STATUS AND CONSERVATION OF UNGULATES IN THE KUMAON HIMALAYA WITH SPECIAL REFERENCE TO ASPECTS OF ECOLOGY OF BARKING DEER (*Muntiacus muntjak*) AND GORAL (*Nemorhaedus goral*)

SUMMARY

SUMMARY

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

Wildlife Science

BY

ORUS ILYAS

DEPARTMENT OF WILDLIFE SCIENCES
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2001

THESIS

STATUS AND CONSERVATION OF UNGULATES IN THE KUMAON HIMALAYA WITH SPECIAL REFERENCE TO ASPECTS OF ECOLOGY OF BARKING DEER (*Muntiacus muntjak*) AND GORAL (*Nemorhaedus goral*)

SUMMARY

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

Wildlife Science

BY

ORUS ILYAS

DEPARTMENT OF WILDLIFE SCIENCES
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2001

1. INTRODUCTION

Research on status and conservation of ungulates in Kumaon Himalaya with special reference to aspects of ecology of barking deer (*Muntiacus muntjak*) and goral (*Nemorhaedus goral*) was carried out from January 1996 to December 1998. The following were the objectives of the study :

1.1 To investigate the status, distribution and abundance of ungulates in extant oak forest patches of Kumaon Himalaya.
1.2 To investigate the seasonal abundance and habitat utilisation pattern of goral and barking deer in oak/pine ecosystems.
1.3 To investigate the feeding ecology of goral and barking deer in oak/pine forest ecosystems.
1.4 To quantify the threats to conservation of ungulates in oak forest ecosystem in the Kumaon Himalaya.
1.5 To prepare a conservation strategy for the ungulate community in Kumaon Himalaya.

2. METHODOLOGY

To fulfil these objectives, several sets of methodologies were used.

2.1 Vegetation studies

Intensive vegetation studies were carried out at different surveyed sites in Kumaon Himalaya during pre-monsoon 1997. Binsar Wildlife Sanctuary was covered during post-monsoon 1997. A total of 634 sampling plots were established at 19 sites. Circular plot method was used to collect the vegetation data. Trees were sampled in 10 m radius circular plot whereas shrubs were counted in 3 m circular plot. The ground vegetation was quantified in four 0.5 m x 0.5 m plots at each sampling point. Density, diversity and species richness of trees, shrubs, regenerating trees, herbs, grasses and density of individual species was calculated. Values for these parameters from each sampling point were used to calculate mean density, diversity and richness for different sites. Ordination of habitat variables, sites and tree species was performed using Principal Component Analysis (PCA). Cluster analysis was used to classify sites according to tree species composition to investigate the tree species associations.

2.2 Status and distribution of ungulates in Kumaon

Existing forest trails were monitored to quantify the direct and indirect evidences of ungulate species for determining status, distribution and abundance at each site. Pellet groups of different species were quantified in 634 circular vegetation plots. The sightings of different ungulate species were used to calculate encounter rates in terms of 100 hours of observations for each site. The number of pellet groups in each plot was used to calculate pellet group density (pellet groups/ha) for each species in each plot. The individual values of pellet group densities were added together to calculate mean pellet group densities for each species. To investigate the factors governing distribution of ungulates at landscape level, Discriminant Function Analysis (DFA) was performed.

2.3 Abundance and population structure of barking deer and goral in Binsar

Data on abundance of barking deer and goral were collected using direct and indirect methods. The data pertaining to population structure of barking deer and goral were collected by direct observations in Binsar. Four existing forest trails were selected for sampling. Monitoring of the trails was carried out at dawn and dusk between 0600 to 0930 hours and 1700 to 1930 hours respectively. Abundance estimation of barking deer and goral was also done by pellet group counts. 60 permanent plots, each of 10 m radius, were established along three, one km each, long transects. These plots were cleared before onset of each season and pellet groups of barking deer and goral accumulated in each plot during each season were counted. The sightings of barking deer and goral along each trail were summarised to calculate encounter rate (groups/km) for each trail in each season. Pellet group density (pellet groups/ha) was calculated for each species. Pellet group density was converted into animal density (individuals/km^2) by dividing the total number of pellet groups recorded on a transect with the mean defecation rate and number of days over which pellet groups were accumulated following Mayle *et al.* 1996. The Kruskal-Wallis one way ANOVA and t-test were used for testing the significant differences between mean encounter rates, mean pellet group densities and mean group size between trails, transects and different seasons and years.

2.4 Habitat use of barking deer and goral in Binsar

The data on habitat use by barking deer and goral in Binsar were collected by using direct and indirect methods. Four existing forest trails were monitored in early morning and evening hours. For each sighting of barking deer and goral on trail, data on: a) altitude, aspect, slope, and location, b) vegetation type and vegetation factors, c) disturbance factors (cutting, lopping, cattle dung and fire) were collected. Data on pellet groups quantified in permanent circular plots were also used for investigation of habitat use. The direct sighting data and attributes of habitat were organised in species-habitat attributes matrix, transformed, standardised and subjected to Principal Component Analysis (PCA). Logistic regression analysis was done on the random and animal centred plots. Significant differences in mean values of habitat attributes between animal centred plots (plots with pellet groups of either species) and available plots were tested using t-test.

2.5 Feeding ecology of barking deer and goral in Binsar

Data on the feeding ecology of barking deer and goral were collected by indirect method only. Permanent slides of all potential food plants were prepared for using them as reference slides. Pellet groups of barking deer and goral were collected separately for micro-histological studies. 25 slides were prepared for each species for each season. A total of twenty field of views were observed for each slide. Above ground biomass available to barking deer and goral were estimated by clipping ten 0.50 x 0.50 m quadrate in oak and pine habitat on monthly basis. Harvested and dried grasses and herbs were also used in crude protein estimation by the Kjeldahl method following Munro and Fleck (1969). 95% Bonferroni Confidence intervals were constructed to compare proportions of browse plants species consumed by barking deer and goral with that of available proportions of browse species in oak habitat.

2.6 Threats assessment in Kumaon and Binsar

Data on various threat parameters were collected during the general survey of extant oak patches carried out in pre and post-monsoon seasons of 1997 using a questionnaire approach and by quantifying lopping, grazing, cutting and cattle dung abundance in 634 circular plots established for vegetation sampling. To evaluate the impact of forest fire on woody vegetation, sampling was carried out in a burnt oak patch of Binsar and data were collected around 100 randomly located sampling points. All threat variables assessed in and around each oak patch were converted on ordinal scale of 1 to 4. Ordinal scores for different threat parameter at different sites were added together to calculate a mean threat score for each site. The mortality in tree layer due to fire was calculated for various tree species and different girth class categories. Simultaneous 95% Bonferroni confidence intervals were calculated following Byers *et al.* (1984) to find out the significant difference in mortality among various tree species and girth class categories.

3. RESULTS

3.1 Vegetation studies

The tree density (number of individuals/ha±SD) was maximum in Duku and minimum at Kunjakharak. Tree species diversity was maximum in Binsar and tree species richness was maximum at Gasi. The tree diversity and richness was found to be negatively correlated with altitude ($P<0.05$). Shrub density and diversity was maximum at Mukteshwer whereas shrub richness was maximum at Pandavkholi.

The shrub diversity and richness was also negatively correlated with altitude ($P<0.05$). Herb density (number of individuals/m^2±SD) was maximum at Pindari. Herb species diversity and richness was maximum at Sunderdunga. The herb diversity and richness was positively correlated with altitude ($P<0.05$). Grass density was maximum at Kunjakharak. Grass diversity was maximum at Maheshkhan. Grass species richness was maximum at Pandavkholi. The grass diversity and richness was negatively correlated with altitude ($P<0.05$).

A total of 68 tree species were identified at all the surveyed sites of Kumaon Himalaya. A total of 28 tree species were identified in different patches of Nainital district. The density of individual species varied between sites in Nainital district. A total of 47 tree species were identified in different oak patches of Almora district. *Rhododendron arboreum* and *Ilex dipyrena* were found to be common at all sites of Almora, while *Quercus glauca, Stranvaesia nussia, Albizia lebbek* were present only at Binsar. A total of 44 tree species were identified in oak patches of Pithoragarh district. Maximum number of tree species were found in Daphiyadhura (23) followed by Munsiyari (20) and Duku (17). The overall abundance (density values for each species at 19 sites combined) was highest for *Rhododendron arboreum* (105.9 individuals/ha) followed by *Quercus leucotrichophora* (84.4 individuals/ha), *Quercus floribunda* (81.5 individuals/ha), *Lyonia ovalifolia* (73.9 individuals/ha) and *Persea duthiei* (58.6 individuals/ha).

The density of 11 dominant tree species was plotted against the altitude gradient. Each species occupied a unique altitude range. Tree densities were highest in middle altitude zone rather than in low or high altitude zone. The density of regenerating tree species was maximum at Mukteshwer. Maximum diversity and species richness of regenerating species was found at Sitlakhet. Among *Quercus* species the density was highest for *Quercus floribunda* and lowest for *Quercus lanuginosa*. Among the co-associate species of *Quercus*, the density was high for *Symplocos* sp. and *Rhododendron arboreum.*

The principal component analysis of habitat variables extracted six components, which explained a maximum of 86.2% of variance in the data matrix. The first PC accounted for 29.4% of the variance while the second PC accounted for 26% of variance. The first component was related to altitude as it had highest loading on PC I. The PC II represented gradients of shrub, tree and herb layer since variables related to these layers had high loadings on PC II. Ordination of 19 sites was done by transposing data matrix of 27 habitat variables. Gradients for the first and second PC were already identified while doing *R*-mode analysis. PC I accounted for about 31.1% variation while PC II accounted for about 17.3 % of variation. Both components together explained about 48.4% of variation. A total of 66 tree species were identified at different surveyed sites. PCA was performed using *R*-mode strategy to see how different tree species were distributed in tree density space. First PC explained 15% of variance while second PC explained about 13% of variance. Distribution of tree species on PC I was influenced by the gradient of altitude. Tree species on PC II were distributed according to the slope gradient.

Out of the seven identified clusters of surveyed sites the first cluster included Duku, Mechh and Sobla. The second cluster included Gasi and Munsiyari while Pindari and Sunderdunga formed third cluster. The fourth and fifth cluster comprised of Binsar, Daphiyadhura, Gandhura and Majtham respectively. Jageshwer, Sitlakhet, Mukteshwer and Maheshkhan belonged to sixth group. The seventh cluster comprised of Binayak Kunjakharak, Gager and Pandavkholi. A total of 10 clusters of tree species were identified.

3.2 Status and abundance of ungulates in Kumaon

During the surveys, direct and indirect evidences of six ungulate species were collected These species were barking deer (*Muntiacus muntjak*), goral (*Nemorhedus goral*), sambar (*Cervus unicolor*), serow (*Capricornis sumatrensis*), Himalayan tahr (*Hemitragus jemlahicus*) and musk deer (*Moschus moschiferus*). While barking deer and goral were recorded from 15 sites, sambar was recorded from seven sites. There were no direct sightings of serow and Musk deer, but pellet groups of these species were recorded from different places. The encounter rate of barking deer was maximum in Binsar (16.04groups/100 hours), while the encounter rate of goral was highest in Kunjakharak (54.5 groups/100 hours). The encounter rate of sambar in Mukteshwer and Maheshkhan was 8.69 groups/100 hours and 3.92 groups /100 hours respectively. Himalayan tahr was sighted only in Pindari, where its encounter rate was 13.3 groups/ 100 hours. The mean pellet group density (pellet groups/ha±SE) of barking deer differed significantly between sites and it was highest in Binsar. The mean pellet group density of goral also differed significantly between sites and it was maximum in Kunjakharak. The mean pellet group density of sambar was maximum in Maheshkhan and the differences between sites were significant. Mean pellet group density of serow was highest in Sunderdunga and the differences between sites were also significant.

The DFA produced three discriminant functions which accounted for 52.6%, 29.1% and 18.3% of variance respectively. The DF1 represented the gradient of altitude. The DF2 represented gradient of increasing tree density along with decreasing ground cover values while the DF3 represented gradient of shrub as well as tree cover. The location of different species within three dimensional plot was used to explain habitat variables governing distribution at macro level for each species. The barking deer mainly occurred at lower altitudes in areas with high shrub densities, high ground cover and low tree densities and cover. The sambar occurred in low altitude areas with very high shrub and tree densities with low ground cover. The goral occupied middle altitude areas with medium shrub and tree densities, low shrub and tree cover with medium ground cover. The serow was distributed at very high altitudes in areas with high tree and shrub cover. In terms of tree and shrub cover requirements, goral occupied open forested areas followed by barking deer, sambar and serow which is found in closed canopy forests.

3.3 Abundance and Population structure of barking deer and goral in Binsar

The overall encounter rate of barking deer (all data combined) was 0.11 groups/km and it varied between trails. The overall encounter rate of goral was 0.08 groups/km. The encounter rate of barking deer was highest during post-monsoon season of 1998 (0.127 groups/km) while the encounter rate for goral was maximum in post-monsoon season of 1996 (0.112 groups/km). The barking deer pellet group density was maximum during post-monsoon season of 1997 while goral pellet group density was maximum during post-monsoon season of 1998. There was significant difference between pellet group densities of barking deer in different seasons. However there was no such significant difference in goral pellet group densities between different season. The overall mean density of barking deer and goral was highest during post monsoon season (5.9±4.7 and 3.3±0.56 respectively).

The group size of barking deer ranged from 1 to 3 individuals in all seasons. Approximately 83% barking deer groups were of one individual. The overall mean group size of barking deer was 1.17 and 1.06 in pre and post-monsoon season and it did not differ between seasons. The group size of goral ranged from 1 to 9 individuals and 39% of groups comprised of one individual. The overall mean group size of goral was 2.2 in both seasons. The sex ratio in barking deer as well as goral was found to be male biased. A total of 188 individuals of barking deer were classified for age and sex composition. Out of 188 individuals, 119 (63.29%) were adult males, 40 individuals (21.27%) were adult females and 5 individuals were (2.6%) sub-adults, 1 (0.53%) fawn and 23 individuals (12.23%) remained unidentified. A total of 270 goral were classified for age and sex composition. Out of 270 individuals, 106 individuals were (39.25%) adult males, 64 individuals (23.70%) were adult females, 21 individuals (7.77%) were sub adults, 4 individuals were fawns (1.4%) and 75 individuals could not be classified (27.7%).

3.4 Habitat Use of barking deer and goral in Binsar

During pre-monsoon season, the first two principal components accounted for 32.3% of variance in direct sighting data matrix of barking deer. The first factor was highly positively correlated with altitude, tree cover, richness and density while it was negatively correlated with slope and grass cover. During post-monsoon season, the first two components accounted for 30% of variation in data matrix. The first factor was highly positively correlated with tree cover, tree density and altitude but was negatively correlated with ground cover and grass density. The second factor was positively correlated with shrub cover, density, diversity and richness. In case of goral, during pre-monsoon season, the first two factors accounted for 36.9% of the variation in data set. The first factor was highly positively correlated with altitude, slope, shrub richness and shrub height. The second factor was highly positively correlated with grass cover and richness but was negatively correlated with tree cover. The available and utilised plots were plotted against first and second factor. During post-monsoon season, the first two factors accounted for 29.8% of variation in habitat data. The first factor was highly positively correlated with altitude and negatively correlated with tree cover and tree density. The second factor was highly positively correlated with gradient of herb i.e. herb density, diversity and richness.

The mean values of different habitat variables between available and utilised plots of barking deer differed significantly. Barking deer used forested areas with high tree density, cover and diversity. During post-monsoon season, the available and utilised plots differed with respect to percent grass cover, shrub number, shrub cover, shrub diversity, shrub density, tree number, tree cover, tree diversity, tree density, tree richness, and percent withered stone. Except for percent grass cover, all habitat variables had significantly higher values in utilised plots. There were significant difference between mean values of available and utilised plots of goral during pre-monsoon season viz.-a-viz. herb density, rockiness, shrub number, and shrub density. The utilised plots had significantly higher values for these variables. During post-monsoon season, a greater number of variables showed significant differences. The available and utilised plots differed significantly with respect to grass cover, percent herb cover, herb diversity, litter cover, rockiness, tree number, tree diversity, tree density and tree species.

3.5 Dietary spectrum

A total of 1714 and 1389 plant particles were evaluated during pre and post-monsoon season in 1998 in order to determine the dietary spectrum of barking deer in Binsar. Based on the identification of fragments, the browse to grass ratio was 87% and 13% in pre-monsoon and 78% and 22% in post-monsoon season. The diet of barking deer comprised of eight tree species, six shrub species and 18 herb species during pre-monsoon season whereas during post-monsoon season, eight tree, eight shrub and 19 herb species were identified. It was not possible to identify grasses at species level from plant fragments. A total of 18 tree, 19 shrub and 21 herb species were recorded in oak habitat and a total of 3489 individuals belonging to these species were recorded from which the proportional availability was calculated. The number of tree, shrub and herb species available and utilised by barking deer showed no significant difference in pre-monsoon season. The barking deer preferred eight species and avoided five species while other species were utilised in proportion to their availability in pre-monsoon season. The number of tree, shrub and herb species available and utilised also did not differ significantly in post-monsoon season. The barking deer preferred and avoided six plant species in each category while rest of the species were utilised in proportion to their availability.

The browse to grass ratio in goral diet was 12% and 88% and 3% and 97% during pre and post-monsoon seasons respectively. From the identified browse particles, fragments of one tree species, five shrub species and 11 herb species were identified in pre-monsoon season where as in post-monsoon season two tree species, one shrub species and six herb species were identified in the goral diet. During pre-monsoon season, goral utilised 10 browse species in proportion to their availability, avoided four species and none were preferred. During post-monsoon season goral utilised three browse species in proportion to their availability and avoided *Quercus leucotrichophora*. The above ground biomass was considerably lower in oak habitat compared to pine habitat in pre and post-monsoon season. The crude protein values were significantly higher in oak habitat compared to oak-pine habitat in all seasons. The maximum crude protein values were recorded in pre-monsoon season in 1998.

3.6 Threat assessment in Kumaon and Binsar

Jageshwer, Gager, Sitlakhet, Mukteshwer and Munsiyari were found to be the most threatened sites as values of threat index were found to be maximum (3.5, 3.14, 3.0, 3.0 and 3.0 respectively). Least threatened sites were found to be Duku (1.4), Pindari (1.5) and Binsar (1.7). Identified threats to the forest of Binsar Wildlife Sanctuary were excessive dependency of the locals for the fuel wood, fodder, timber, extraction of minor forest produce and plant mortality due to summer fires. A total of 141 *Mawas* (house holds) were identified in ten surveyed villages of Binsar and all villages were found to be totally dependent on the resources of Binsar for (i) fuel wood (ii) Fodder and *Arundinaria* extraction, (iii) Timber, (iv) Medicinal plants (v) Pine seed and *Rhododendron* flower and for wild meat.

