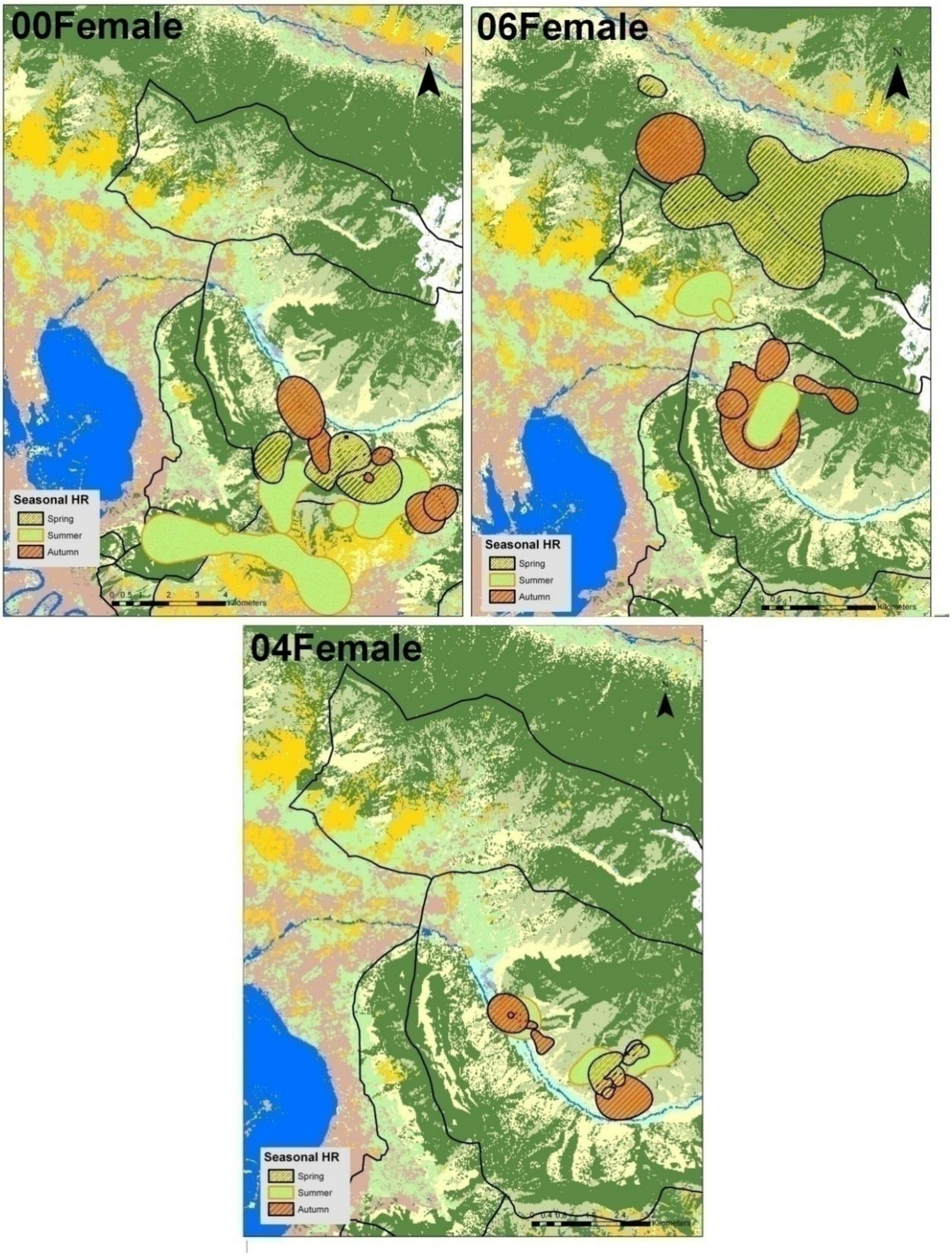

Figure 5.12. Map showing seasonal home ranges of female animals (n=3) Spring, Summer and Autumn in Dachigam landscape, during 2009-2011.

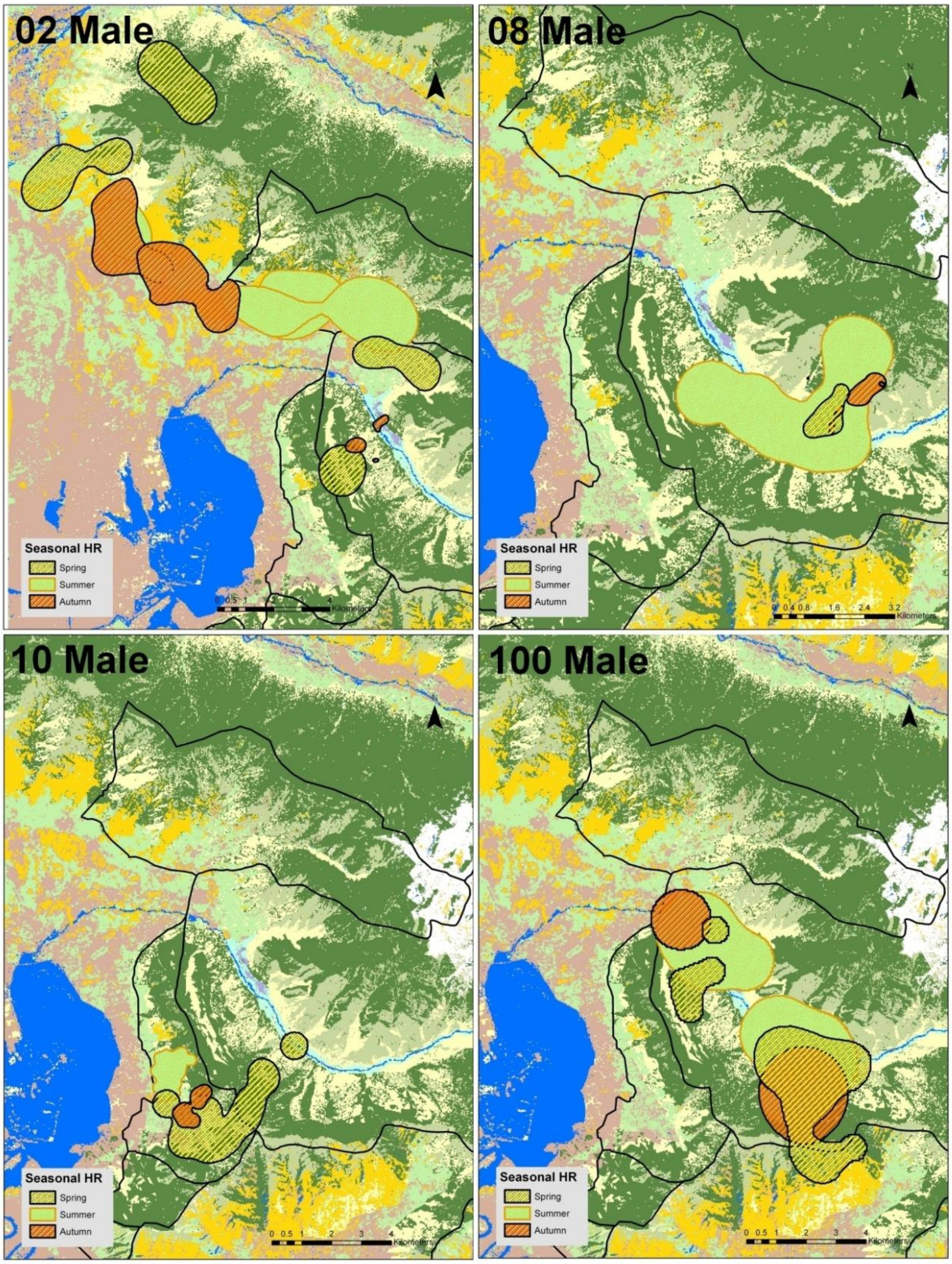

Figure 5.13. Map showing seasonal home ranges male animals. (n=3), Spring, Summer, Autumn in Dachigam landscape, during 2009-2011.

Table 5.9. Comparisons of 95% kernel home range size (Km^2; S.E.) among years and within season of adult black bears in Dachigam landscape, during 2009-2011.

Type	Year	N	Spring	N	Summer	N	Autumn
	2009	-	-	-	-	4	3.73 (1.6)*
	2010	4	11.93 (5.8)	5	21.15 (9.1)	6	23.68 (8.9)
	2011	7	23.46 (8.0)	6	21.81 (7.6)	6	8.51 (4.5)
			$F_{2,14}$= 1.33; P=0.26		**$F_{2,14}$= 0.003; P=0.95**		**$F_{2,14}$= 3.13; P=0.06**
	2009	-	-	-	-	1	3.69*
Male	**2010**	1	9.57	2	38.52 (26.0)	3	16.87 (10.5)
	2011	4	16.36 (6.0)	3	27.42 (16.9)	2	15.96 (14.9)
			$F_{1,4}$= 2.60; P=0.20		**$F_{1,4}$= 0.14; P=0.72**		**$F_{2,5}$= 0.78; P=0.48**
	2009	-	-	-	-	3	7.47 (3.4)*
Female	**2010**	3	15.07 (6.9)	3	23.66 (10.1)	3	38.37 (14.7)
	2011	3	32.92 (17.4)	3	23.47 (5.2)	3	9.22 (5.3)
			$F_{1,5}$= 0.90; P=0.39		**$F_{1,5}$= 0.001; P=0.98**		**$F_{2,8}$= 3.47; P=0.09**

* Individual not used in comparison analysis because radio collaring of black bear was started in autumn 2009.

5.3.3.4. Core area analysis

The core area was delineated at between 25 to 31% of the volume of the probability density function with a mean of 29% volume. The core area of 00F, 02F, 04F, 06F, 08M, 10M, 100M bears was 6.98 km^2, 9.07 km^2, 0.95 km^2, 3.31 km^2, 1.22 km^2, 0.99 km^2, and 0.03 km^2 respectively (Figure 5.14).

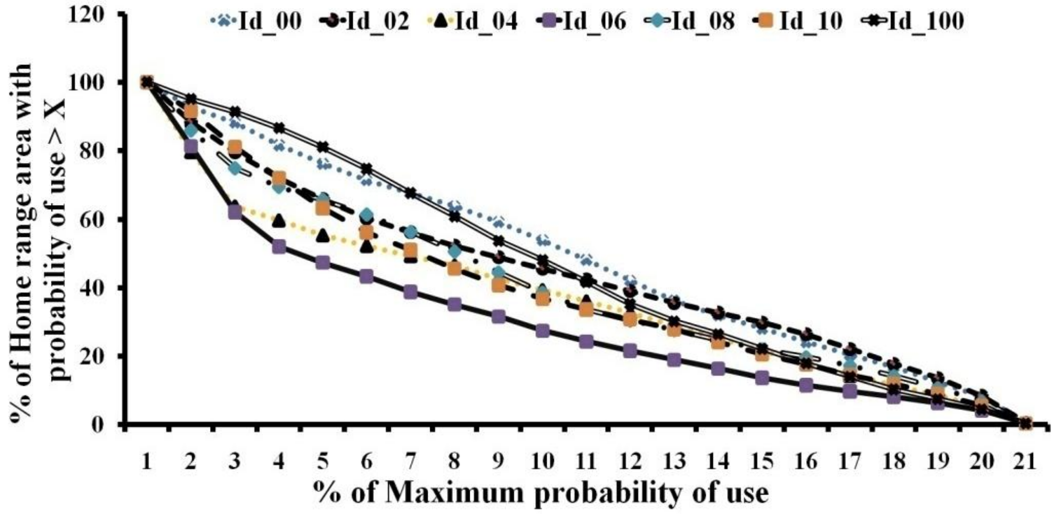

Figure 5.14. Core area determination curves for all 7 radio collared animal at Dachigam landscape during 2009-2011.

5.3.3.5. Home range overlap

The varied degree of overlap was observed between the sexes of black bear. The degree of home range overlap between 00F and 02M was 9.65 % (5.2 km^2), 00F and 08M was 17.86 % (9.62 km^2), 00F and 10M was 18.2% (9.80 km^2), 00F and 100M was 42.88% (11.41km^2), 04F and 02M was (1.96km^2), 04F and 08M was 100% (6.05 km2), 04F and 100M was 36.5% (4.94 km2), 06F and 02M was (24.63km^2) 06F and 100M was (2.62 km^2). (Figure 5.15;Table 5.10).

Table 5.10. Home ranges overlap between male and female black bears in Dachigam landscape, Kashmir, during 2009-2011.

Animal overlap (ID-Sex)	Area (Km^2)
00F_02M	5.20
00F_08M	9.62
00F_10M	9.80
00F_100M	11.41
04F_02M	1.96
04F_08M	6.05
04F_100M	4.94
06F_02M	24.63
06F_100M	2.62

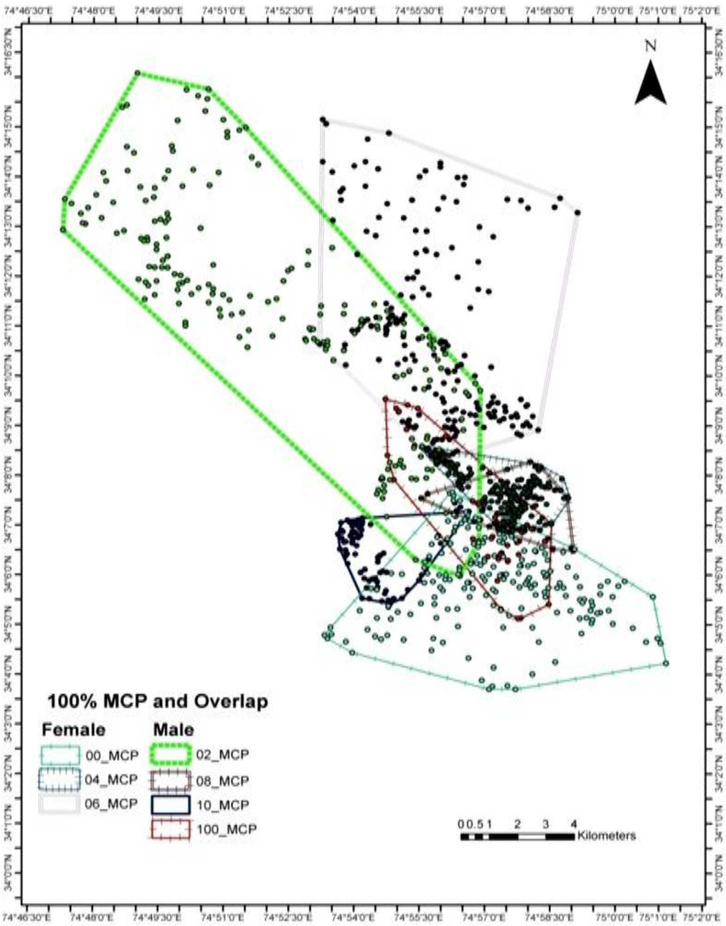

Figure 5.15. Home range overlap of male and female collared animals during 2009-2011 estimated using minimum convex polygon method in Dachigam landscape, Kashmir.

5.3.4. Movement pattern analysis of black bear at Dachigam landscape.

The Mean Daily Seed ranges from 124 m/day (F06) to 450 m/day (M100) with an average of 267m/day. Among the four males the MDS was highest for M100 (450m/day) and among the three females it was highest for F00 (266 m/day). The maximum step distance among the males was largest for M00 (10057m), and among the females it was for F06 (8794m). The largest mean step distance was observed for M100 (1730.8 m) followed by F06 (1004.2 m) and it was smallest for M10 (376.9 m). Among the males the maximum distance travelled in a day was highest for M02 (9634 m) and among it was largest for F06 (7822m). The number of different relocation sites was highest for F06 (0.192 new site/day), followed by M02 (0.180 new site/day) and it was lowest for M10 (0.038 new site/day) (Table 5.11).

Table 5.11. Mean (± SE) values of movement variables measured for 7 radio-collared black bear at Dachigam landscape, Kashmir, during 2009-2011.

ID	Mean daily speed (m/day)	Maximum distance (m/day)	Maximum step distance (m)	Mean step distance (m)	New sites/day
Male 02	210(±54)	9634	10057	938.5 (±67.8)	0.180
Male 08	442(±73)	2260	2349	622.1 (±72.04)	0.059
Male 10	266(±39)	1609	1762	376.6 (±31.93)	0.038
Female 04	176(±41)	3941	4380	513.7 (±42.11)	0.053
Female 00	203(67)	5230	981	789.5 (±48.61)	0.076
Female 06	124(±49)	7822	8794	1004.2 (±71.87)	0.192
Male 100	450(±56)	7402	7853	1730.8 (±237.51)	0.081

Turning angles: - There was no consistent pattern was evident in the distribution of turning angles among the radio-collared black bears. The distribution of turning angles was bimodal for five black bears while for other two it was bell-shaped. As majority of black bears posses' bimodal distribution of turning angles for most of the movement paths so, the central tendency was not measured. The turning angle distributions peaked near 0° and 180° for most of the movement paths (Figure 5.16).

Step length: - For all of the radio-collared black bears the majority of steps were falling between 500m to 1500m. The step length for individuals F00, M02, F06 was larger than other four individual. The variations among the step length were high in individuals using areas within the boundary of Dachigam NP. The frequency of step length was highest for the steps with length 500m to 1500m for all individuals. The frequencies of smaller step length were high for M08 and M100 among all whereas the frequency of large steps was highest for M02 (Figure 5.17).

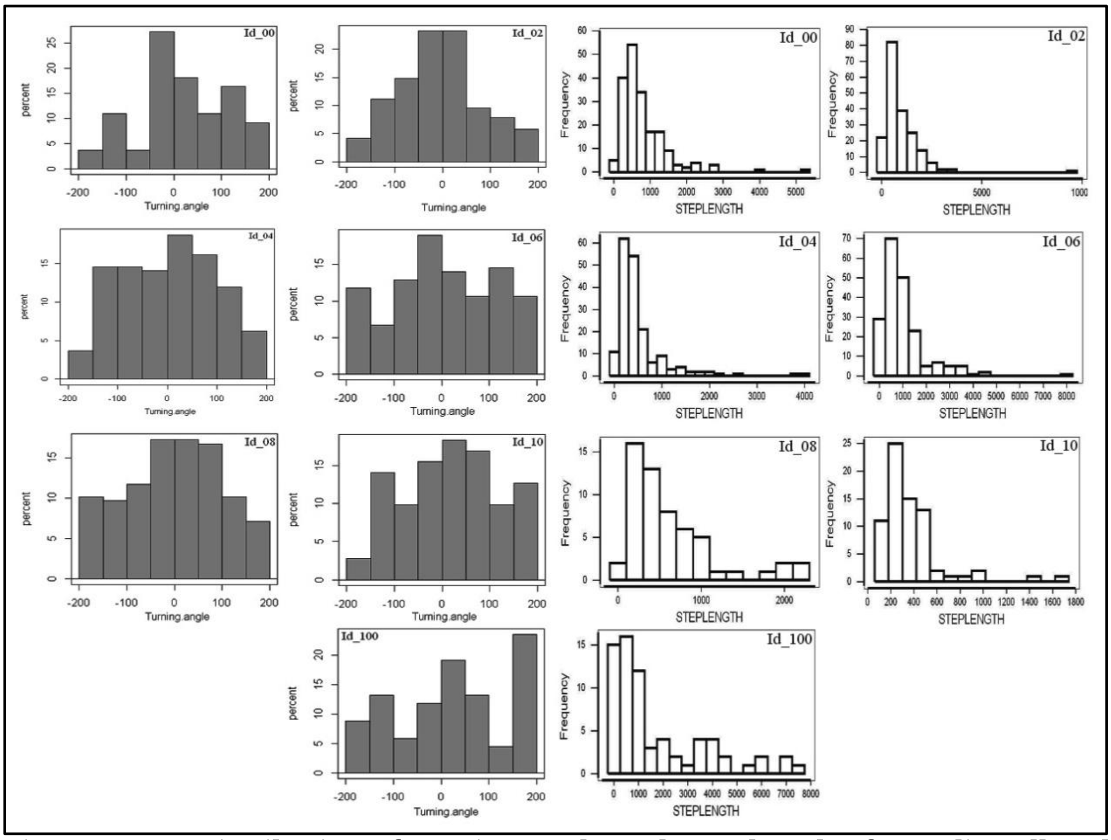

Figure 5.16. Distribution of turning angle and step length of 7 radio-collared black bear at Dachigam landscape during 2009-11.

5.3.5. Analysis of black bear movement path tortuosity

To understand the path tortuosity seven-day continuous locations were used to generate path segments and 5-10 such paths were selected randomly in all seasons for radio-collared black bear at Dachigam. The overall fractal dimension D was calculated to understand the path tortuosity. There was a significant difference in the fractal D values of the movement paths of radio collared black bears among the seasons (Mann-Whitney, U = 19, P<0.02) (Figure 5.17). The fractal D value was highest for summer (1.76 ± 0.30) followed by spring (1.59 ± 0.08), autumn (1.37 ± 0.24) and lowest for winter season before hibernation (1.29 ± 0.21) (Figure 5.18). The fractal D value for Id_02 was highest in spring (1.8 ± 0.15), and summer (1.7 ± 0.27) whereas, during autumn the fractal D value were similar and largest for Id_02 and Id_06, but during winter it was highest for Id_10 (1.3 ± 0.06). The average distance travelled by black bear in seven days was largest in autumn (13.9 ± 2.9), followed by summer (8.3 ± 1.7), spring (6.7 ± 2.1) and was smallest for winter (4.2 ± 0.8). The movement path trajectories are shown in Figure 5.19.

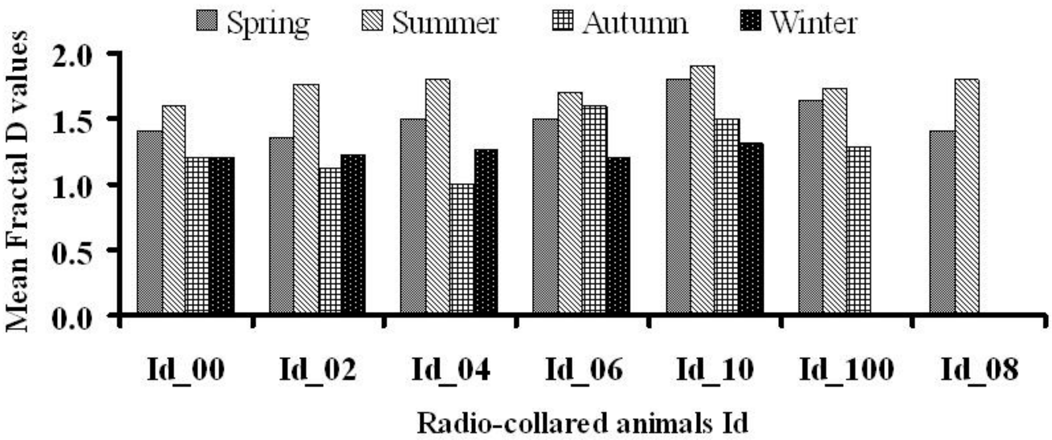

Figure 5.17. Estimated mean fractal D value for movement paths of 7 radio-collared black bears in different seasons at Dachigam landscape during 2009-11.

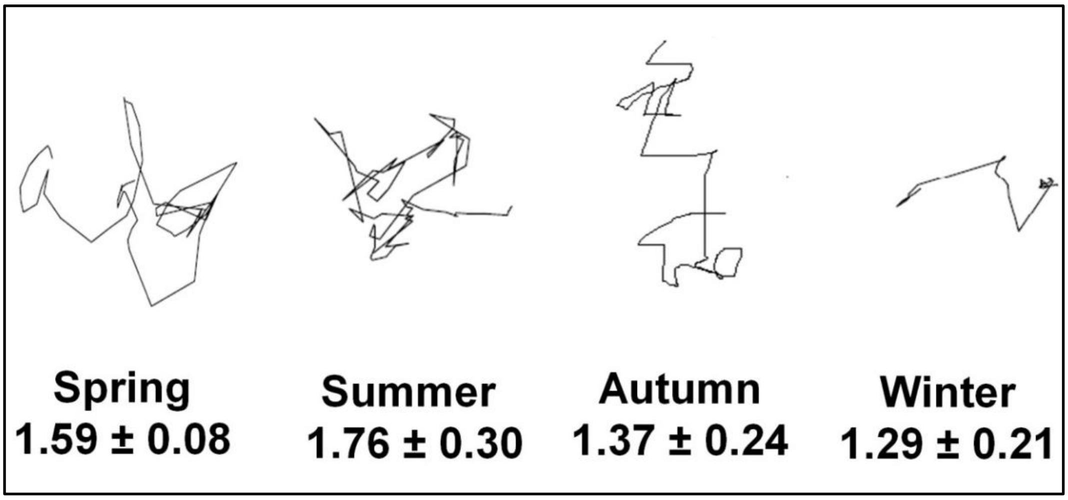

Figure 5.18. Figure showing example movement path trajectories of radio-collared black bear at Dachigam landscape in different seasons with the mean fractal D values.