A total of 1944 trees belonging to 16 different species were sampled, of which 677 (34.8%) trees were found dead due to fire. Percent tree mortality was highest in *Cedrus deodara* (100%), *Swida oblonga* (83.3%). The relative percent mortality was however, highest in *Quercus leucotrichophora* (16.9%). The overall tree mortality differed significantly between different girth classes. It was maximum in girth class ≤50 cm (21.35%) which was significantly higher than expected. The mortality was significantly higher then expected in *Quercus leucotrichophora* in girth classes ≤ 50 cm and 151-200 cm., while it was lower then expected in girth class 101-150 cm. A total of 155 saplings of different tree species were recorded during 1996 which increased to 382 in 1998. Correspondingly, the diversity of saplings also increased marginally from 0.59 in 1996 to 0.65 in 1998.

A total of 465 seedlings belonging to 17 species and 601 seedlings belonging to 13 tree species were recorded during 1996 and 1998. 30.7% of seedlings belonged to *Swida oblonga*, followed by *Quercus leucotrichophora* (28.6%), while during 1998 maximum number of seedlings found were of *Quercus leucotrichophora* (36.1%), followed by *Swida oblonga* (21.6%), *Rhododendron arboreum* (11.14%). *Quercus* species (*leucotrichophora* and *floribunda*) showed increase in their proportion from 1996 to 1998, but the increase was significant for *Quercus leucotrichophora* only.

3.7 Conservation strategy

The barking deer, sambar, goral, serow, Himalayan tahr and musk deer in Kumaon Himalaya are important elements of biodiversity of Himalayan landscape and some of these species are major prey items for endangered leopard which is distributed widely throughout much of the area. Therefore the conservation of these is of paramount importance. The Kumaon Himalaya, particularly the middle-altitude oak forests and higher altitude coniferous forests, has a very low protected area coverage. Currently only two sanctuaries i.e. Binsar Wildlife Sanctuary and Askot Wildlife Sanctuary covering an area of approximately 700 km^2 (3.4% of total area) exist in Kumaon. There is, therefore, a need to create more protected areas in the Kumaon Himalaya in order to conserve the different ungulate species and their predators. Hussain *et al.* (1997) have suggested creation of two protected areas in Nainital and Almora districts. The protected area in Nainital district will include Kilbury, Binayak and Kunjakharak areas, which have excellent populations of leopard, barking deer, goral and Sambar. These areas still have low human and livestock populations. The protected area recommended in Almora district include Pindari and Sunderdunga reserve forests which apart from serow and Himalayan tahr will conserve the highly endangered musk deer and Himalayan black bear (*Selenarctos thibetanus*).

Apart from declaration of two protected areas, it is also recommended that the managers must evolve the guideline for conservation of patches of oak forest outside the protected areas. These patches are under tremendous lopping, cutting, livestock grazing pressure. The ungulate community is under heavy poaching pressure which needs to be regulated. The lopping of the oak trees to provide fodder to livestock has assumed alarming proportions throughout the Kumaon Himalaya. This threaten the very existence of oak species and hence of all faunal elements inhabiting these forests. Sound eco-development planning should be done to provide alternatives of fuel, fodder and timber to the people staying inside the protected areas in order to reduce the dependency on resources of Protected Areas. The dependency of local people on the resources of protected areas has often given rise to conflict between the local communities and the wildlife managers. The clash between the dependency of local people and the conservation interests of the protected area has been more counterproductive than to achieve conservation of biodiversity through protected area coverage. It has been long recognised that in developing world where the protected areas have high dependency of local people, the conservation of biological diversity is possible if the interests of local communities are taken care of. Also increase in conservation awareness of local people is of fundamental importance for long term conservation of protected area values. However in India the protected area managers have ignored the importance of conservation education and eco-development (a term synonymous with removal of dependency of local communities by providing alternatives) activities until recently. The managers take the eco-development activities as part of routine management of protected areas and these should be with a thorough understanding of nature, magnitude and level of dependency.

STATUS AND CONSERVATION OF UNGULATES IN THE KUMAON HIMALAYA WITH SPECIAL REFERENCE TO ASPECTS OF ECOLOGY OF BARKING DEER (*Muntiacus muntjak*) AND GORAL (*Nemorhaedus goral*)

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

Wildlife Science

BY

ORUS ILYAS

DEPARTMENT OF WILDLIFE SCIENCES
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2001

TO MY PARENTS &

MY SISTER Dr. FRAH

DEPARTMENT OF WILDLIFE SCIENCES
(Formerly Centre of Wildlife & Ornithology)
ALIGARH MUSLIM UNIVERSITY, ALIGARH-202002 [INDIA]

Ref. No. ....   Dated ....

CERTIFICATE

This is to certify that the thesis titled **"Status and conservation of ungulates in the Kumaon Himalaya with special reference to aspects of ecology of barking deer (*Muntiacus muntjak*) and goral (*Nemorhaedus goral*)"** submitted for the award of Ph.D. degree in Wildlife Science, of Aligarh Muslim University, Aligarh is the original work of **Ms. Orus Ilyas**. The candidate has carried out this work under my supervision.

Jamal A. Khan

Jamal A. Khan, Ph. D.
Senior Lecturer

15th December, 2001

Tel. — Office : 0571-701052,   Telefax : 0571-701205,   Email : cwo@del6.vsnl.net.in

CONTENTS

ACKNOWLEGEMENTS

I take this opportunity to express my heartfelt thanks to the multitude of persons who indirectly or directly helped me on each step towards the completion of this thesis.

First and foremost, I must acknowledge the efforts of the visionary founder Chairman of the Department of Wildlife Sciences (DWS), Prof. A.H. Musavi for providing a positive platform to my passion for wildlife.

I am thankful to Dr. Asad R. Rahmani, now Director, Bombay Natural History Society and Prof. H. S. A. Yahya, currently on leave for academic pursuit in USA, for providing technical support and excellent research facilities to me at the DWS.

Thanks are due to Mr. Ashok Singh, former CCF of UP, Dr. R. L. Singh, current CCF, UP, the DFO's of Almora, Pithoragarh, Nainital and the staff of the Forest Department for granting me the permission, legal and administrative support in conducting field work in the Kumaon Himalaya.

Mr. Samar Singh, former Secretary General, WWF India. Wildlife Society of India, and the UGC provided me the necessary financial assistance during the study period. The financial assistance on time was the backbone of my research work and had it not been for them, this work would have been just a dream.

I wish to place on record my sincere thanks to Dr. Jamal A. Khan-my teacher and supervisor for his esteemed guidance and support throughout the work.

I thank Mr. Afifullah Khan, Lecturer, DWS and my co-supervisor for his help in field and for providing facilities in the DWS. Thanks are also due to Dr. Satish Kumar for his suggestions during the data analysis.

Dr. Salim Javed, Ornithologist, ERWDA, UAE deserves special words of thanks for his help in data analysis and bearing with me patiently in the capacity of a teacher and a friend during his term as lecturer at DWS.

Prof C. Barrette provided all his literature on barking deer to me. I am extremely grateful to him for his help. I wish to place on record my deep sense of gratitude and sincere thanks to Mr. Avenash Datta, former director, WWF-India, for his support, help and guidance throughout my work in Kumaon. Thanks are due to Mr. Parikshit Gautam for providing valuable support during the Binsar work.

Thanks to all the residents of Binsar Wildlife Sanctuary and specially to Ms. Mukti Datta and her parents, Mr. Vivek Datta and Mrs Merry Datta for their much needed help and hospitality. I am thankful to my landlord Mr. And Mrs Pradeep Lal Shah, my neighbours Anjali, Nyima, Marten, Mr. Gopal Bisht, Manager, Tourist Reception Centre and locals such as Pitamber Pandit, Radha, Deewan da and his family, Pankaj and forest guard Ganga Singh. Special thank goes to Mr. Rajan, Postman of the Binsar for being always ready for all possible help.

Ambu, Anand and Poonam have been very loyal and efficient while assisting me in field. I wish Poonam was alive today to see the fruits of her contribution in this thesis. May her soul rest in peace.

Thanks are due to my friends and colleagues Dr. Ashfaq Ahmad, Corbett Foundation, Ramnagar, Shah and Aisha for help in field. Thanks are also due Junaid, Shahid, Khurshid, Sangeeta, Neelam, Asghar, Zakir, Reyaz and Tanveer at DWS, and Damyanti, Hina, Sabiha and Tarannum at my hostel in AMU for providing congenial environment and support during the data analysis and thesis writing.

Special thanks are due to my friends Faiza Abbasi and Tahmina Shafiq for their immense help in preparation of this thesis and also for their moral support during the time of depression. I thank Mr. Parwez, my friend for encouragement throughout the preparation of this thesis.

I am grateful to the staff of the DWS particularly Mrs. Nasreen Husain, Librarian, Mr. Moonis, Mrs. Anjum and Mr. Masroor for their help. Mr. Ram Gopal, Umar, Chotey Khan, Tanveer, Ghaffar and Jaseem have provided worthy help during the preparation of this thesis.

I acknowledge the valuable suggestion of Mr. D.C. Kala, while conducting the field work. I collected essential information about the Kumaon region by consulting the library of G. B. Pant Institute of Himalayan Research and Development, Kosi, Almora. I am extremely thankful to Dr. Palni, Director, GBPIE&D for his kind permission to use the library and laboratory. The lab work would have been difficult without the help and guidance of Dr. Shubhrat Sharma and Dr. Nadeem of the Institute. Special thanks are due to Dr. S. S. Samant for his help in plant identification.

Thank are also due to Mr. S. K. Mukherjee, Director Wildlife Institute of India for giving me the permission to consult the library. Thanks are also due to Mr. Rana, Librarian, WII for his help. I am also thankful to Dr. G. S. Rawat for enhancing my knowledge about the plants of Kumaon.

Back at AMU too, I am thankful to Prof. Samiullah, Chairman, Department of Botany who graciously provided his kind permission and help for carrying out the lab work at his laboratory in the department. I extend my sincere thanks to Dr. Masroor for helping me in the laboratory work in physiology lab of the Botany department. Dr. Hayat, Mr. Zaki and the other researchers in Botany Department were very co-operative during the lab work and they all deserve an honest word of gratitude. I take this opportunity to thank Dr. Athar A. Khan, Lecturer, Department of Botany. I thank the librarian of the Botany Department for providing me all possible support. Thank is also due to Dr. Yasmeen, RA of the Botany Department.

My sincere thanks go to Prof. Yaseen Ansari, former Dean and Principal of the Engineering college, AMU, Aligarh for his encouragement and moral boost up.

My sincere thanks to Prof. S. P. Gupta, Chairman, Department of History for giving me permission to consult the library. I also extend my sincere thanks to Dr. Farhat Hasan, Reader, Department of History for providing me literature on the history and back ground of the Kumaon Himalaya.

All said and done I arrive at a certain stage of acknowledging efforts which wells up my eyes because no combination of any of the 26 letters can justify what my parents have put in to bring me up to the threshold of a Doctoral degree. A small bunch of people whom we lovingly called family has also been with me through thick and thin. I am fortunate to have unconditional support and encouragement from my sisters Dr. Frah, Dr. Hamrah, Ms. Mobushshera and Ms Iram; my brothers in law Prof. Ashhar and Mr. Zia Siddiqui and my niece and nephews Abdullah, Nida, Asma, Ibtisam, Arsalan. I know completion of this thesis will bring a glitter of pride in their eyes and make my father smile at me from his abode in heaven.

List of Tables **Page No.**

List of Figures **Page No.**

CHAPTER 1

INTRODUCTION

1.1 RATIONALE

India, being one of the 12 "Megadiversity" nation of the world, is home to approximately 45000 plant species including 15000 flowering plants, 5000 species of algae, 1600 species of lichen, 20000 species of fungi, 2700 species of bryophytes and 600 species of pteridophytes. It also has about 75000 species of animals including 50000 species of insects, 4000 species of mollusc, 2000 species of fish, 140 species of amphibians, 420 species of reptiles, 1200 species of birds and 410 species of mammals (Anonymus 1994). The great diversity of life forms, evolved as a consequence of tremendous variation in climatic conditions and topography, is distributed in a variety of habitat types ranging from tropical thorn forest in west to mangroves and rainforest in east and north east; temperate forest and alpine grasslands in Himalaya in north to moist and dry tropical forests in southern India. Ruthless exploitation of forest for revenue generation, large scale clearance of forest for agriculture and human settlements, industrial development accompanied with rampant poaching and hunting in past have taken a heavy toll of India's forest cover and its wildlife wealth.

The destruction of natural forest has led to severe reduction, fragmentation and degradation of forest cover. As a consequence, a large number of plant and animal species, communities and unique vegetation/habitat types have been subjected to drastic decline in abundance, distribution and coverage. This loss is reflected in a number of faunal and floral species being regarded as either extinct or near extinct, highly endangered, threatened and vulnerable. The problem of tiger conservation in India explains as well as symbolises the crisis which the country is facing in general conservation of its biodiversity wealth as a consequence of past destruction of natural resources. Numbering around 40000 at the turn of last century, its entire population is currently estimated to be between 3000 to 4000. The habitat of tiger has drastically shrunk and is highly fragmented with individual populations averaging around 30 to 50. Even these individual populations are under tremendous poaching and biotic pressures. Like tigers, many other majestic large herbivores (elephant, rhino, wild buffalo etc.) have followed the same trail of decline in abundance and reduced distribution with very limited options for management and conservation.

The process of destruction of natural resources, although widespread, has not been uniform spatially across different bio-geographic zones of India and within each zone. The Himalaya, which covers 6.4% of area in India, constitute a significant unit for conservation of biodiversity. It harbours a great diversity of faunal and floral species distributed in a variety of topography types and climatic conditions. The Himalaya is divisible in four provinces namely north-west Himalaya, west Himalaya, central Himalaya and east Himalaya (Rodgers *et al.* 2000). The destruction of forest resources in Himalaya has been alarmingly high during last three centuries as compared to other bio-geographic zones. Before India's independence, British as well as local kings exploited forest resources indiscriminately for revenue generation. Within Himalaya also, the destruction of forest has been more in west Himalaya as compared to other three bio-geographical provinces. The negative consequences of forest destruction in west Himalaya are well known. These included frequent flooding in plains, excessive siltation of rivers and dams in plains due to increased soil erosion in water catchment areas, severe hardships to local people who depended on forest resources a great deal for their daily sustenance and general loss and impoverishment of biodiversity. The hardships to local village communities have been so severe that these have given rise to very powerful people's movements (e.g. Chipko movement in Garhwal division) against continued exploitation of already depleted forest resources.

The Kumaon division in west Himalaya, which covers an area of 21032 km^2, has also not escaped the trail of destruction. Once extensively covered with moist temperate oak forest with abundant wildlife, the landscape in Kumaon today is dominated by either the chir-pine forest or terrace fields, human settlements, barren lands and fragmented oak forest. The British cleared large areas of oak and deodar forests for revenue generation. Cleared areas were planted with chir-pine (*Pinus roxburghii*) which is fire resistant and ruderal in nature. Simultaneously the local people cleared forest for agriculture and also exploited the remaining forested areas for their timber, fuelwood, fodder, grazing and food requirements. This led to large scale fragmentation and degradation of oak and deodar forests resulting in endangered status of middle-altitude oak forest (Singh and Singh 1986). The wildlife populations also declined in abundance. Rampant poaching and illegal hunting also added to negative impact of habitat loss and degradation on the abundance of wildlife. Although no precise estimates are available as to how abundant the general wildlife was, the descriptions provided by hunter turned naturalist-the legendary Jim Corbett (1989) indicate widespread distribution and high abundance of large predators such as tiger (*Panthera tigris*), leopard (*Panthera pardus*), Himalayan black bear (*Selenarctos thibetanus*) and their respective prey species such as goral (*Nemorhaedus goral)*, barking deer (*Muntiacus muntjak)*, sambar (*Cervus unicolor*) and serow (*Capricornis sumatraensis)*. The tiger has already become locally extinct from much of the lower and middle ranges in Kumaon and leopard and black bear survive in relict and fragmented population with extremely low abundance. The prey species also survive in fragmented landscape and are under tremendous poaching pressure from local people.

The fragmentation of habitat and its subsequent degradation is known to have negative consequences for animal populations inhabiting them. One immediate direct impact is the fragmentation of larger animal and plant populations (Gilpin and Soule 1986). Once divided into smaller units the animal and plant populations face greater risk of local extinction either due to deterministic events (catastrophes, fires, heavy snow etc.) or due to stochastic events (e.g. random variation in birth or death rate of a population). Smaller populations also have the risk of heavy inbreeding in the long run if these populations are completely isolated and become smaller and smaller due to their continued poaching. Inbreeding leads to loss of genetic variability of a population and have less viability of survival due to loss of general fitness, reduced decease resistance and greater demographic stochasticity. Thus wildlife populations in fragmented environment pose serious challenge for managers in terms of their management for long term conservation. Such populations require continuous monitoring and heavy research input on various aspects of their ecology. Going by the magnitude of destruction of oak forest in Kumaon which led to large scale fragmentation of animal and plant populations, the task of wildlife conservation is enormous. Majority of oak forested areas are small with high levels of isolations. These patches harbour relatively small wildlife populations and patches are under heavy biotic pressures from the local people. Conservation of wildlife resources in Kumaon may thus require some prioritisation of areas in terms of their overall viability and their value in terms of the biodiversity these contain.

Although India has made significant progress in conserving its biodiversity values through establishment of protected areas, lack of conservation planning has resulted in uneven distribution of protected areas in different bio-geographic zones and within different provinces. There are currently 566 protected areas in India spread over an area of 153000 km^2 or 4.66% of country's geographical area (Rodgers *et al.* 2000). As already stated not only the distribution of protected areas is uneven, many of the established protected areas may have very little viability in the long term due to high dependence of local people and also for not protecting the entire range of biodiversity of a region. This is precisely the case with protected areas in Kumaon Himalaya. Currently there are two wildlife sanctuaries in Kumaon Himalaya. These are Binsar Wildlife Sanctuary and Askot Wildlife Sanctuary covering approximately 45 and 600 km^2 of areas respectively. Both sanctuaries have very high level of human dependencies with little documentation of biodiversity values.

In order to conserve biodiversity of a region through establishment of protected areas, it is essential that the current status and spatial distribution of elements of biodiversity is known which should be taken into consideration for conservation planning. Also threats to elements be known so that mitigation measures may be taken prior and after the establishment of protected areas. A review of available information on plant and animal communities in oak forest of Kumaon showed lack of information on animal communities (e.g. avian, mammalian etc.) as well as spatial distribution of extant oak patches and threats faced by these. Therefore prior to any conservation planning it was essential that studies be conducted to map the extant oak patches and data on status of elements of biodiversity are collected.

Large mammals by virtue of their larger body size and home ranges are, relatively speaking, more prone to decline as a consequences of fragmentation and degradation of their habitat as compared to other smaller animals such as birds or insects. They are also hunted for a variety of reasons. Therefore their abundance in a patch may be used as an indicator of general wellbeing of entire range of biodiversity. Ungulates species, which sustain large predators as well as play vital role in vegetation dynamics were thus selected for the present investigation. Though the majestic tiger has vanished from much of Kumaon, the extant oak patches still harbour populations of leopard and black bear, which are partly being sustained by the ungulate community. The ungulate community which is comprised of barking deer, sambar, goral on lower and middle altitudes and Himalayan tahr, serow and musk deer on higher altitudes are some of the least studied species of Indian region and therefore the present investigation was not only needed for conservation planning but also to fill the gaps in our understanding on aspects of ecology of these species.

1.2 OBJECTIVES

The following were the objectives of this study:

1. To investigate the status, distribution and abundance of ungulates in extent oak forest patches of Kumaon Himalaya.
2. To investigate the seasonal abundance and habitat utilisation pattern of goral and barking deer in oak/pine ecosystems.
3. To investigate the feeding ecology of goral and barking deer in oak/pine forest ecosystems.
4. To quantify the threats to conservation of ungulates in oak forest ecosystem in the Kumaon Himalaya.
5. To prepare a conservation strategy for the ungulate community in Kumaon Himalaya.

1.3 DURATION OF THESIS

The field work for this study was started in January 1996 in the Binsar Wildlife Sanctuary and continued till December 1998. The general survey for assessment of status of ungulates was carried out in pre-monsoon 1997. A total of 36 months were spent in data collection in field. A total of 36 months were spent in data summarisation, analysis and thesis writing.

1.4 ORGANISATION OF THESIS

There are a total of eight chapters in this thesis. The chapters 3, 4, 5, 6, 7 and 8 have four section each: introduction, methodology, results and discussion. The detail of each chapter is as follows:

Chapter 1 deals with rationale of undertaking the present investigation.

Chapter 2 provides the details of extensive and intensive study areas.

Chapter 3 deals with vegetation studies carried out in whole of Kumaon Himalaya. Attempts have been made to develop understanding of general gradients in vegetation of Kumaon which has relevance to understanding distribution pattern of ungulate species in Kumaon.

Chapter 4 provides data on status, abundance and factors governing distribution of all major ungulate species found in Kumaon Himalaya.

Chapter 5 deals with the seasonal abundance and population structure of barking deer and goral in Binsar Wildlife Sanctuary.

Chapter 6 provides analysis of seasonal habitat utilisation pattern of barking deer and goral in Binsar Wildlife Sanctuary.

Chapter 7 deals with feeding ecology of barking deer and goral. Data were also collected on the nutritional status of ground cover vegetation in two different habitat in different seasons.

Chapter 8 deals with the assessment of threats in Kumaon Himalaya with special reference to Binsar Wildlife sanctuary. Data were collected on fire, fuel wood, fodder and extraction of timber and non timber forest products.

Chapter 9 deals with strategy for conservation of ungulate communities in Kumaon landscape.

1. 5 LITERATURE REVIEW

The oak forest ecosystem is very well studied by several workers of the Nainital University, Kumaon University and the G.B. Pant Institute of Himalayan Environment and Development. Duthie (1906) revised the catalogue of plants of Kumaon and Garhwal. Osmaston (1927) published the forest flora of the Kumaon. Many researchers like Sahni (1982), Singh and Singh (1987), Babu (1977), Gupta (1968) and Hajra and Rao (1990) have published accounts of the flora and vegetation of this region. Other workers have carried out studies on different aspects of oak forest ecosystem (Gupta 1968, Saxena and Singh 1982, Tiwari 1982, Singh *et al.* 1984, Singh and Singh 1984, Saxena *et al.* 1985, Singh *et al.* 1987, Pangtey and Samant 1988, Pangtey *et al.* 1988, Rikhari *et al.* 1989, Pangtey *et al.* 1990, Rawal and Pangtey 1991, Samant and Pangtey 1991 a and b, Adhikari *et al.* 1992, Rawal and Pangtey 1994, Dhar *et al.* 1997).

However very little documentation exists about the animal communities especially mammals and birds which constitute significant component of overall biodiversity of Kumaon. Hudson (1930) documented 124 bird species in Nainital and Briggs (1931) documented 83 bird species in Ranikhet forest. Tak (1995) documented 127, 94 and 82 species of birds in Nainital, Almora and Pithoragarh districts in Kumaon. It is recently that Hussain *et al.* (1997), Aisha and Khan (1999), Tehmina *et al.* (1997) and Aisha and Khan (2000) have studied aspects of avian communities at different locations of Kumaon. Orus (1998) and Orus *et al.* (1998) have studied general aspects of biodiversity conservation in Binsar Wildlife Sanctuary and status and distribution of ungulates in Kumaon Himalaya.

CHAPTER 2

STUDY AREA

2.1 EXTENSIVE STUDY AREA

The field surveys were carried out in extant patches of oak forest in entire Kumaon Himalaya (28° E 43' 55" and 30° E 30' 12" N latitude and 78° E 44' 30" and 80° E 45" E longitude) and a total of 19 oak patches were covered (Fig. 2.1 and Table 2.1). A total of five, seven and seven patches were sampled in Nainital, Almorah and Pithoragarh districts respectively.

2.1.1 Details of patches covered

2.1.1.1 Kunjakharak

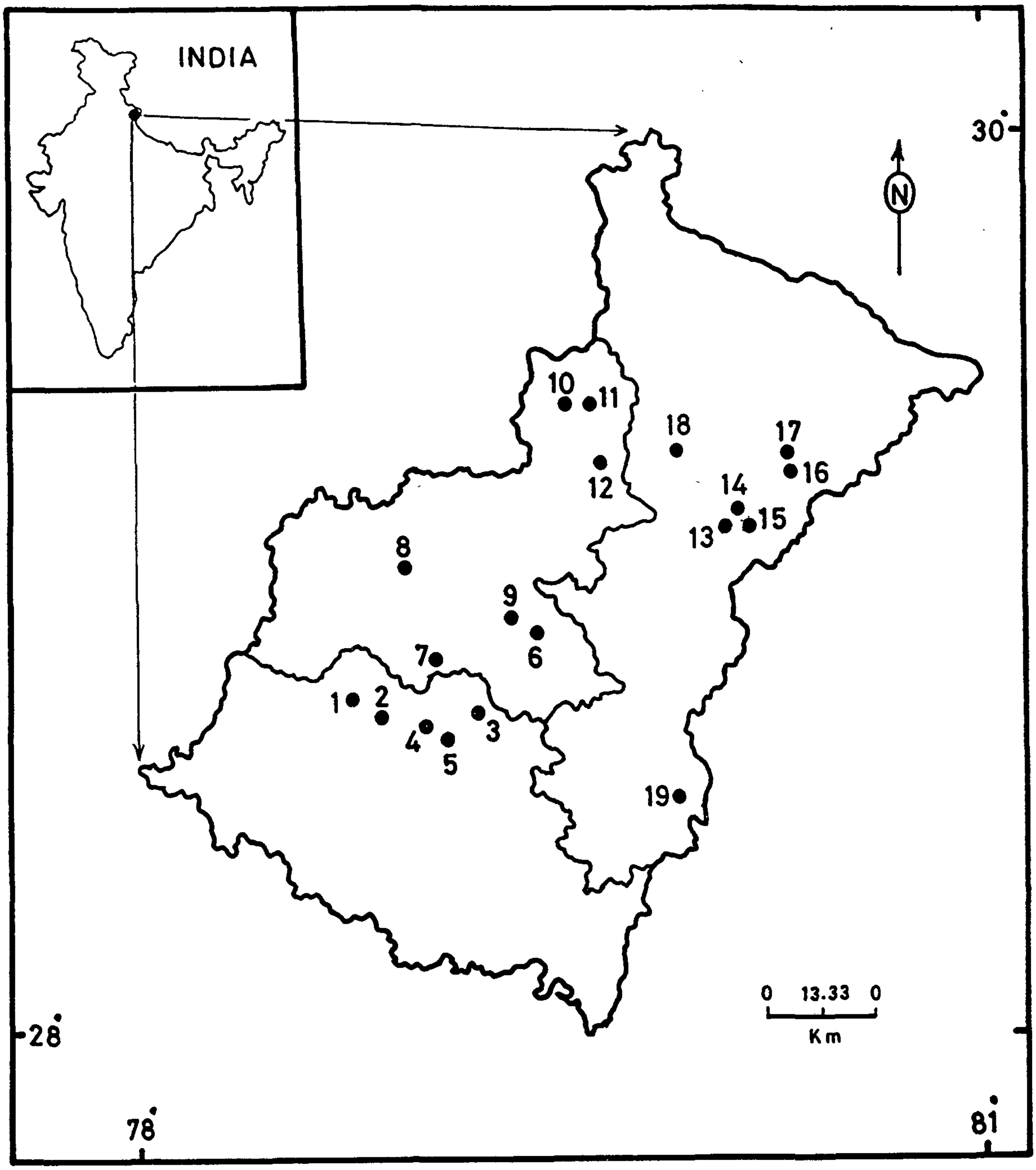
Kunjakharak, covering an area of approximately 14.5 km^2, is located in Nainital district (29°33' 3.75" N latitude and 79° 33' 3.75" E longitude). The altitude varies from 1900 to 2400 m. *Quercus semecarpifolia* and *Quercus floribunda* were main oak species found in this patch. Other tree species present were *Cedrus deodara, Rhododendron barbatum* and *Vibumum mullaha.* The overall tree density was estimated to be 280 individuals/ha.

2.1.1.2 Binayak

This oak patch has 15.3 km^2 of area and is located adjacent to Kunjakharak in Nainital district (29° 27' 45.4" N latitude and 79° 24' 31.8" E longitude). The altitude varies from 1900 to 2500 m. The forest is mixed with many coniferous tree species such as *Taxus baccata, Abies pindrow* and *Cedrus deodara*. The tree density was estimated to be 452 individuals/ha and main oak species found were *Quercus leucotrichophora* and *Quercus floribunda.*

Figure 2.1 Location of extant oak patches surveyed in Kumaon Himalaya

(for site names, see table 2.1)



2.1.1.3 Mukteshwer

This oak patch is maintained by the Indian Veterinary Research Institute (IVRI) in Nainital district (29° 28' 34.05" N latitude and 79° 38' 28.12" E longitude) and its area is approximately 15.7 km². The altitude varies from 1500 to 2340 m. *Quercus floribunda* was dominant tree species and other associates were *Ilex dipyrena, Quercus leucotrichophora* and *Rhododendron* sp. The tree density was 891 individuals/ha.

2.1.1.4 Gager

The area of Gager is approximately 3.25 km² and is located in Nainital district (29° 26' 11.35" N latitude and 79° 30' 31.9" E longitude). The altitude varies from 1700 to 2300 m. The tree density was 949 individuals/ha. The main tree species found are *Quercus floribunda, Rhododendron arboreum and Viburnum mullaha.*

2.1.1.5 Maheshkhan

This patch covers 22 km^2 and lies at 29° 24'16.2" N latitude and 79° 33' 50.62" N longitude in Nainital district. The altitude varies from 1900 to 2300 m. The tree density was 565 individuals/ha and dominant tree species were *Quercus leucotrichophora, Quercus floribunda, Cedrus deodara and Lyonia ovalifolia.*

2.1.1.6 Jageshwer

This patch lies at 29° 29'3.24" N latitude and 79°33'3.75"E longitude in Almorah district and covers an area of 21 km^2. The altitude ranges from 1900 to 2100 m. The tree density was 842 individuals/ha. Dominant tree species found in this patch were *Quercus leucotrichophora, Litsea umbrosa, Persea duthiei and Swida oblonga.*

2.1.1.7 Sitlakhet

This patch is approximately 11.25 km² in size and it lies at 29° 35' 45.90" N latitude and 79° 33' 3.75" E longitude in Almorah district. The altitude ranges from 1900 to 2100 m. Tree density was 788 individuals/ha and dominant tree species were *Quercus leucotrichophora, Litsea umbrosa, Persea duthiei.*

2.1.1.8 Pandavkholi

This site lies at 29° 35' 19.45" N latitude and 79° 27' E longitude in Almorah district and covers an area of 13.23 km². The altitude varies from 1800 to 2500 m. The tree density is 779/ha and the main tree species include *Quercus floribunda, Ilex dipyrena, Euonymus tingens and Symplocos theifolia*

2.1.1.9 Binsar

The details are provided under the intensive study area.

2.1.1.10 Sunderdunga

This patch lies at 30°13'30.32" N latitude and 79°54' 18.5" E longitude in Almorah district and covers an area of about 25.75 km². The altitude varies from 2500 m to alpine zone. It is covered mainly by mixed conifer forest. Tree density was estimated to be 589 individuals/ha and dominant tree species were *Abies pindrow, Betula utilis and Quercus lanata.*

2.1.1.11 Pindari

It is a famous tracking route to the Pindari glacier in Almorah district and is located at 30° 11' 11.29" N latitude and 79° 59' 31.9" E longitude. The area of Pindari is approximately 21.5 km² and altitude varies from 2400 m to alpine zone. The tree density was 389 individuals/ha. *Taxus baccata, Abies pindrow, Betula utilis, Quercus lanata and Rhododendron barbatum* were dominant tree species.

2.1.1.12 Gasi

This patch has an area of about 49.50 km² in Almorah district and lies at 30°4' 48.38" N latitude and 80° E longitude. The altitude varies from 2300 to 2900 m. Dominant tree species were *Symplocos theifolia, Litsea umbrosa, Persea duthiei and Quercus floribunda*. The tree density was 1006 individuals/ha.

2.1.1.13 Gandhura

Ghandhura lies at 29 51'40" N altitude and 80 14' 16.9"E latitude in Pithoragarh district and covers 54 km^2. The tree density was 892 individuals/ha. The altitude varies from 1500 to 2600 m.

2.1.1.14 Daphiyadhura

The area of this patch is 35 km² and it is located in the Pithoragarh district. The altitude ranges from 1300 to 2440 m. The tree density was 904 individuals/ha and the dominant tree species were *Lyonia ovalifolia, Rhododendron, Quercus lanata, Quercus semecarpifolia and Quercus leucotrichophora.*

2.1.1.15 Majtham

This fragmented oak patch is also a part of the Askot Wildlife Sanctuary in district Pithoragarh and its area is about 25 km². The altitude ranges from 1300 to 2700 m. The tree density was 965 individuals/ha and the dominant tree species recorded were *Quercus lanata, Myrica esculenta, Lyonia ovalifolia* and *Rhododendron arboreum.*

2.1.1.16 Duku

This site lies at 30° 1' 56.25" N latitude and 80° 30' E longitude in district Pithoragarh. The area is approximately 52 km² and elevation ranges from 2100 to 3500 m. The main tree species were *Quercus floribunda, Persea duthiei, Rhododendron arboreum* and the tree density was 837 individuals/ha.

2.1.1.17 Sobla

This oak patch lies between 30° 4'1.62" N latitude and 80°34'15"E longitude in the Pithoragarh district and covers an area of 28 km². The altitude ranges from 1900 to 3500 m. The dominant tree species were *Abies pindrow, Quercus lanata, Pinus wallichiana, Taxus baccata, Betula utilis* and the tree density was 847 individuals/ha.

2.1.1.18 Munsiyari

This oak patch lies at 30° 5' 3.24" N latitude and 80° 14' 41.25" E longitude in the Pithoragarh district and covers an area of 30.5 km². The elevation ranges from 2100 to 2500 m this patch is close to Milam glacier. Main tree species were *Quercus semecarpifolia, Taxus baccata, Rhododendron* and *Betula utilis* and the estimated tree density was 409 individuals/ha.

2.1.1.19 Mechh

This oak patch is in Champawat range in Pithoragarh district and covers an area of 23.25 km². The altitude ranges from 2100-2200 m. The dominant tree species were *Quercus lanata, Rhododendron arboreum, Myrica esculenta, Lyonia ovalifolia* and the tree density was 651 individuals/ha.

2.1.2 Topography

The topography in surveyed patches was hilly with moderate to steep slopes. The slope goes up to 85°. Majority of the areas were inaccessible by Jeep and one had to cover large distances on foot to reach areas such as Pindari, Sunderdunga and Milam.

2.1.3 Climate

There is an altitudinal gradient in climate. The mean annual temperature decreases as the altitude increases. The mean temperature for different altitudes is given in Table 2. 2. Ozenda (1954) showed that there is a general decrease of 0.55°C temperature for every 100 m rise in the elevation and this holds good even at high altitudes. Similarly the annual rainfall increases with altitude and peaks at about 1200 m (4100 mm) and then gradually declines to 670 mm at 2700 m (Saxena *et al.* 1985). The maximum rainfall (73-89% of total) occurs during rainy season (June to September).

2.1.4 Vegetation

The Kumaon Himalaya is divisible into subtropical (300 to 1500 m), temperate (1500 to 3500 m) and alpine (>3500 m) zones (Saxena *et al.* 1985). The vegetation in the Kumaon Himalaya is predominantly forest and mostly belongs to moist temperate type (Champion and Seth 1968). There are five main forest types found in the Kumaon Himalaya. These are *Shorea robusta* forests (found up to 1200 m), pine forests (1200-2400 m), oak forests (1300-3200 m), mixed broadleaf forests (foothills to 3300 m) and *Betula utilis* forest (3200-3500 m). The surveys conducted in this study largely covered oak patch at 18 sites in altitude range of 1200 to 3500 m.

The major tree species found in different sites included *Quercus leucotrichophora, Quercus lanata, Quercus floribunda, Quercus semecarpifolia, Tsuga dumosa Rhododendron arboreum*, in association with *Viburnum spp., Myrica esculenta, Alnus nepalensis, Swida oblonga, Lyonia ovalifolia, Persea duthiei* and *Lindera pulcherrima*. The dominant shrub species were *Myrsine africana, Arundinaria* sp., *Berberis aristata, Rubus ellipticus, Rubus biflorus, Rubus paniculatus* sp., *Daphne sp., Mahonia napaulensis* and *Pyracantha crenulata*. The tree and shrub composition varied between sites and along altitudinal gradient.