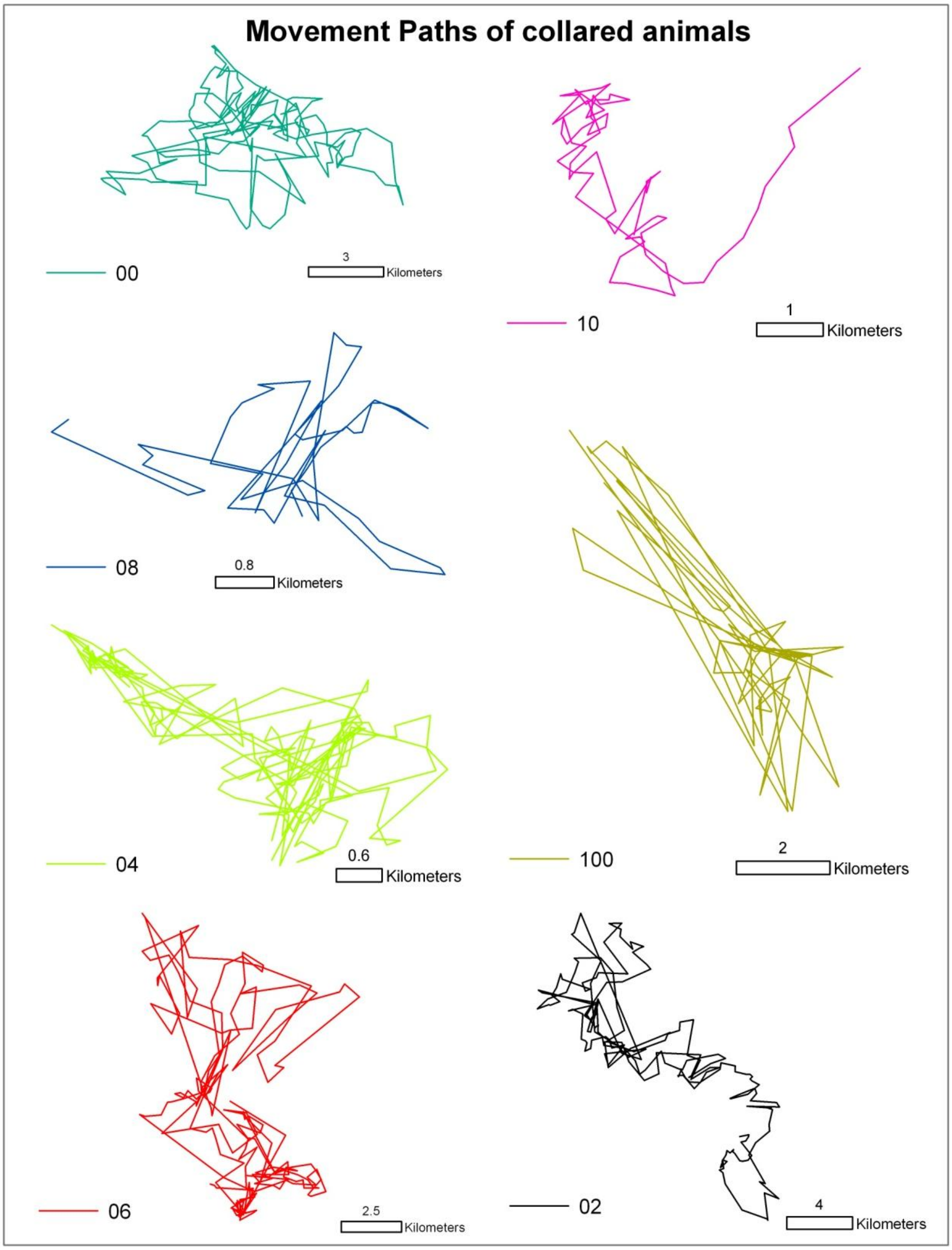

Figure 5.19. Movement paths trajectories of Asiatic black bear in Dachigam landscape during 2009-11.

5.3.6. Effect of habitat variables on the movement pattern of black bear in Dachigam landscape

The effect of habitat variables on the movement patterns of black bear was assessed for seven black bears at Dachigam landscape. The interaction of habitat variables varied across different scales of analysis and among the animals. The effect of different habitat variables was not similar hence analyzed separately.

Animal Id_00. This individual selected areas which were intermediate to high in terrain ruggedness, closer to natural food as well as horticulture crop lands. At 0.5Km scale ruggedness, density of road were strong covariates, where ruggedness was positively related ($\beta = 2.48$, $P = 0.000$) and road density was negatively related ($\beta = -0.84$, $P = 0.005$). At 1km scale of analysis terrain ruggedness and distance to natural food patch were significantly correlated ($P = 0.000$), whereas ruggedness was positively related ($\beta = 2.09$) and distance to natural food patch negatively effecting the movement patch ($\beta = -1.18$). At 2 km scale terrain ruggedness, distance to natural food, distance to horticulture cropland, trail density were positively related ($P < 0.005$) and density of road ($P = 0.001$) negatively explaining the movement patch selection (Figure 5.20; Table 5.12).

Animal Id_02. The movement path of this individual shows a varied affect of habitat variables with changing scales. At 0.5 km scale natural food patch, trail density and distance to horticulture cropland were the strong covariates ($P = 0.005$) and selected areas which were low to moderate in ruggedness ($\beta = -0.32$, $P = 0.005$), close to natural food patch ($\beta = 1.53$, $P = 0.000$), distant to horticulture cropland ($\beta = -0.82$, $P = 0.05$), and posses high density of human used trails ($\beta = -0.77$, $P = 0.05$). At 1 km scale distance to natural food and trail density were strong covariates and selected movement paths close to natural food ($\beta = 0.88$, $P = 0.000$) and avoided areas with high density of human use trails ($\beta = -0.71$, $P = 0.003$). At 2km scale selected areas which were smooth or gently rugged ($\beta = 0.33$, $P = 0.04$), which were far from human use trails ($\beta = -0.47$, $P = 0.007$) (Figure 5.20; Table 5.13).

Animal Id_04: The 04 female during the study period confined her movements to the boundary of Dachigam NP. At 0.5 km scale this individual selected areas for movement with high terrain ruggedness ($\beta = 1.59$, $P = 0.000$), close to natural food patch ($\beta = 1.05$, $P = 0.01$) and far from horticulture crop lands ($\beta = -2.10$, $P = 0.000$).

Table 5.12. Logistic regression coefficients, standard errors, and Wald statistic for various variables used in the movement analysis of black bear M00,at three scale s 0.5 km, 1km and 5km at Dachigam Landscape during 2009-2011.

0.5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	2.48	0.43	5.793	0.000
Food_d	-0.26	0.46	-0.578	0.563
Road_d	-0.84	0.33	-2.542	0.011
Stream_d	0.05	0.37	0.151	0.88
Trail_d	-0.70	0.48	-1.459	0.145
Crop land	-0.11	0.33	-0.339	0.034
1km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	2.09	0.27	7.835	0.000
Food_d	-1.18	0.31	-3.83	0.000
Road_d	-0.19	0.22	-0.878	0.380
Stream_d	-0.31	0.21	-1.526	0.127
Trail_d	0.11	0.22	0.529	0.597
Crop land	0.08	0.19	0.412	0.680
5km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.16	0.14	8.214	0.000
Food_d	0.89	0.14	6.591	0.000
Road_d	-0.38	0.15	-2.599	0.009
Stream_d	0.12	0.13	0.976	0.329
Trail_d	0.38	0.14	2.727	0.006
Crop land	0.30	0.12	2.587	0.010

Table 5.13. Logistic regression coefficients, standard errors, and Wald statistic for various variables used in the movement analysis of black bear F02,at three scale s 0.5 km, 1km and 5km at Dachigam Landscape during 2009-2011.

0.5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	-0.32	0.15	-2.223	0.465
Food_d	1.53	0.46	3.376	0.001
Road_d	-0.46	0.34	-1.390	0.165
Stream_d	0.48	0.31	1.533	0.125
Trail_d	-0.77	0.36	-2.176	0.030
Crop land	-0.82	0.39	-2.136	0.033
1km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	-0.05	0.20	-0.266	0.790
Food_d	0.88	0.25	3.589	0.000
Road_d	0.00	0.18	0.010	0.992
Stream_d	-0.02	0.18	-0.120	0.904
Trail_d	-0.72	0.25	-2.897	0.004
Crop land	0.08	0.17	0.473	0.636
5km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	0.33	0.16	2.032	0.042
Food_d	0.27	0.16	1.660	0.097
Road_d	0.26	0.15	1.690	0.091
Stream_d	-0.30	0.16	-1.880	0.060
Trail_d	-0.47	0.18	-2.670	0.008
Crop land	-0.22	0.14	-1.579	0.114

Table 5.14. Logistic regression coefficients, standard errors, and Wald statistic for various variables used in the movement analysis of black bear F04,at three scale s 0.5 km, 1km and 5km at Dachigam Landscape during 2009- 011.

0.5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.59	0.4749	3.360708	0.000778
Food_d	1.05	0.4498	2.340151	0.019286
Road_d	-0.62	0.4165	-1.50564	0.132157
Stream_d	0.41	0.377	1.089655	0.275933
Trail_d	-0.49	0.4396	-1.11943	0.262961
Village_d	-2.10	0.4088	-5.15166	0.00E+00
1km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.24	0.26	4.737	0.000
Food_d	1.12	0.31	3.622	0.000
Road_d	-0.12	0.26	-0.463	0.643
Stream_d	1.00	0.25	3.927	0.000
Trail_d	0.21	0.26	0.790	0.430
Village_d	-0.24	0.19	-1.292	0.196
5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.36	0.25	5.493	0.000
Food_d	-1.12	0.26	-4.292	0.000
Road_d	-0.18	0.21	-0.856	0.392
Stream_d	-1.29	0.25	-5.205	0.000
Trail_d	0.47	0.18	2.524	0.012
Village_d	-0.30	0.16	-1.944	0.052

Table 5.15. Logistic regression coefficients, standard errors, and Wald statistic for various variables used in the movement analysis of black bear F06,at three scale s 0.5 km, 1km and 5km at Dachigam Landscape during 2009-2011.

0.5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	2.16	0.41	5.213	0.000
Food_d	-0.81	0.40	-2.036	0.042
Road_d	-0.14	0.22	-0.658	0.510
Stream_d	-1.39	0.37	-3.728	0.000
Trail_d	-0.49	0.28	-1.776	0.076
Village_d	0.67	0.23	2.873	0.004
1 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.52	0.28	5.361	0.000
Food_d	-0.07	0.10	-0.719	0.815
Road_d	-0.19	0.17	-1.132	0.258
Stream_d	-1.12	0.26	-4.372	0.000
Trail_d	-0.55	0.21	-2.610	0.009
Village_d	0.26	0.19	1.419	0.156
5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.35	0.23	5.889	0.000
Food_d	-0.84	0.25	-3.425	0.001
Road_d	-0.19	0.15	-1.313	0.189
Stream_d	0.69	0.20	3.426	0.001
Trail_d	-0.62	0.18	-3.409	0.001
Village_d	0.19	0.15	1.309	0.190

At 1 km scale areas which were moderate to high in ruggedness ($\beta = 1.23$, $P = 0.000$), close to food ($\beta = 1.12$, $P = 0.005$) and water stream ($\beta = 0.99$, $P = 0.000$) were selected by this individual and their habitat were strongest predictor for the movement path selection among all variables. At 2 km scale the terrain ruggedness, distance to natural food, distance to water stream, trail density was significantly explaining the movement path selection. The ruggedness (β = 1.36, *P* = 0.000), and trail density (β = 0.46, *P* = 0.05) were positive predictors whereas distance to natural food (β = -1.12, *P* = 0.000) and distance to stream were negatively related (β = -1.29, *P* = 0.000) (Figure 5.20; Table 5.14).

Animal Id_06: The terrain ruggedness, distance to food, distance to stream, trail density were the strongest predictors at of the three scales of analysis. At 0.5 km scale this female selected paths which were distant from natural food (β = -0.80, *P* = 0.04), close to horticulture food (β = 0.66, *P* = 0.004) and distant to water stream (β = -1.39, *P* = 0.000). At 1km scale areas with high ruggedness (β = 1.54, *P* = 0.000), distant from stream (β = -1.12, *P* = 0.000) and with low trail density (β = -1.29, *P* = 0.009) were selected for the movement. At 2 km scale the ruggedness (β = 1.34, *P* = 0.000) and distance to stream (β = 0.68, *P* = 0.000) were positive predictor and distance to natural food (β = -0.84, *P* = 0.000) and human trail density (β = -0.61, *P* = 0.000) were the negative predictors for the movement path of this female black bear at the landscape (Figure 5.20; Table 5.15).

Animal Id_08: This male bear restricted his movements to the boundary of Dachigam NP. At 0.5 km scale the interaction of any of the predictor covariates was not significantly explaining the movement patch selection, since distance to road, stream were positive predictors, ruggedness, distance to natural food and trail density were negative predictors of the movement path selected by black bear in Dachigam landscape. At 1km this male selected areas which were moderate to high ruggedness (β = 1.20, *P* = 0.04), distant from water stream (β = -1.39, *P* = 0.02) were selected for movement. At 2km scale distance to road and human trail density were significantly explained the movement patch selection and distance to road (β = 1.08, *P* = 0.02) was positively related, whereas human trail density was negatively affected the path selection (β = -3.03, *P* = 0.02) (Figure 5.20; Table 5.16).

Animal Id_10: At 0.5 km scale terrain ruggedness, distance to food patch, distance to stream, road densities were the strongest covariates. The areas which were ruggedness (β = 1.52, *P* = 0.000), close to natural food patch (β = 1.62, *P* = 0.005), close to stream (β = 0.93, *P* = 0.04) and distant from road (β = -2.38, *P* = 0.01) were selected for movement. (At 1 km scale terrain ruggedness (β = 2.06, *P* = 0.001) and distance to road (β = 2.87, P = 0.000) were the strongest covariates and were positive predictors of the movement of black bear. At 2 km scale the ruggedness (β = 4.40, P = 0.000) and road density (β = 1.42, P = 0.01) were positive predictors and significantly influencing the path selection of black bear (Figure 5.20; Table 5.17).

Animal Id_100: This male has used areas which were flat and moderate in ruggedness at all scales of analysis. At 0.5 km scale ruggedness, road density and distance to natural food were the strongest covariates. Ruggedness (β = -2.03, P = 0.001) and distance to road (β = -0.57, P = 0.005) were negative predictors, and distance to natural food patch (β = 1.25, P = 0.005) was positive predictor. At 1 km scale distance to natural food patch (β = 4.33, P = 0.000), distance to stream (β = 2.20, P = 0.02) were the strongest predictors and were positively related with the movement path. At 2 km scale distance to road and distance to natural food patch were strongest covariates. The distance to natural food (β = 0.72, P = 0.01) was positively related and distance to road (β = -0.60, P = 0.02) was negatively related and this individual selected areas close to natural food patch and distant from roads (Figure 5.20; Table 5.18).

Table 5.16. Logistic regression coefficients, standard errors, and Wald statistic for various variables used in the movement analysis of black bear M08,at three scale s 0.5 km, 1km and 5km at Dachigam Landscape during 2009-2011.

0.5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	-2.59	0.79	-3.259	0.371
Food_d	-4.00	1.71	-2.337	0.348
Road_d	2.67	0.94	2.833	0.234
Stream_d	3.80	1.11	3.428	0.439
Trail_d	-6.88	2.75	-2.502	0.252
Village_d	0.29	0.04	6.660	0.829
1 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.20	0.61	1.973	0.049
Food_d	2.92	1.09	2.690	0.102
Road_d	0.65	0.26	2.478	0.249
Stream_d	-1.39	0.32	-4.364	0.025
Trail_d	-5.32	1.13	-4.697	0.089
Village_d	0.05	0.02	2.871	0.928
5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	-0.61	0.31	-1.976	0.318
Food_d	-0.84	0.53	-1.583	0.113
Road_d	1.08	0.49	2.200	0.028
Stream_d	0.90	0.59	1.520	0.193
Trail_d	-3.03	1.30	-2.324	0.020
Village_d	0.98	0.28	3.493	0.210

Table 5.17. Logistic regression coefficients, standard errors, and Wald statistic for various variables used in the movement analysis of black bear M10,at three scale s 0.5 km, 1km and 5km at Dachigam Landscape during 2009- 2011.

0.5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	1.52	0.56	2.723	0.006
Food_d	1.62	0.59	2.752	0.006
Road_d	-2.38	0.43	-5.563	0.049
Stream_d	0.93	0.40	2.360	0.164
Trail_d	-1.54	0.37	-4.124	0.930
1 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	2.07	0.67	3.110	0.002
Food_d	1.10	0.56	1.985	0.965
Road_d	2.87	0.82	3.519	0.000
Stream_d	0.02	0.02	1.330	0.387
Trail_d	-0.72	0.33	-2.198	0.592
5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	4.40	0.84	5.238	0.000
Food_d	0.81	0.50	1.611	0.107
Road_d	1.43	0.57	2.514	0.012
Stream_d	0.51	0.47	1.091	0.275
Trail_d	0.54	0.38	1.441	0.150
Z.Village	-0.89	0.57	-1.573	0.116

Table 5.18. Logistic regression coefficients, standard errors, and Wald statistic for various variables used in the movement analysis of black bear M100,at three scale s 0.5 km, 1km and 5km at Dachigam Landscape during 2009-2011.

0.5km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	-2.04	0.88	-2.317	0.037
Food_d	1.25	0.98	1.278	0.041
Road_d	-0.57	0.34	-1.712	0.067
Stream_d	0.95	0.52	1.832	0.174
Trail_d	-0.29	0.16	-1.846	0.648
Village_d				
1 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	-0.24	0.70	-0.351	0.726
Food_d	4.33	1.10	3.955	0.000
Road_d	-0.14	0.11	-1.311	0.020
Stream_d	2.21	0.95	2.320	0.312
Trail_d	0.70	0.69	1.012	0.385
Village_d				0.220
5 km scale				
Covariate	**β Coefficient**	**SE**	**Wald**	**Significance**
Ruggedness	-0.09	0.34	-0.258	0.796
Food_d	0.72	0.29	2.458	0.014
Road_d	-0.61	0.26	-2.313	0.021
Stream_d	-0.39	0.38	-1.044	0.296
Trail_d	0.17	0.32	0.519	0.604
Village_d	-0.31	0.28	-1.107	0.268

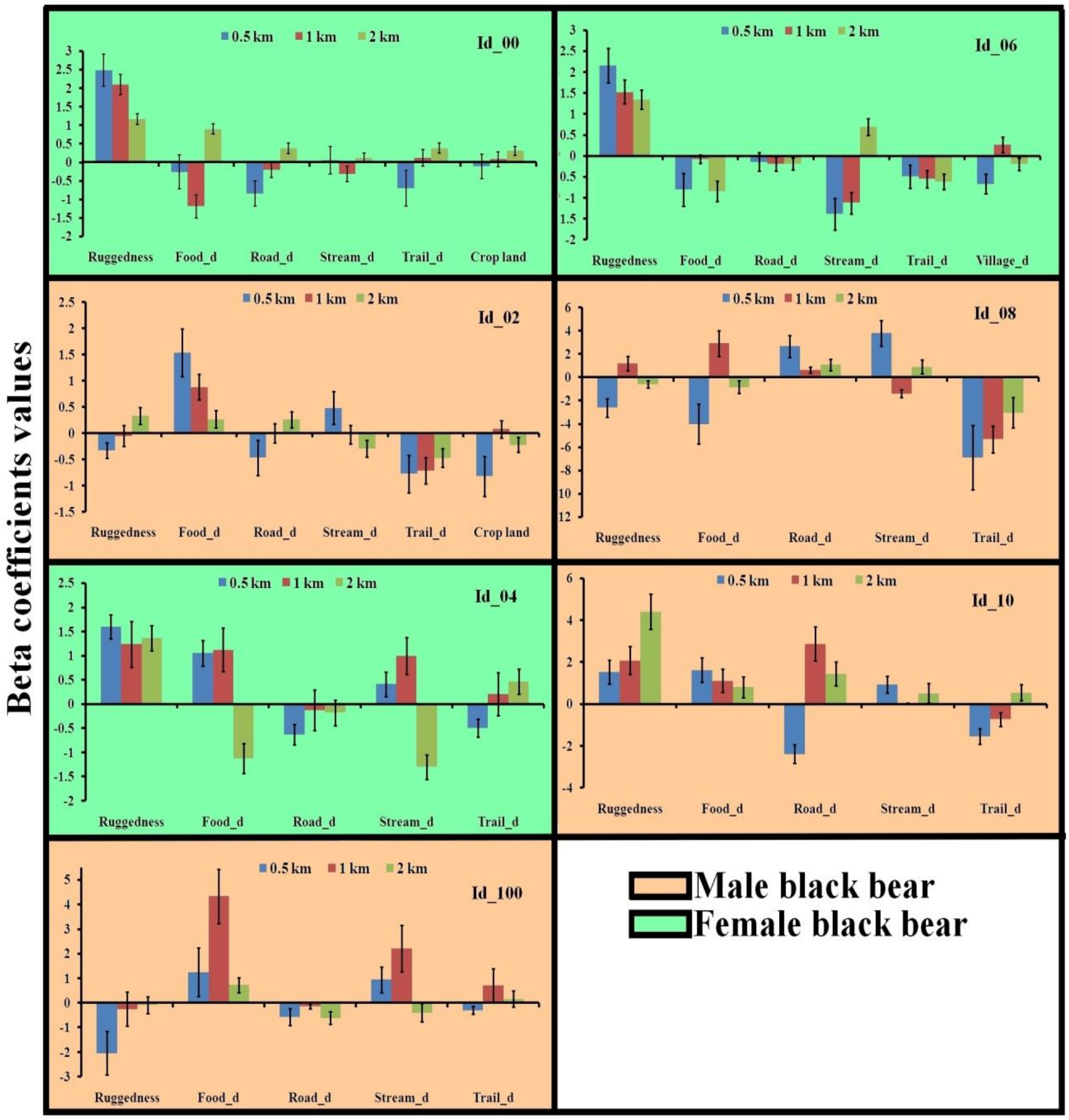

Figure 5.20. Beta β- coefficients ± SE for the logistic regression models predicting the movement path selection by black bears at Dachigam landscape during 2009-11. The models were created for path segments of 0.5, 1 and 2km for 7 black bears.

5.4. Discussion

5.4.1. Selection of best utilization based analysis for black bear home range estimation.

It is imperative to select most suitable utilization distribution based method for the home range analysis since it can surprisingly affect the home range estimates (Seaman and Powell 1996) (Figure 5.2). Based on the AIC_c, the bivariate exponential power model was ranked lowest among the four parametric models for all the collared black bears (Table 5.3), whereas the model with highest support was bivariate normal with 11 variables for all bears except M08 bear. The bivariate exponential model assumes more uniform space use as compared with other parametric models (Horne and Garton 2006).

Similarly, Horne and Garton (2006) also found that the bivariate exponential power model performed poorly in comparison to other parametric models in Red Deer and American Black Bear. Studies also stated that the increase in sample size and with more parameters, the models were likely to perform better (Horne and Garton 2006; Wang et al. 2012).

The best model in the case of M08 was bivariate normal with six variables with lowest AIC_c value (1891.7). Wang et al. (2012) brought out that the best model was not always the one with most parameters, perhaps due to the relatively large sample size (> 50 locations) used for all estimations. Whereas, Hair et al. (2010) stated that with the larger sample sizes, model fitting becomes less sensitive to the number of parameters included.

The bivariate circle was the second best supporting model AIC_c in three cases (M100, M10 and F06), since these animals were covering larger distances and also exploited croplands where the habitat was fragmented, forested habitats were amalgamate with croplands and human habitations. These individuals have used both distributed and undisturbed habitats in almost equal proportions. The bivariate exponential power model was the lowest support among all parametric models with highest AIC_c value.

While using the CVC criteria the best supporting model was Adaptive kernel in case of four individuals (M100, M10, F06, F04) but for the remaining three individuals F08, F00 and M02 the best supporting model was fixed kernel with lowest

CVC_c value of 1846.7, 6772.6 and 7131.5 respectively. In the present study, fixed kernel model was highly competitive with adaptive kernel model ($\Delta CVC>2$) similarly to Wang et al. (2012). The CVC value was also highest in all of the cases except M10, M02 bears with lowest support among all the four parametric and two non-parametric models. Among the parametric models, the CVC_c value suggest that bivariate normal model performed best in all of the cases except M100 individual where the best model was bivariate circle. Based on the CVC_c criteria among all the models adaptive kernel and fixed kernel performed best but adaptive kernel model is best among the two kernel methods.

Seaman and Powell (1996) argued that using a fixed value of 'h' throughout an animals' range is preferable to using variable (or 'adaptive') kernel, as adaptive kernel tend to overestimate the home range size. Following Seaman and Powell (1996) fixed kernel methods was selected to maintain consistency in the h value, since adaptive kernel estimates were likely to affect the home range size positively (overestimate).

Keeping following criteria fixed kernel was used for the home range analysis in the thesis: 1) fixed kernel model was highly competitive with adaptive kernel model ($\Delta CVC>2$) and best for three bears out of four; 2) adaptive kernel method tend to overestimate the home range size; 3) some of the software do not have adaptive kernel analysis model.

5.4.2. Comparisons of home range estimates generated using different software.

The findings of the present study have supported the doubt that different home range programs will produce different results (Table 5.4). The home range generated using six software programs differed significantly at 75% and 50%, whereas at 95% isopleths the difference was not significant. The home range estimates of HRT tool was largest among all the programs and it was 1.4 fold larger than the home range size generated by the Ad hoc and LSCV estimators of AMA extension. The home range estimates through AMA, ABODE and Biotas software were more or less similar with little differences (Figure 5.3). The estimates of GME tool were lower than the HET, AMA, ABODE, Biotas, and higher than Animal Space Use Beta 1.3 (ASU) and HOME RANGE (HR). The Animal Space Use Beta 1.3 and HOME RANGE programs estimates were smallest among all six software programs. The home range program HRT tool and AMA extension might be more sensitive to outlier locations, thus they are exaggerating the area used by an animal (Table 5.4). The inclusion of outlier locations in the home range estimation might exaggerate home range size, whereas occurrence of excursion might not be obvious. It is important to distinguish the brief sally outlier locations with core or center of activity of an animal. The HRT and AMA program might be giving more importance to the area that received little use in the form of excursion. Hence, it may lead to potential bias in the home range size estimation. The estimates of ASU and HR were smaller among all tested programs in the present study. It is important that the user should understand how the outliers were treated by the software program. It appears that the program ASU and HR were giving low density value to the pixels surrounding the outlier locations, thus underestimating the home ranges size (Laver 2005a). These programs might have over smoothened the utilization distribution of the black bear. The estimates of some programs for 95% and 75% isopleths were larger and 50% isopleths were smaller and vice-versa, whereas the GME estimates were consistent and seems to be more realistic.

The individuals such as F04 and M02 were monitored for the longest time during the study and F04 individual restricted her movements to the boundary of Dachigam NP and not covered large distances whereas, M02 bear covered large area in the landscape and was more frequent doing long distance sallies for exploiting the food resources in the croplands of the landscape. Almost all programs have produced similar estimates of home range for F04 individual for which the locations were close because this individual has evenly used the home range area, whereas in the case of individuals such as F06, M10, M02 the estimates were significantly deferred. The difference in the estimates for bears that has done long sallies may be because of inconsistency in density values to the pixels surrounding the locations which are outliers and more distantly placed location clusters on the periphery of the home range by the software programs.