2.1.5 History and land use pattern

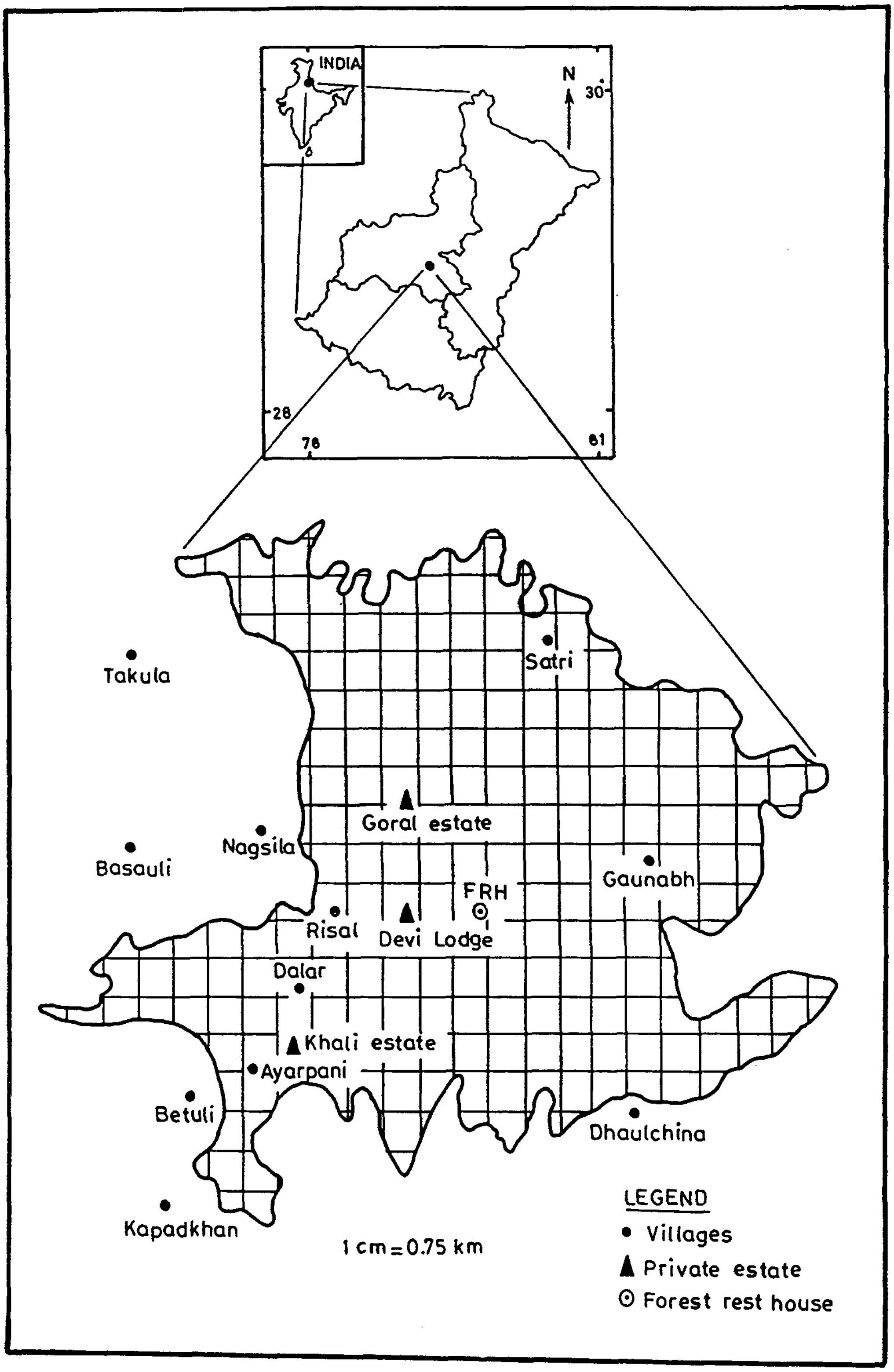
Gorkhas ruled Kumaon before the British acquired the area in 1815. Thus from 1815 to 1947, the area remained under British colonial rule. During the British period this area was declared as "Non-Regulated Area", hence the rules and regulations implemented here were quite different from those of plains (Mittal 1990). Most of the human population of Kumaon originally migrated from the plain of Uttar Pradesh, Maharastra and Gujarat, where for quite a long period forest had not been a significant part of the landscape (Tiwari and Singh 1987).

Economic life of people in Kumaon depended upon land and its cultivation before the British rule. The villages were almost self-sufficient units and most of the needs of the people of the villages were satisfied locally. The occupation of people was generally hereditary. After accession to the British, the region experienced a change in economy from agriculture to agro-based and industry based. Tea, iron and other small products formed the main industry of Kumaon Himalaya during the British colonial rule. Dr. John's Forbs Royle, Superintendent of the Botanical Garden of Saharanpur recommended to government for the introduction of tea plantation in the year 1827. Tea nurseries were first time started in 1836 and later provincial government in 1841 sent Dr. Falconer, the Superintendent of the Botanical Garden at Saharanpur to inspect these tea plantations in Kumaon and choose suitable sites for tea plantation (Atkinson 1882). Two sites Bharatpur near Bhim Tal in Naini Tal and Lachhmesar in Almora district were selected for tea plantation. Owing to encouragement received from officials the area occupied by tea plantation increased to 3342 acres but in later year there was sharp decline in the production of tea in Almora and Nainital districts. It was confined to few acres only. This had happened due to heavy Russian import duty on Indian tea and also the monopoly of the Chinese trade, which was in hand of Tibetan officials. The Kumaon Himalaya once had extensive oak forest. However, under the British rule, significant changes took place in land use pattern. The British encouraged extensive clearance of oak forest for development of agriculture and for developing chir-pine (*Pinus roxburghii*) plantations. The chir-pine trees were planted mainly due to their economic value as source of resin and timber (Guha 1994).

2.2 INTENSIVE STUDY AREA

The Binsar Wildlife Sanctuary (Fig. 2.2) was selected as intensive study area for the present study. The Binsar Wildlife Sanctuary (hereafter Binsar) is located 30 km from Almora town in north east direction and it lies at 29° 42' 3.2"N latitude and 79°45' E longitude. It was declared as a wildlife sanctuary in May 1988. It covers an area of about 45 km^2 which includes about 4 km^2 of core zone. The sanctuary is hilly with steep slopes. The highest elevation is 2440 m whereas elevation of surrounding villages inside the sanctuary barely reaches up to 1500 m in altitude. Four different seasons were recognised in Binsar, which are pre-monsoon season from March till June. Monsoon season from June till September and a post-monsoon season from September till December. The winter starts from December and last till March. Considerable precipitation occurs often as snowfall in association with western disturbances passing eastward across North India. Maximum rainfall is received during July and August. Binsar receives approximately 120 cm of rainfall annually with nearly 75% of the annual rainfall occurring during June to September. Winter precipitation, though only about 15 percent of the annual total is of significant economic importance for the winter crops, and is associated with the passage of the western disturbance. The temperature varies seasonally. Figure 2.3 provides the temperature values recorded during the months of April, May, June, September, October, November and December in 1998. The average maximum temperature recorded was 28 °C in June while the average minimum temperature recorded was 1°C in January. In April, May and June, the average minimum temperature recorded was 8°C, 10°C and 16°C while mean maximum temperature was 22°C, 24°C, 27°C respectively. During September, October, November and December, the average minimum temperature recorded was 13°C, 11°C, 8°C and 5°C while mean

Figure 2.2 Map of the intensive study area



maximum temperature recorded was 22°C, 19°C, 18°C and 17°C respectively (Fig. 2.3). The relative humidity increases rapidly with the onset of the monsoon and is generally above 80 percent during July to September. The driest part of the year is the pre-monsoon period, when the humidity may become as low as 35% during afternoons (Fig. 2.4).

Binsar represents characteristic flora element of moist temperate type of forest described by the Saxena and Singh (1982). The oak forest is mainly in the centre of Binsar and surrounding ranges are mostly covered with the chir-pine forests interspersed with agricultural land. The oak forest on lower altitudes consists of tree species such as *Alnus nepalensis* and *Quercus leucotrichophora* and shrub species such as *Berberis aristata, Rubus ellipticus.* On higher altitudes (around 2400 m), the oak forest comprises of *Quercus floribunda, Quercus leucotrichophora, Quercus glauca, Rhododendron arboreum, Lyonia ovalifolia* with fern species such as *Aetherium spp., Polistichum sp., Pteridium sp.,* and shrub species such as *Myrsine africana, Rubus biflorus, Daphne papyracea* etc. The chir pine forest comprises of *Pinus roxburghii* along with *Viburnum cotinifolium*, among shrub *Pyracantha crenulata*, *Myrsine africana, Desmodium* spp (Appendix-I).

The sanctuary is rich in the faunal diversity. A total of 166 species of bird species including two pheasant species i.e., kaleej (*Lophura leucomelana*) and koklas (*Pucrasia macrolopha*) and 11 species of mammals such as Leopard (*Panthera pardus*), wild pig (*Sus scrofa*), barking deer (*Muntiacus muntjak*), goral (*Nemorhaedus goral*), Indian porcupine (*Hystrix indica*). Himalayan Yellow throated marten (*Martes flavigula*) have been documented. During October 1998 a pair of Himalayan black bear (*Selenarctos thibetanus*) was also recorded.

Table 2.1 Details of areas surveyed during pre-monsoon of 1997 in the Kumaon Himalaya.

Site name	Site code	District	Approximate size (km^2)	Number of plots
Kunjakharak	1	Nainital	12	20
Binayak	2	Nainital	20	30
Mukteshwar	3	Nainital	25	31
Gagar	4	Nainital	10	30
Maheshkhan	5	Nainital	12	30
Jageshwar	6	Almora	25	35
Sitlakhet	7	Almora	10	15
Pandavkholi	8	Almora	15	40
Binsar	9	Almora	45	60
Sunderdunga	10	Almora	>100	35
Pindari	11	Almora	>100	35
Gasi	12	Almora	>100	40
Gandhura	13	Pithoragarh	50	30
Daphiadhura	14	Pithoragarh	35	50
Majtham	15	Pithoragarh	25	20
Duku	16	Pithoragarh	65	40
Sobla	17	Pithoragarh	30	40
Munsiyari	18	Pithoragarh	>100	25
Mechh	19	Pithoragarh	50	20

Table 2.2 Mean annual temperature and annual rainfall at different altitudes. Source: Saxena *et al.* (1985).

Altitude (m)	Temperature (°C)	Rainfall (mm)
240	-	1070
300	22.5	1500
600	20.8	3120
900	19.2	3970
1200	18.8	4100
1500	16.2	3720
1800	14.6	3050
2100	13.1	2200
2400	11.4	1300
2700	9.8	670
3000	8.3	-
3300	6.9	-
3600	5.3	-
3900	3.8	-
4200	2.2	-
4500	0.7	-

Figure 2.3 Mean monthly minimum and maximum temperature in Binsar Wildlife Sanctuary during 1998

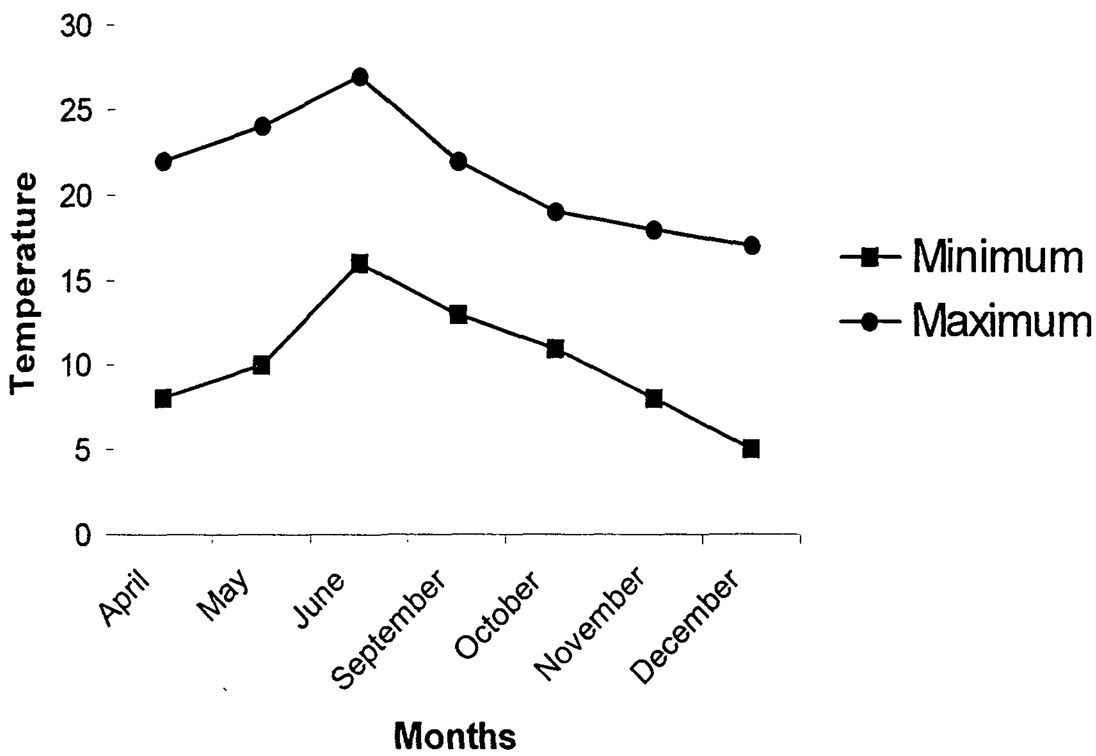
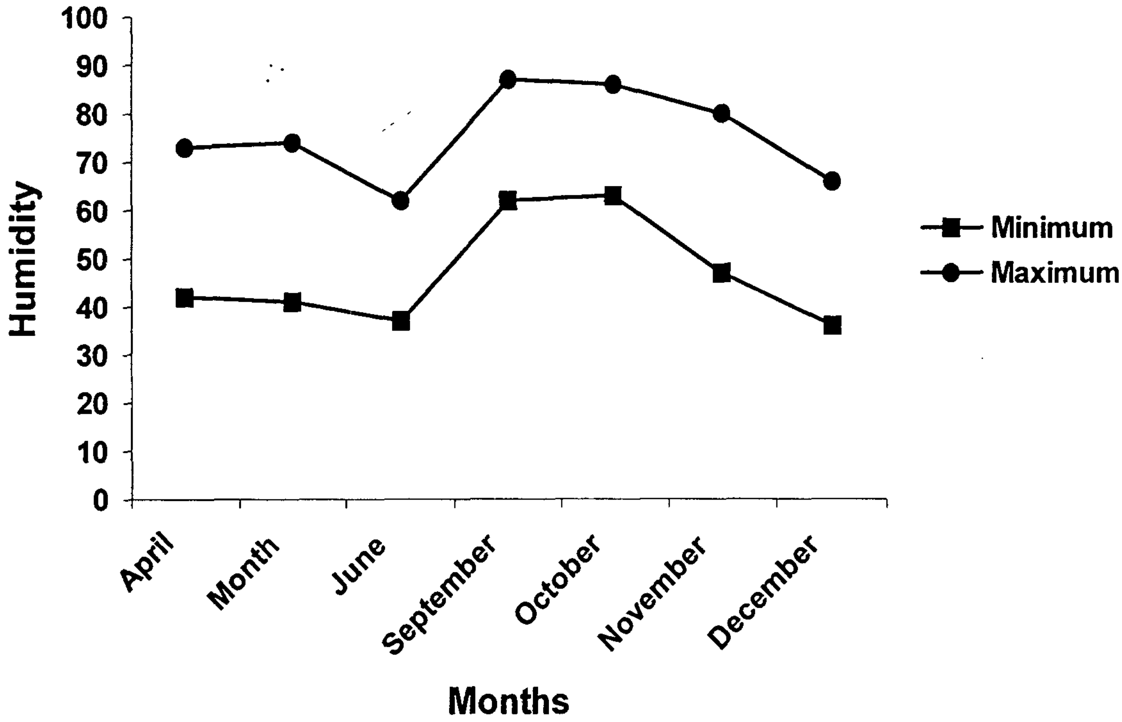


Figure 2.4 Mean monthly minimum and maximum percent humidity in Binsar Wildlife Sanctuary during 1998



CHAPTER 3

VEGETATION STUDIES

3.1 INTRODUCTION

The oak forest ecosystem in Kumaon Himalaya has been studied in detail in past by plant ecologists (e.g. Osmaston 1926, Gupta and Singh 1962, Ralhan *et al.,* 1982, Saxena and Singh 1982, Saxena *et al.* 1985, Upreti *et. al.* 1985, Singh and Singh 1986, Rawat and Pangtey 1994, Tewari and Singh 1985, Rawal and Singh 1988). These studies have contributed immensely to our understanding of different aspects of forest ecosystem such as general species composition and population structure, regeneration patterns of different species, altitudinal variation in species composition and patterns of diversity, phenology of tree and shrub layers, environmental gradients governing distribution of trees and shrubs and nutrient dynamics. These studies, though intensive, have largely been conducted at specific sites in smaller forest stands and therefore many findings may have limited application in exploring relationships between different attributes of vegetation at landscape level.

Developing general understanding of vegetation and also of patterns if any in different vegetation attributes at landscape level is of fundamental importance not only from the point of view of plant ecology but also from the perspective of gaining understanding of patterns in relationships between plant and animal communities. The plant communities as well as their different attributes generally have greater influence of abiotic factors in governing their spatial distribution. For example Saxena *et al.* (1985), who studied the altitudinal variation in vegetation of Kumaon, found that altitude played an important role in governing not only the composition of communities but also the morphology and diversity. Herbivores which depend to a large extent on vegetation for their various requirements may also respond to such environmental gradients simultaneously and hence common environmental gradients may be found governing distribution of plants and animals. Hussain *et al.* (2000) studied factors governing the distribution of pheasant species in the Kumaon Himalaya and found that several attributes of vegetation co-varied with altitude. The abundance and distribution of pheasants was also found to be principally governed by the gradient of altitude. It is therefore desirable that ecological studies which attempts to explore the factors governing abundance and distribution of different animal species at micro or macro level should also take into consideration underlying factors governing the plant communities and their different attributes.

The field surveys, conducted at 19 oak patches to assess the current status of ungulates, provided opportunity to gather extensive data on vegetation which could be used to develop understanding of variation in general vegetation across different sites. It was presumed that such an understanding would be helpful in exploring pattern of distribution of ungulate communities at landscape level. This chapter presents the results of vegetation analysis. The data presented in this chapter are unique in the sense that such extensive vegetation sampling at 19 sites spread over an area of 21032 km^2 has been attempted for the first time in Kumaon and very occasionally in India.

3.2 METHODOLOGY

3.2.1 Data collection

Intensive vegetation studies were carried out at different surveyed sites in Kumaon Himalaya during pre-monsoon 1997. Binsar Wildlife Sanctuary was covered during post-monsoon 1997. A total of 634 sampling plots were established at 19 sites. The plots were established systematically at 100 m interval along forest trails. In order to avoid sampling the relatively disturbed vegetation along trails, plots were located at least 10 m either side of trail.

Tree species and their individuals were counted in 10 m radius circular plot for density, diversity and species richness estimation. Tree cover was measured using grided mirror of 25 x 25 cm in four directions around the circular plot. The mirror was kept horizontally at 1.25 m above the ground level and grids which were covered more than 50% by foliage were counted and expressed as percent tree cover. All shrub species and their individuals were counted in 3 m radius circular plot. Shrub height was measured using a measuring tape. Shrub cover was measured by ocular estimation in 5 equal shrub cover categories of 0-20%, 21-40%, 41-60%, 61-80% and 81-100%. Regenerating tree species and their individuals were also counted in 3 m radius circular plot at each sampling point

The ground cover composition was quantified by laying four quadrates of 0.50 m x 0.50 m dimension at four locations within 10 m circular plot. All grass and herb species and their individuals were counted within each plot. The ground cover was estimated by point intercept method (Canfield 1941). A meter tape was laid on the ground in four directions and intercepting materials (herbs, grass, litter, bare-ground, weathered stone) was recorded at each 5 cm interval. Data on various disturbance attributes were collected at each sampling plot. Number of cut and lopped trees and number of cattle dung piles were counted within 10 m radius circular plot. The presence/absence of fire around sampling point was also recorded.

3.2.2 Data analysis

Density of trees, shrubs, regenerating trees, herbs, grasses and of individual species was calculated for each sampling plot using the following formula:

$$D = \frac{\text{No. of individuals}}{\text{Area}}$$

Density values for each layer as well as individual species for each plot were added together to calculate mean densities and standard deviation for different sites. Species diversity and richness of trees, shrubs, herbs and grasses for each plot were calculated by using Shanon–Weiner Index (*H'*) species diversity and Margelefs index (*RI*) for species richness using the following formula:

$H' = -\Sigma$ pi x log pi and RI = S-1/ ln N

where pi is the proportion of i^{th} species in sample, S is the number of species in sample and N is the number of total individuals. These values were used for calculation of mean diversity and richness for different sites.

Ordination of habitat variables, sites and tree species was performed using Principal Component Analysis (PCA). For ordination all the sampling plots of 19 sites were pooled together and considered as one sample. The data pertaining to habitat variables and vegetation attributes were organised in sample-variable and sample-species abundance matrix. These matrix were subjected to Natural log and Arcsine transformation to improve normalcy in the data. The transformed data were than standardised by calculating the mean and standard deviation of each column of the data matrix following Zar (1984):

$$S = \frac{a - \text{mean}}{\text{Standard deviation}}$$

Where a is the transformed value of each cell of the matrix.

The main objective of performing PCA was to identify general gradients in vegetation of Kumaon and to ordinate the sites and tree species. The first PCA was performed on the data matrix of 32 habitat variables in order to extract few un-correlated components.

Q-mode analysis was performed for ordination of sites. Data were transposed in such a manner that the sites (SU's) were at the variable space and the entire habitat variables were at the site space. All the sites were arranged in two-dimensional space. Gradients (habitat variables) were already identified by *R* mode analysis. Arrangement of sites was explained according to the first two components, which explained the maximum variation in the data set.

A total of 62 tree species were recorded during vegetation sampling. Density (number of individuals/ha) for each tree species was calculated for all 19 surveyed sites. PCA was performed on tree species data matrix for ordination of the tree species in tree density space. Arrangements of tree species along first two components were interpreted. All factor analysis were performed using computer program SPSS (Norusis 1990).

Cluster analysis was used to classify sites according to tree species composition to investigate the tree species associations. Simple linkage cluster analysis was performed on the presence/absence data of tree species at each site for the association between the sites as well as the tree species. Cluster analysis was also performed using computer program SPSS.

11 oak and its associate tree species were selected to find out the influence of altitude on tree species distribution in Kumaon. The sites were classified into 5 different altitude categories on the basis of their mean altitude values. The first category (1800 m to 2000 m) included five sites, which were Maheshkhan (1996 m), Sitlakhet (1901 m), Mechh (1839 m), Majtham (1984 m) and Gandhura (1906 m). The second category (2000 m to 2200 m) included three sites, which were Mukteshwer (2164 m), Gager (2049 m) and Jageshwer (2119 m). Third category (2200 m to 2400 m) included following seven sites: Kunjakharak (2293 m), Binayak (2213 m), Gasi (2228 m), Duku (2247 m), Sobla (2201 m), Daphiyadhura (2303 m) and Binsar (2236.67 m). Fourth category (2400 m-2600 m) included only Pandavkholi (2520 m). The last category of 2600 m to 2800 m included Sunderdunga (2666 m), Munsiyari (2731 m) and Pindari (2719 m) areas. The density of 11 tree species was calculated according to these altitude zones. Tree species which were selected for calculation of densities in different altitudinal categories were: *Quercus leucotrichophora, Quercus floribunda, Quercus semecarpifolia, Quercus lanata, Quercus lamellosa, Quercus glauca, Rhododendron arboreum, Pinus roxburghii, Myrica esculenta, Lyonia*

ovalifolia and *Aesculus indica.* The plant nomenclature follows Polunin and Stainton (1984).

3.3 RESULTS

3.3.1 Density, diversity and richness of tree and shrub species

Table 3.1 presents the values of mean tree density, diversity and species richness for each site. The tree density (number of individuals/ha±SD) was maximum in Duku (1063.5±951.9) followed by Gasi (984.89±299.93) and it was minimum at Kunjakharak (265.92±149.4). Tree species diversity was maximum in Binsar (1.52±0.34) and it was minimum at Kunjakharak (0.59±0.49). Tree species richness was maximum at Gasi (1.46±0.37) and lowest at Mukteshwer (0.63±0.51). The tree diversity and richness was found to be negatively correlated with altitude ($P<0.05$).

Shrub density was found to be maximum at Mukteshwer (27280±12355) followed by Gager (26390±12310), while it was lowest at Munsiyari (6803±4760, Table 3.2). Shrub diversity was maximum at Mukteshwer (1.50±0.44) and minimum at Kunjakharak (0.63±0.41). Shrub richness was maximum at Pandavkholi (1.32± 0.39) and minimum at Kunjakharak (0.61±0.38). The shrub diversity and richness was also negatively correlated with altitude ($P<0.05$).

3.3.2 Density, diversity and richness of herb and grass species

Herb density (number of individuals/m²±SD) was maximum at Pindari (39.13±21.53), followed by Sobla (35.48±33.92) while it was minimum at Kunjakharak (4.25±3.14). Herb species diversity was maximum at Sunderdunga (1.23±0.29) and lowest at Kunjakharak (0.35±0.41). Herb species richness was also highest for Sunderdunga (1.2±0.38) and minimum for Kunjakharak (Table 3.3). The herb diversity and richness was positively correlated with altitude ($P<0.05$).

Table 3.4 provides the values of grass density, diversity and richness. The grass density was maximum at Kunjakharak (33.55±17.7) followed by Binayak (28.0±14.02) and it was minimum at Gasi (2.33±4.25). Grass diversity was maximum at Maheshkhan (0.79± 0.45) and minimum at Sobla (0.01 ±0.23). Grass species richness was maximum at Pandavkholi (0.71±0.45) and minimum at Sobla (0.01±0.20). The grass diversity and richness was negatively correlated with altitude ($P<0.05$).

3.3.3 Tree species composition

A total of 68 tree species were identified at all the surveyed sites of Kumaon Himalaya. Tables 3.6, 3.7 and 3.8 provide the density values of individual tree species at different sites in Nainital, Almora and Pithoragarh districts. A total of 28 tree species were identified in different patches of Nainital district. Maximum number of tree species were recorded at Gager (n=19) and lowest at Kunjakharak (n=10). *Quercus leucotrichophora* and *Quercus floribunda* along with *Rhododendron arboreum* and *Lyonia ovalifolia* occurred in all the patches, while other species were patchily distributed. The density of individual species varied between sites in Nainital district. The density for *Quercus leucotrichophora* was highest in Gager whereas density of *Quercus semecarpifolia* was highest in Kunjakharak. The density of *Quercus floribunda* was highest in Mukteshwer. Among the co-associates of *Quercus, Rhododendron arboreum* and *Viburnum* *cotinifolium* had their highest densities in Gager whereas density of *Myrica esculenta* was highest in Maheshkhan.

A total of 47 tree species were identified in different oak patches of Almora district. Maximum number of tree species was recorded from Binsar (n=26) followed by Gasi (n=19) and Jageshwer (n=18). *Rhododendron arboreum* and *Ilex dipyrena* were found to be common at all sites of Almora, while *Quercus glauca, Stranvaesia nussia, Albizia lebbek* were present only at Binsar. *Abies pindrow* was recorded in Pindari, while *Betula utilis* was recorded from Sunderdunga and Pindari. *Quercus leucotrichophora* was found to have maximum density (369 individuals/ha) at Sitlakhet. The density of *Quercus floribunda* was found to be maximum in Pandavkholi. The *Quercus semecarpifolia* was recorded only in Gasi where its density was 15.9 individuals/ha. The *Quercus glauca* was recorded in Binsar only where its density was very low. Among the co-associate species, *Rhododendron arboreum, Viburnum cotinifolium* and *Myrica esculenta* had their highest densities at Jageshwer, Pindari and Binsar respectively.

A total of 44 tree species were identified in oak patches of Pithoragarh district. Maximum numbers of tree species were found in Daphiyadhura (23) followed by Munsiyari (20) and Duku (17). *Rhododendron arboreum* and *Lyonia ovalifolia* were found to be common in all the patches. *Quercus leucotrichophora* was recorded from all the patches except in Munsiyari. *Quercus leucotrichophora, Quercus lanata, Quercus lamellosa* and *Quercus floribunda* were recorded from Majtham. The density (individuals/ha) was found to be maximum for *Persea duthiei* (508) at Sobla followed by *Lyonia ovalifolia* (256) at Majtham, and *Quercus lanata* (255) at Gandhura.

The overall abundance (density values of 19 sites combined) was highest for *Rhododendron arboreum* (105.9 individuals/ha) followed by *Quercus leucotrichophora* (84.4 individuals/ha), *Quercus floribunda* (81.5 individuals/ha), *Lyonia ovalifolia* (73.9 individuals/ha) and *Persea duthiei* (58.6 individuals/ha)

3.3.4 Altitudinal variation in species abundance

The density of 11 dominant tree species was plotted against the altitude gradient (Fig. 3.1) Each species occupied a unique altitude range. Tree densities were highest in middle altitude zone rather than in low or high altitude zone. *Quercus lanata and Quercus lamellosa* reached their greatest abundance between 1800 to 2000 m altitude but their distribution extended up to 2400 m. Density of *Quercus leucotrichophora* was highest between 2000-2200 m of altitude. *Quercus glauca* was present between 2200-2400 m range. Density of *Quercus floribunda* was highest between 2400 to 2600 m. The density of *Quercus semecarpifolia* was maximum in 2600-2800 m altitude range. *Pinus roxburghii* also reached its greatest abundance between 1800 to 2000 m, but its distribution extended up to 2600 m. *Rhododendron arboreum* was present throughout the Kumaon Himalaya but its abundance was maximum between 2000 to 2400 m. Abundance of *Myrica esculenta* was also high at low altitude (1800-2000 m) but its distribution extended up to 2600 m. *Lyonia ovalifolia* was distributed all over the Himalaya but its abundance decreased with increase in altitude. *Aesculus* *indica* is also distributed all over the Kumaon but its abundance is maximum in middle altitudinal zone.

In general it was found that *Quercus leucotrichophora, Quercus floribunda, Pinus roxburghii, Rhododendron arboreum, Myrica esculenta, Lyonia ovalifolia and Aesculus indica* had wider distribution ranges than *Quercus semecarpifolia, Quercus glauca, Quercus lanata and Quercus lanuginosa.*

3.3.5 Density, diversity and richness of regenerating species

Table 3.5 provides data on density, richness and diversity of regenerating tree species. The density was maximum at Mukteshwer (20406±1955) and it was minimum at Kunjakharak (2050±2199). Maximum diversity of regenerating species was found at Sitlakhet (1.36±0.56) and it was lowest at Kunjakharak (0.28±0.43). Species richness of trees was also maximum at Sitlakhet (1.34±0.39) and was found to be lowest at Kunjakharak (0.26±0.38).

Table 3.9 provides the regeneration of individual tree species at different sites and also the overall values for 19 sites. The density varied between different sites for each species. Among *Quercus* species the density was highest for *Quercus floribunda* (1881.38± 4533) and lowest for *Quercus lanuginosa* (21.03±60.54). Among the co-associate species of *Quercus*, the density was high for *Symplocos* sp. (578.92±1803), *Rhododendron arboreum* (564.92±697.54), *Lyonia ovalifolia* (473.58±1163) and low for *Maytenus rufa* (0.31±1.35), *Prunus cornuta* (0.53±2.33), and *Symplocos theifolia* (0.47±2.0).

3.3.6 General ordination

The principal component analysis of habitat variables extracted six components, which explained a maximum of 86.2% of variance in the data matrix. The first PC accounted for 29.4% of the variance while the second and third PC accounted for 26% and 10.9% of variance. The list of the variables along with the loading on first three components is given in Table 3.11.

The first component was related to altitude as it had highest loading on PC I. PC I was significantly negatively correlated with altitude. It was found to be significantly positively correlated with grass density, diversity and richness and negatively significantly correlated with herb density, diversity and richness. The PC I was also significantly positively correlated with number of cut trees. The PC II represented gradients of shrub, tree and herb layer since variables related to these layers had high loadings on PC II. It was found to be positively correlated with herb density, diversity and richness, shrub diversity and height, tree density, diversity and richness. The PC II was however significantly negatively correlated with proportion of ground cover.

3.3.7 Ordination of sites

Ordination of 19 sites were done by transposing data matrix of 27 habitat variables. Gradients for the first and second PC were already identified while doing *R*-mode analysis. PC I accounted for about 31.1% variation while PC II accounted for about 17.3 % of variation. Both components together explained about 48.4% of variation (Table 3.12). Fig. 3.2 shows the arrangement of sites in ordination space defined by PC I and II. Four broad clusters are clearly recognisable. Sunderdunga, Pindari and Munsiyari are present at the lower end of PC I and PC II and have similar habitat conditions. Duku, Sobla, Gasi and Daphiyadhura, which have high loading on PC II but low on PC I, form another cluster of sites. These sites have high shrub richness, shrub diversity, and tree density and tree diversity. Mechh, Majtham, Gandhura, Jageshwer, Pandavkholi and Binsar, having high loadings on both components, form third cluster. Gager, Maheshkhan, Mukteshwer, Binayak and Kunjakharak, with high loading on PC I and low on PC II form the fourth cluster of sites which have similar habitat conditions.

3.3.8 Ordination of tree species

A total of 66 tree species were identified at different surveyed sites. PCA was performed using *R*-mode strategy to see how different tree species are distributed in tree density space. First PC explained 15% of variance while second PC explained about 13% of variance. Figure 3.3 shows the ordination of tree species in tree species density space. Distribution of tree species on PC I was influenced by the gradient of altitude. Tree species are distributed according to the increasing altitude on PC I. *Quercus glauca, Quercus leucotrichophora, Lyonia ovalifolia, Stranvaesia nussia, Myrica esculenta* are distributed on low altitudes and therefore have low loading on PC I. *Quercus semecarpifolia, Tsuga dumosa, Abies pindrow, Taxus baccata, Betula utilis* are high altitude species and, therefore, have high loading on PC I.

Tree species on second PC are distributed according to the slope gradient. Tree species such as *Quercus leucotrichophora, Pinus roxburghii,* *Lyonia ovalifolia, Myrica esculenta,* and *Quercus semecarpifolia* are present at the lower end of the PC II. These species are characteristic of upper slope and less moist areas. Tree species such as *Quercus glauca, Maytenus rufa, Stranvaesia nussia, Taxus baccata, Rhododendron barbatum, Betula utilis* etc. are present at the positive end of the PC II which are distributed in moist areas with moderate slopes.

3.3.9 Classification of sites

Figure 3.4 presents the results of classification of sites on the basis of tree species composition. A total of seven clusters were identified. The first cluster included Duku, Mechh and Sobla. The second cluster included Gasi and Munsiyari while Pindari and Sunderdunga formed third cluster. The fourth and fifth cluster comprised of Binsar, Daphiyadhura, Gandhura and Majtham respectively. Jageshwer, Sitlakhet Mukteshwer and Maheshkhan belonged to sixth group. The seventh cluster comprised of Binayak Kunjakharak, Gager and Pandavkholi.

3.3.10 Classification of tree species

Figure 3.5 presents the dendrogram of tree species classification. A total of 10 clusters were identified. The first cluster has elements, which represent *Quercus semecarpifolia* dominated forest. Other co-associates of *Quercus semecarpifolia* include *Tsuga demosa, Toona serrata, Pyrus pashia, and Lindera pulcherima. Quercus lanata* and *Quercus lamellosa* were other oak species encountered with *Quercus semecarpifolia.* The second cluster included *Quercus glauca* with *Maytenus rufa, Albizia, Stravesia nussia, Pyrus sp.* This vegetation type is present in moist areas such as near streams and valleys in low to mid altitude areas. Third cluster has 10 tree species and this vegetation type is dominated by *Abies pindrow, Juglans regia*. It was encountered in areas such as Sobla and Dhaphia. Fourth group has 9 tree species and these species are present in a wide altitude range. Fifth cluster represents *Betula utilis* forest having *Taxus baccata, Aesculas indica* and it is encountered in Sunderdunga area. *Quercus floribunda* alongwith *Acer oblongum, Alnus nepalensis, Viburnum mullaha, Euonymus tingens* form a separate vegetation type and it is found at Kunjakharak, Binsar, Gager etc. The seventh cluster has *Quercus leucotrichophora* as dominant species and the associate species such as *Rhododendron arboreum, Persea duthiei, Lyonia ovalifolia, Ilex dipyrena*, and *Viburnum cotinifolium.* This vegetation type is mainly distributed in the middle altitude zone. The eighth cluster represents the *Cedrus deodara* forest. The ninth cluster is *Pinus roxburghii* forest and it has other species such as *Swida oblongum, Myrica esculenta, Symplocos theifolia* and *Euonymus tingens.*

3.4 DISCUSSION

The vegetation studies carried out under the present investigations differ considerably from the previous studies on vegetation in Kumaon Himalaya. The previous studies on vegetation have focussed largely on describing structure, composition and diversity of a particular forest type (e.g. oak, chir pine etc.). The present study has looked at oak forests at different sites with the perspective of relating features of vegetation with that of animal communities and therefore data on various aspects have been presented site wise. In analysing data, no distinction has been made between various types of oak forests. Therefore the comparison of data has been restricted to available information on oak forests only.