The results reflect that the data used for the home range analysis is also leading to the difference in the estimates among the programs. The differences in the home range size among the programs varied in statistical significance between the subsets of the data. Apart from statistical consideration of the programs the sample size difference among the individuals and data subsets possibly explaining the difference in the results observed using different software programs. Similar kinds of the results were obtained by Olfenbuttel (2005). For the kernel based analysis, the program evaluates points value for summarize the different kernels to produce utilization distribution across the area of interest. The resulting utilization distribution is therefore sensitive to the resolution of the evaluation grid, and more importantly, to the bandwidth selection (i.e. smoothing parameter) of the kernels (Walter et al. 2009). The inconsistency in the resolution of the evaluation grid of equal utilization distribution value, by the software program which is inherent in them, may be another factor resulting difference in the estimates.

The mean shape index was calculated to understand the patterns of home range shape generated through various programs. The shape index value differed significantly for the home range generated by different programs ($P<0.005$). The shape of the home range is important since the area occupied in the home range also defines the habitat availability of the animal (Wang et al. 2012). In the home range the availability and spatial distribution of resources plays important role in spatial utilization of the home range. The shape index value of the home range generated through ASU was 1.87 ± 0.09, which is highest among all the shape index values calculated for other programs and it was lowest for the home range shape generated with Biotas (Table 5.4; Figure5.3). High value of the shape index indicates complexity in the shapes. The outlier locations or the periphery locations of the home range define the shape of the home range. The inconsistency in density value of the pixels surrounding the outlier locations may be responsible for the dissimilarity in the home range shapes generated with different programs.

The GME program is considered best among the compared programs in the present study because it has produced consistent and realistic results. It also provide opportunities for users to customize the analysis by giving options, where almost all home range analysis parameters can be entered by the user based on type of the dataset. In the present study the home range generated with GME program were considered for the further analysis since, the estimates were more ecologically meaning full.

5.4.3. Home range analysis of black bear in Dachigam landscape.

5.4.3.1. Do home range of Asiatic black bear tend to Asymptote?

To ensure that the sampling duration covers the full range of behavior exhibited by the animal, home range asymptote analysis is necessary (Lever 2005). In the present study asymptote analysis was carried out for all of the radio collared animals. The analysis was done using the preliminary dataset collected for all the study individuals. In the present study it was done by using both 100% MCP (Figure 5.4) and 95% Kernel methods (Figure 5.5). Harris et al. (1990) suggested that home range analysis should be done by using the data that encompasses the full range of the behavior of animal and also suggested that use of randomly adding location for asymptote analysis in case of irregular and discontinuous data, and they did not mention about the re-sampling of the locations (Hansteen et al. 1997) as a means to deal with the stochasticity inherent in the method.

The point in time where the home range reaches asymptote is the number of location required to estimate home range. For Individuals Id_02, 04, 06 and 100 the home range reached asymptote using 100% MCP at 244, 256, 276 and 372 locations. But for other three Id_00, 08, 10 it does not reached asymptote which may be because of the short monitoring time. Studied stated that if home range does not reach asymptote indicates that the user may not have a representative sampling duration for the time period. The home range reached asymptote by using 95% Kernel methods for three bears Id_02, 04, and 06 at 256, 263 and 294 locations but for the other four it not reached asymptote. Since, the individual Id_00 was monitored for almost two years, still the home range has not reached asymptote, may be this individual poses multi-scaled home ranges or its home range is not stabilized (Gautestad and Mysterud 1993, 1995).

Gautestad and Mysterud (1995) brought out that home ranges are not asymptotic, but rather increase according to the power law which may be true in the case of MCP based method. The kernel based methods are relatively more robust towards the sample size (Seaman et al. 1999). Though it is widely accepted that the home ranges tend towards an asymptote given sufficient sampling period (Haris et al. 1990; Hansteen et al 1997; Otis and White 1999), provided when the individuals are not transient or dispersing (Harris et al. 1990b). The use of Kernel based methods is suggestive over MCP method. Since the MCP method is very sensitive to its outliers, as increase in observations (locations) can lead to increase in outliers which result in increase MCP area, whereas the Kernel method objectively treats outliers and thus models home range robustly.

The home range reached asymptote for three individual in the study indicates that these individuals have stabilized their home ranges and the monitoring period was adequate for the home range analysis. However, in the case of some individuals home range did not reached asymptote might be because the monitoring time for Id_08, 10 and 100 was short and Id_00 have not stabilized its home range.

5.4.3.2. Overall home range size of black bear at Dachigam landscape

The space use pattern of American black bears has been studies extensively but there are few studies where the space utilization patterns were assessed for Asiatic black bear. In India the present study was the first where the space use was assessed on annual as well as seasonal basis.

In Dachigam landscape the overall mean 100% MCP home range of bears was 44.97 ± 17.98 and the mean 95% Kernel home range was 47.88 ± 20.12 (Table 5.6). The mean home range size of black bear in Dachigam were smaller than the home range reports by other studies in Taiwan (53.8 Km^2 ± SD 30.7; Hwang et al. 2010), China (107.5 Km^2; female; Trent 2010), Japan (56.4 km^2± 51.3; male ± SD; 20.7 km^2 ± 18.4; Female ± SD; Koike and Hazumi 2008).

The largest 100% MCP home range was of M02 (124.67 km^2), and it was smallest for M08 (9.62 km^2) (Figure 5.6). The home range of two male individuals M08 and M10 was small which is because of the fact that the numbers of locations were less, thus small sample size has influenced the accuracy of the estimate, whereas the 100% MCP home range of M100 was 23.09 km^2, since this individual has not explored the areas outside of Dachigam NP. The M02 home range was largest among all radio collared individuals since this individual has explored larger areas outside the boundary of Dachigam. The resource availability in the home range of this individual was patchy, largely in the form of crop lands where the forested habitats were amalgamate with croplands and human habitations. As per Charoo et al (2011) bear human conflict management have become challenging task in Dachigam landscape. This individual was also reported to be involved in conflict with locals and it has been many times sighted in croplands of the landscape which was derived away by the local villagers to mitigate conflict.

The average home range of female black bear was 48.79 km^2 ± 21.9 and the largest home size of F06 was 84.11 km^2 which is smaller than the home range home range reported in Taiwan (117 km^2) by Hwang et al. (2010) and China (107 km^2) by Trent (2010) (Figure 5.7),whereas it was larger than the home range of female reported from Japan (20.7 km^2± 18.4; Mean ± SD).

The home range of black bear in the present study was influenced by the availability of food resources in the landscape (Figure. 6.1 and 6.2; Table 6.3). Since the individuals who have explored areas outside Dachigam can be attributed with the fact that during low food availability in Dachigam bears were exploiting croplands and orchards in the landscape. The size of home range in other studies was attributed to food availability (Amstrup and Beecham 1976; Eubanks 1976; Lindzey and Meslow 1977; Alt et. al. 1980; Garshelis and Pelton 1981; Hugie 1982) since the large home ranges for males may be influenced by their metabolic requirements because of larger body size (Carr 1983) and their breeding strategy (Amstrup and Beecham 1976).

The largest 95% kernel home range was largest of M02 (151.92 km^2) among all individuals followed by F06 (76.52 km^2) (Table 5.6). The home range estimated by kernel methods was larger than the MCP estimates. The home range at 55% kernel isopleths was largest for M02 (38.40 km^2) followed by F00 (13.84 km^2) and was smallest for M10 (1.13 km^2). The average 55% kernel home range was 10.05 km^2± 5.04.

The home range of female with cub (F04) was smaller than other two solitary female (F02, F06) since it was not moving and exploring much may be because of high food availability within its home range or probably to avoid cub infanticide. The solitary female home ranges were much larger as these two female did not have a cub and therefore could explore larger area outside the Dachigam NP in agriculture croplands and human habitations. This is similar to the observations made on American Black bear by Smith and Pelton (1990). Studies reported that the habitat richness can determine home range size (Koehler and Pierce 2003), the male home range size may also be the function of large body size (Harestad and Bunnell 1979;

Quigley 1982), breeding behavior (Rogers 1977). Clark (1991) observed that female bear exhibits site fidelity and males have generally traveled large distance to encounter female. The reproductive success of males likely depends on their ability to breed with several females (Orians 1969; Rogers 1987; Powell et al. 1997). Hence, it is beneficial for male to travel large distances, less attached to specific areas, and occupy large areas that overlap with ranges of many females, whereas for the females it may not be the case, so females usually maximize fitness through detailed knowledge of resource abundance, phenology, and location within their home ranges (White et. al. 1996). Thus, they are less mobile, show site fidelity and occupy areas which are adequate to ensure ample food for self-maintenance and the development of young (Amstrup and Beecham 1976). The home ranges of black bear of both sexes were having smaller home ranges in comparison to other studies (Taiwan, China), possibly related to the habitat quality.

5.4.3.3. Yearly as well as seasonal home range of black bear at Dachigam landscape.

The annual home ranges of black bear were estimated for individuals who were tracked year round. The average annual kernel home ranges at all the three isopleths (95%, 75% and 50%) were largest during 2010 than 2011 (Table 5.7; figure 5.8 and 5.9). Studies brought out that the annual home ranges were largely influenced by the availability of food in the habitat (Gittleman and Harvey 1982) and food abundance affects home range size of Asiatic black bear (Kozaki et al. 2011). The home range size or movement increases in times when food production was low for American black bear (Reynolds and Beecham 1980; Garshelis and Pelton 1981; Kasbohm et al. 1998). The annual 95% kernel home range of black bear in 2010 was 45.94 km^2 ± 20.5 and during 2011 it was 43.73 km^2± 14.1 (Table 5.7). The food production in Dachigam landscape was low during 2010 in comparison to 2011. The larger home range size during 2010 can be attributed with the fact that 2010 was the low food production year in wild as well as orchards in the landscape. The Oak mast abundance especially affects American black bears in the eastern United States, where current bear distribution closely matches oak distribution (Vaughan 2002). Similarly, in Taiwan Hwang et al. (2010) documented the shift in the home range during low production of Oak mast.

In Dachigam the hard mast food crop is largely represented by Walnut which is important food source of black bear in autumn before going under hibernation. The fluctuation in the food production on walnut tress largely effects the movement and ranging pattern of black bear. The nut production fails every alternate year in the landscape and 2010 was the crop failure year.

The present study findings showed similar patterns reported by other studies on black bear elsewhere in Asia and America (Reynolds and Beecham 1980; Garshelis and Pelton 1981; Kasbohm et al. 1998; Kozaki et al. 2011). Powell et al. (1997) found that in years when hard mast was abundant, male and female home ranges were smaller than in years when hard mast was scarce.

The home range site fidelity was tested to understand the possible sift in the home range site. It was tested for only four individuals who were monitored for two consecutive years 2010 and 2011. Out of four bears used for testing site fidelity, two individuals showed site fidelity (P<0.05) based on the MRPP test (Table 5.8). The individuals M00 and F02 show shift in their home ranges where as F04 and F06 showed site fidelity. The overlap was considerably high (>80%) among the years for three individuals. The shift in the home range of male can be attributed with the reproductive strategies and the spatio-temporal heterogeneity of resource inherent in the landscape. The shift in home range has been largely observed in male individuals in comparison to the female (Sinclair 1979).

The home range size of black bear differed significantly among the seasons ($F_{2,18}$ =0.58, P=0.56) (Table 5.6) (Figure 5.10 and 5.11). The difference in the seasonal home range is attributed with the availability and spatial distribution of food resources in Dachigam. The average 95% kernel home range of black bear during spring was 22.79 km^2± 8.23, 16.64 km^2 ± 4.5 and for the autumn it was 13.56 km^2 ± 4.8 (Table 5.5). The availability of food resources was sparse and low during spring in Dachigam leading to larger movements in the latter half of the spring season where as during summer the food availability was homogenously distributed in the landscape. The seasonal home range in the present study is completely different to what has been published which is may be because of the sample size. Among the years the seasonal home range did not differed significantly which can be attributed with the seasonal availability of food resources follows a similar pattern over the years in this landscape (Table 5.9).

In Dachigam landscape spring is the season when food availability is very low which cause bear to move large distance in search of food which leads to increase in the home range size. In spite of hard mast crop failure year the food availability is higher in summer and autumn when compared with spring. Powell et al. (1997) found fall and summer home ranges sizes were smaller in years when hard mast abundance was high. The food production during 2010 was high in comparison to 2011, hence the home range during summer and autumn were smaller than spring (Table 5.6) which is similar to Powell et al. (1997).

The results of the seasonal home range of the present study supported the fact that seasonal movements exhibited by black bear appear to be governed by the temporal availability, distribution, phonological availability and the abundance of preferred food (Amstrub and Beecham 1976; Garshelis and Pelton 1981).

5.4.3.4. Core area and the home range overlap analysis

The core area or the center of activity of black bear was analyzed to understand the shifting pattern of use within the home range of black bear at Dachigam. Harris et al. (1990) brought out that the core area if exists is useful in understanding the behavior of the animal and the clear interpretation of the shifting and space utilization pattern in home range. The core area of the animal in the home range is the space used exclusively for the daily activity by the animal. Harris et al. (1990) also stated that in some cases home ranges might overlap, while the core areas may be mutually exclusive. In the present study the core area was delineated between 25% to 31% volume of the probability density function with the mean 29% (Figure 5.14). By adopting the method suggested by Harris et al. (1990), the core area was estimated by plotting the percentage of home range with probability of use >x against the percentage of maximum probability of use. Animal generally use space disproportionately within the boundaries of their home range. The areas receiving concentrate use by resident animals can be termed as core areas. The estimates of the core area for the individuals which were tracked for the shorted duration were more conservative. Powell (2000) stated that core area may not exist in case of individuals were have not stabilized there home ranges which could be due to even or a random use of space by thr animal. In the present study the core areas were deleniated by following Laver (2005) which was considered as more robut rather reporting by simply as percentage use area at some arbitrarily defined probability. The results suggested that core areas does not exists for all radio collared individuals since, some individuals were showing shifting pattern of use in the landscape.

Range overlap was observed between the collared male and the female collared black bears in the study area (Table 5.10; Figure 5.15). This was similar to the observations made in other studies on American black bears (Amstrup and Beecham 1976; Lindzey and Meslow 1977; Reynolds and Beecham 1980; Garshelis and Pelton 1981; Elowe 1984; Garner 1986; Powell 1987; Hellgren 1988; Smith and Pelton 1990; Clark 1991; Oli et al. 2002). However, the estimated home range sizes were influenced by small sample size (number of locations per bear and number of bears included in analyses). The extensive home range overlap among the individuals in the present study can be attributed with the resource availability in their home ranges. The patchy distribution of food resources in Dachigam forced the bears to exploit the food resources unevenly. During autumn black bears were observed feeding in large group in oak patch, in riverine habitat of lower Dachigam. Studied conducted elsewhere also corroborated the findings of the present study (Garshelis and Pelton 1981; Hwang et al. 2002). Asiatic black bear tend to feed on preferred food types stated by many studies in Japan and China (Hwang et al. 2002; Trent 2010; Koike et al. 2012).The availability of preferred food in the landscape also affects the space utilization by the black bear thus, leading to extensive overlap in the home ranges. The tolerance among the individuals for common resource utilization can also be related with the family relationship, age, sex, reproductive status and habitat productivity (Jonkel and Cowan 1971; Lindzey and Meslow 1977; Garshelis and Pelton 1981). Powell (1987) suggested the lower productivity of the habitat can influence the territorial behavior of black bear, whereas small home range with high degree of overlap can be attributed with high productivity of habitat. There are many studies available where factors of home range overlap were evaluated for Asiatic black bear. In habitat of black bear in Dachigam landscape is highly productive in terms of food resources which are available in the form of hard mast walnut, Oak acorns inside Dachigam and ample amount of croplands along with orchards in the surrounding areas of natural habitat of black bear. The main factor behind the extensive overlap among the radio-collared black bear in the present study can be attributed with the highly productive black bear habitats of Dachigam.

5.4.4. Movement pattern analysis of black bear in Dachigam landscape

5.4.4.1. Assessing movement parameters of black bear in Dachigam landscape

Analyzing movement pattern helps to understand how animals interact with their environment and it play vital role in understand the foraging behavior and other ecological aspects of an animal. The movement of black bear is largely influenced by the availability of food resources in different studies. The mean daily speed (MDS) of black bear in Dachigam was 267m/day suggested that black bears movement in Dachigam were slow may be attributed with the food resource availability in Dachigam (Table 5.11). Many studies brought out that the distribution and abundance of foods, particularly mast, largely affects the movement patterns of black bear (Jonkel and Cowan 1971; Garshelis and Pelton 1981; Rogers 1987; Hightowe 2003). There was a significant difference in the food availability of black bear in Dachigam which may be affecting the movement patterns and ranging patterns of black bear in the landscape. During autumn and spring season black bear have to cover large distance since the resource availability in the landscape becomes patchy. Similar effects of hard mast availability on fall movements of black bears have been observed across the distribution range of black bear (Jonkel and Cowan 1971; Novick and Stewart 1982; Rogers 1987).

The maximum distance per day covered was largest for M02 (9634m) and it was lowest for M10 (1609). The individuals who were using areas outside Dachigam were covering larger distances than the individuals which have restricted their movements to the boundary of Dachigam. The number of different relocation sites were highest for F06 (0.192 sites/day) followed by M02 (0.180), M (0.081) and lowest rate of selection of new site was for M10 (0.038) and F04 (0.053) (Table 5.10). The rate of new site use was highest for individuals which have used large area outside Dachigam NP. The individuals which have not explored areas outside Dachigam NP possessed low rate of new site use. The large number of location clusters in the home range of such individuals can be attributed with higher rate of new site selection (Figure 5.8 and 5.9). Dachigam NP is surrounded by large number of orchards where bears were causing damage. One of our radio-collared animals was found to be involved in conflict with humans and caused damage to croplands, and it was derived back to forests by locals. The large number of long distance sallies by such bears also corroborate the findings related to new site selection. There was no consistent pattern was evident in the distribution of turning angles among the radio-collared black bears (Figure 5.16)

5.4.4.2. Black bear path tortuosity in Dachigam landscape

To assess the path tortuosity continuous location data was used to generate movement path for seven days and 5-10 such segments were used to quantify fractal D or the path tortuosity. The path tortuosity differed significantly among the seasons (Mann-Whitney; $U=19$, $P<0.02$) (Figure 5.17). The higher D value indicates more circuitous path and mean D value of radio collared black bear was highest for summer (1.76± 0.30) followed by spring (1.59± 0.08), autumn (1.37± 0.24) and lowest during winter (1.29± 0.21) (Figure 5.18). The movement of black bear during summer was more circuitous since the food availability in the Dachigam was homogenously distributed. The homogenous availability of food resources prompt bear to take more turns leading to increase in the fractal D value. However, during autumn the food resource becomes patchy in distribution leading to more linear movement (Figure 5.19). During autumn season bears were moving linearly towards the food recourse patches. Less number or low frequency of turns leads to lower fractal D values. The fractal D value was lowest for movement paths during winter which can be attributed with small distance and straight or linear paths.

5.4.4.3. Effect of habitat variables on the movement patterns of black bear in Dachigam landscape.

The linkage between animal behavior and landscape pattern is particularly amenable for the empirical analysis since certain behaviors of a species is strongly influenced by landscape pattern (Wiens and Milne 1989; Crist et al. 1992) and movement behavior in particular; represent how an animal responds to spatial pattern (With 1994).

The impact of road and other linear features on the movement path of black and grizzly bear have been studied by many researchers (Mattson et al. 1987; Brody and Peltion 1989; Jensen 2009), whereas for the Asiatic black bear this is the first study where approach was used to understand the movement behavior. The Dachigam landscape comprises of forested habitats surrounded with human habitation, croplands, and there were large number of roads and forest trails exits in the landscape. In the present study an attempt was made to look at the effects of various variables and disturbance on the movement path selection of black bear. Previous studies have stated that fragmented landscape often restricted the movements of animals to suboptimal patches, surrounded by unsuitable habitats and roads (Saunders et al. 1991; Andren 1994) (Figure 5.20).

It was hypothesized that the impact of linear variable on the movement is scale dependent and various studies also corroborated the study hypothesis. A part from disturbance variables the topographic and ecological variable were also used in the analysis. The possible bias in the movement pattern analysis in the present study can be attributed low sample size. The numbers of radio-collared bears were fewer (7 individuals) and the monitoring duration was also short and for two individuals it was as less as 6months (range of 6 to 26 months), hence the data was not polled and results were interpreted separately for all bears (Table 5.2).

The results indicated that the effect was not similar for all study individuals. The terrain ruggedness was positively explaining the movement path selection for four individuals out of which one was male (M10) and three females (F00, F04, F06) (Figure 5.20). These individuals have used areas which were moderate to high in ruggedness. Individual F00 preferred areas which were less disturbed and avoided areas with high density of road and human trails network (Table 5.11). The movement path of this female is influenced by the availability of road, human use trails and the distance to food patch. At final scale of 0.5 km and 1km this individual has used areas which were devoid of natural food, road, trail and croplands. The availability of natural food patches were very low in the home range area of this female and hence explaining the path selection, whereas at 5km scale with low to moderate road density were also used. During the crop production time this individual has used areas for movement which were close to road with moderate to high disturbances. Studies on the movement behavior of animals stated that bears can negotiate disturbances in the case of abundant food resources (Novick 1979; Barner 1990; Mattson 1990; Blanchard and Knight 1991). The individual M06 have covered large amount of area in the landscape and possess large home range size. The influences of variables on the movement path selection by this individual were similar to the F00, since this individual has also used similar type of landscape.

Individual M02 have avoided areas which were high in ruggedness at 0.5Km (β=-0.3268, P=0.000) and 1km (β= -0.05, P=0.79) scale but for long distance sallies have selected less rugged areas (β= 0.33, P=0.04). The availability of natural food patches (β=1.539, P= 0.001; β=0.88, P=0.000; β=0.27, P=0.097) was high in the home range of this individual, hence showing preference to natural food patches at all the three scales. At 0.5km and 1km scale areas with high density of road were avoided by this individual. There was a negative relationship of this individual with the distance to cropland, since this individual have moved through forested habitats of the landscape and shown little preference for movement in croplands habitat. This individual has avoided areas which were having high density if human used trails at all scale of analysis and selected area for the movement which was devoid of human disturbance, rich in availability of natural food resources.

Individual F04 have never explored areas outside the boundary of Dachigam NP during the monitoring period (Figure 5.8 and 5.9). Since the area where she has stabilized her home range possess moderate to high rugged terrain. At small scale of analysis there was positive relationship with distance to natural food resources (β= 1.052, P=0.01; β= 1.12, P=0.000) whereas negative (β=-1.12, P=0.000) at 5km scale, which indicates that she has selected areas for the movement which were close to natural food patch. The negative relationship with the human used trails at 0.5km scale indicates that she have avoided areas which were having disturbance, since the frequency of smaller step were high and also showed little tolerance to disturbance at large scale (1km and 5km). In general she has selected areas for movement which with having abundant natural food, water and devoid of disturbed.

Individual M08 has also restricted his movements to the boundary of Dachigam NP and preferred areas with low to moderately rugged. Interestingly at all scales of analysis M08 has used areas close to road (positive relationship) and avoided human use trails (negative relationship). At scale of 0.5km scale M08 has moved in areas which were devoid of natural food, whereas at 1 and 5km scale areas with large number of natural food patches, close to water bodies and roads were selected for movement. The availability of natural food patches was low hence has to cover large distances for foraging. The roads inside Dachigam NP were used for patrolling by the wildlife department personals and were used less frequently. In Alberta, a study by Nielson et al. (2004) reported the occurrence of large number of berry species and other species. Selection of areas close to road by M08 can be attributed with the occurrence of food species along the roadside. The area where M08 stabilized its home range was having more frequent disturbances due to the movement of tourist, nature lovers, army soldiers which may be the fact behind avoidance of area with human trials for movement path selection (Figure. 5.9).

Individual M10 have used areas which were moderate to high in ruggedness (positive correlation), having abundant natural food patches, close to water and devoid of disturbances (negative correlation). The M10 was radio-collared during autumn at a site close to road and it was moving close to the road since the availability of food plant species was also high along the roads. The availability of food along the road may be the fact behind the preference of areas close to road. During the autumn season the distribution of food resources becomes patchy and the valley areas were rich in walnut tree patches. Most of the fruits patches were close to road in the home range of M10.

The individual M100 selected flat and less rugged areas where availability of natural food recourses was high and close to water bodies. It has avoided road side areas for the movement path selection at all scales of analysis. At 0.5km scale M100 avoided areas far from human use trails. At 1km scale the positive relationship with the human use trails can be attributed with distribution of large number of food plants species along the human use trails in the middle elevation areas of Dachigam where the density of trails were high. Individual M100 selected areas for movement which was high in food availability, close to water bodies, devoid of roads and with less amount of disturbance.

The studies on American black bear and Grizzly bear stated the impact of different landscape feature to the movement patterns (McLellan and Shackleton 1988; Roever et al. 2010). The results of the present study corroborated the findings of the other studies where it was stated that linear features in the landscape were avoided by animal for movement (Shepard et al. 2008). The maintenance and restoration of landscape permeability for black bear is importance for the long term survival of black bear in Dachigam landscape. It will also help in minimizing the bear-human conflict in the landscape. The functional corridors and permeability plays important role in maintenance of genetic viability and the growth of population. The roads and conversion of forested habits into human croplands and other development have profound effects on the population of animal species (Anderson 2002; Forman et al 2003). The habitat fragmentation due to road and human encroachment has proved to be lethal for the species by way of making the species demographic and genetic isolated (Forman et al. 2003).

5.5. Summary of findings and discussion.

1). Amongst the kernel based utilization distribution methods for home range analysis, the fixed kernel method was found to be best. The results of comparison of the home range analysis software indicated that GME is the best home range estimation programs.

2). Using kernel method, out of the total seven radio-collared bears, the home range reached asymptote for three bears. Out of total, two individuals did not possess core areas in their home ranges since they showed multiple center of activity which may be due to multiple reasons such as: spatio-temporal change in food availability in their home ranges, they do not posses site fidelity and potential bias due to data discontinuity.

3).The overall home range size of male bear was larger than female bear and was similar to the findings from other studies on Asiatic black bear.. There was a significant difference in the home range size among the years (2010>2011) which may be due to high food productivity during 2010.

4). Home range showed site fidelity for two bears among the four compared. The home range shifts were large among the males than females. The shift in the home range could be attributed to the reproductive strategies and the spatio-temporal heterogeneity of resource inherent in the landscape.

5).The movements of bear were largely influenced by the availability of food resources in the landscape. The bears moved faster and in linear fashion during autumn whereas, there movement were slow and the paths were more circuitous during summer.

6).The results indicated that the effects of habitat variables were not similar for all study individuals and resilience to human disturbance also varied individually. Areas with high human trail and road density were avoided for movement path selection by bears which was concurrent to the findings of the other studies elsewhere.

CHAPTER – 6: FOOD AND FEEDING HABITS OF ASIATIC BLACK BEAR AT DACHIGAM NATIONAL PARK

6.1. Introduction

Asiatic black bears (*Ursus thibetanus*) are omnivores in their feeding habits throughout their distribution ranges (Schaller 1969; Wang et al. 1995; Hashimoto and Takatsuki 1997; Hwang et al. 2002; Sathyakumar and Viswanath 2003). Their diet mainly comprises of fruits, grasses, herbs, insects but sometimes they feed on animal matter (Schaller 1969; Manjrekar 1989; Hashimoto and Takatsuki 1997; Hwang et al. 2002; Sathyakumar and Viswanath 2003). The food habits of Asiatic black bear are well documented by many studies conducted throughout its geographical and ecological distribution range. The diet of black bear shows large variability which can be attributed with the local availability and abundance of different food items in its habitat. Studies on habitat utilization suggest that black bears select the habitats with high food abundance and they follow the phenological changes on the reproductive and vegetative parts of the fruiting plant species (Davies et al. 2006; Koike et al. 2008). Sathyakumar and Viswanath (2003) reported the role of black bear as a seed disperser as well as seed predator. Feeding habits may be influenced by foraging energetics which involves time spent in food search and nutritional benefits (Krebs and Davies 1993). Studies on diet and diet selection revealed that selection is probably the consequence of complex interactions of external, internal and phylogenetic factors (Litvaitis 2000). The study on the food habits can provide important information such as the nutritional health, which is vital for the reproduction and population growth of animals (Jonkel and Cowan 1971; Bunnell and Tait 1981; Rogers 1987). Meticulous understanding of the food habits is necessary requirement for the natural history of a species. Food habits have been investigated for the variety of reasons. In human dominated landscape it is important to understand the "economic food niche" of species such as black bear. Economic losses due to livestock depredation and crop damage are serious concerns.

Black bear distribution, movement and its home range is reported to be largely governed by the availability of major food items in Dachigam NP (Manjrekar 1989). Increasing human population resulted in encroachment and degradation of black bear habitat and affects the quality as well as quantity in terms of food availability. Black bears consume food in crop lands and orchards that are close to bear habitats and are thus involved in crop and livestock depredations (Charoo et al. 2011). Increasing black bear humans interactions makes the survival of black bear in North-western Himalayan landscape challenging (Sathyakumar and Choudhury 2007; Charoo et al. 2011). Studies on black bear food habits can play a vital role in understanding and improving the habitat quality in terms of food resources. It may be helpful in black bear population management and reducing crop damage by black bear which are close to its habitats. It was attempted to understand the relation between availability of different food type in different seasons and utilization of these food resources by black bears.

The habitat selection by a species should reflect availability of basic components of habitat such as food, water and the type of cover (Costello and Sage 1994). Food is one of basic necessities of a habitat which is responsible for the survival of any species and in case of species such as black bear the food availability governs their movement and ranging patterns which was well documented (Lindzey and Meslow 1977; Landers et al. 1979; Hugie 1982; Novick and Stewart 1982; Elowe 1984; Young and Beecham 1986; Hellgren et al. 1991; Kozakai et al. 2011). The food availability was rarely quantified to assess the seasonal changes among the different habitats elsewhere before. In the present study it was attempted to quantitatively assess the food availability in the different black bear habitat types among different seasons in Dachigam NP. The food availability in Dachigam was assessed for all of our study years to understand yearly changes in food availability as well.

6.1.1. Nutritional analysis of black bear diet

A number if researchers have (Wainio and Forbes 1941; King and McClure 1944; Beck and Beck 1955; Burns and Viers 1973; Landers et al. 1979) evaluated nutritional value of various food items typically consumed by the black bears. Beeman and Pelton (1980) reviewed several nutrition studies and found most food items high in carbohydrates and low in protein. Nutritive value of seasonal diets, however, was not evaluated. Many studies stated the importance of fruit items to black bear diet, as black bear prefer large amount of fruits in diet (Schaller 1969; Beeman and Pelton 1980; Manjrekar 1989; Hwang et al. 2002; Sathyakumar and Viswanath 2003; Koike et al. 2008). However the field studies on foraging habits of black bear shows that black bear do not feed on fruits randomly, but instead display marked preferences (Eagle and Pelton 1983), The food choice of black bear can mainly be attributed to two basic principal factors: the nutritional composition of food (Manjrekar 1989) and its relative spatial and temporal availability (Koike et al. 2008). The variability of diet items chosen by the black bear in different habitats has been documented through a number of studies (Manjrekar 1989; Koike et al. 2008). The black bears are particularly suitable subjects since a considerable amount of information on several aspects of their feeding habits and physiology is available through number of published studies in India (Schaller 1969; Manjrekar 1989; Sathyakumar and Viswanath 2003) and elsewhere (Hwang et al. 2002; Koike et al. 2008). As black bear shows high degree of frugivory and vivid predilection for different types of nutrients suggest that the nutrients content might be an important determinant of food choice in Dachigam. The seasonal fruit choice by black bear corresponds to the presumed seasonal physiological requirements for example- in autumn black bear may feed largely on food items which were rich in lipids, whereas during spring diet is dominated by food items which are rich in protein as after hibernation black bear need protein for the structural growth. It was hypothesized that food selection by black bear in different seasons is related to the physiological requirements and the nutritional composition of the food item. The information on nutrients composition of the major food items of black bear at Dachigam was generated to test whether the food selection was positively related to the nutritional composition of food item.

6.2. Methods

The food and feeding habits of the Asiatic black bear in Dachigam NP was investigated during June 2007 to October 2011. Six habitat types were identified based on vegetation data analysis for plant community classification and were mapped using GIS (Singh et al. 2002). In total 13 transects/trails along with 120 vegetation sampling plots covering all habitat types of the study area were used to collect scat scamples and to monitor food availability.

6.2.1. Phenological monitoring of bear food plant species

To understand the seasonal availability of food resources the phenological change on vegetative and reproductive parts of important food plant species (trees, shrubs and herbs) of black bear was recorded after every 15 days on permanent sampling plots (n=120). Based on the direct feeding observations and scat analysis carried out during 2007, 14 important food plants (trees and shrubs) were selected for phenological and abundance quantification of vegetative and reproductive plant parts in all different habitats. Data on plant part production and basal area per hectare in square meters was recorded. The abundance of leaf buds, young leaves, mature leaves, flower bud, flowers, young fruits and mature fruits in relation to maximum crown volume was estimated (Dasilva 1994). The abundance of different plant part for all selected species were given a score from 0 – 5 on all sampling plots (Dasilva 1994). The score of 5 points indicates that the particular plant part was found in all parts of tree crown and shrub cover on a plot. This allowed me to estimate the absolute abundance and to compare availability between plants parts.

Species-specific contribution was calculated using the formula:

$$\boldsymbol{W_i = (\sum A_i \ / \ n_i) * B_i}$$

Where, W_i is the abundance of plant parts, A_i is the phenological score, n_i is the number of individuals, and B_i is the basal area per hectare in square meters, all for species i (Dasilva 1994). Summed total of all species, and each plant parts, was used to calculate the overall abundance.

6.2.2. Food availability quantification in Dachigam National Park

6.2.2.1. Distribution and Abundance of Food Species

To quantify fruit availability in Dachigam food species were sampled by using a circular plot of 10m radius and the tree crown volume (m^3) of black bear food tree species and percent cover (m^2) of relevant shrub species in a plot were measured. For the quantification, 12 important black bear food plant species were selected based on the results of direct feeding observation (% frequency observation) during the study period. For each bear food tree species 15-20 individuals were marked in sampling plots in different habitat types representing different elevation classes and other habitat variables related to the distribution of the food species in three bear seasons: spring (after hibernation when bear emerges from hibernation), summer (breeding season) and the autumn season (hyperphasis before going in hibernation). The measured Individuals of trees and shrub species used in quantification were permanently marked for the seasonal consecutive repeats. The phenological changes were monitored by the method suggested by Koch et al. (1995) and Rawal et al. (1991)

To calculate crown volume three measurements on each tree within the plot: (1) crown width from east–west, (2) crown width from north–south, and (3) crown height were made. The clinometer was used to calculate tree height and measuring tape for the measurement of DBH for all measured tree species in the study area. The tree crown volume was calculated using the method suggested in Inman and Pelton. (2002). For the tree crown volume calculation formula for different crown shape was used suggested by (www. warnell.forestry.uga.edu). The crown shape of most of the trees was Paraboloid (*Morus* sp., *Juglans regia, Celtis australis* and *Prunus* sp.) and Fatcone (*Quercus robur*) shape. The fruit production was estimated when the majority of fruits of an individual tree or shrub patch were ripened state. To estimate fruit production for trees, the fruit seen within a measured volume of tree crown using a 15-45 power spotting scope were counted which was mounted on tripod (Inman 1997). While sampling fruits on tree magnification was decided after taking several measurements at different distance. A conic volume was within the view of the scope when viewing the tree crown, some of this volume was within the tree crown and some was falling outside the crown. The sample volume was calculated by subtracting the volume of cone outside the tree crown from the total volume of the cone.

The volume of the two cones was calculated by using the formula suggested by Inman (1997). The distance from the spotting scope to the mid-width point of the tree crown where the sample was taken (M) was determined by measuring the distance from the scope to the base of the tree (D) along with the angle from the scope to the base (θ Bottom) and the angle form the scope to the sample (θ Top) (Figure 6.1).

$$\mathbf{M = (\cos\theta\ Bottom \ast D) / \cos\theta\ Top}$$

Two samples at random locations within each tree crown were taken and averaged to estimate production for the individual tree. For estimation of fruits on shrubs, fruits were sampled within a 0.5 m^2 area of shrub coverage in the sampling plot. Fruits were counted in the randomly tossed square of 0.5 m^2 sampling grid into the patch of *Prunus* spp. and other species. Fruits were counted from the top of the plant crown to the ground. Two 0.5 m^2 samples were taken at each individual patch, and the mean of the 2 samples was used as the estimate of production for that shrub species patch in the plot.

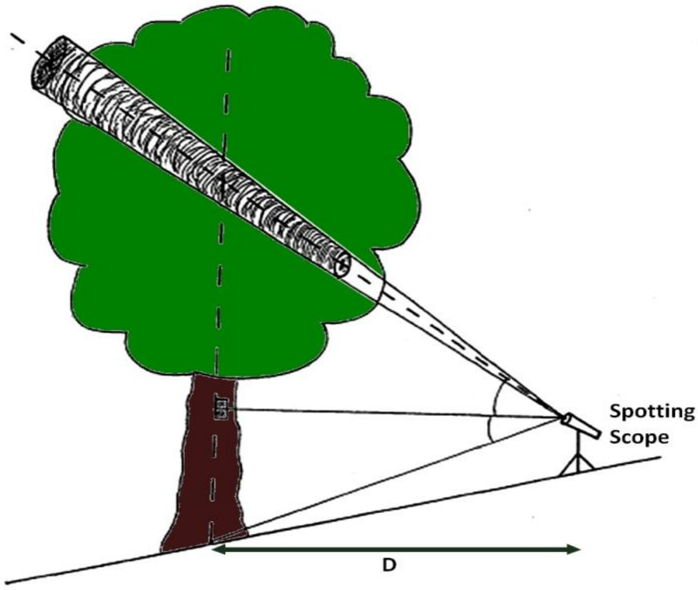

Figure 6.1. Picture showing fruit sampling using spotting scope in tree crown to estimate fruit production per m^3 of tree crown volume

6.2.2.2. Food availability index calculation for fruit abundance estimation

The food availability estimated by using a food availability index value (FAI). The FAI was estimated by the summation of the mean density (#/Km^2) of food plant species in the habitat, mean frequency of occurrence in the habitat, mean fruit/m^3 on the tree species, was converted to mean fruits/km^2 for each habitat and for the shrub species, mean fruits/km^2 for habitat types and the mean percent coverage was calculated for palatable grasses. The significant differences in mean values were tested using the non-parametric test. It was attempted to generate the seasonal FAI which combines tree, shrubs, frequency of occurrence, fruit production data and the grass cover percentage. For the comparison of these various type of data among the habitat, values of each data type was converted to a scale of 0-1 of each species. A value of 1 was given to the data type for the habitat having the highest abundance of a given food and its abundance in other habitats was scaled relatively. When each food was given a maximum value of 1, information regarding abundance of a species relative to other species was masked. To account for this, each abundance value was multiplied by a factor of 1-4, depending on its percent occurrences on plots in the habitat (s) rated 1. Species occupying 1-25% of the sampling plots were multiplied by 1, those found on 26-50% by 2, 51-75% by 3, and 76-100% multiplied by 4 (Costello and Sage 1994). Finally food availability index was estimated by summing all the data types recorded for all the bear food plants species for each habitat type in all bear foraging seasons.

6.2.3. Nutritional analysis of black bear food items

6.2.3.1. Sample collections protocol and nutritional analysis

Samples approximately 0.2 – 0.5 kg of each food species consumed by black bear over different foraging seasons and from different habitat were collected. The nutritional analysis was carried out only for the major food (>5%) species only based on the percentage frequency of occurrence in diet. The samples were collected to ensure that they were similar to what was consumed by the black bear based on the scat analysis and the direct feeding observations. For most of the fruits 10 to 15 samples were collected in different seasons from the study area. The collected samples were dried in a cool and dark place. Dry matter was calculated by a two-step process involving both field and oven-drying. In field, samples weighted shortly after collection and then were dried at ambient temperature in the dark place. Initial moisture was calculated by subtracting the constant dry weight of the sample from the weight obtained shortly after collection. Immediately before chemical analysis, an accurately weighted small portion of the previously dried samples were dried again at 105° C to remove any absorbed atmospheric water to calculate the true dry matter of each sample.

The samples were analysed at a private lab in Delhi and the G.B Path University, Panthnagar. The samples were first analysed for acid detergent fiber with residual ash (ADF) (Von Soest et al. 1991), nitrogen (N) content using a macro-Kjeldahl method (Williams 1984), Crude protein (CP) levels were calculated as CP = % N x 6.25 using the standard formula (Williams 1984) and bound protein was determined as acid-detergent crude protein (Yeager et al. 1997), Fiber analysis was carried out following previously described methods (Von Soest et al. 1991), Crude fat was measured in seeds and nuts only by following Cunniff (1996) and the total energy content of various food items was estimated by using Bomb calorimeter (Prus, 1975).

$$H_c = \frac{Wc\,\Delta\,T}{Ms}$$

H_c = Heat of compustion of the fuel samples c/g, W_c = water equivalent of the calorimeter assembly, (2883.31 Cal/ C^0), ΔT is Rise in temperature, ^0C, and M_s is mass of sample unite burnt in grams (g).

Ash, and nitrogen-free extract was not determined. The crude ash usually has little direct nutritional use because the ash component in plant is highly variable in composition and amount; many plants are high in silica, an element of no nutritional value (Crampton and Haris 1969). Most food items typically consumed by bears were low (<5%) in ash content (Wainio and Forbes 1941; Landers et al. 1979). Ether extract and nitrogen-free extract are generally readily available sources of nonspecific energy (Crampton and Harris 1969). The protein content of a feed may be an indirect measure of its digestible energy because protein is usually highly digestible (Crampton and Harris 1969:48). A food with a high ADF content, a measure of the level of cellulose, may be regarded as relatively un-digestible because bears lack cecum and their simple stomach is too acidic to support microbes necessary for the digestion of the cellulose (Rogers 1976).

6.2.4. Food habit analysis

To understand the feeding habits of black bear following three methods were adopted

6.2.4.1. Observations on direct feeding and feeding signs

Observations on bear food and feeding habits were made opportunistically during day time and this includes regular monitoring of five radio-collared bears. Black bear feeding signs were observed during the systematic field work on transects, and vegetation sampling plots (Green et al. 1997). A feeding sign at one location (e.g., broken branches, fruiting bush, fallen fruits, fruiting tree, stone turning, digging, browsing sign on herbs and rake marks on trees) was considered as a single unit (Plate 3.1).

6.2.4.2. Post ingestion analysis

Asiatic black bear scats were collected systematically as well as opportunistically during the routine field work. The information on collected scat samples such as date, scat condition (fresh/old), habitat type and GPS location were recorded. Scat analysis was carried out following Smith (1984). Collected scats were soaked in water, washed using 0.7mm sieves and dried in sun light. The hair samples were examined for medullary and cuticular characteristics (Putman 1984; Kohn and Wayne 1997). For seed identification reference fruits species were collected and for vegetation matter reference slides (key to species) were prepared for palatable plants form study area. The fruit seeds were identified by comparing with reference and the undigested vegetation material which was left after washing the sample was dried in oven and microscopic slide was prepared for examination of tissues and was compared with the reference slides (key to species) of grass and herbs species. Each food item was classified into forage class: reproductive plant parts (flowers, fruits, nuts and seeds), herbs and grasses, anthropogenic food (cultivated food crops), animal matter (bones, animal tissue and hairs), and insects. Each scat sample was considered as a sample unit for statistical analysis to understand the diet composition of black bears. Collected scats were divided into four seasons spring, summer, autumn and winter based on plant phenology in the study area. The percentage frequency of occurrence of different food items in black bear scat was calculated for all the seasons during the study period

$$\boldsymbol{FO_i}(\%) = (\boldsymbol{n}/\mathbf{N}) * \mathbf{100}$$

Where, N was the total number of fecal samples and n_i the number of samples containing food item i and FO_i (%) is percentage frequency of occurrence (Hwang et al. 2002). The seasonal diet variation was tested using the Chi-Square test for variation. To understand the species diversity in bear scat among the seasons, Shannon Weiner index (H) value was calculated and compared across the seasons (Hashimoto 2002). Based on direct feeding observations, Spearman rank correlation was carried out between the abundance score and the percent contribution of plant part to diet of black bear to understand the preference of food type. For the yearly comparison of diet the percentage data of different food categories was transformed using Arcsine and the Levene’s test was used to understand the diet variation (Schultz 1985). All data analysis was carried out using software program SPSS 16.0, Biodiversity pro and Microsoft Excel.

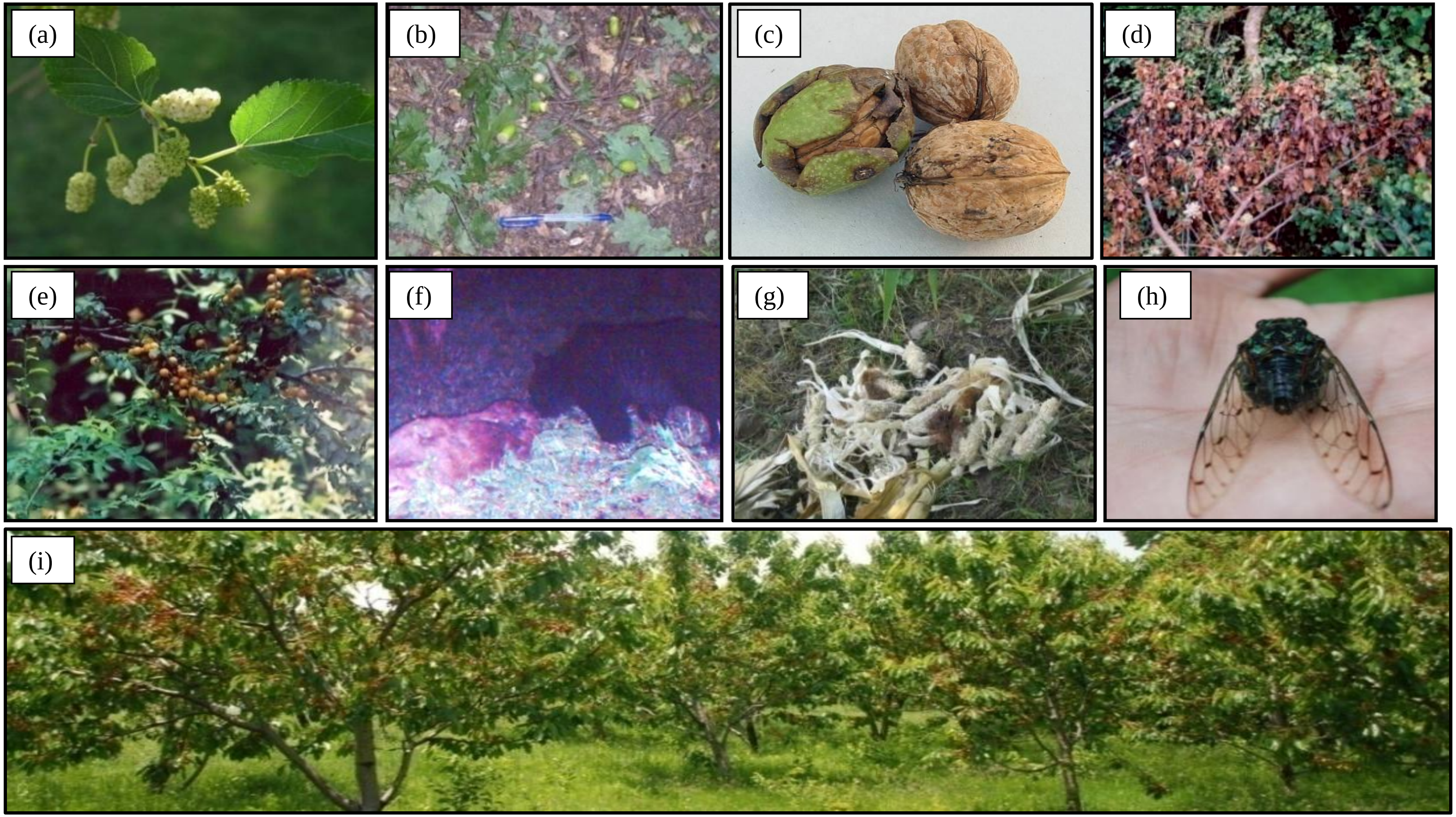

Plate 6.1. Asiatic black bear food species in Dachigam National Park (a) *Morus alba*, (b) Oak acorns, (c) Walnuts, (d) Apple, (e) *Prunus armeniaca*, (f) black bear feeding on hangul carcus (g) Maize crop damaged, (h) Insect, (i) Cherry orchard.

6.3. Results

6.3.1. Phenological availability of important food plants of black bear in Dachigam NP

The availability of vegetative and reproductive parts on important food plants for black bear which includes trees, shrubs and herb varied across seasons. The abundance of plant parts in terms of flowers, leaves and fruits exhibited marked seasonal pattern. The leaf-buds were most abundant in spring (March-May) but young leaves appeared during a brief period of leaf turnover during last spring and summer (June-August). The productions of mature leaves peaked in September and were available throughout the summer and in early months of autumn on all species (Figure 6.2). The abundance score of reproductive plant parts, such as flowers, fruits was consistently lower than vegetative parts, also showed seasonal variation in abundance.

The availability of flower-buds was highest in early months of spring on all species (tree, shrubs) and the abundance of mature flowers was highest in late spring and early summer (Figure 6.2). Young fruits were available mostly in late spring and early summer (April-July) but the availability of mature fruit was highest in late summer and autumn (September-November). In December fruits were available on some species but in low abundance. There was no food availability in January-February months of winter. The availability of palatable herbs and grasses was highest in spring (Figure 6.3).

6.3.2. Fruit availability estimation in Dachigam

6.3.2.1. Distribution and Abundance of Food Species

The mean density for *Morus alba*, *Celtis australis*, *Prunus armeniaca* and *Juglans regia* were 81.10 ± 12.5, 46.32 ± 7.6, 106.1 ± 16.4, 24.21 ± 5.4 respectively was highest among the tree species and the mean density *Prunus prostata*, *Berberis lycium*, P*runus trumontosa*, and *Rubus fruticocus* were 260.04 ± 36.8, 255.83 ± 47.5, 178.98 ± 34.6, 177.92 ± 34.4 respectively and highest among the shrub species (Table 6.5). The abundance of grass/herbs did not differ among the habitats except the non forested open grass and scrub land (P = 0.05, n= 121), where percent coverage was very high in comparison to other habitats. The abundance of *Mor*us spp, *Celtis australis*, Oak, *Prunus* spp., differed among the different habitats in the study period (P = 0.05, n=121) (Table 6.2).

The density of different fruit plant species used by black bear differed significantly among the habitats (Friedman's test; Q = 10.86, P = 0.054, alpha = 0. 05, P-value computed using the Monte Carlo simulations). The riverine habitat was having the highest density of fruiting species such as the density of *Morus alba, Prunus* spp followed by low temperate habitat (Table. 6.2). In Oak plantation habitat the other fruit bearing species were *Juglan regia*, *Prunus prostrata* and *Beriberis lycium* which were in low abundance.

6.3.2.2. Fruit abundance estimation

The mean abundance of fruits was significantly different among the seasons (Kruskal-Wallis test: K = 35.3, *P* <0.0001, alpha= 0.05 at 1000 Monte Carlo simulations). The fruit abundance on most of the species was highest in summer followed by autumn and minimum during spring season. Highest mean number of fruits on *Morus* spp and *Prunus* spp., was found in riverine habitat followed by low temperate habitat and fruits were available on 11 species but there were no mature fruits on one (*Qurcus robur*) out of 12 species (Table. 6.3). In autumn, the mean fruit availability on *Juglan regia* (433446.0 fruits/ha) and *Celtis australis* (4062419.0 fruits/ha) was highest in riverine habitat followed by lower temperate for *Juglans regia* and lower temperate pine mixed for *Celtis australis*. During autumn the fruits were available only on eight species out of 12 main fruit species of black bear. Where, as in spring the fruits were available only on three species out of 12 species. The highest mean fruit availability was recorded in riverine habitat on *Morus alba* (621524.1 fruits/ha), *Morus nigra* (32215.2 fruits/ha) trees and *Vibernum contifolium* (32439.2 fruits/ha) shrub followed by lower temperate habitat. There were no fruits in temperate grass and scrub land habitat during the spring season out of total 12 species.