The range of tree density (265 to 1063 trees/ha), diversity (0.59 to 1.52) and richness (0.63 to 1.46) recorded in this study are well within the range of values reported for different oak forests (540 to 1300 trees/ha, and 0.00-2.95, Saxena and Singh 1982, Tiwari and Singh 1985, Upreti *et al.* 1985). However the tree diversity values recorded in this study are quite low (all values <2.0) as compared to values (2.63 and 2.28) recorded by Saxena *et al.* (1985) who found the maximum tree diversity in middle ranges. The tree diversity declined on both sides. Saxena *et al.* (1985) concluded that harsh climate seems to be congenial for the development of dominance while moderate climate i.e. high rainfall and moderate temperature is favourable for diversification. The range of shrub density (6803 to 27280 individuals/ha) and diversity (0.63 to 1.50) recorded under this study is also similar to values reported by Saxena and Singh (1982) and Rawal and Pangtey (1994). However it should be noted that the shrub diversity values are again very low compared to values reported by other workers. The values of tree and shrub density, diversity and richness showed significant negative correlation with altitude. The only variables which showed positive correlation or no correlation are shrub height and shrub cover respectively. Whittaker (1972) noted that generally it is not possible to predict the species diversity of one stratum of the vegetation from the diversity of the other strata of the vegetation. However not only the tree and shrub diversities were found to be positively correlated but also the values of cover and density were positively correlated. This is quite in contrast to the inverse relationship between shrub and tree diversity recorded by Saxena and Singh (1982) for Q. *leucotrichophora, Quercus lanuginosa* and *Quercus floribunda* forests in Kumaon Himalaya. Also the positive correlation in tree and shrub cover does not follow the usual inverse relation suggested by Whittaker (1956) and Reiners (1967). Saxena and Singh (1982) suggested that the inverse relationship between the two life form would occur only after a certain limit in the cover of larger life form has been attained.

The density, diversity, species richness and cover of grass and herb layer generally showed inverse relationships with some of the negative correlations being significant such as between grass density and herb diversity, species richness and cover. While the herb layer density, diversity and richness increased, grass density, diversity, and richness decreased with altitude. Therefor high altitude sites had higher herb density, diversity and richness and low altitude sites such as Kunjakharak had higher grass density, diversity and richness. Saxena and Singh (1982) found higher herb diversity in open canopy forest than the closed canopy forests. The negative correlation between tree cover and altitude suggest that generally forest at higher altitude were with more open canopy thereby favouring higher growth of herbs than the forest at low and middle altitude sites.

The tree species composition and abundance of dominant and co-dominant species at various sites recorded under this study is similar to species composition and abundance pattern for individual species reported by Saxena and Singh (1982) and Rawal and Pangtey (1994) from Kumaon. The sites showed dominance of one or the other oak species in tree layer thus belonging to a particular forest type. In general sites in Almora and Pithoragarh had higher number of tree species (mean number of tree species/patch 17±4.9 in Almora and 16.9±3.8 in Pithoragarh) compared to sites in Nainital districts (14.8±3.4). Majority of patches in Almorah and Pithoragarh districts were in the middle altitude range which harbour highest tree diversity as suggested by Saxena and Singh (1982).

The distribution of individual tree species along altitude showed that each species showed peak abundance at a particular altitude but its distribution extended beyond their main forest types. Thus the species form a continuum along altitude as suggested by Wittacker (1967), McIntosh (1967) and Saxena *et al.* (1985). However Saxena *et al.* (1985) recorded highest abundance of *Quercus leucotrichophora* at about 1800 m which differs from the highest abundance of *Quercus leucotrichophora* recorded under present investigation between 2000-2200 m. Saxena *et al.* (1985) also recorded *Quercus semecarpifolia* to have wider altitudinal ranges compared to *Quercus floribunda.* However the *Quercus floribunda* has been recorded to have wider altitudinal range as compared to *Quercus semecarpifolia* under the present investigation.

The maximum density of regenerating species was found at Mukteshwar and minimum at Kunjakharak. The forests at Mukteshwar is under the control of Indian Veterinary Research Institute and is well protected unlike other patches.

On the other hand Kunjakharak forests in Nainital is highly disturbed and extensive summer forests fires are very frequent which is perhaps responsible for low density of regenerating species. The diversity and species richness values are also lowest for Kunjakharak site.

The regeneration of different tree species differed between sites but in general all *Quercus* species had good regeneration between sites as well as for all sites combined except for the *Quercus lamellosa*. This is in contrast to observations of Saxena and Singh (1982) who reported lowest regeneration for *Quercus leucotrichophora* in *Quercus leucotrichophora* forests as well as in mixed forests. Saxena and Singh (1982) did not record any seedlings at any of the 56 stand studied. However observations of Saxena and Singh (1982) pertain to the Gola river catchment area (155 km^2) only and does not reflect a correct picture of regeneration of *Quercus leucotrichophora* for whole of Kumaon Himalaya.

The ordination carried out under the present investigation is one of the most comprehensive attempt at understanding the patterns of relationship among various habitat variables at landscape level. The altitude plays a powerful role in shaping the vegetation communities as PC I was found to be significantly correlated with it. Attributes of grass and herb layer co-varied with altitude. The second PC is a gradient related to attributes of shrub and tree layer. Together both gradients separate all the 19 sites succinctly into four broad clusters. These results are in conformity with those of Rawal and Pangtey (1994) who ordinated 51 forest stands using tree composition data. They found distribution of stands along Y axis to be related to the altitude gradient. However the separation of stands along X axis was not clear and it was interpreted to be the gradient of tree basal cover. The altitude range (1600 to 3100 m) of forests stand covered by Rawal and Pangtey (1994) closely resembles with that of present study and therefore the results confirm to each other. However Rikhari *et al.* (1989) ordinated 18 forest stands distributed between 1450-2450 m altitude range and found that forest stands were arranged according to soil moisture gradient. Such arrangement of stands as well as tree and shrub attributes are more characteristic of micro level than at macro and landscape level. This comes out clearly in ordination of tree species where the PC I is again related to altitude whereas the PC II is related to slope gradient.

The classification of sites on the basis of tree species composition produced seven clusters of sites. Each cluster has sites which are similar in their tree species composition. The classification results are quite different from those of ordination results which was expected. However sites which were placed differently along first and second axis in ordination are clubbed together. For example Duku and Sobla which are close to each other in ordination space are combined with Manch. Similarly Gasi is combined with Munsiyari. Moreover Binsar is clubbed with Daphiyadhura. Therefore it should be noted that attempts to interpret forest classes from the ordination of forest stands is fraught with erroneous interpretation and should not be attempted. Rawal and Pangtey (1994) ordinated 51 forest stands and interpretation of different forest types was based on relative position of forest stands in the two-dimensional ordination space. This may not provide a correct classification of forest types, which one may achieve by using a suitable classification strategy. The ordination space represents gradients which are a linear combination of several non-correlated abiotic and biotic factors.

Table 3.1 Mean tree density (number of individuals/ha), diversity and richness of trees in different oak patches of Kumaon Himalaya.

Site	Density ± SD	Diversity ± SD	Richness ± SD
Binayak	409.63 ± 226.26	1.23 ± 0.45	1.28 ± 0.50
Binsar	965.57 ± 471.30	1.52 ± 0.34	1.44 ± 0.43
Daphiyadhura	774.52 ± 318.11	1.29 ± 0.35	1.12 ± 0.43
Duku	1063.59 ± 951.91	1.42 ± 0.45	1.41 ± 0.49
Pindari	338.74 ± 95.13	0.72 ± 0.36	0.68 ± 0.40
Gager	946.89 ± 233.91	1.31 ± 0.35	1.25 ± 0.39
Gandhura	863.98 ± 365.78	1.15 ± 0.38	1.00 ± 0.38
Gasi	984.89 ± 299.93	1.51 ± 0.38	1.46 ± 0.37
Jageshwer	826.21 ± 324.22	1.34 ± 0.39	1.31 ± 0.50
Kunjakharak	265.92 ± 149.47	0.59 ± 0.49	0.68 ± 0.56
Maheshkhan	575.77 ± 184.67	1.13 ± 0.41	1.05 ± 0.39
Majtham	964.97 ± 342.86	1.52 ± 0.21	1.30 ± 0.39
Mechh	652.05 ± 238.99	1.37 ± 0.19	1.29 ± 0.27
Mukteshwer	870.11 ± 338.7	0.65 ± 0.51	0.63 ± 0.512
Munsiyari	472.61 ± 232.16	1.29 ± 0.49	1.45 ± 0.54
Pandavkholi	772.31 ± 247.22	1.32 ± 0.36	1.21 ± 0.38
Sitlakhet	802.60 ± 236.86	1.29 ± 0.34	1.28 ± 0.47
Sobla	881.37 ± 346.05	1.01 ± 0.42	0.98 ± 0.43
Sunderdunga	519.99 ± 253.47	0.92 ± 0.37	0.85 ± 0.37

Table 3.2 Mean shrub density (number of individuals/ha), diversity and richness at all the surveyed sites of Kumaon Himalaya.

Site	Density ± SD	Diversity ± SD	Richness ± SD
Binayak	15547.51 ± 9083.14	1.45 ± 0.49	1.32 ± 0.48
Binsar	19003.43 ± 11146.26	1.40 ± 0.51	1.38 ±0.56
Daphiyadhura	7433.17 ± 10266.83	0.87 ± 0.48	0.74 ± 0.42
Duku	12675.6 ± 6535.09	1.36 ± 0.42	1.15 ± 0.49
Pindari	13517.44 ± 10699.42	0.92 ± 0.60	0.79 ± 0.55
Gager	26390.85 ± 12310.21	1.13 ± 0.49	1.18 ± 0.44
Gandhura	6980.88 ± 4336.52	0.71 ± 0.47	0.61 ± 0.43
Gasi	8119.17 ± 4740.42	1.19 ± 0.36	1.17 ± 0.43
Jageshwer	16417.83 ± 10691.61	1.02 ± 0.57	1.02 ± 0.59
Kunjakharak	6966.45 ± 7671.40	0.63 ± 0.41	0.61 ± 0.38
Maheshkhan	22160.67 ± 11416	1.27 ± 0.45	1.24 ± 0.49
Majtham	13101.88 ± 8529.33	1.27 ± 0.62	1.11 ± 0.63
Mechh	8964.17 ± 5784.47	1.19 ± 0.51	1.15 ± 0.49
Mukteshwer	27280.49 ± 12355.18	1.50 ± 0.44	1.18 ± 0.44
Munsiyari	6803.72 ± 4760.45	0.76 ± 0.36	0.74 ± 0.39
Pandavkholi	8778.06 ± 5560.45	1.37 ± 0.37	1.32 ± 0.39
Sitlakhet	16925.98 ± 7929.29	0.99 ± 0.42	1.08 ± 0.53
Sobla	17062.06 ± 10910.03	1.43 ± 0.45	1.15 ± 0.43
Sunderdunga	10083.05 ± 7090.39	0.98 ± 0.46	0.87 ± 0.39

Table 3.3 Mean herb density (number of individuals/m²), diversity and richness of herb species at different sites of Kumaon Himalaya.

Site	Density ± SD	Diversity ± SD	Richness ± SD
Binayak	10.3 ± 8.1	0.69 ± 0.45	0.66 ± 0.45
Binsar	5.83 ± 4.81	0.45 ± 0.51	0.65 ± 0.64
Daphiyadhura	11.98 ± 10.24	0.84 ± 0.48	0.90 ± 0.49
Duku	34.75 ± 24.47	1.17 ± 0.92	0.99 ± 0.46
Pindari	39.13 ± 21.53	1.14 ± 0.44	1.04 ± 0.51
Gager	11.90 ± 13.12	0.76 ± 0.43	0.74 ± 0.45
Gandhura	08.42 ± 6.18	0.67 ± 0.51	0.68 ± 0.55
Gasi	28.40 ± 22.21	1.01 ± 0.54	0.98 ± 0.51
Jageshwer	17.31 ± 15.94	1.02 ± 0.55	1.04 ± 0.64
Kunjakharak	4.25 ± 3.14	0.35 ± 0.41	0.53 ± 0.56
Maheshkhan	7.53 ± 11.68	0.51 ± 0.57	0.75 ± 0.68
Majtham	22.85 ± 14.45	0.96 ± 0.44	0.76 ± 0.47
Mechh	24.60 ± 9.62	1.10 ± 0.38	0.92 ± 0.49
Mukteshwer	12.48 ± 8.97	0.79 ± 0.37	0.69 ± 0.38
Munsiyari	27.64 ± 15.79	0.99 ± 0.35	0.85 ± 0.39
Pandavkholi	11.43 ± 14.06	0.83 ± 0.62	0.87 ± 0.61
Sitlakhet	10.87 ± 8.82	0.79 ± 0.62	1.01 ± 0.71
Sobla	35.48 ± 33.92	1.07 ± 0.52	0.89 ± 0.51
Sunderdunga	27.89 ± 41.89	1.23 ± 0.29	1.20 ± 0.38

Table 3.4 Grass density (number of individuals/m^2), diversity and richness of grass species at all surveyed sites of Kumaon Himalaya.

Site	Density±SD	Diversity±SD	Richness±SD
Binayak	28.90 ± 14.02	0.76 ± 0.39	0.61 ± 0.31
Binsar	16.1 ± 13.49	0.72 ± 0.55	0.70 ± 0.52
Daphiyadhura	10.88 ± 11.22	0.29 ± 0.43	0.29 ± 0.44
Duku	08.15 ± 8.18	0.29 ± 0.33	0.25 ± 0.32
Pindari	04.40 ± 6.25	0.23 ± 0.41	0.25 ± 0.41
Gager	28.83 ± 27.79	0.69 ± 0.46	0.54 ± 0.35
Gandhura	10.61 ± 10.88	0.54 ± 0.49	0.69 ± 0.56
Gasi	02.33 ± 4.25	0.01 ± 0.25	0.01 ± 0.27
Jageshwer	22.90 ± 15.17	0.79 ± 0.44	0.70 ± 0.39
Kunjakharak	33.55 ± 17.7	0.49 ± 0.33	0.40 ± 0.29
Maheshkhan	28.17 ± 19.83	0.79 ± 0.45	0.54 ± 0.35
Majtham	23.70 ± 17.76	0.66 ± 0.31	0.39 ± 0.19
Mechh	18.40 ± 11.79	0.51 ± 0.37	0.33 ± 0.27
Mukteshwer	24.26 ± 0.44	0.65 ± 0.44	0.51 ± 0.38
Munsiyari	09.08 ± 8.64	0.31 ± 0.37	0.25 ± 0.35
Pandavkholi	19.40 ± 18.76	0.32 ± 0.39	0.71 ± 0.45
Sitlakhet	14.00 ± 10.38	0.79 ± 0.45	0.27 ± 0.33
Sobla	04.30 ± 7.06	0.01 ± 0.23	0.01 ± 0.20
Sunderdunga	07.27 ± 18.02	0.25 ± 0.36	0.33 ± 0.47

Table 3.5 Density (number of individuals/ha), Diversity and richness of regenerating tree species at all the surveyed sites of Kumaon Himalaya.

Site	Density±SD	Diversity±SD	Richness±SD
Binayak	5330.77 ± 6664.08	0.76 ± 0.56	0.62 ± 0.54
Binsar	4639.93 ± 5246.87	0.99 ± 0.65	0.86 ± 0.58
Daphiyadhura	3479.63 ± 2155.51	0.86 ± 0.48	0.88 ± 0.43
Duku	8194.84 ± 6122.49	0.86 ± 0.45	1.04 ± 0.45
Pindari	3520.47 ± 3165.99	0.29 ± 0.36	0.32 ± 0.41
Gager	6152.77 ± 7053.58	0.84 ± 0.56	0.69 ± 0.49
Gandhura	7414.33 ± 3768.29	1.15 ± 0.49	1.20 ± 0.42
Gasi	17335.54 ± 6181.71	1.34 ± 0.36	1.34 ± 0.33
Jageshwer	6699.82 ± 5618.9	0.94 ± 0.52	0.95 ± 0.49
Kunjakharak	2050.97 ± 2199.59	0.28 ± 0.43	0.26 ± 0.38
Maheshkhan	5563.41 ± 5873.77	0.59 ± 0.64	0.53 ± 0.57
Majtham	13194.95 ± 7089.46	0.78 ± 0.39	1.05 ± 0.45
Mechh	4826.73 ± 3378.6	0.75 ± 0.50	0.82 ± 0.49
Mukteshwer	20406.53 ± 19554.42	0.34 ± 0.31	0.27 ± 0.27
Munsiyari	2079.16 ± 2287.76	0.65 ± 0.68	0.54 ± 0.58
Pandavkholi	5241.99 ± 4387.07	0.66 ± 0.47	0.69 ± 0.49
Sitlakhet	6954.20 ± 2939.28	1.36 ± 0.56	1.34 ± 0.39
Sobla	6037.81 ± 4659.14	0.46 ± 0.46	0.53 ± 0.49
Sunderdunga	2284.11 ± 2560.22	0.39 ± 0.44	0.29 ± 0.37

Table 3.6 Density (number of individuals/ha) of different tree species in different oak patches of Nainital district. UN = unidentified species.

Tree species	Kunjakharak	Binayak	Mukteshwer	Gager	Maheshkhan
Abies pindrow	0	2.12	0	0	0
Acer oblongum	1.59	2.12	0	6.37	0
Aesculus indica	0	7.4	0	0	0
Cedrus deodara	17.5	45.65	0	2.12	10.62
Eucalyptus sp.	0	0	0	0	5.31
Euonymus sp	0	0	0	21.23	0
Euonymus tingens	0	0	5.14	1.06	0
Holoptelea integrifolia	0	0	0	0	2.12
Ilex dyperina	1.59	26.54	12.33	1.06	0
Litsia umbrosa	6.25	35.03	7.19	3.18	0
Lyonia ovalifolia	11.15	25.48	14.38	129.51	31.84
Malus sikkimensis	0	0	0	30.78	3.18

Myrica esculenta	0	0	13.35	31.85	74.31
Persea duthiei	0	12.74	20.55	4.25	21.23
Pinus roxburghii	0	1.06	7.19	32.91	18.05
Pinus wallichiana	0	14.86	4.1	0	0
Pyrus mellus	0	0	0	7.43	3.18
Pyrus sp.	0	0	0	0	2.12
Quercus floribunda	19.10	81.74	648.24	133.76	83.86
Quercus leucotrichophora	15.92	76.43	90.40	321.66	229.29
Quercus semecarpifolia	133.76	0	0	0	0
Rhododendron arboreum	38.2	36.09	31.85	145.43	67.94
Symplocos theifolia	0	1.06	0	3.18	0
Swida oblonga	0	0	1.02	20.17	5.30
Taxus baccata	0	55.20	0	0	0
UN11	0	0	2.05	0	5.30
UN12	0	0	0	6.37	0
Viburnum cotinifolium	35.03	28.66	0	46.71	1.06

Table 3.7 Density (numbers of individuals/ha) of different tree species at all the surveyed sites of Almora district of Kumaon Himalaya. UN= unidentified species.