6.3.2.3. Fruit abundance index

The relative abundance data for all the selected species were used to generate food abundance indices for spring, summer and the autumn season in the study area. The fruit abundance index (FAI) was highest for the riverine habitat in all seasons. The FAI value for spring was 4.37, for summer was 3.57 and for autumn it was 4.97. The second highest value of FAI was for Lower Temperate habitat in all seasons 3.39 during spring, 2.98 during summer and 3.43 during autumn which is primarily because the high density of tree and highest availability of mean fruits/ha was highest in riverine and lower temperate habitat in comparison to other habitats (Table 6.4).

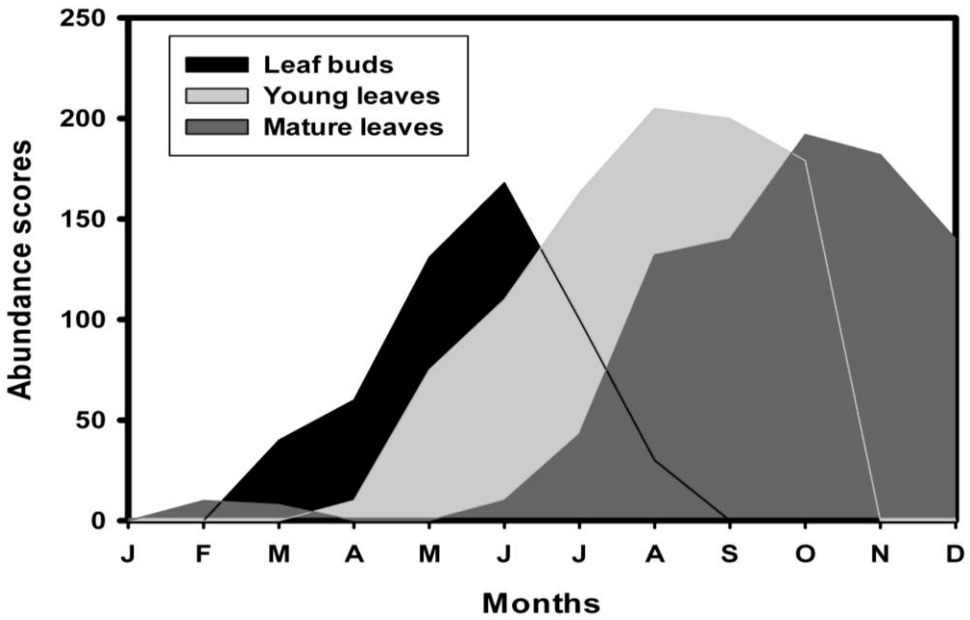

Figure 6.2. Abundance scores of vegetative parts for important plants of Asiatic black bear at Dachigam National Park, India during 2007-2011.

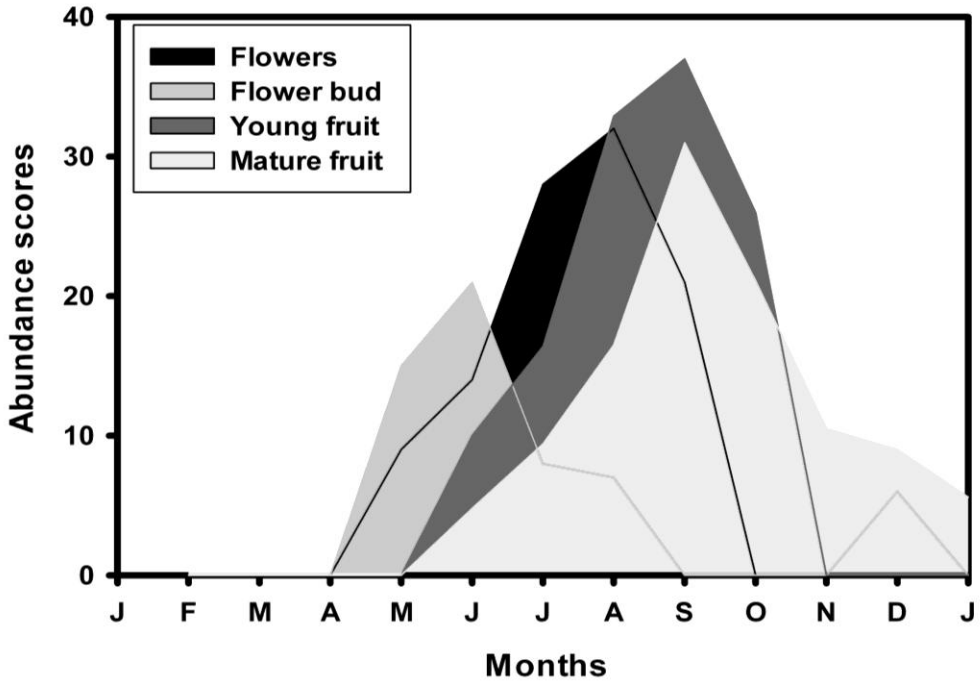

Figure 6.3. Abundance scores of reproductive parts for important food plant of Asiatic black bear at Dachigam National Park, India during 2007-2011.

Table 6.1. Estimated fruit abundance (mean no. of fruits/ha) within different habitats during different seasons (availability of only those species which were having fruits during the respective season were given in the table)

SUMMER	**Riverine**	**Lower Temperate**	**Lower temp pine mixed**	**Mid Temperate**	**Oak plantation**	**Temperate grasslands**
Morus alba	2803914.9	2084313.9	1477212.5	342909.4	-	-
Morus nigra	536875.5	412262.8	178434.4	158001.4	-	-
Prunus ceracifera	183901.4	122628.8	103011.6	108364.8	-	-
Prunus armeniaca	73396.8	102959.3	31336.7	25524.7	29076.4	29076.4
Juglans regia	561412.2	225681.9	388445.8	563085.8	-	-
Quercus robur	-	-	-	-	8334.5	-
Celtis australis	4481718.5	2981283.9	3556663.3	2760618.8	-	-
Rubus fruticosus	107022.0	26615.1	46789.9	46083.5	-	-
Prunus prostata	2533422.3	3125760.4	3023205.5	2498944.0	-	-
Berberis lycium	1540378.0	4884765.9	2615862.8	1264509.6	-	-
Vibernum continifolium	13.7	91652.6	122404.9	173882.9	31822.8	-
Rosa webiana	12031.0	98321.2	52012.3	37829.32	-	154308.5
AUTUMN						-
Juglans regia	433446.0	201245.5	379264.9	489581.7	-	-
Quercus robur	-	-	-	-	2475322.7	-
Celtis australis	4062419.1	2413605.6	3148601.6	2214144.7	-	-
Rubus fruticosus	59429.0	7877.1	13617.7	9797.6	-	-
Berberis lycium	89.1	1805.0	7534.4	4509.6	-	-
Vibernum continifolium	-	-	-	-	-	-
Rosa webiana	137.4	21589.2	32015.0	99472.3	-	98453.9

						-
SPRING						-
Morus alba	621524.1	424038.7	215365.5	48986.2	-	-
Morus nigra	32215.2	42712.3	14555.1	10412.7	-	-
Vibernum continifolium	32439.2	38333.9	145528.8	116228.2	38376.9	-

Table 6.2. Table showing the food index values in all different habitats among different seasons at Dachigam National Park

Habitat types	Spring	Summer	Autumn
Riverine habitat	4.38	4.98	3.08
Lower temp	3.39	3.44	2.99
Lower temp pine mixed	2.53	2.86	2.09
Mid temp	2.26	2.61	1.77
Oak plantation	1.08	1.19	1.09
Temp grasslands	0.54	0.54	0.51

Table 6.3. Mean density (per hectare) of fruiting tree and shrub species in Lower Dachigam National Park.

Tree species	**Density (#/hectare)**	**SE**
Morus nigra	13.42	3.2
Celtis australis	46.32	7.6
Morus alba	81.10	12.5
Juglans regia	24.21	5.4
Qurcus robur	5.79	4.1
Prunus cerasifera	22.37	5.4
Prunus armeniaca	106.1	16.4
Pyrus malus	11.32	4.2
Rubous pun.	26.32	10.3
Rosa webiana	133.71	30.5
Vibernum continifolium	95.80	26.5
Rosa bageriana	116.86	25.9
Rubous fruticosus	177.92	34.4
Prunus tomentosa	178.98	34.6
Prunus prostata	260.04	36.8
Berberis lycium	255.83	47.5

Table. 6.4. The mean density of fruiting trees and shrub species in different habitats (# plots) used for the food availability index value calculation

Habitat types/ Species	Low temp (n=41)		Mid temp (n=21)		Oak plantation (n=2)		Riverine (n=14)		Temp pine (n=31)		Temp grass (n=12)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Cel aus	43.5	12.3	22.7	11.4	-	-	78.1	19.4	54.6	25.7	-	-
Mor nig	10.3	6.2	-	-	-	-	14.5	7.4	-	-	-	-
Mor alb	68.8	16.2	12.13	6.77	-	-	86.4	13.6	49.4	21.8	-	-
Jug reg	27.96	9.58	13.6	10.7	47.8	47.8	82.1	14.3	6.83	3.62	-	-
Qur rob	-	-	-	-	5.78	207	-	-	-	-	-	-
Pru cer	79.5	31.5	84.9	11.1	-	-	38.5	10.2	67.5	29.3	-	-
Pru arm	50.5	12.6	68.2	22.2	-	-	97.6	12.3	38.7	20.1	37.2	22.5
Ros web	93.2	43.1	139.5	78.1	-	-	86.3	51.3	36.4	36.4	520	152
Rub fru	223.7	71.4	163.8	80.6	-	-	123.3	56.2	-	-	425	115
Pru pro	307.6	69.2	334	106	91	23.3	156.2	50.4	373	123	95.5	68.6
Vib sp.	111.9	39.3	412	106	-	-	135.6	45.7	45.5	31.6	-	-
Ber lyc	257.9	68.4	72.8	36.8	1656	510	316	116	409	173	-	-

6.3.3. Nutritional composition of black bear food items

Among the food plant species (herbaceous, fruit bearing) consumed by black bear, herbs were rich in crude protein content (21%) and were high in fibers (31%). The food species consumed by black bear were generally high in protein and fibers during spring (Table 6.5). The fruit species such as *Prunus* spp., *Morus* sp. were low in protein as well as fat but moderate in fiber content, the other fraction were high particularly carbohydrate, sugar. The Oak acorns were a notable exception, being low in both protein and fiber content. However, among fruits oak acorns were high in fats (14.8%) and carbohydrates. The highest content of fat were insects (18.5%) and animal material (23.3%) (Table 6.5). The highest content of protein was recorded in animal material (mammals) (63%) and insects (43%).

Table 6.5. Crude protein and acid-detergent fiber (ADF) content of food items consumed by Asiatic black bear at Dachigam National Park, during 2007-11.

Sample species	**Composition (% dry matter)**				**Energy**
	Crude protein	ADF	Other fractions	Fat	**Cal/g**
Herbaceous material	21	36	42.9	0.1	0.97
Prunus cerasifera	9	32	57.2	1.8	3.34
Prunus prostrata	7	24	65.9	1.2	3.01
Prunus armeniaca	12	21	65.5	1.5	4.50
Morus alba	11	26	62.3	0.7	3.01
Pyrus malus	12	22	64.9	1.1	4.18
Celtis australis	5	19	71	5.0	
Juglans regia	8	14	70.6	7.4	4.51
Qurcus robur	9	5	63.2	14.8	3.68
Insect	49	21	11.5	18.5	6.1
Mammal	63	4	9.7	23.3	

6.3.4. Direct feeding observations

During the study period, 162 feeding observations were made. There was a seasonal variation in the diet of black bear at Dachigam NP during the study period. Out of total observations, black bears were mostly found (66%) feeding on fruit bearing plant species followed by herbs and grasses (10.5%), feeding in crop lands and orchards (14.3%), animal carcasses (5.8%) and insects (2.8%) (Figure 6.4). In total 27 species were recorded through direct feeding observations, out of which 15 species (Berries, Hard mast fruit species) were fruit bearing, three herbs (*Dipsacus mitis, Hedera nepalensis*), three crops (maize, cherry, apple), three animal species (hangul, langur, livestock species) and four insect species (honey bees, beetles, ants, cicada) (Table 6.6).

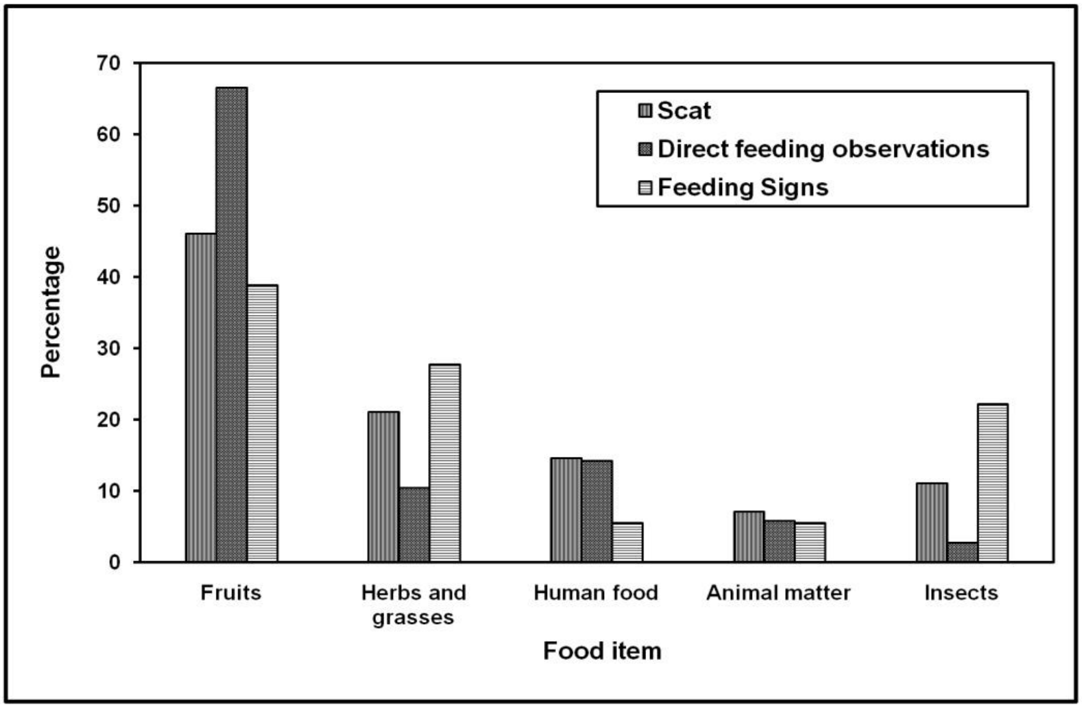

Figure 6.4. Asiatic black bear diet based on scat analysis, direct feeding and feeding sign observation in Dachigam NP, India, 2007-2011.

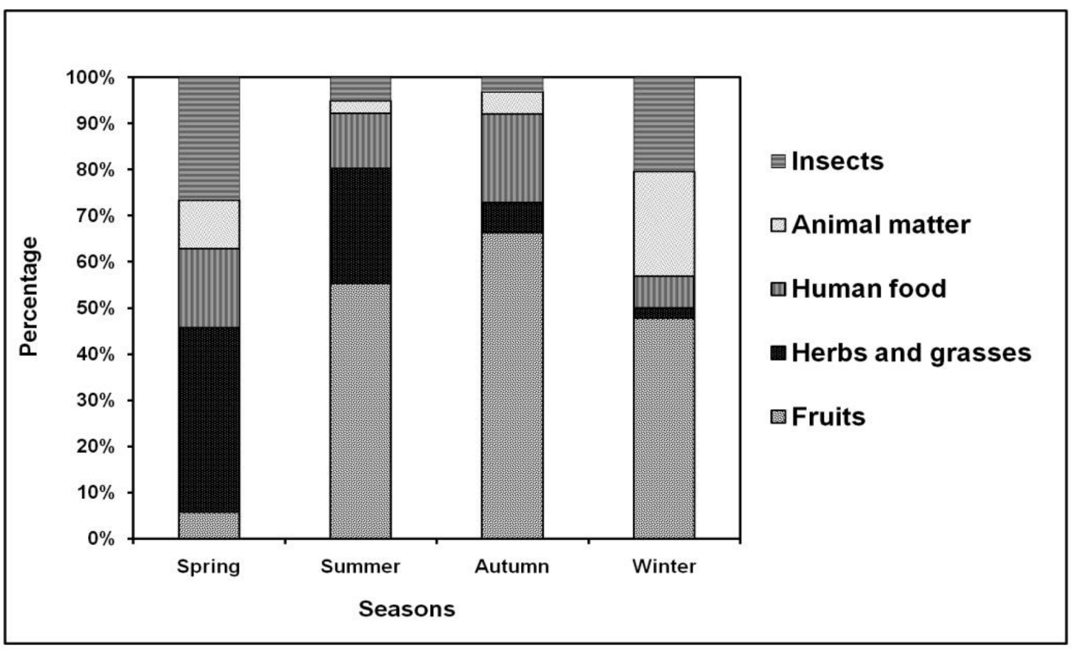

Figure 6.5. Asiatic black bear diet in different seasons based on scat analysis at Dachigam NP, India during 2007-2011. (χ^2= 157.39, P <0.001)

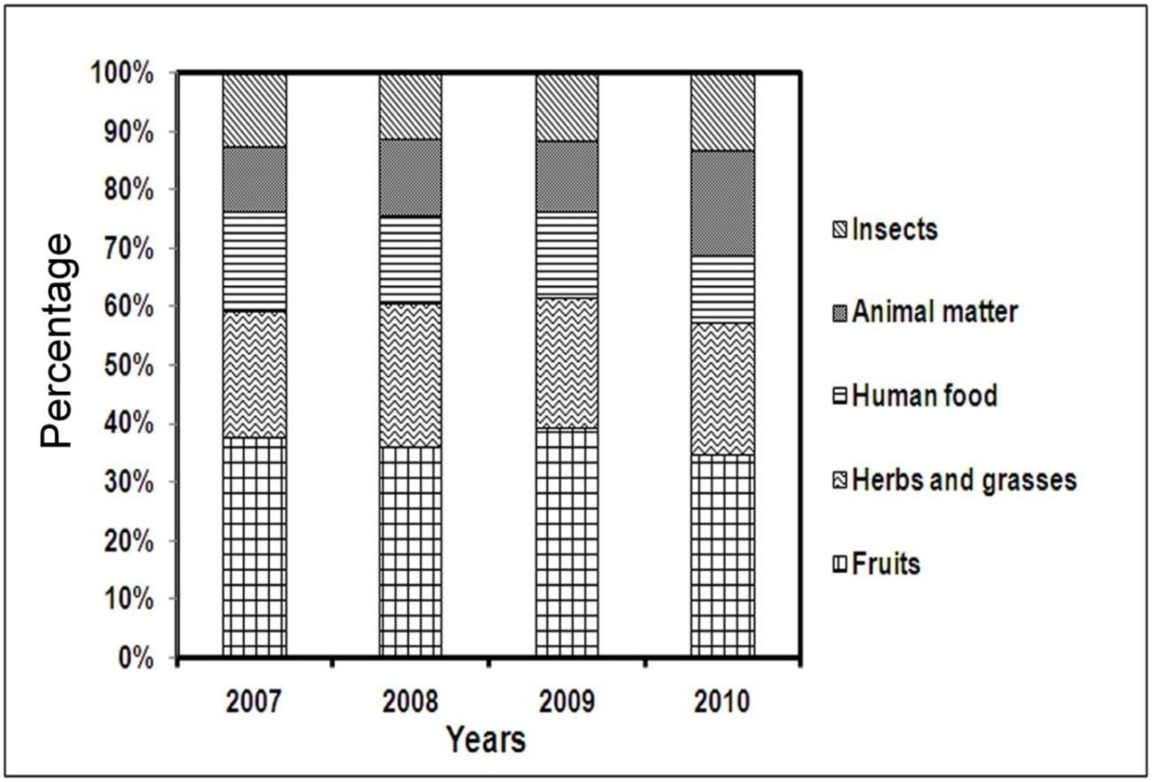

Figure 6.6. Percentage contribution of different food categories to Asiatic black bear diet at Dachigam NP, India during 2007-2011. (Levene's test, F = 0.01, *P* =0.99)

6.3.5. Feeding site surveys

The black bear feeding sign types included stone turning, digging, browsing, and feeding signs on fruit bearing plant species systematically on transects (n=13) twice a month. In total 110 black bear feeding signs were recorded in different seasons. The percentage of feeding signs on fruit bearing plants (38.8%) was highest followed by grazing signs (27.7%) on herbs and grasses, digging signs for insects (22.2%), human food (5.5%) and on animals carcasses (5.5%) (Figure 6.4).

6.3.6. Scat collection and analysis

A total of 451 black bear scats collected from June 2007 to October 2010 were analysed. Out of which 101 were of spring, 175 of summer, 115 of autumn and 87 of winter. Of the total analyzed scats about 7% had animal matter, 46.11% had fruits (soft mast, hard mast), 11% having insects, 21% were remains of herbs and grasses and 14% were human food remains (anthropogenic food) (Figure 6.5). There was a significant difference in the diet of black bear in different seasons (χ^2= 157.39, df = 12, P <0.001). The diet of black bear in spring was dominated by herbs and grasses (40.0%) followed by insects (26.6%) and anthropogenic food (17.1%). In summer, fruits contributed major proportion (55.3%) of the black bear diet followed by herbs (24.8%), anthropogenic food (11.8%), and the contribution of insects and animal matter was as low as 5% and 2.8% respectively. The diet of black bear in autumn was largely composed of fruits 66.4% followed by 19.2% human food (anthropogenic). In winter, prior to hibernation, diet was dominated by fruits (47.73%), followed by animal matter (22.7%), and insects (20.4%) (Figure 6.5).

Based on the bear feeding observations, feeding signs and scat analysis black bear diet at Dachigam NP was composed of 41 species (34 species of plants, three animal species and four insects species) (Table 6.6 and 6.7). In spring, the percentage frequency of occurrence of herb and grasses was highest followed by insects, animal matter, anthropogenic food and minimum for fruit bearing plant species. Whereas in summer the frequency of occurrence of berries i.e. *Prunus* spp., *Morus* spp., *Rosa* spp., *Rubus* spp. was highest followed the frequency of occurrence of herbs and grasses was low (Table 6.8). In summer, the frequency of occurrence of anthropogenic food was considerably high than in spring. In autumn, the percentage frequency of occurrence of hard mast fruit bearing was highest followed by berries and soft mast bearing species, herbs, human food but the frequency of occurrence of insects and animal matter was minimum. In winter, before hibernation, the frequency of occurrence of hard mast fruit species was highest followed by animal matter and was low for anthropogenic food, herbs and insects (Table 6.6). No considerable difference was observed in frequency of occurrence of species in all study years. There was no significant variation in different categories of food types in black bear diet among years (Levene's test, F = 0.01, df = 3, P =0.99) (Figure 6.6). The spring, diet of black bear in 2008-09 was composed herbs, grasses and animal matter where as in spring 2010 bear ate fruit bearing species (*Viburnum* spp.) as well as herbs, grasses and animal matter. Fruits were dominant in summer diet for all years but animal materials mainly *Hangul* (2.6%) was found in 2008 and the occurrence of anthropogenic food was unswerving in all of the years from 2007 to 2010. In autumn, bears feed mainly on hard mast (nuts, acorns) fruit bearing species followed by berries, anthropogenic food and animal matter (Hangul, Langur and livestock). In winter prior to hibernation, the frequency of occurrence of hard mast fruits i.e. *Celtis australis, Juglans regia*, *Quercus robur* was highest followed by berries of *Rosa* spp. and *Rubus fruticosus*. Among all seasons, frequency of occurrence for the livestock was highest during winter. However, no livestock remains were found in winter scats of year 2009.

The Shannon Weiners Index (H`) value for bear diet species was highest for summer (1.126), followed by autumn (1.016), spring (0.981) and winter (0.885).

6.3.7. Preference of food type by black bear

Spearman rank correlation was carried out to understand the selection. Positive correlation between consumption and abundance were strongest (P < 0.001) for mature and young fruits (Table 6.8). Significant positive correlation (P < 0.005) was also found for leaf buds. No significant positive correlations were detected for flower bud, flower, young and mature leaves.

Table 6.6. Percentage frequency of occurrence of different food items of Asiatic black bears based on scat analysis (n=451) at Dachigam National Park, India, 2007-2011.