Tree species	Pandavkholi	Sitlakhet	Jageshwar	Gasi	Sunderdunga	Pindari	Binsar
Quercus leucotrichophora	1.59	369.75	213.83	13.54	0	0	175.69
Quercus floribunda	287.42	0	0	39.81	0	0	131.10
Quercus semecarpifolia	0	0	0	15.92	0	0	0
Quercus glauca	0	0	0	0	0	0	1.59
Rhododendron arboreum	46.18	152.87	246.59	17.52	20.93	123.7	192.14
Rhododendron barbatum	0	0	0	0	249.32	20.01	0
Lyonia ovalifolia	15.92	40.34	141.04	59.71	30.93	0	122.08
Pinus roxburghii	0.79	121.02	28.21	0	0	0	14.33
Symplocos theifolia	93.95	0	47.32	442.68	0	0	45.65
Litsea umbrosa	0	16.99	16.38	138.54	0	0	0
Viburnum cotinifolium	63.69	2.12	28.21	0	5.46	30.02	85.45
Myrica esculenta	1.59	23.35	16.38	0	0	0	21.23

Pyrus pashia	0	0	9.09	0	0	0	5.84
Alnus nepalensis	0.79	0	4.54	15.92	0	0	0.53
Persea duthiei	3.98	4.25	50.05	143.3	0	0	45.12
Euonymus tingens	57.32	0	10.09	19.1	0	0	6.37
Malus sp	0	4.25	2.72	0	0	0	0
Ilex dipyrena	119.43	2.12	9.09	12.74	49.13	31.85	13.27
UN11	0	12.74	0.91	0	0	0	0
UN3	0.79	0	0	23.08	0	0	0
Euonymus sp	35.03	10.62	2.72	0	0	0	2.65
Swida oblonga	0	16.99	13.65	0	0	0	14.33
UN4	0	0	0.91	0	0	0	0
Lindera pulcherrima	50.16	0	0	5.57	0	0	38.75
UN5	0.79	0	0	0	0	0	2.65
UN6	0	0	0	0.79	0.91	0	0
UN7	0	2.12	0	0	0	0	0
UN8	0	0	0	0	13.65	0	0
Pyrus sp	0	2.12	0	2.39	0	0	5.84

Cornus macrophyla	0	2.12	0	0	0	0	0
Viburnum mullaha	0	0	0	55.73	1.82	0	10.08
Acer oblongum.	0	0	0	6.37	49.14	151.96	0.53
Cassia sp	0	0	0	6.37	0	0	0
Toona serrata	0	0	0	1.59	0	0	0
Prunus sp.	0	0	0	0	1.82	0	0
Taxus baccata	0	0	0	0	151.05	11.83	0
Juglans regia	0	0	0	0	5.46	0	0
Betula utilis	0	0	0	0	8.19	3.64	0
Hippophae salicifolia	0	0	0	0	0	11.83	0
Prunus cornuta	0	0	0	0	0	3.64	0
Abies pindrow	0	0	0	0	0	0.91	0
Stranvaesia nussia	0	0	0	0	0	0	1.06
Un9	0	0	0	0	0	0	4.78
Cedrus deodara	0	0	0	0	0	0	0.53
Maytenus rufa	0	0	0	0	0	0	5.8
Albezzia lebbek	0	0	0	0	0	0	0.53

Aesculus indica	0	0	0	0	0.91	0	0

Table 3.8 Density (numbers of individuals/ha) of different trees species at all the surveyed sites of Pithoragarh District. UN= unidentified species.

Tree species	Gandhura	Daphiadhura	Sobla	Duku	Majtham	Mechh	Munsiyari
Quercus leucotrichophora	19.11	0.64	3.98	28.66	27.07	17.5	0
Quercus lanata	255.84	221.02	0	6.37	187.89	224.52	0
Quercus lamellosa	5.31	0.64	0	0	3.18	0	0
Quercus floribunda	0	2.79	28.66	80.41	7.96	0	5.09
Quercus semecarpifolia	0	0	0	0	0	0	129.93
Rhododendron arboreum	99.79	314.65	42.99	10.85	199.04	127.39	98.08
Rhododendron barbatum	5.94	0	0	0	0	0	0
Pinus roxburghii	149.68	0	0	0	19.11	0	0
Lyonia ovalifolia	208.07	181.53	11.15	7.96	256.37	85.98	31.84
Myrica esculenta	114.65	5.73	0	3.18	132.16	121.02	0
Euonymus tingens	6.37	1.26	0	26.27	14.33	14.33	6.37
Euonymus sp	2.12	0	0	0	0	0	0

Cupresus torulosa	2.12	0	0	0	0	0	0
Swida oblonga	7.43	20.38	0	0	3.18	0	0
Cornus macrophyla	7.43	0	0	0	0	9.55	0
UN11	2.12	0	2.39	0	0	0	3.82
Symplocos sp.	6.37	16.56	0	87.57	0	0	0
Cedrus deodara	0	6.37	0	0	0	0	0
Lindera pulcherrima	0	24.84	0	71.65	0	0	17.83
Viburnum mullaha	0	13.38	44.59	16.72	58.92	4.77	21.58
Acer oblongum	0	0.64	31.05	18.31	0	0	34.39
Alnus nepalensis	0	14.02	29.46	0	35.03	1.59	3.82
Persea duthiei	0	7.01	508.75	254.77	0	38.22	0
Ilex dipyrena	0	0.64	23.88	38.21	0	6.36	22.92
Pyrus pashia	0	2.54	0	0	14.33	0	0
Un10	0	18.47	0	0	0	0	0
Un11	0	3.82	0	0	0	0	0
Mellus sp	0	0.64	0	0	0	0	0
Juniperus salicifolia	0	0.64	0	0	0	0	0

Litsia umbrosa	0	5.09	0	54.14	0	0	0
Toona serrata	0	0	11.94	0	0	0	0
Aesculus indica	0	0	82.80	43.78	3.18	0	8.92
Juglans regia	0	0	1.59	9.55	0	0	8.92
Un13	0	0	5.57	0	0	0	0
Un14	0	0	17.52	0	0	0	0
Viburnum cotinifolium	0	0	0.79	0	0	0	7.64
Un15	0	0	0	11.14	0	0	0
Alnus sp.	0	0	0	7.96	0	0	0
UN1	0	0	0	0	3.18	0	7.63
Un12	0	0	0	0	0	0	20.38
Betula utilis	0	0	0	0	0	0	20.38
UN3	0	0	0	0	0	0	5.09
Tsuga dumosa	0	0	0	0	0	0	17.83
Taxus baccata	0	0	0	0	0	0	15.28

Table 3.9 Abundance of regenerating tree species at different sites in Kumaon Himalaya. UN = unidentified species.

Tree Species	Kunjakharak	Binayak	Mukteshwer	Gager	Maheshkhan	Pandavkholi	Sitlakhet
Acer oblongum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aesculus indica	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Un10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Betula utilis	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cedrus deodara	0.0	0.0	11.41	0.0	11.79	0.0	47.15
Cassia sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euonymus tingens	0.0	35.36	22.81	129.66	11.79	194.48	495.05
Euonymus sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Un11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ilex dipyrena	0.0	11.79	22.81	23.57	0.0	8.84	47.15
Prunus cornuta	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lindera pulcherima	0.0	0.0	11.41	0.0	0.0	822.14	0.0
Litsia umbrosa	35.36	707.21	490.49	23.57	11.79	61.88	518.62
Lyonia ovalifolia	17.68	11.79	0.0	153.23	35.36	8.84	259.31
Malus sikkimensis	0.0	0.0	0.0	47.15	11.79	0.0	0.0
Maytenus rufa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Myrica esculenta	0.0	0.0	0.0	35.36	23.57	0.0	282.89
Pinus wallichiana	0.0	0.0	0.0	0.0	23.57	0.0	0.0
Persea duthiei	0.0	0.0	34.22	117.87	70.72	26.52	235.74
Pinus roxburghii	0.0	0.0	91.25	35.36	58.93	0.0	282.89
Prunus sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus mellus	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrus sp	0.0	35.36	34.22	589.34	2157.0	17.68	306.46
Pyrus pashia	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Quercus floribunda	424.33	2534.18	20064.33	2911.36	2298.44	2917.26	0.0
Quercus lamellosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quercus lanata	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Quercus leucotrichophora	0.0	589.34	570.33	1261.20	412.54	0.0	2475.25
Quercus semecarpifolia	1290.66	0.0	0.0	0.0	0.0	0.0	0.0
Rhododendron barbatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhododendron arboreum	141.44	117.87	0.0	188.59	247.52	229.84	638.49
Symplocos sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos theifolia	0.0	11.79	0.0	35.36	0.0	618.81	0.0
Swida sp	0.0	0.0	102.66	436.12	58.93	0.0	518.62
Un12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Taxus baccata	0.0	931.16	0.0	0.0	0.0	0.0	0.0
UN1	0.0	0.0	0.0	0.0	47.15	0.0	212.16
UN3	0.0	0.0	0.0	11.79	0.0	0.0	0.0
Toona serrata	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Abies pindrow	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Viburnum cotinifolium	106.08	94.30	68.44	94.30	0.0	106.08	471.48

Viburnum mullaha	0.0	0.0	0.0	0.0	0.0	0.0	70.72

Table 3.9 continuing

Tree Species	Jageshwar	Gasi	Sunderdunga	Pindari	Binsar	Gandhura	Daphiadhura	Sobla
Acer oblongum	0.0	0.0	474.84	2394.42	0.0	0.0	0.0	88.40
Aesculus indica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	141.44
Alnus nepalensis	0.0	0.0	0.0	0.0	0.0	0.0	42.43	8.84
Un10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Betula utilis	0.0	0.0	0.0	30.31	0.0	0.0	0.0	0.0
Cedrus deodara	0.0	0.0	0.0	0.0	0.0	0.0	14.14	0.0
Cassia sp	0.0	26.52	0.0	0.0	0.0	0.0	0.0	0.0
Viburnum mullaha	0.0	1396.75	20.21	0.0	17.68	0.0	35.36	371.29
Euonymus tingens	40.41	636.49	0.0	0.0	0.0	0.0	0.0	0.0
Euonymus sp	20.21	61.88	0.0	0.0	88.40	129.6	0.0	0.0
Un11	0.0	0.0	0.0	0.0	0.0	0.0	14.14	0.0

Ilex dipyrena	40.41	97.24	383.92	333.40	58.93	0.0	0.0	221.0
Prunus cornuta	0.0	0.0	0.0	10.10	0.0	0.0	0.0	0.0
Juglans regia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lindera pulcherrima	0.0	318.25	0.0	0.0	412.54	0.0	120.23	0.0
Litsia umbrosa	151.55	2280.76	0.0	0.0	5.89	0.0	7.07	247.52
Lyonia ovalifolia	101.03	26.52	20.21	0.0	424.33	1178.6	14.14	8.84
Malus sikkimensis	0.0	0.0	0.0	0.0	0.0	0.0	226.31	0.0
Maytenus rufa	0.0	0.0	0.0	0.0	5.89	0.0	240.45	0.0
Myrica esculenta	101.03	0.0	0.0	0.0	47.15	235.74	756.72	0.0
Pinus wallichiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Persea duthiei	545.56	963.58	0.0	0.0	194.48	11.79	0.0	3845.4
Pinus roxburghii	10.10	0.0	0.0	0.0	153.23	2498.8	388.97	0.0
Prunus sp	0.0	70.72	10.10	0.0	0.0	0.0	289.96	0.0
Pyrus mellus	0.0	0.0	30.31	0.0	0.0	0.0	0.0	0.0
Pyrus sp	0.0	0.0	60.62	0.0	241.63	0.0	91.94	0.0
Pyrus pashia	1414.3	0.0	0.0	0.0	607.02	0.0	445.54	0.0
Quercus floribunda	0.0	1485.15	0.0	0.0	701.32	0.0	0.0	548.09

Quercus lamellosa	0.0	123.76	0.0	0.0	0.0	35.36	0.0	0.0
Quercus lanata	0.0	0.0	0.0	0.0	0.0	2050.9	0.0	0.0
Q. leucotrichophora	2323.7	35.36	0.0	0.0	583.45	259.31	0.0	0.0
Q. semecarpifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
R. barbatum	0.0	0.0	313.19	0.0	0.0	0.0	0.0	0.0
R. arboreum	585.98	256.36	636.49	980.0	265.21	919.38	0.0	247.52
Symplocos sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Symplocos theifolia	202.06	7938.47	0.0	0.0	459.69	483.26	0.0	8.84
Cornus macrophyla	262.68	0.0	0.0	0.0	353.61	70.72	0.0	0.0
Un12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Taxus baccata	0.0	0.0	0.0	30.31	0.0	0.0	0.0	0.0
UN1	0.0	0.0	0.0	0.0	11.79	11.79	0.0	26.52
UN3	0.0	150.28	0.0	0.0	0.0	0.0	0.0	0.0
Toona serrata	0.0	0.0	0.0	0.0	5.89	106.08	0.0	0.0
Abies pindrow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Viburnum cotinifolium	747.63	0.0	111.13	121.24	76.61	0.0	0.0	0.0

Table 3.9 continuing

Tree Species	Duku	Majtham	Mechh	Munsiyari	Mean±SD
Acer oblongum	44.2	0.0	0.0	183.88	167.67 ±551.17
Aesculus indica	123.76	0.0	0.0	0.0	13.96±41.91
Alnus nepalensis	35.36	70.72	0.0	0.0	8.28±19.48
Un10	53.04	0.0	0.0	0.0	2.79±12.17
Betula utilis	0.0	0.0	0.0	70.72	5.32±17.29
Cedrus deodara	0.0	0.0	0.0	0.0	4.45±11.34
Cassia sp	0.0	0.0	0.0	0.0	1.40±6.04
Euonymus tingens	0.0	35.36	0.0	0.0	84.29±178.68
Euonymus sp	26.52	0.0	0.0	0.0	17.19±36.48

Un11	0.0	0.0	0.0	0.0	0.74±3.24
Ilex dipyrena	229.84	0.0	0.0	212.16	89.0±123.11
Prunus cornuta	0.0	0.0	0.0	0.0	0.53±2.33
Juglans regia	35.36	0.0	0.0	0.0	1.86±8.11
Lindera pulcherrima	309.41	0.0	0.0	0.0	104.95±156.28
Litsia unbrossa	848.66	0.0	0.0	84.87	288.17±550.32
Lyonia ovalifolia	150.28	5091.9	724.89	113.15	473.58±1163.14
Malus sikkimensis	0.0	0.0	35.36	0.0	4.96±13.22
Maytenus rufa	0.0	0.0	0.0	0.0	0.31±1.35
Myrica esculenta	0.0	583.45	212.16	0.0	81.19±151.01
Pinus wallichiana	0.0	0.0	0.0	0.0	1.24±5.41
Persea duthiei	1661.9	70.72	53.04	0.0	415.17±931.69
Pinus roxburghii	0.0	0.0	0.0	0.0	164.77±569.84
Prunus sp	0.0	0.0	0.0	0.0	4.25±16.26
Pyrus mellus	0.0	0.0	0.0	0.0	1.60±6.95
Pyrus sp	106.08	0.0	0.0	0.0	187.13±500.26
Pyrus pashia	0.0	0.0	247.52	0.0	120.16±346.11

Quercus floribunda	1635.4	0.0	0.0	0.0	1881.38±4533.34
Quercus lamellosa	0.0	0.0	0.0	0.0	21.03±60.54
Quercus lanata	0.0	2722.7	1732.6	0.0	382.27±830.60
Quercus leucotrichophora	574.61	901.70	335.93	325.32	567.87±731.20
Quercus semecarpifolia	0.0	0.0	0.0	0.0	67.93±296.10
Rhododendron barbatum	0.0	0.0	0.0	0.0	36.96±111.41
Rhododendron arboreum	643.33	3200.1	77.93	367.75	564.94±697.54
Symplocos sp	0.0	0.0	0.0	0.0	47.46±206.86
Symplocos theifolia	990.10	159.12	0.0	0.0	578.92±1803.33
Cornus macrophyla	0.0	636.49	0.0	0.0	151.86±215.73
Un12	0.0	0.0	0.0	70.72	3.72±16.22
Taxus baccata	0.0	0.0	0.0	0.0	69.75±224.58
UN1	0.0	0.0	0.0	0.0	16.28±48.98
UN3	0.0	0.0	0.0	0.0	8.53±34.43
Toona serrata	0.0	0.0	0.0	0.0	5.89±24.30
Abies pindrow	0.0	0.0	0.0	42.43	2.23±9.73
Viburnum cotinifolium	0.0	141.08	0.0	268.74	126.71±189.49

Viburnum mullaha	0.0	318.25	0.0	367.75	136.74±331.41

Table 3.10 Values of Pearson product moment correlation coefficients between different habitat attributes.

Habitat variables	ALT	CD	TC	GC	GD	GDIV	GR	HC	HD	HDIV	HRIC	TL
Altitude (ALT)	1.00											
Cattle dung (CD)	-.087*	1.00										
Cut trees (TC)	-.187	.115*	1.00									
Grass cover (GC)	.032	.127*	-.122	1.00								
Grass density (GD)	-.317**	.234**	.053	.401**	1.00							
Grass diversity (GDIV)	-.322**	.087*	.055	.167**	.609**	1.00						
Grass richness (GR)	-.275**	.043	.039	.105**	.481**	.885**	1.00					
Herb cover (HC)	.142**	-.059	-.098*	.208**	-.189**	-.142**	-.172**	1.00				
Herb density (HD)	.183**	-.059	-.114**	.098*	-.254	-.187	-.202**	.581**	1.00			
Herb diversity (HDIV)	.149**	-.070	-.022	.016	-.171**	-.076	-.079**	.329**	.686**	1.00		
Herb richness (HRIC)	.140**	-.072	-.029	.004	-.148**	-.066	-.025	.184**	.463**	.812**	1.00	
Lopped trees (TL)	-.146**	.156**	.228**	.003	.255**	.131**	.106**	-.166**	-.140**	-.035	-.027	1.00
Shrub cover (SC)	.001	-.207**	-.094*	.009	-.060	.080*	.077*	.226**	-.186**	.175**	.183**	-.155**

Shrub density (SD)	-.246**	-.073	.216**	-.131**	-.001	.133**	.107**	.008	-.028	.033	-.005	-.076
Shrub diversity (SDIV)	-.200**	-.024	.141**	-.232**	-.009	.083*	.092*	-.031	-.028	.064	.081*	-.069
Shrub height (SH)	.231**	-.182**	-.102**	-.164**	-.277**	-.136**	-.097*	.195**	.170**	.159**	.126**	-.090*
Slope (SLP)	.133**	-.173	.364**	-.023	-.087*	-.014	-.004	.054	.093*	.123**	.077*	-.065
Shrub richness (SR)	-.225**	-.019	.209**	-.209**	.048	.128**	.138**	-.094*	.-.106**	-.006	.051	-.027
Tree cover (TC)	-.095*	-.090*	.115**	-.169**	-.201**	-.062	-.047	.012	-.143**	-.128**	-.109**	-.278**
Tree density (TD)	-.228*	-.049	.281**	-.280	-.108**	.033	.035	-.111**	-.126**	-.051	.049	.048
Tree diversity (TDV)	-.150**	.029	.178**	-.345**	-.059	.07	.065	-.086*	-.-.035	.016	.023	.044
Tree richness (TR)	-.120**	.044	.159**	-.268	-.040	.038	.027	-.053	-0.30	-.003	.013	.005

Table 3.10 Continuing

Habitat variables	SC	SD	SDIV	SH	SLP	SR	TC	TD	TDV	TR
Shrub cover (SC)	1.00									
Shrub density (SD)	.420**	1.00								
Shrub diversity (SDIV)	.207**	.470**	1.00							
Shrub height (SH)	.363**	.304**	.258**	1.00						
Slope (SLP)	.091*	-.041	-.009	.125**	1.00					
Shrub richness (SR)	.226**	.456**	.900**	.196**	-.052	1.00				
Tree cover (TC)	.178**	.349**	.255**	.030	-.118**	.202**	1.00			
Tree density (TD)	.050	.329**	.279**	.074	-.057	.281**	.283**	1.00		
Tree diversity (TDV)	.051	.249**	.400**	.126**	-.019	.418**	.052	.429**	1.00	
Tree richness (TR)	-.079*	.200**	.363**	-.137**	-.035	.410**	.030	.333**	.896**	1.00

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

Table 3.11 Principal Component Analysis of the habitat variable showing component loading on three principal components.