	Spring			Summer				Autumn					Winter	
Food items	2008 (n=19)	2009 (n=31)	2010 (n=24)	2007 (n=27)	2008 (n=78)	2009 (n=56)	2010 (n=14)	2007 (n=29)	2008 (n=41)	2009 (n=35)	2010 (n=10)	2007 (n=13)	2008 (n=48)	2009 (n=26)
Fruits (Berries)														
Prunus cerasifera	-	-	-	48.1	37.2	51.8	21.4	6.9	53.7	37.1	-	-	-	-
Prunus armenaica	-	-	-	40.7	19.2	46.4	64.3	48.3	-	8.6	-	-	-	-
Prunus prostata	-	-	-	29.6	53.8	39.3	35.7	10.3	34.1	28.6	-	-	-	-
Prunus tomentosa	-	-	-	14.8	17.9	19.6	7.1	-	-	-	-	-	-	-
Morus nigra	-	-	-	40.7	39.7	26.8	57.1	-	-	-	-	-	-	-
Morus alba	-	-	-	37.0	37.2	32.1	42.9	-	-	-	-	-	-	-
Pyrus malus	-	-	-	-	-	-	-	24.1	70.7	34.3	10.0	-	4.2	-
Rubenia sp.	-	-	-	-	-	-	-	6.9	-	-	-	7.7	14.6	-
Berberis lycium	-	-	-	14.8	24.4	8.9	14.3	-	-	-	-	-	-	-
Rubus fruticosus	-	-	-	-	-	-	-	3.4	9.8	28.6	-	30.8	-	-
Rosa webbiana	-	-	-	-	2.6	-	-	-	4.9	-	-	-	18.8	19.2
Rosa bageriana	-	-	-	-	-	-	-	-	-	-	-	15.4	10.4	-
Viburnum	-	-	12.5	25.9	11.5	23.2	-	-	-	-	-	-	-	-

	Spring			Summer				Autumn				Winter		
Food items	2008 (n=19)	2009 (n=31)	2010 (n=24)	2007 (n=27)	2008 (n=78)	2009 (n=56)	2010 (n=14)	2007 (n=29)	2008 (n=41)	2009 (n=35)	2010 (n=10)	2007 (n=13)	2008 (n=48)	2009 (n=26)
continifolium														
Viburnum grandiflorun	-	-	9.3	13.8	15.6	19.4	-	-	-	-	-	-	-	-
Pyrus communis	-	-	-	-	-	-	-	44.8	56.1	28.6	-	-	-	-
Fruits (Hard mast)														
Juglans regia	-	-	-	-	-	-	-	75.9	43.9	62.9	30.0	30.8	16.7	7.7
Quercus robur	-	-	-	-	-	-	-	31.0	26.8	25.7	60.0	38.5	8.3	-
Celtis australis	-	-	-	-	-	-	-	-	-	-	-	30.8	28.9	26.9
Herbs and Grasses														
Taraxicum officinale	5.3	16.1	20.8	-	-	-	-	-	-	-	-	-	-	-
Dipsacus mitis	36.8	32.3	16.7	3.7	-	3.6	-	-	-	-	-	-	-	-
Dioscrea deltoidea	21.1	12.9	-	-	-	-	-	-	-	-	-	-	-	-
Hedera nepalensis	-	6.5	-	-	-	-	-	-	-	-	-	-	-	-

	Spring			Summer				Autumn				Winter	
Food items	2008 (n=19)	2009 (n=31)	2010 (n=24)	2007 (n=27)	2008 (n=78)	2009 (n=56)	2010 (n=14)	2007 (n=29)	2008 (n=41)	2009 (n=35)	2010 (n=10)	2007 (n=13)	2008 (n=48)	2009 (n=26)
Heraculum lanatum	10.5	12.9	12.5	-	-	-	-	-	-	-	-	-	-	-
Dephnene ofeojedus	-	-	8.3	-	-	-	-	-	-	-	-	-	-	-
Geranium nepalense	2.5	-	4.0	-	-	-	-	-	-	-	-	-	-	-
Poa annua	5.0	-	4.0	-	-	-	-	-	-	-	-	-	-	-
Lychanis alba	-	-	17.0	-	-	-	-	-	-	-	-	-	-	-
Colchicum luteum	10.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Eremurus himalaicus	-	3.2	-	-	-	-	-	-	-	-	-	-	-	-
Podophyllum hexandrum	15.8	-	-	-	-	-	-	-	-	-	-	-	-	-
Insects	-	-	-	-	-	-	-	-	-	-	-	-	4.2	-
Honey bees	21.1	3.2	4.1	-	-	-	-	-	-	-	-	-	-	-
Beetles	-	16.1		-	-	-	-	-	-	-	-	-	-	-

	Spring			Summer				Autumn					Winter	
Food items	2008 (n=19)	2009 (n=31)	2010 (n=24)	2007 (n=27)	2008 (n=78)	2009 (n=56)	2010 (n=14)	2007 (n=29)	2008 (n=41)	2009 (n=35)	2010 (n=10)	2007 (n=13)	2008 (n=48)	2009 (n=26)
Ants	5.2	-	4.1	-	9.0	-	-	-	-	-	-	-	-	
Cicada	15.8	-	-	-	-	5.4	-	-	-	-	-	-	-	-
Animal matter														
Deer (Hangul)	-	-	4.2	-	2.6	-	-	-	7.3	2.9	-	-	2.6	-
Livestock [a]	-	-	-	-	-	-	-	-	9.8	-	-	7.7	6.3	-
Langur	-	-	-	-	-	-	-	-	2.4	-	-	-	12.9	-
Other unidentified [b]	5.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Human food														
Cherry crop	-	-	-	14.8	39.7	17.9	21.4	-	-	-	-	-	-	-
Cultivated Apple	-	-	-	-	42.3	-	-	31.0	4.9	-	-	-	-	-
Maize	-	-	-	-	-	-	-	5.7	19.5	8.6	-	-	-	-
Unidentified	-	6.5	16.7	7.4	16.7	1.8	-	-	-	-	-	-	2.1	-

[a] - livestock (goats, sheep, cow), [b] - during analysis I found hair sample of unidentified species

Table 6.7. Diet composition of Asiatic black bears based on scat analysis (n=451), direct feeding observations (n=162) and feeding sign observations (broken branches, climbing signs on fruiting trees, carcasses remains) at Dachigam National Park, India, 2007-2011.

Food items Category		Methods		
	Species	Scat	Direct feeding	Feeding signs
Fruits (Berries)	*Prunus cerasifera*	111	26	13
	Prunus armeniaca	78	7	7
	Prunus prostata	104	11	9
	Prunus tomentosa	33	2	1
	Morus nigra	65	-	5
	Morus alba	63	10	8
	Pyrus malus	51	-	10
	Rubenia sp.	10	1	-
	Berberis lycium	30	4	1
	Rubus fruticosus	19	8	1
	Rosa webbiana	18	7	2
	Rosa bageriana	7	-	-
	Viburnum continifolium	29	5	-
	Viburnum grandiflorun	18	-	7
	Pyrus communis	46	10	-
	Salix babyloniea	-	-	1
Fruits (Hard mast)	*Juglans regia*	79	12	8
	Quercus robur	44	31	16
	Celtis australis	22	14	9
Herbs and Grasses	*Taraxicum officinale*	14	-	1
	Dipsacus mitis	21	2	-
	Dioscrea deltoidea	4	-	-
	Hedera nepalensis	5	1	1
	Heraculum lanatum	7	-	-
	Dephnene ofeojedus	4	-	-
	Geranium nepalense	-	-	1
	Poa annua	1	-	1
	Lychanis alba	-	-	2
	Colchicum luteum	2	-	-
	Eremurus himalaicus	-	1	-
	Podophyllum hexandrum	3	-	-
Insects	Honey bees	11	1	1
	Beetles	5	-	1
	Ants	7	-	1
	Cicada	3	-	1

Food items Category		**Methods**		
	Species	**Scat**	**Direct feeding**	**Feeding signs**
Animal matter	Deer (Hangul)	9	3	1
	Livestock [a]	14	-	-
	Langur	2	-	-
	Other unidentified [b]	1	-	-
Human food	Cherry crop	48	1	-
	Cultivated Apple	44	5	1
	Maize	13	-	-

[a]livestock (goats, sheep, Cow), [b]during analysis I found hair sample of unidentified species

Table 6.8. Spearman rank correlation coefficients comparing consumption and abundance of plant part group of black bear food at Dachigam National Park, India, 2007-2011.

	Consumption						
Abundance	**Leaf bud**	**Young leaves**	**Mature leaves**	**Flower bud**	**Flowers**	**Young fruit**	**Mature fruit**
Leaf Bud	0.68^{*}	0.51	-0.14	0.60^{*}	0.51	0.13	-0.20
Young leaves	0.05	0.13	0.57^{*}	0.26	0.13	0.76^{**}	0.67^{*}
Mature leaves	-0.37	-0.08	0.52	-0.02	-0.08	0.07	0.77^{**}
Flower bud	0.28	0.24	0.27	0.51	0.24	0.58^{*}	0.62^{*}
Flowers	0.71^{**}	0.53	-0.09	0.63^{*}	0.53	0.31	0.17
Young fruit	-0.12	0.14	0.65^{*}	0.28	0.14	0.77^{**}	0.78^{**}
Mature fruit	-0.28	-0.04	0.64^{*}	0.07	-0.04	0.35	0.94^{**}

***** = significant at the 0.05 level, ****** = significant at the 0.01 level.

Plate 6.2. Scat analysis to understand food habits of Asiatic black bear at Dachigam National Park (a, b) slide of herbaceous matter in scat, (c, d, e) slides of hair sample recorded in scat, (f, g) seeds of *Prunus armeniaca* and *Prunus cerasifera*, (h) micro-histological examination of slides using microscope at WII laboratory.

6.4. Discussion

6.4.1. Seasonal availability of food resources in Dachigam National Park

There was a seasonal variation in the phenological availability of the reproductive and vegetative parts of important black bear food items in Dachigam NP. The food availability in Dachigam NP was highest in summer. During winters, there is very little ground layer vegetation available for bears, as most of the study area is covered by 3-4 feet deep snow cover. All of the fruit bearing species have spring flowering and hence flower buds and mature flowers showed peak in spring and early months of summer. The reproductive parts of plants such as flowers and fruits were found to be low in abundance than vegetative parts and also showed seasonal variation in abundance (Figure 6.2). Young fruit were available mostly in late spring and early summer (April-July) but the availability of mature fruits were highest in late summer and autumn (September-November) and minimum in December month of winter. There was no food availability in January and February (Figure 6.3). The seasonal variation in phenological change and food availability shows similar patterns as suggested by others for temperate forests central Himalayan landscape (Rawal et al. 1991).

During spring, *Morus* spp. and *Berberis lycium* were the only fruit bearing plant species. In summer, the fruit availability was as high as 90% with most of the species having 70 to 80% mature fruits. In autumn, out of total 14 important plant species fruits were available on eight species and species such as *Juglans regia* and *Quercus robur* were having maximum availability of mature fruits (80 - 90%) (Figure 6.3). In winter fruits were available up to the December only.

6.4.2. Fruit abundance in Dachigam National Park

The relative abundance of food on plant in an area affected by plant biology such as most of the fruiting species has alternate food failure years and the seasonal change is because of the phonological availability patterns. The seasonal changes in availability of food among the habitat were related to the floristic composition and the environmental factors associated with the habitat type (Table 6.1). For examples the fruit availability in riverine habitat was highest in all of the seasons because of the highest density of fruiting tress and with diverse species composition (Table 6.3 and 6.4). The diversity and richness of fruit bearing plant species was highest in riverine habitat followed by low temperate habitat. In contract, Oak plantation habitat was devoid of other fruit species except Oak tree. The marked seasonal changes in the phenology of plants were related to the climatic conditions in the landscape. The abundance of food in temperate grass and scrub land habitat was lowest because of non availability of fruit bearing tree species. The fruit abundance index value differed significantly among the seasons ($P<0.005$) (Table 6.2). Food availability index was highest in riverine habitat in all seasons followed by low temperate habitat >Low temperate mixed> Low temperate pine > Mid-temperate> Oak Plantation> Temperate grass and scrub land habitat. As fruit availability in a habitat affects the movement and ranging patterns of black bear as studied elsewhere (Garshelis and Pelton 1981; Powell et al. 1997; Kasbohm et. al. 1998; Kozakai et al. 2011). The study on food availability estimation will help for the bear population management as the spatial distribution, abundance and annual production level of hard-mast trees as both- stable and alternative food affects the movement and ranging patterns. Studies on food habits and habitat use highlights the importance of seasonal food availability assessment among the different habitat types (Brody and Pelton 1988; Costello and Sage 1994; Hwang et al. 2002; koike 2010)

6.4.3. Food habits of black bear at Dachigam National park

The omnivorous habit of Asiatic black bears as reported by earlier studies was recorded in the present study also. Seasonal variation in the black bear diet at Dachigam NP followed the same general pattern as for Asiatic black bears in other areas of its distribution ranges (Reid et al. 1991; Hazumi 1994; Harlow et al. 2002; Hashimoto 2002; Hwang et al. 2002). In spring, both species of black bears largely depends on green, luscious vegetation. In summer, soft mast fruits were the main components of the black bear diet. In autumn, bears diet shifts from soft mast to hard mast fruits, because of the availability. The hard mast fruits such as oak (*Quercus robur*) acorns and nuts of walnut (*Juglans regia*) contain relatively high amount of fat which black bear prefer before hibernation as reported by Garshelis and Pelton (1981) and many in Hwang et al. (2002). Hard mast comprises of 50-90% of autumn diets of black bears in broadleaf forests throughout Asia which was observed similarly in the present study (Hwang et al. 2002; koike 2010). In autumn black bear diet is composed of largely hard mast because of non availability of other fruit type at that particular time of year (Table 6.6, 6.7; Figure 6.6). The hard mast fruits were high in fat

(Manjrekar 1979; Eagle and Pelton 1983; Kasbohm et al. 1995; Hashimoto and Takatsuki 1997; Kirkpatrick and Pekins 2002). The physiological adaptation in digestive system of bears during autumn helps to assimilate more fat during autumn before hibernation (Brody and Pelton 1988). Asiatic black bears substantially increase intake of fat rich food which leads to increase in body weight as a adaptation before going for hibernation (Nelson et al. 1983). As reproductive success in bears is directly related to body mass in autumn, the availability of high energy foods has an important influence on bears at the population as well as the individual level (Rogers 1976; Blanchard 1987; Stringham 1990; Harlow et al. 2002).

In some areas, fallen hard mast from the previous autumn is reported to be consumed by both Asiatic and American black bears in spring and even summer (Nozaki et al. 1983; Ternent 1995; Huygens et al. 2003), although this was not recorded in present study. In Dachigam no oak acorns were left for bear to feed in spring and summer because of competition between langur and black bear for oak. Scat analysis revealed that there was a considerable amount of anthropogenic food or cultivated food crop in bear diet. Black bears were reported to go for crop depredation during the years of hard mast failure (Hazumi and Maruyama 1986; Eiler et al. 1989; McDonald et al. 1994; Kasbohm et al. 1995; Hashimota and Takatsuki 1997; Hwang et al. 2002; Vaughan 2002; Greenleaf et al. 2009). Charoo et al. (2011) reported incidences of crop damages by black bear were common during peak production time in orchards around Dachigam NP. In the present study area incidences of crop damage by black bears were reported very frequently (Charoo et al. 2011). Insects and animal matter occurred in smaller quantities in the overall diet of the black bears and has been reported by earlier studies (Raine and Kansas 1990; Holcroft and Herrero 1991; Hashimoto and Takatsuki 1997).

The results of Spearman rank correlation between consumption based on direct feeding observations and abundance of different plant part shows that the all of the plant parts were used in relation to availability (Table 6.8). Fruits (young and mature) were the preferred food type of black bear in Dachigam which was similar to other food habits studies throughout its distribution range (Hashimota and Takatsuki 1997; Hwang et al. 2002; Sathyakumar and Viswanath 2003). The diet of black bear in spring is dominated by herbs, leaf and flower buds of tree and shrub species possibly as a strategy for complementing its diet when fruits were not available.

Schaller et al. (1989) reported a shift in the diet of black bear from leafy material in early summer to fleshy fruits and then to fat rich fruits before hibernation and the same has been reported by Manjrekar (1989) at Dachigam NP. Fruits were the main food type selected by black bears in Dachigam NP. The amount of anthropogenic food was highest in late spring and late autumn when the availability of food was low in Dachigam NP. In this study, the diet of black bear was influenced by the seasonal availability of different food types. In temperate zones such as broad leaved deciduous forest marked seasonal change in plant phenology limits the fruiting patterns and compels frugivores and herbivores to temporarily change the diet of black bear (Rogers 1987; Naves et al. 2006; Koike et al. 2008: Koike 2010). The change in diet composition of black bear in this study can be related to the change in fruit availability patterns among the years which has been documented for black bear by Koike (2010) and for other frugivores (Koenig and Knops 2000). The presence of considerable amount of livestock remains in autumn and winter scats indicated that black bear feed on livestock in the surrounding areas of the natural habitats of around Dachigam NP which has been reported by Charoo et al. (2011). The animal matter, primarily domestic animals and deer, can contribute substantially to autumn fattening.

6.4.4. Relationship between nutritional composition and food habits of black bear at Dachigam National Park

The black bear in spring largely feeds on herbs and insects because of the highest content of crude protein in herbaceous plants and insects (Table 6.5) and after hibernation the protein is of much importance for the structural growth which is the main physiological requirement. Most of the bears in Dachigam exhibit only short periods of crepuscular activity during early spring, and a limited activity pattern may be a means of surviving a period of nutritional stress (Garshelis and Pelton 1980). Lactating females and growing cubs have greater protein and energy requirements for body maintenance, and the typical early spring diet may be inadequate to meet this increased requirement. Black bear also do scavenging and livestock depredation to supplement the diet with additional source of fat and protein during the spring or nutritional stress season. In Dachigam landscape maximum percentage of livestock depredation cases were recorded in spring season and the similar trends were also reported elsewhere (Charoo et al. 2011; Witmer and Whirraker 2001; Halbritter et al. 2008). Garshelis and Pelton (1980) reported high level of activity by lactating females probably reflects an increased foraging effort to meet the added protein requirement of lactation and growth. The results shows that most of the soft mast fruits were having similar nutritional value (Table 6.5) and were low to moderate in protein, ADF and fat content but high in other fractions particularly soluble carbohydrate and sugar (hexose) content. The proportion of fruits was highest in summer as the bear start gaining body weight during late spring and summer (Beeman 1975). Most of the protein in these fruits was located in hard coated seed (Wainio and Forbes 1941) which is unavailable to bears as they do not crack or digest the seed coat. During autumn black bear feed largely on hard mast fruits such as *Juglans regia, Qurcus robur* as they were relatively high in fat and energy contents. The bear during autumn needs more energy and fat to combat the cold and nutritional stress during in hibernation period in winter. Earlier studies on black bear foraging habit stated that the increase of body fat reserves, instead of structural growth during autumn, may be of important survival value to black bears by maximizing energy storage for the winter hibernation period and the negative foraging period of early spring. The results of the present study stated the relative importance of various food items to black bear diet in different seasons. For the future it is recommend studying the nutritional requirements and the relative digestibility of food items by black bear which will present the more accurate understanding of the black bear diet.

6.5. Summary of major findings and discussion

1). Seasonal variation in the phenological availability of reproductive and vegetative parts of bear food items was observed. During spring, *Morus* spp. and *Berberis lycium* were the only fruit bearing plant species and fruit availability was highest during summer whereas, during autumn fruits were availability only in eight fruit bearing plant species (*Juglans regia, Celtis australis* and *Quercus robur*).

2). Seasonal availability of food among the habitat was attributed to the floristic composition and environmental factors. The food availability index was highest in riverine habitat> Low temperate mixed> Low temperate pine> Mid-temperate> Oak plantation> Temperate grassland and scrubland.

3). Black bear diet varied significantly between seasons with green, luscious vegetation dominating in spring followed by soft mast fruits being the main component during summer. Bear diet shifts from soft mast to hard mast fruits during autumn.

4). Occurrence of considerable amount of anthropogenic food (cultivated crops) during late spring and autumn in bear diet indicates that bears track food resources in the landscape due to spatio-temporal variation in food availability in Dachigam NP.

5). During spring, black bear diet composed of crude protein and calcium rich food items (insects, animal matter, herbs), while in summer, it was composed of food items rich in soluble carbohydrate and sugar (hexose) (fruits, berries). During autumn, black bear diet was dominated by fat rich food items (nuts, acorns)

CHAPTER – 7: GENETIC TRACKING OF ASIATIC BLACK BEAR IN DACHIGAM LANDSCAPE

7.1. Introduction

The population of Asiatic black bear in Dachigam NP is considered as one of the best in India with fairly large number of bears (Sathyakumar 2001). Today, bear population in Dachigam is threatened because of increasing incidences of bear-human conflict cases. Charoo et al. (2011) brought out that bears in the landscape are threatened because of retaliatory killings by locals to reduce conflict. To delineate population boundary and to understand how individuals are moving and interacting across the landscape is vital for the effective management, planning and conservation (Manel et al. 2007; Fraser and Bernatchez 2001). The application of genetic techniques can play important role to answer such important ecological aspects of a species like Asiatic black bear. There are large number of studies available where the population of bears were studied using the genetic tool (Paetkau et al. 1997; Miller et al. 1998; Peacock et al. 2007; Kendall et al. 2009) The genetic tools have proven their effectiveness in complementing the traditional methods of studying population size, structure, individual movements etc. The present study was attempted to answer questions related to the population structure, size, movement patterns and to investigate the spatial utilization patterns by black bear in Dachigam landscape.

Dachigam landscape is under pressure of habitat degradation because of encroachment and land use changes. The conversion of forested habits into cropland and for other developmental activities is leading to habitat fragmentation in the landscape (Figure 4.15). The present study has documented first time the landscape architecture of Dachigam landscape. The findings related to landscape fragmentation in the study area were the basic rationale behind looking at the population structure of black bear in Dachigam. It was hypothesized that the landscape fragmentation would have affected the population of black bear in Dachigam and sub-structuring might have occurred in the landscape. Since habitat fragmentation and creation of island habitats for a species lead to population structuring and consequently leading adverse effects on the distribution and the abundance of the species (Manel et al. 2003; Storfer et al. 2007). Furthermore, the limited dispersal abilities can also limit gene flow over longer distances as well and leading to genetic isolation by distance within populations (Wright 1943, 1946) regardless of habitat structure or landscape barriers. Thus, the present study was attempted to understand that whether the population of black bear still exists in a single panmictic population or the barriers to movement and gene flow have created population structuring within the landscape.

For the conservation management of any population it is imperative to maintain a population at size which should be large enough to prevent inbreeding and loss of genetic variability through drift (Soule 1987; Fraknham 1996). Studied have proved that the fluctuations in population size, unequal sex ratios, and variation in reproductive success generally leads to decline in effective number of breeders consequently low effective population size than their actual census size (Palstra and Ruzzante 2008). Large population can experience significant declines in genetic diversity if effective population size falls below a given threshold (Tredick 2011).

The Social interactions between individuals in mammalian species may influence home range size, site fidelity and access to resources (Carpenter and MacMillen 1976; McLoughlin et al. 2000). Today studying the spatial and social relationship between the interacting individuals as an explanation for these social behaviors has been a recurring theme (Gompper and Wayne 1996) and large number of studies are available (see in Moyer 2004). The advancement in genetic analysis, interpretations and the reliable estimates of genetic relatedness, and the spatial understanding of relationships between genetic relatedness and behavioral patterns of individuals of a species has provided significant information on the species and this technique has provided surprising results.

Many studies have documented the spatial association between related individuals of mammalian species using the genetic tool which includes California ground squirrel *Otospermophilus beecheyi* (Boellstorff and Owings 1995), gray mouse lemur *Microcebus murinus* (Wimmer et al. 2002), banner-tailed kangaroo rat *Dipodomys spectabilis* (Winters and Waser 2003), raccoon *Procyon lotor* (Ratnayeke et al. 2002), lion *Panthera leo* (Van Orsdol et al. 1985) and black bear Moyer (2004). However, the hypothesis that genetic relatedness explains spatial association has been contradicted in other species including the harbour seal *Phoca vitulina* (Schaeff et al. 1999), the snowshoe hare *Lepus americanus* (Burton and Krebs 2003), and the wild chimpanzee *Pan troglodytes schweinfurthii* (Goldberg and Wrangham 1997).

Rogers (1987) studied the spatial association among the related American black bears. Subsequently studies on other large carnivores have considered these observations as evidence of widespread natal philopatry and have interpreted territorial, foraging, and mating behaviors accordingly. However, the influence of genetic relatedness on spatial organization was not attempted on a species like Asiatic black bear. Based on these limited observations, genetic relatedness is frequently invoked to explain space sharing and home range overlap in many black bear populations. However, Schenk et al. (1998) found that the spatial distribution and pattern of home range overlap were independent of the genetic relatedness of the females involved. Furthermore, Powell (1987) documented that female offspring establishing a home range separated from that of the mother and noted that the degree of overlap in his study area was extensive enough that it was unlikely that home range overlap occurred exclusively among related individuals. Contradictory statements on this subject necessitate the genetic tracking of black bear and other large carnivore species.

In Dachigam landscape, the increasing incidences of bear-human conflict have made bear population management as a challenging task (Charoo et al. 2011). During the field study, it was observed that bear captured outside Dachigam were released inside Dachigam to reduce conflict at the fringes of Dachigam NP. It is a miss-understanding of the locals that the most of the conflicting bears belong to Dachigam NP. Thus, to answer question related to the origin of conflicting bear and the practice of releasing conflicting bears inside Dachigam is an effective way to reduce conflict the present study was designed.

To answer such conservation and management related issues the present study was initiated with three main questions: 1) To test whether the black bears in Dachigam NP and the surrounding landscape make up a single, panmictic population or the barriers to movement and gene flow have created population structure within the landscape; 2) To test wheather genetic relatedness influence spatial utilization patterns of black bear in Dachigam landscape; 3) Molecular tracking of black bear in Dachigam landscape.

7.2. Methods

7.2.1. Study design and samples collection method

The intensive study area of about 90 Km^2 in lower Dachigam was divided into 23, 2x2 km grids for homogenous sampling of the study area (Boulanger et al. 2007; Mowat and Strobeck 2000). In each grid a hair snare (made of barbed wire) was deployed along with a camera trap for the hair sample collection (Mowat and Strobeck 2000; Boulanger and McLellan 2001) (Figure 3.4). All hair traps were baited with honey/apple/rotten meat/maize to attract bears. The hair traps were checked once in three days for both hair and camera captures. The camera captures and hair samples were tallied (wherever possible) to avoid mixing up of hairs of two animals.

7.2.2. The laboratory process involved following steps:

7.2.2.1. DNA isolation from hair samples

DNA was extracted from the black bear hairs using Qiagen DNeasy tissue kit (*Qiagen, Germany*) following the manufacturer's protocol with the recommended alterations as proposed by Thakur et al. (2011) while DNA was extracted from reference blood samples using PCI protocol (Sambrook et al. 1989). The extracted DNA was quantified using the spectrophotometric measurement of UV absorption by following Thakur (2011). The quality of the isolated DNA was assessed by using Gel electrophoresis. The DNA bands were visualized by placing the DNA containing Gel by using High Performance UV Transilluminator and the photographs of the gel were taken using gel documentation system (Figure 7.1).

7.2.2.2. Selection of microsatellite markers

A set of 20 microsatellites were selected based on the degree of polymorphism and their wide coverage on the genome (Kitahara et al. 2000; Bellemaina et al. 2007; Shih et al. 2009) (Table 7.1; Figure 7.2). The selected primers were synthesized and forward primer of each marker was labelled with one of the fluorescent dyes (FAM, VIC, PET, NED) at the 5′ end.

The selected microsatellite markers have been used for almost all bear species and out of which 10 primers were of Asiatic black bear and found to be effective in the individual identification of black bears. The GPS locations of the identified genotype were plotted on the study area map for the tracking of the genotyped individuals.

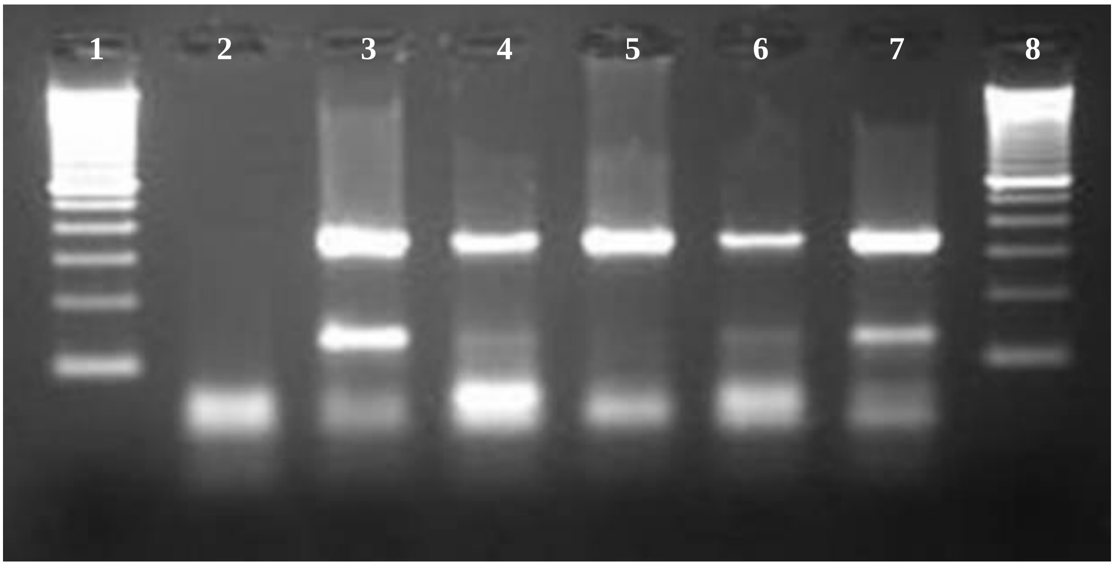

Figure 7.1. Multiplex PCR results [Lane1 & lane 8- 100bp DNA ladder, lane 2-ve control, 3-7 amplified products with three microsatellite loci]

Figure 7.2. Generation of multiplex panel using program Multiplex Manager

Table 7.1. Six multiplex panels of twenty microsatellite markers used for analysis.

Multiplex(MP)	Loci name	Dye	Size range	Ta
MP 1	MSUT 2	FAM	77–91	50
	MSUT 5	PET	167–171	50
	MSUT 6	VIC	183–193	50
	MSUT 8	NED	106-110	50
MP 2	UT 4	FAM	157–182	56
	G10 J	VIC	80-88	56
	G10 H	PET	241-249	56
	MSUT 1	NED	170–174	56
	UT 3	NED	256-282	56
MP 3	UT 29	FAM	204–236	64
	UT 1	VIC	176–192	64
	UT 31	PET	315–369	64
	UT 23	NED	349–382	64
MP 4	MSUT 4	PET	85–101	44
	MSUT 7	FAM	114–116	44
MP 5	UT 36	FAM	276–309	62
	UT 35	VIC	218–247	62
	UT 25	VIC	314–333	62
MP 6	MSUT 3	PET	220–222	55
	UT 38	NED	196–232	55

7.2.2.3. Polymerase Chain Reaction (PCR)

Initial standardizations of PCR cycling conditions were attempted with reference samples and then the similar conditions were followed for amplification of microsatellites with DNA extracted from hair samples. The standardized combinations of microsatellite loci were pooled to get high throughput genotyping and successfully six multiplex PCRs were generated (Table 7.1).

Following Qiagen (Mainz, Germany) Multiplex PCR kit, PCR reactions were set up in a 15 μL of reaction volume containing 7.5 μL of 2× Qiagen Multiplex PCR Master mix, 0.50 μL of 10 μM of each primer pair (3.0 μL for six loci), 1 μL of DNA elutant (~ 20 ng) and 3.5 μL of RNase-free water. The amplification conditions were 15 min initial heat activation of Hot Start (Mainz, Germany) *Taq* DNA polymerase at 95^0C, followed by 35 cycles of denaturation at 94^0C for 30 s, annealing at specific temperature (table 1) for 90 s and extension at 72^0C for 60 s with a final extension at 60^0C for 30 min. Amplification was checked on 2% agarose gel (Figure 7.1) and fluorescence-based genotyping was performed on ABI 3130 Genetic Analyser (Applied Biosystem, Foster City, USA). Scoring of allele was performed using Gene Mapper software (version 3.7, Applied Biosystem). All the samples were genotyped twice to get the confident allelic data and the samples which did not produce band and the genotype in the first PCR & capillary electrophoresis, they were repeated further and only the samples producing duplicate genotype data was considered for further analysis to minimize the genotyping errors *i.e.* the issues of allele drop out and scoring of false alleles. An electropherogram showing alleles of four microsatellite loci with duplicate genotyping is shown in figure (Figure 7.3)

7.2.3. Statistical analysis for genetic diversity and population structure analysis:

7.2.3.1. Genetic diversity assessment of black bear in Dachigam NP.

The typographic errors and frequency of the occurrence of null alleles for each locus was tested using the computer program MICROCHECKER version 2.2 (Van-Oosterhout 2004). Multi-locus genotype data was used in identification of the unique individuals in the dataset of 56 samples using GENEALEX version 6.41 software (Peakall and Smouse 2006) and a unique genotype ID was given to the each identified individual. Genetic diversity estimates *i.e.* observed (*N*a) and effective number of alleles (*N*e), inbreeding coefficient, observed (*H*o) and expected heterozygosity (*H*e) were performed using GENEALEX version 6.41 software (Peakall and Smouse. 2006). Polymorphic information content (PIC), a measure of marker's informativeness was calculated using CERVUS version 3.0 (Kalinowski et al. 2007). Deviation of loci from Hardy–Weinberg equilibrium (HWE) was estimated using Chi square test as implemented GENEALEX version 6.41 software (Peakall and Smouse 2006).

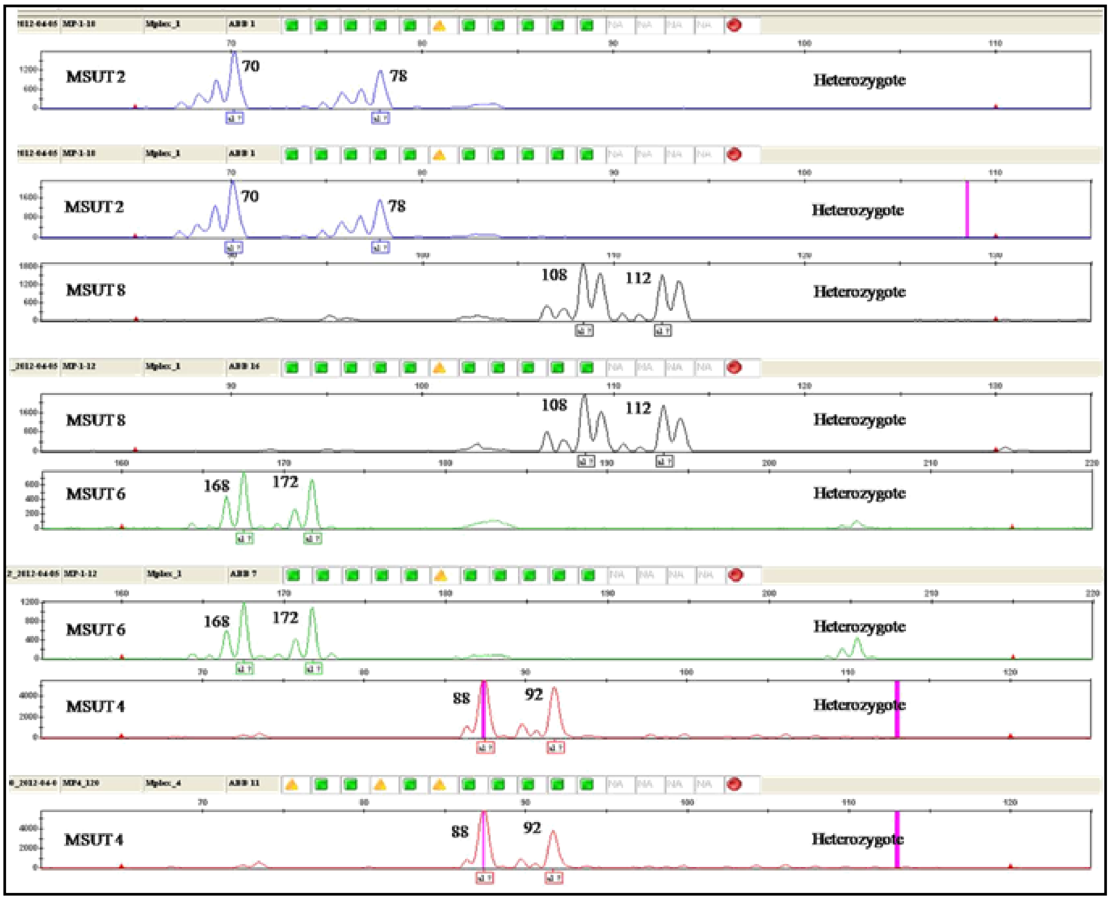

Figure 7.3. Electropherogram showing alleles of four microsatellite loci (duplicate genotyping) with ABB samples

7.2.3.2. Population structure analysis (is it necessary to add this?)

The Bayesian clustering approach was used to determine whether discernible discrete population structure was present in the black bear population of Dachigam landscape. Program STRUCTURE (Pritchard et al. 2000) uses this approach to identify genetic discontinuities among individuals and using maximum-likelihood approach, assigns individuals to an appropriate number of putative clusters (K) or populations of origin. These models attempt to maximize HWE and linkage equilibrium within reconstructed clusters (Guillot et al. 2009). Therefore the admixture models were used since these models assumes that individuals in the analysis can be originated from multiple clusters and tested value of K between 1 and 10 assuming correlated allele frequencies. Analyses were conducted with a burn-in length 10,000 and 100,000 Markov Chain Monte Carlo (MCMC) chains. The model log-likelihood was used to determine the best-fit model (i.e., highest likelihood value).

7.2.3.3. Estimation of effective population size

The effective population size (N_e) can be estimated using four indirect methods *i.e.* the temporal (Waples 1989), linkage disequilibrium (Waples and Do 2008), allele rarefaction (Hedgecock et al. 2007) and heterozygote excess (Pudovkin et al. 1996). We examined N_e estimates using information on linkage disequilibrium based on point-in-time samples, and corrects for biases resulting from the presence of rare alleles. Since, alleles with very low frequencies can bias results therefore the analysis was performed after removing alleles with frequencies (P_{crit}) lower than 0.05, 0.02, and 0.01. The parametric and jackknife, both the procedures were applied to construct 95% confidence intervals. The N_e estimates was computed using program LDNE (Waples and Do 2008).

7.2.3.4. Analysis for understanding the genetic relatedness and the space utilization

Genetic relatedness was established among the radio-collared individuals and the individuals identified using hair samples collected from hair snares. The genealogical or genetic relationship between the identified individuals of unknown ancestry and the radio collared black bear was estimated using maximum likelihood method as implemented in ML-RELATE computer program (Kalinowski et al. 2006) and program Kinship (Goodnight et al. 2004) to estimate the relatedness between pairs of black bears at Dachigam. This method uses the allele frequencies of the population to weight the relationship based on the population allele frequency (Blouin et al. 1996).

For the spatial utilization patterns the home ranges were generated for radio-collared individuals (See home range chapter 5) and the genetically identified individuals from the non-invasively collected from systematically placed hair snares in Dachigam NP.

The distance between the centroids of core home ranges for overlapping individuals and non-overlapping individuals generated for the radio-collared as well as genetically tagged animal was determined by using the Nearest Feature extension in ArcView 3.2 (Jenness 2004). The distance between the centroid of the overlapping pair was compiled by following the Moyer (2004). The home ranges were categorised into three types based on the degree of overlaps between the home ranges. The individuals for which home range overlap was not observed were placed under non-overlapping (NO), in case of overlapping home ranges (YO) and whereas for the individuals the core area of the home range overlapped were categorized as (CO).

To examine the association between genetic relatedness and the space utilization patterns of black bears in the study area two methods were used. Firstly, the genetic relatedness matrix were compared with the corresponding geographic distance by using the nonparametric Mantel test (Mantel 1967) as implemented in the program PC-ORD 4.0 (McCune and Mefford 1999).

7.2.3.5. Molecular tracking of black bear in Dachigam landscape.

The molecular tracking technique was used to track the movement and origin of black bears in Dachigam (Figure 7.4). The hair samples were collected from Dachigam NP and from the conflict sites in the landscape (Orchard fencing etc) and the GPS location, date of damage in cropland and livestock depredation were recorded. Genetic analysis was carried out for the individual identification and was plotted on the map of Dachigam by using GIS tools.

7.3. Results

7.3.1. DNA sampling and genetic analysis

A total of 80 numbers of samples were collected in during the study period. DNA was extracted from all of these hair samples and were tried to amplify on the 20 selected microsatellite markers. Out of 20 microsatellites, 3 loci (G10H, MSUT3 and UT 23) did not amplify and four loci showed low success rate *i.e.* UT 29 (77.78%), MSUT 5 (72.22%), UT 31 (38.89%) and UT 3 (44.44%) (Figure 7.4). Therefore, data generated from these loci was excluded and data from those microsatellites producing high success rate (>95%) was subjected for further analysis for individual identification and diversity estimates.

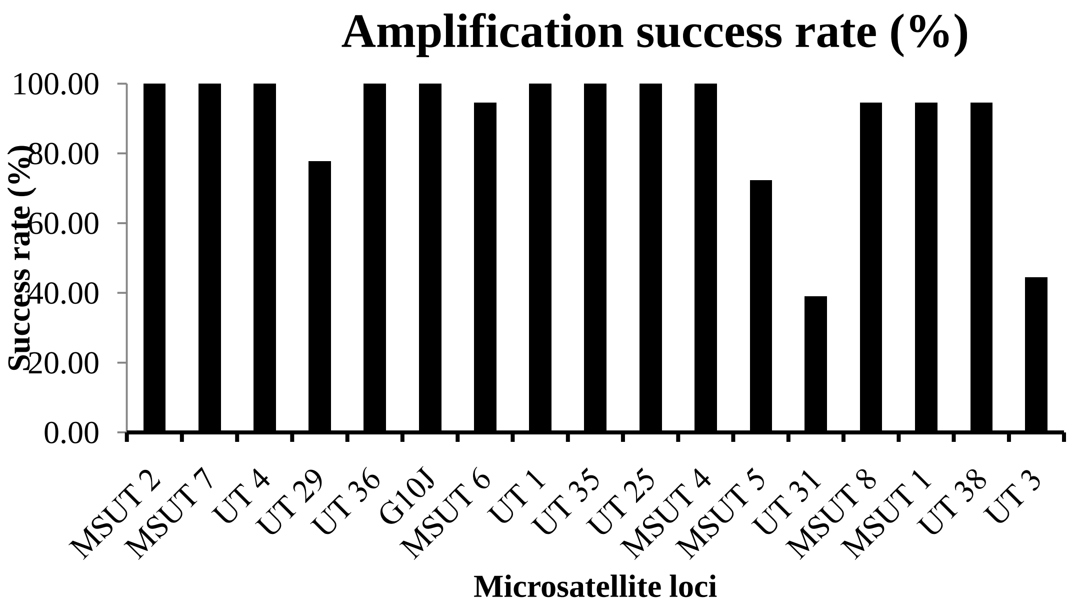

Figure 7.4. Microsatellites amplification success rate with Asiatic black bear DNA samples.

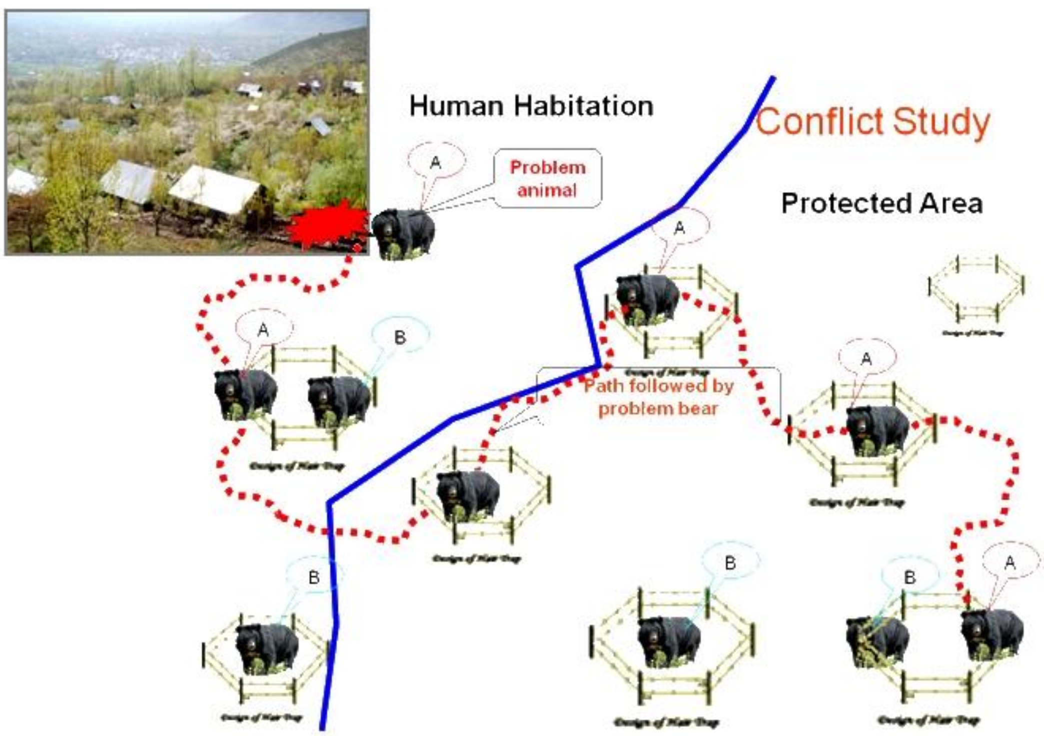

Figure 7.5. Picture showing molecular tracking of conflicting bear in Dachigam landscape

7.3.2. Identification of individuals through multi-locus genotyping

Each sample was genotyped twice to minimize the genotyping errors for individual identification. Only those samples were considered for individual identification that produced identical genotypes in duplicate genotyping. Few samples were repeated as they did not produce the identical genotypes in first run. The genetic analysis was started with 80 hair samples and 24 samples did not amplify at all. This occurred as the starting material was low (because of less hairs or hairs without root) and seven hair samples did not produce identical genotypes even after repeating thrice. In total genotype was achieved for 64 hair samples that produced identical genotypes in duplicate genotyping and 18 unique genotypes were identified in a pool of 64 genotypes (Table 7.2). All the genotypes except ABB 5, ABB 9, ABB 16 & ABB 17 were recaptured and genotype ABB 3 was recaptured as maximum as 9 times in the genotype data of 64 samples.

A graph was plotted between matching genotype verses unique genotypes with increasing locus combination and was found that a combination of five or more loci are necessary to get the unique genotype Using a single locus MSUT 2, we found that the nine individuals were of unique genotypes while other nine individuals were of similar genotypes. On increasing the locus combination as maximum as five (MSUT 2+MSUT 7+UT 4+UT 36+G10J), all the 18 genotypes were become unique and there was no matching genotype. No unique genotype was captured on further increasing the loci combination and therefore, we conclude a combination of five loci was required to identify the unique genotypes (Figure 7.6).

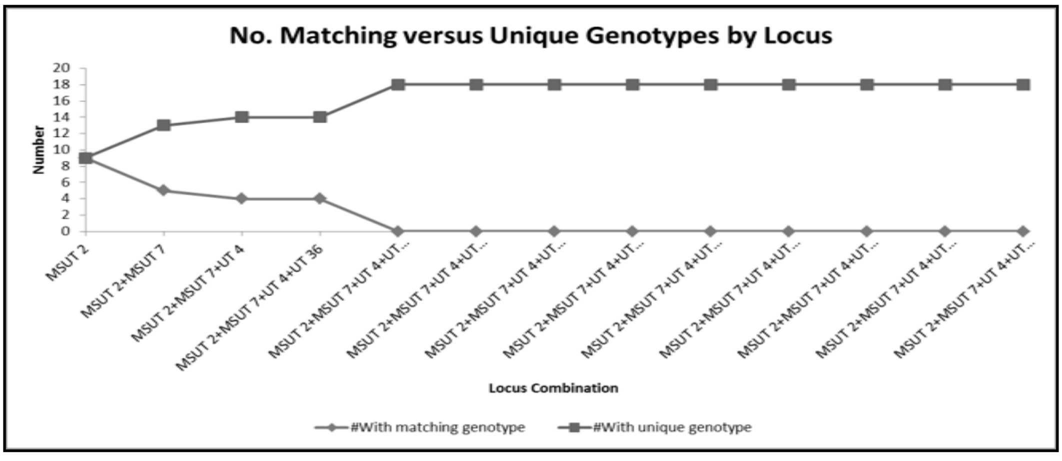

Figure 7.6. Identification of unique genotypes with increasing locus combination

Table 7.2. Identification of unique individuals using multi-locus genotype data at Dachigam landscape

Sample ID	**Unique Genotype ID**	**Tag**	**Recaptures of the individuals**
MT 229	696911011615316928928992941711712102142062103223468999118118168168186194g	ABB 1	5
MT 111	697711411615316128928982921711711901902062103183228997108128168168190202g	ABB 2	6
MT 118	697711611615315328928988901731731861862022103183228797108114168168194194g	ABB 3	10
MT 231	697910811414916128928980821731732062142022103303508993108118152176182190g	ABB 4	7
MT 230	697910811414916128928982881731732062142022103303508993108118176176182190g	ABB 5	4
MT 116	698311411415316128928982901711712102142022103183468793112118168168186194g	ABB 6	4
MT 130	698511411815315328929380801751751781782022063183188799001681682022 02g	ABB 7	4
MT 124	698911611615316128929780941671672142142022103183468797108120168168198210g	ABB 8	6
MT 129	717511611614915328928978821731731782142102103183188795108114160168182198g	ABB 9	1
MT 232	717710811215316129329782901712071781782062183303348791108120160170186190g	ABB 10	9
MT 101	717711611615716929329790921812071781782062183303308793108120168168186230g	ABB 11	5
MT 119	717911411415315328928982900018618620221031834687931081281681681942 02g	ABB 12	1

Sample ID	**Unique Genotype ID**	**Tag**	**Recaptures of the individuals**
MT 120	7183114114153161289289829016117521421420221033034687931101281681681902 30g	ABB 13	4
MT 123	71851161161531612892938080169207214214202210326330939310811416816800g	ABB 14	7
MT 115	738311411415316128928968821711711782142022103183468993110128168168230230g	ABB 15	3
MT 122	738311411415316128928982901711711782142022103463468793110128168168230230g	ABB 16	2
MT 125	73831141141571692892899294171207178214206210346346879310811000190190g	ABB 17	7
MT 114	838311611615316128929374801671672142142022103263309191114122168168190194g	ABB 18	5

7.3.3. Assessment of genetic diversity and population structure

7.3.3.1. Genetic diversity estimates

All the 13 loci showed enough polymorphism in the population of Asiatic black bear in Dachigam National Park and the summary of the diversity measures are presented in Table 7.3. Altogether, 85 different alleles were found across 13 loci. The number of observed alleles ranged from 3 (UT36) to 9 (MSUT 2& G10J), with overall mean number of alleles per locus of 6.53 (± 1.89). The observed number of alleles for all loci exceeded the effective number of alleles, which varied from 1.55 (MSUT 1) to 6.35 (UT 38) with mean 4.04 ± 1.63. Observed (*H*o) and expected heterozygosity (*H*e) ranged from 0.188 (MSUT 1) to 0.94 (MSUT 8 and UT35) and from 0.36 (MSUT 1) and 0.84 (MSUT 2 & UT 38), respectively. The H_e values were higher than H_o values for all the 13 loci with no exception. PIC ranged from 0.34 to 0.82 with an average of 0.66. PIC value for loci UT 36 and MSUT 1 was lower than 0.5 while 11 loci showed PIC higher than 0.5 which is normally considered as informative in population genetic studies (Botstein *et al.* 1980) and therefore, the microsatellite markers for the present study were chosen correctly and could be employed for further genetic studies on black bears. Few loci (MSUT 7, MSUT 6, UT 1 & MSUT 1) showed considerable inbreeding estimates but the black bear population did not show any inbreeding as mean FIS estimates (0.09) did differ significantly from zero. Seven of the 13 loci confirmed to HWE (P > 0.05) while six loci (MSUT 7, UT 4, MSUT 6, UT 1, UT 35 and MSUT 1) deviated significantly from HWE (P < 0.05). Out of the 6 loci that deviated from HWE, 4 loci (MSUT 7, MSUT 6, UT 1 and MSUT 1) showed significant null allele estimates, therefore, this could be one of the reasons from departure from HWE equation.

The Model-likelihoods from program STRUCTURE indicated that all bears in the landscape most likely to belong to one panmictic population (K=1) lacking substantial genetic structuring in the population (Figure 7.7). However, results also revealed slight degree of population structure based on moderate or feeble gene flow over long distances.

Table 7.3. Genetic diversity estimates of Asiatic black bear population at Dachigam National Park

Locus	Na	Ne	Ho		He	PIC	FIS	HWE (P-value)	Null allele frequencies
								Chakraborty	Brookfield 2
MSUT 2	9.00	6.29	0.89	0.84	0.82	-0.057	0.586	-0.03	0.00
MSUT 7	6.00	2.79	0.33	0.64	0.58	0.481	0.046*	0.32†	0.19†
UT 4	5.00	3.00	0.83	0.67	0.61	-0.250	0.001*	-0.11	0.00
UT 36	3.00	1.58	0.33	0.37	0.34	0.096	0.056	0.05	0.03
G10J	9.00	5.64	0.89	0.82	0.80	-0.081	0.571	-0.04	0.00
MSUT 6	8.00	4.59	0.29	0.78	0.75	0.624	0.000*	0.45†	0.36†
UT 1	6.00	3.38	0.44	0.70	0.66	0.368	0.000*	0.23†	0.15†
UT 35	4.00	2.95	0.94	0.66	0.60	-0.430	0.002*	-0.18	0.00
UT 25	7.00	4.60	0.72	0.78	0.75	0.077	0.313	0.04	0.03
MSUT 4	7.00	4.47	0.89	0.78	0.74	-0.145	0.315	-0.07	0.00
MSUT 8	8.00	5.40	0.94	0.82	0.79	-0.155	0.093	-0.07	0.07

MSUT 1	5.00	1.55	0.18	0.36	0.34	0.505	0.000*	0.34†	0.27†
UT 38	8.00	6.35	0.71	0.84	0.82	0.162	0.096	-0.11	0.65
Mean (SE)	6.53± 1.89	4.04±1.63	0.64±0.28	0.67±0.16	0.66±0.16	0.09			

Where, Na- Observed number of alleles; Ne- Effective number of alleles; Ho- Observed heterozygosity; He-Expected heterozygosity; HWE- Hardy-Weinberg Equilibrium; *Departure from HWE (*P*<0.05); †null alleles present; and frequency predicted as proposed by Chakraborty et al., 1992, Brookfield et al, 1996.

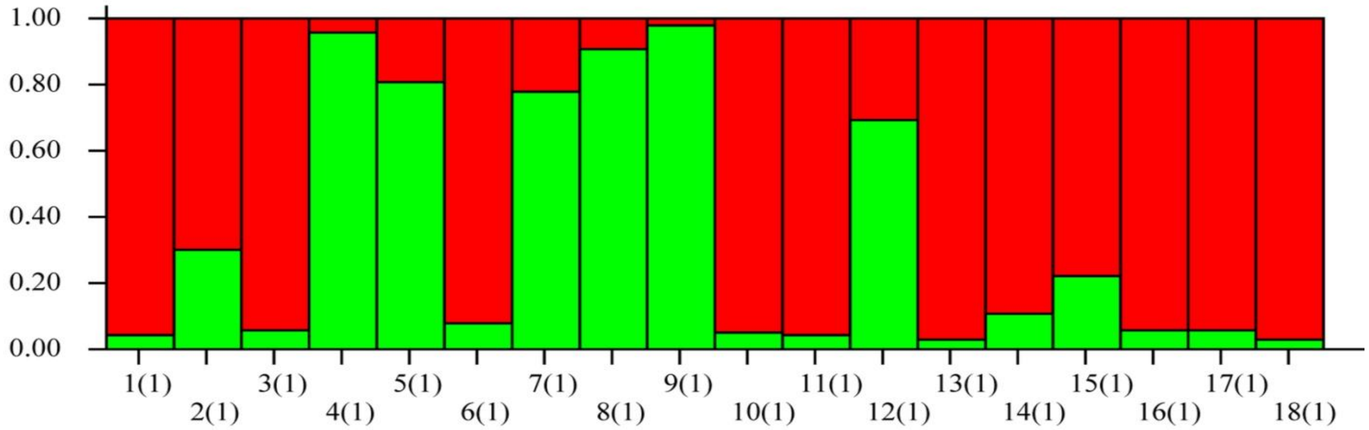

Figure 7.7. Barplot from Structure analysis showing assignment of individual genotypes from Dachigam Landscape.

7.3.3.2. Estimating effective population size

Using LD method, N_e estimates were found to be stable at allele frequencies 0.02 and 0.01(Table 7.5) and the actual N_e estimates was presumed 18.1 at P_{crit} 0.01 because there were high number of alleles with low allele frequencies in our data sets. No difference in the confidence intervals was observed in N_e estimates using jackknife and parametric procedures.

Table 7.4. Effective population size (N_e) estimated using linkage disequilibrium (Waples and Do, 2008) in Asiatic black bear population.

N_e at frequency (0.05)	N_e at frequency (0.02)	N_e at frequency (0.01)	95% CI (parametric)	95% CI (JackKnife)
10.7	18.1	18.1	13.1-26.7	13.2-26.5

7.3.3.2. Relatedness and spatial organisation

The average value of relatedness for known mother-offspring pairs was *R*= 0.428 (90% CI 0.391-0.452). The upper confidence limit of this value is lower than the theoretically expected value of 0.5. The mean relatedness values and the 90% confidence intervals for all of the three categories of individuals are given in Table 7.5. The mean relatedness value *R* for core area overlapping bears was 0.238 (90% CI 0.166-0.318), for overlapping home ranges (YO) it was 0.124 (90% CI 0.039-0.224) and for the non-overlapping home ranges (NO) it was *R*= -0.092 (90% CI -0.059-0.011).

The Mantel test indicated a negative relationship ($P<0.05$) but not significant between the relatedness of overlapping black bears and the distance between the home range centers. The Standardized Mantel Statistic ($r = - 0.532$; $P=0.074$) indicates that the relatedness negatively influenced by the geographic distance, hence related individuals were more likely to have home ranges close together than farther apart.

Table 7.5. The mean genetic relatedness and the 90% confidence interval around the mean estimated using the bootstrap technique (10,000 bootstrap samples) for three categories of home range overlap among black bear at Dachigam landscape.

Categories of HR overlap	Mean relatedness	Confidence Interval
NO	-0.092	-0.056-0.011
YO	0.124	0.039-0.224
CO	0.238	0.166-0.318

7.3.3.3. Molecular tracking of black bear in Dachigam landscape.

Out of the total 18 identified individuals, five black bears belong to Dachigam NP which was reportedly involved in conflict in the surrounding areas of Dachigam (ABB 4, ABB6, ABB 7, ABB 11 and ABB 13) and there were two individuals hair trapped in Oak patch of Dachigam NP (ABB 8 and ABB 18) during autumn season (Figure 7.8).

7.4. Discussion

7.4.1. Genetic diversity in Dachigam bear populations

The genetic variability found in black bear population of Dachigam was consistent with the variability reported in other populations of Asiatic black bear. The mean hetrozygosity in the present study was 0.67 which was higher than the 0.66 reported by Saito et al. (2008) from Japan. The genetic diversity was higher than the 0.414 Newfoundland bears (Paetkau et al. 1997), 0.51 costal Louisiana (Triant et al. 2004) and 0.39 central California (Brown et al. 2009) whereas lower than 0.82 Ontario (Paetkau et al. 1997), 0.80 mainland Alaska (Peacock et al. 2007).

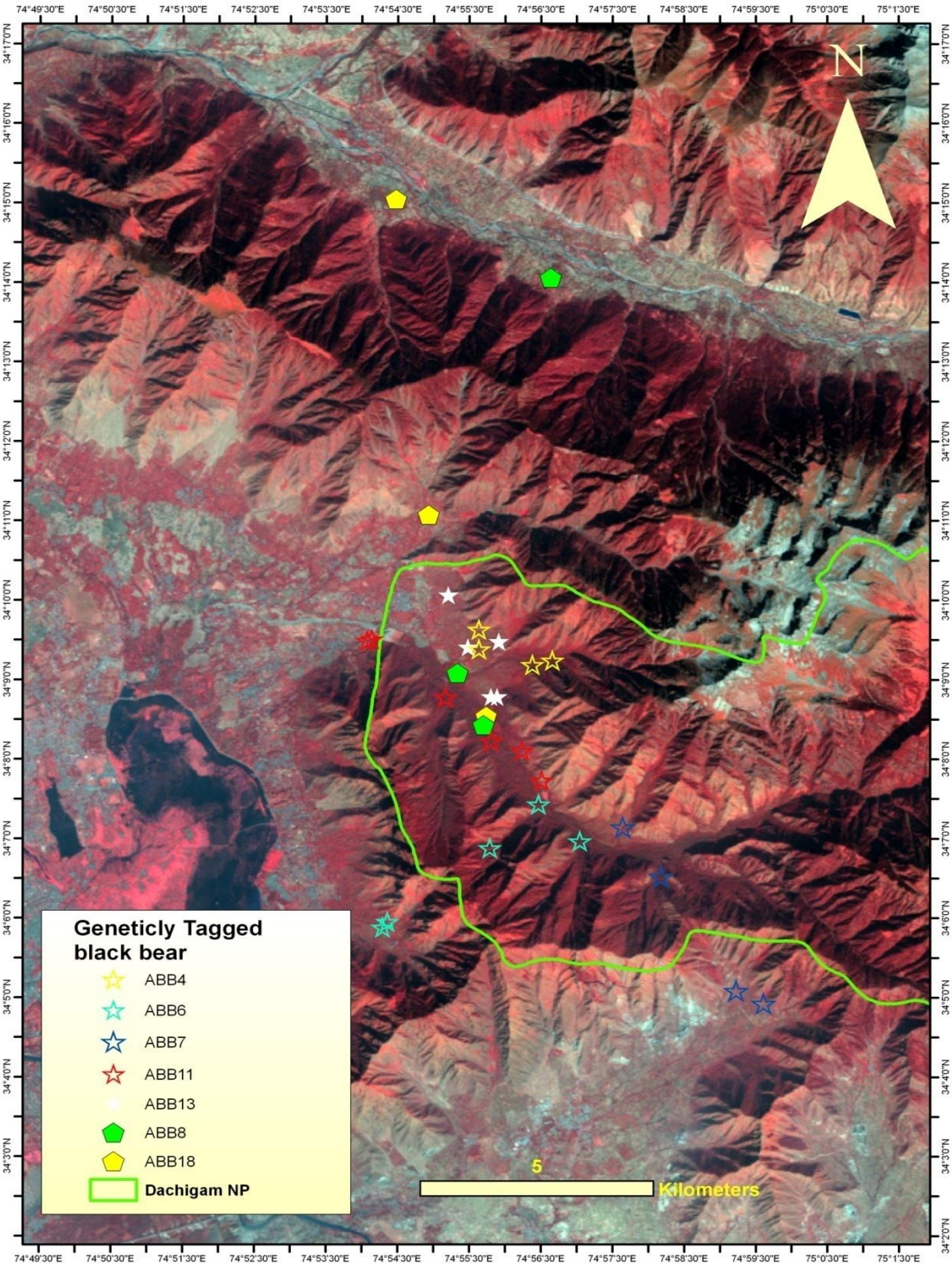

Figure 7.8. Map showing the recapture sites of conflicting individuals and there movements in Dachigam landscape.

7.4.2. Population structuring and effective population size of black bear in Dachigam landscape

The analysis based on the nuclear DNA microsatellite analysis revealed that the black bear population in Dachigam is a single panmictic population with an evidence of slight genetic structuring as a function of geographic distance. The Bayesian clustering methods, assignment tests and neighbor-joining trees indicated minimal genetic structuring in the Dachigam bear population. The results of the present analysis were also corroborate by the findings based on radio-collaring of black bear in Dachigam, since they were covering long distance (Figure 5.8 and 5.9). However, it was believed that the current status of landscape fragmentation in Dachigam can lead to population structuring by way of barriers to the movement of bear in the landscape in the form of human settlements and land use change was not correct and the current level of fragmentation is not a treat to the population fragmentation. The slight structuring patterns show in the Barplot (Figure 7.7) may be resulted because there were few individuals who were residing in highly fragmented forest close to human habitations. Despite of the land use change in Dachigam the forests of Dachigam still holds connectivity and supporting large number of bears. So, as on know the present level of development and fragmentation may not have adverse effects on the population by way of restricting gene flow.

The estimated N_e effective population size of black bear in Dachigam suggests that the population is healthy and viable. The Ne estimates were near equal to the identified individuals (census number or individual identified for the analysis) that indicates the presence of large number of breeders in the population. Frankham (1995) observed demographic ratios of N_e/N in many studies of wild populations to have a median value of 0.11. Interpretation of N_e determined using the LD methods can be difficult as they are sensitive to various parameters, including the samples size and large fluctuation in Ne from generation to generation (Waples and Do 2010).

7.4.3. Genetic relatedness and spatial organization

Large number of studies has documented home range overlap among the individuals of black bear and the findings of the present study have also corroborated the results of such studied on black bear (Carpenter and MacMillen 1976; Nielson and Woolf 2001; see chapter 5). Studies by Lindzey and Meslow (1977), Reynolds and Beecham (1980) and many more also stated that home range overlap is an inherent part of the spatial organization of many populations of black bear but in some places the overlap is extensive (Garshellis and Pelton 1981; Powell 1987 and Smith and Pelton 1990) due to seasonal availability of food resources. However, Rogers (1987) found that yearling female black bears establish their home range within the home range of mother which is subsequently observed in other black bear populations (Garshelis and Pelton 1981; Schwartz and Franzmann 1992). The findings of these observations led to the hypothesis that genetic relatedness drives female spatial organization and explains home range overlaps, whereas Schenk et al (1998) tested this hypothesis and found no relationship between spatial proximity and genetic relatedness among the bears which were having home range overlap or closely located. In the present study there was a negative relationship between the home range centriods distance and the genetic relatedness among the pair of individuals in the study area. The relationship was not significant which can be attributed with the availability of food resources in Dachigam. Moyer (2004) attributed the lack of relationship between relatedness and space use pattern with the concurrent acorn mast failure in the habitat. In Dachigam the seasonal home range of black bear differed significantly and largely governed by the availability of food throughout the year.

The spatial arrangement and overlap of black bear ranges can also be influenced by the distribution and availability of resources (Powell 1987; Schenk et al. 1998). The home range overlap was more extensive during autumn since the food availability becomes patchier in Dachigam. The findings of the present study were similar to the studies conducted elsewhere by Pacas and Paquet (1994) and Samson and Huot (2001). The genetic relatedness also has influence on the spatial arrangement of the home ranges since the relatedness was high among the individuals possess overlap than un-overlapping individuals. The results of the present study don’t strongly support the phenomena advocated by Moyer (2004) and the results were more conservative since the sample size was low.

7.4.4. Molecular tracking of black bear in Dachigam landscape.

By using the molecular tag seven conflicting individual bears were tracked in the landscape. There were bears which belong to Dachigam NP but they used to damage in croplands as well as orchards in the surrounding areas of Dachigam. The present study has demonstrated the significance of molecular tracking in wildlife management. It was difficult to track the movements of species such as black bear since they are active during crepuscular time. The movements of bears from Dachigam to the surrounding areas were high during spring and early summer season because the availability of food becomes very low in Dachigam (Figure 6.1 and 6.2). By using the molecular tracking technique it was proved that during autumn season bears congregate in the Oak patch inside Dachigam to feed on oak acorns. The results of the molecular tracking corroborated the findings of the radio-collaring study. Individual ABB 8 and ABB18 belong to area as war as 10km crow fly distance from Dachigam also found to use Oak patch during autumn (Figure 7.5). Studies on the movement of bear were in coherence with the findings of the present study (Jonkel and Cowan 1971; Powell 1987).

During the study it was observed that the management of Dachigam NP was releasing the bears inside Dachigam which were captured from conflict locations in the landscape. This practice may not be an effective method for minimizing the conflict, since such individuals moved back to the native area. The tendency of black bear to move back to the native direction rather than settle after release has made this species the subject of numerous studies of homing ability and such type of behavior was documented in Nielson and Brown (1988). The molecular tracking of bears is also useful in tracking the beast (conflicting bear) in the landscape by collection of samples barbed wire fencings of the orchards and croplands (Figure 7.5). Molecular tracking is found to more effective in tracking the animals since it is more economical and it helps in identification of the conflicting animal.

7.5. Summary of major findings and discussion

1). Individual identification through multi-locus genotyping was found to be an effective tool in identification of bears in the study area as evident from identification of 18 individuals from 64 samples. For the identification of individuals, a combination of five or more loci would be necessary.

2). The genetic variability found in black bear population of Dachigam was consistent with the variability reported by other studies and there is no genetic threat to Dachigam bear population in the near future.

3). The black bear population in Dachigam was a single panmiactic population and no structuring was observed except for two individuals that showed little deviation which could be attributed to landscape fragmentation.

4). The relationship between the genetic relatedness and the spatial organization of the home ranges was not significant and the home range overlap was large due to spatio-temporal changes in food availability. Since, the sample size was low the genetic relatedness results are more conservative.

CHAPTER - 8.0: CONCLUSION AND MANAGEMENT RECOMMENDATION

8.1 Conclusion

In this study, several aspects of spatial ecology of black bear has been studied including the seasonal and annual home ranges, movement patterns and feeding habits. The main objective of the study was to understand the factors influencing the spatial ecology of black bear.

A review was carried out for the selection of most suitable computer program of the home range analysis and suggestion was made for the future researchers to decide which tool is best for the home range analysis. In total, five most popular software programs were tested for the home range size estimation by adopting the utilization distribution technique. After the selection of most suitable program the comparison has been done between two utilization distribution methods of kernel analysis (fixed and adaptive).

The seasonal and annual home ranges of black bear were generated and the factors influenced the ranging patterns of bear were evaluated. The seasonal differences in the home range size among the male and female individuals were also evaluated. The home range overlap, site fidelity and the core areas used by black bear also studied for the seven collared individuals.

The availability of bear food items and fruit abundance was estimated for different seasons in Dachigam NP. The nutritional analysis of important food items was carried out for understand the preferences. The food habit of bear was studied by adopting three methods: direct feeding observations, indirect feeding sign observation and the post ingestion analysis of scat samples. The seasonal and yearly diet of black bear was documented.

The home range size of black bear at Dachigam was slightly smaller than reported by previous studies from Taiwan, China and Japan, perhaps due to higher overall productivity and abundant food resources in Dachigam, in comparison to other areas where the home range was studied. The seasonal home range of black bear also differed significantly in the present study, where autumn home ranges were larger than summer and spring. The home range of M02 and F06 were largest among all individuals since, these individuals were captured outside Dachigam NP from the cropland and were released in Dachigam. These two individuals have used large amount of area both inside and outside Dachigam. During second half of autumn the food availability in the landscape becomes very low and only available in the form of Oak acorns and fruits of *Celtis australis* in Dachigam NP. These two individuals were doing large distance sallies to feed in such fruit patches in Dachigam making their home range large. For rest of the five individuals, the annual home range reflected the habitat composition of the study area.

The summer home ranges were smaller than autumn, perhaps due to highest overall productivity of habitats in Dachigam. The food resources during summer were homogenously distributed in the landscape, with wild berries such as *Prunus* spp., Mulberries in Dachigam NP and Cherry, Apple, and Maize in orchards and agricultural croplands in the surrounding areas of Dachigam.

The spring home ranges were smaller than summer and autumn possibly due to feebleness and food stress, as they could not able to cover large distance and the availability of fruits is also low in Dachigam. In spring bears in Dachigam feed largely on herbs, grasses, insects which are rich source of protein and calcium and abundant, which they acquire without covering large distance.

The autumn home ranges were largest among all seasons for all individuals probably since the food availability in the landscape becomes patchy, thus bears cover large distance to feed on such patchily distributed fruit species.

The kernel home ranges of the male bears were larger than the female in Dachigam which is corresponding to the other studies on American black bears. The large difference in the home range size of male individual can be attributed with the low sample size in terms of number of individuals collared and number of locations or the small monitoring duration. Out of the total seven individuals the home range size reached asymptote for three bears, indicates that still there is need to monitor such bears until home range size reach asymptote.

The large amount of home range overlap and site fidelity showed by bears indicates, the availability of food resources was abundant and reflect the resource composition in the study area, in general and specifically in the composite home range of radio-collared bears during the study period.

Abundant food resources are often negatively correlated with home range size in mammals (Litvaitis et al. 1986), including black bears (Powell et al. 1997). It has been found that a combination of natural and human-induced forest fragmentation leads to increased home range size and movements of bears to locate suitable habitat. However, if food is abundant and diverse, then fragmentation may have the opposite effects and lead to smaller home ranges and increased population density, even in areas with very little remaining habitat (Mollohan and LeCount 1989).

The movement patterns of black bears in Dachigam were influenced by the availability of food items at spatial as well as temporal scales. Black bear in Dachigam generally avoided roads and human use trails for movement, but in case of individuals who have restricted their movement to the boundary of Dachigam showed little resilience towards the roads. The results of movement analysis indicated that topographic factors have less influence on the movement path selection of black bear compared to disturbance and ecological factors such as food and water. The movement path of black bear is most circuitous during summer followed by spring and autumn, perhaps due to the more random availability of food items in summer than spring and autumn.

The results shows that black bear movement paths becomes more circuitous to avoid human contact, the vegetation and topographic cover may facilitate the animals movement through high use trails and road density. The present study suggests that the cumulative effects of trails, roads, and other developments are of potential conservation concern for black bear in the landscape so the human developments should be regulated to maintain the habitat contiguity.

The genetic analysis of the black bear indicates that the bear population in Dachigam holds considerable amount of genetic variability and there were no threat in terms of population fragmentation. The bear population in Dachigam was a single panmiactic population and no structuring was observed in the present study. Present status of Landscape fragmentation and land use change is affecting the genetic structure of bears in the landscape. The relationship between the genetic relatedness and the home range organization was not significant and since the overlap between in the home ranges was extensive, which was largely due to the availability of food resources. The relationship results were conservative since the sample size was low and better sample size may bring the picture clear in terms of influence of genetic relatedness on the spatial organisation.

The molecular tracking of bears in the landscape was useful in identification of bear and monitoring their movement patterns. The results based on the molecular tagging of bears were concurrent with the patterns suggested by the radio-collaring study. Using molecular tag five conflict bears were identified belonging to Dachigam NP and these bears were moving outside Dachigam during spring and early summer for raiding croplands and orchards. However, two bears were also located in Oak patch during autumn by using molecular tracking indicating that bears in Dachigam landscape covering long distances to feed on Oak acorns in Dachigam NP.

The food availability in Dachigam varies among the seasons in Dachigam. During spring the food was available in the form of herbs, grasses and in insects whereas, during summer food abundance was highest in the form of berries and small fruits. The food availability was homogenous in distribution in summer whereas, it becomes patchy in autumn. The overall diet of black bear was dominated by fruits followed by herbs and grasses, insects, human food and animal matter. The diet of black bear composed of more than 41 species out of which 34 species were of plants, three animal species and four insects' species. The diet of bear varied among the seasons and was corresponding to the availability of species and reflects the species composition in the different habitats in Dachigam. Occurrence of considerable amount of anthropogenic crops (cultivated crops) in bear diet can be associated with close location of these crops to the natural bear habitat thus, attracting bears and leading to bear-human conflict in the landscape.

The results of this study provides a basic understanding of the spatial availability and utilization pattern of food resources, which will play vital role to understand the space utilization, ranging pattern and factors influencing the movement patterns of black bear on spatial and temporal scale. The findings will be useful to understand the effects of fragmentation and habitat management on diet, space-use, and habitat selection, and for developing a sound conservation strategy for the black bears in Dachigam Landscape.

8.2. Management Recommendations

The investigation on the black bear food habits enables the management of Dachigam NP in food resource management to maintain optimal habitat conditions. Occurrence of considerable amount of anthropogenic crop (cultivated crops) in bear diet can be associated with close location of these crops to the natural bear habitat and hence, the efforts should be made to educate the local communities to stop growing such crops in the close vicinity to the park boundary (Greenleaf et al., 2009). The incremental replacement of horticulture crops with high economic value medicinal plants which are non palatable in such areas of Dachigam NP will allow black bear for gradual transition from human food to natural food which will help in reducing conflict with out hampering the locals economy. Aversive conditioning of bears will be critical as bear accustomed to feed on horticulture crops will seek out alternative food resources in the area. Efforts on proper management of waste in horticulture crops and food processing industries in areas close to bear habitat will help in mitigating bear-human conflict. It is recommended that there is a need to do multi-year studies which involve monitoring of fruit availability on important food species of black bear in Dachigam landscape which will be helpful to understand the seasonal variations in food habits within the years and to understand the stubborn food resources (which do not show seasonal variability) and the alternative food resources (with seasonal changes in availability) or inadvertent (crop, orchards) food resources in the landscape. Better understanding of food and feeding habits of black bear will help in bear-human conflict mitigation in the landscape.

There is a need to develop management strategies for black bear at landscape level, since bears are long ranging species and known to cover long distance. The management intervention in the study areas should be focused on habitat improvement in the form of increasing food availability and decreasing human interference at the landscape level.

The forest fragmentation analysis in this study suggested intermediate level of forest fragmentation and it is likely to increase due of human encroachment on the forest land. The forested fragmentation can adversely impact the movement of bears in the landscape which may lead to demographic as well as genetic isolation of species, hence can leaded to population fragmentation and extirpation. It is recommended to control such developments and steps should be taken to reverse the process of habitat loss by aforestation in such areas with fruit bearing plant species. The connectivity of the forest should be maintained for the term survival and genetic viability of the species.

The molecular tracking study suggested that the current practice of releasing conflicting animals inside Dachigam may not be an effective tool to reduce conflict, since bear possess strong homing tendencies (Rogers L.L. 1988.).

The future management practices need to protect and restore large, contiguous forested habitat for the black bears in the landscape and elsewhere in the distributional range of black bears that may provide a strategy for managing bears in areas where habitats are already highly fragmented.

An increasing human population and a poor socio-economic condition of rural villagers are contributing to extensive habitat loss, bear-human conflict which is leading to retaliatory killing of unprotected black bear populations out side the protected area network of Kashmir valley (Charoo et al. 2011). However, the major threat to black bear conservation and management in Dachigam landscape and in entire Kashmir valley includes habitat encroachment, land use change in the recent pass and retaliatory killing of black bears to minimize black bear human conflict. In Dachigam landscape the habitat management is carried out for Hangul but it is also important to manage habitats for black bear in the landscape which includes habitat inventory, protection, retention and habitat improvement (increasing food rich trees and tree density through manipulation). Few fruiting tree forest strands can be generated in the landscape to stop inter patch movement which negotiates the human habitation.

To ensure the better management of black bear population in Dachigam landscape it is necessary to stop illegal forest encroachment and the local should be encouraged to grow crops which are not preferred by black bear as food, near to the forested habitats and to maintain as well as restore the forest contiguity in the landscape.

There is a need to create awareness among the locals in the landscape, since locals do not understand the basic ecology of the species. They should be encouraged and educated about their co-existence mechanism with the bears in the landscape by increasing their participation in training and awareness programs.

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