Variables	Component		
	1	2	3
Altitude	-0.729	-.0068	0.007
Cattle dung	-0.257	-0.561	0.223
Cut trees	-0.273	0.151	-0.173
% Grass cover	-0.165	-0.836	-0.231
Grass density	0.610	-0.632	0.206
Grass diversity	0.721	-0.408	0.279
Grass richness	0.682	-0.369	0.253
Herb density	0.628	0.564	0.011
Herb diversity	-0.578	0.640	0.102
Herb richness	-0.524	0.646	0.162
% Litter	0.341	0.558	-0.151
Lopped trees	0.400	-0.018	0.692
% Rock	-0.185	0.175	0.532
Shrub density	0.599	0.383	-0.361
Shrub diversity	0.601	0.69	-0.11
Shrub height	-0.537	0.650	0.88

Degree of Slope	-0.558	-0.014	0.436
Shrub richness	0.767	0.603	0.065
Tree cover	0.265	0.131	-0.810
Tree density	0.574	0.620	-0.013
Tree diversity	0.47	0.634	0.387
Tree richness	0.446	0.546	0.349
Eigen values	6.47	5.74	2.4
Percent of total variance explained	29.44	26.09	10.9
Cumulative variance	29.446	55.54	66.52

Table 3.12 Principal Component Analysis of all the surveyed sites in habitat variable space showing component loading.

Variables	Component 1	Component 2
Kunjakharak	0.175	-.865
Binayak	0.477	-0.332
Mukteshwer	0.357	-0.424
Gager	0.819	-0.144
Maheshkhan	0.769	-0.377
Pandavkholi	-0.126	-0.145
Sitlakhet	0.730	0.337
Jageshwer	0.520	0.098
Gasi	-0.251	0.723
Sunderdunga	-0.839	-0.126
Pindari	-0.834	-0.292
Munsiyari	-0.536	-0.374
Gandhura	0.603	0.413
Daphiyadhura	-0.283	0.176
Sobla	-0.526	0.314
Duku	-0.455	0.650

Majtham	0.447	0.434
Mechh	0.462	0.523
Binsar	0.596	0.017
Eigen values	5.91	3.29
Percent of total variance	31.104	17.342
Cumulative variance	31.104	48.447

Figure 3.1 Distribution of tree species according to different altitudinal zone

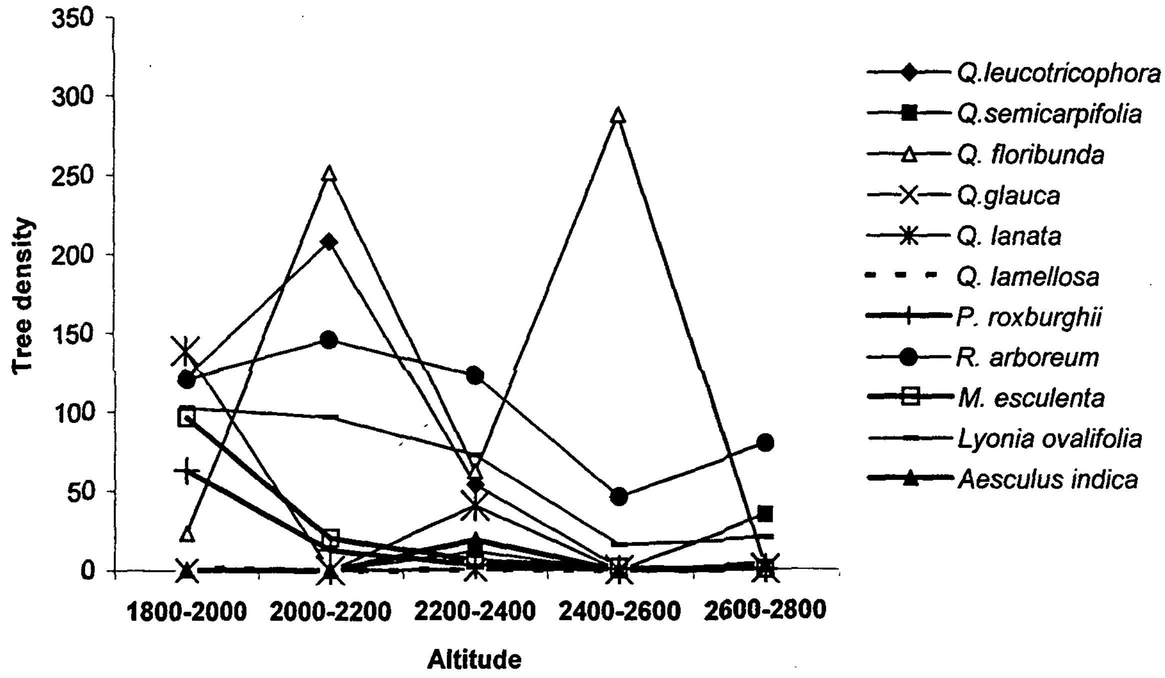


Figure 3.2 Distribution of sites in relation to principal component I and II

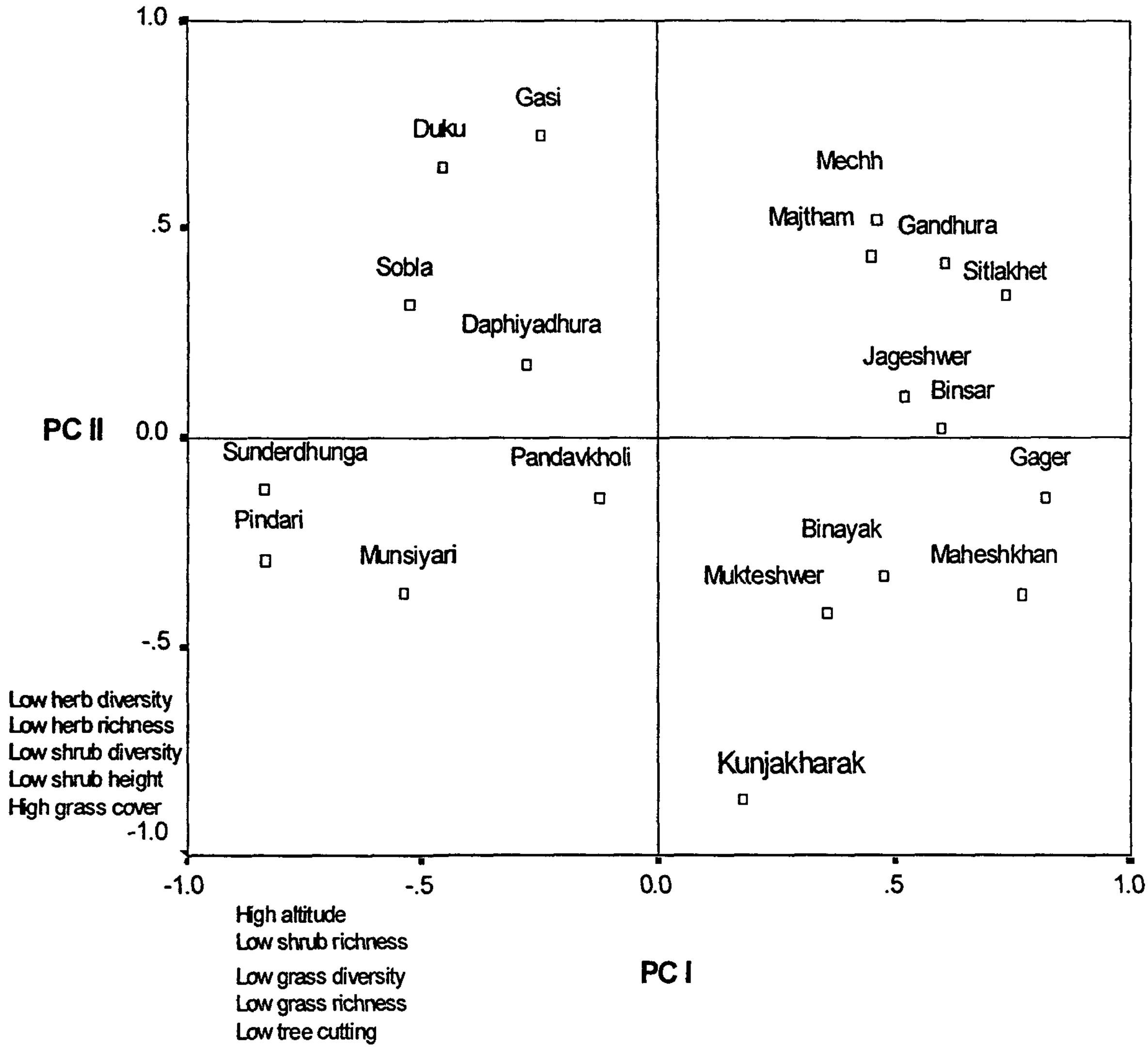


Figure 3. 3 Distribution of tree species in relation to principal component I and II.

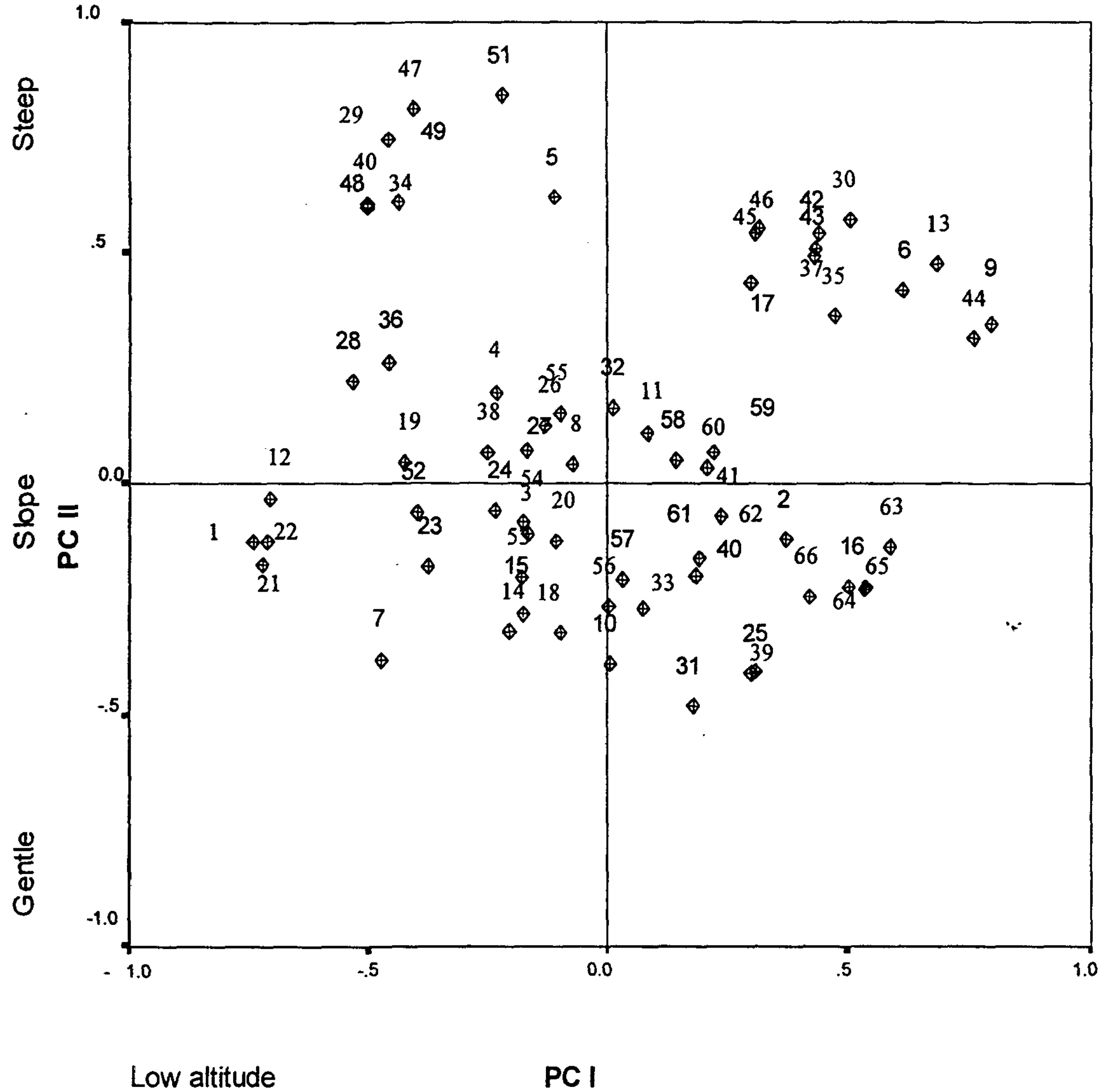


Figure 3.4 Classification of sites according to the similarity in habitat variables.

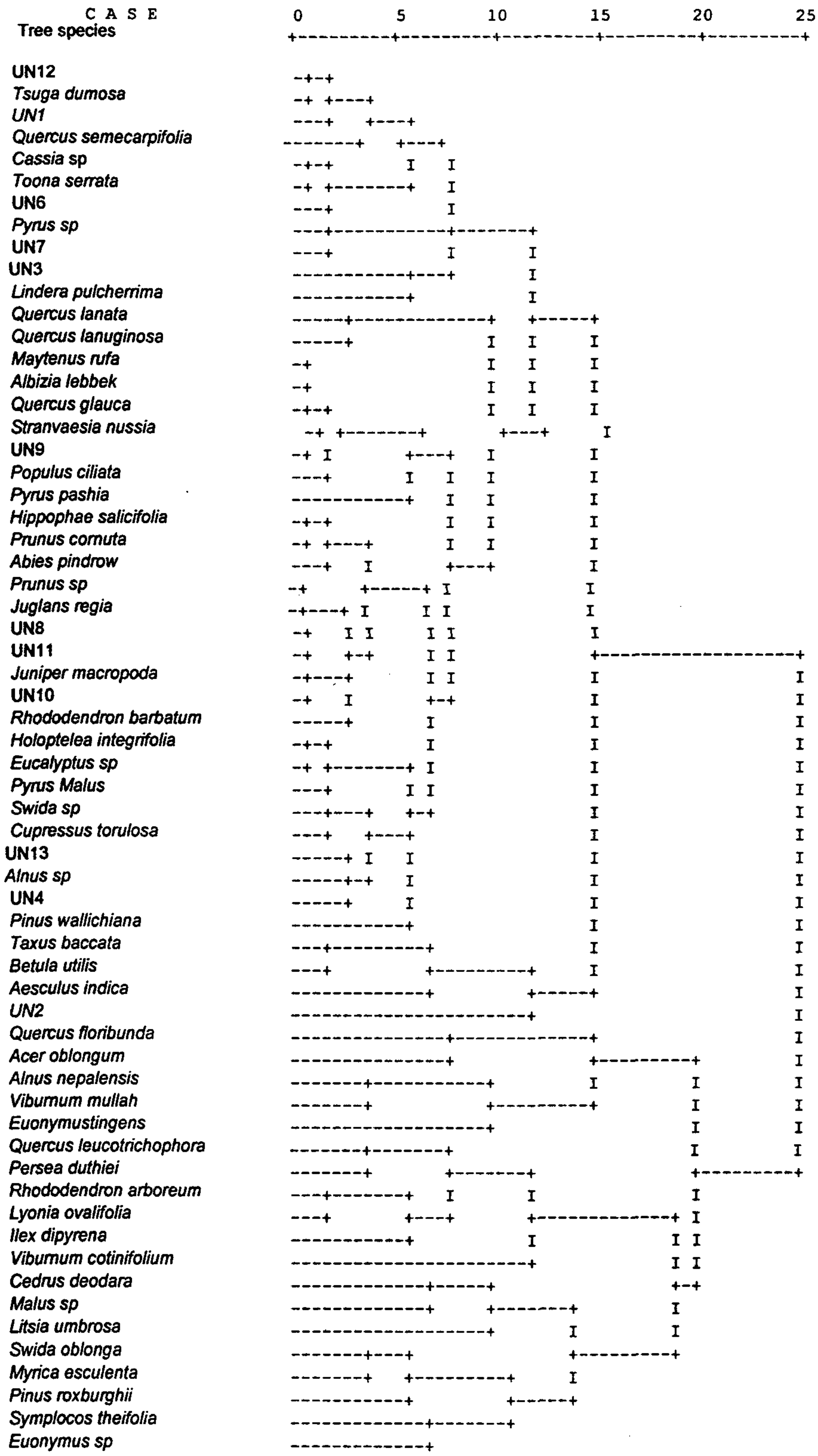
Rescaled Distance Cluster Combine

```
C A S E        0         5        10        15        20        25
Label          +---------+---------+---------+---------+---------+

Duku           -+-----+
Mechh          -+     +-----------+
Sobla          -------+           +-+
Gasi           -------------------+ +-----------------+
Munsiyari      ---------------------+                 +---------+
Pindari        -------+-------------------------------+         I
Sunderdunga    -------+                                         I
Binsar         ---------------------------+---------+           I
Daphiyadhura   ---------------------------+         I           I
Gandhura       ---------+-------------------+       +-----------+
Majtham        ---------+                   I       I
Jageshwer      ---+-+                       +-------+
Sitlakhet      ---+ +--------+              I
Mukteshwer     -----+        +------+       I
Maheshkhan     --------------+      +-------+
Binayak        ---+----------+      I
Kunjakharak    ---+          +------+
Gager          -----+--------+
Pandavkholi    -----+
```

Figure 3. 5 Classification of tree species based on presence / absence data of tree species at different sites.

Dendrogram using Complete Linkage
Rescaled Distance Cluster Combine



CHAPTER 4

STATUS AND DISTRIBUTION OF UNGULATES IN KUMAON

4.1 INTRODUCTION

The Kumaon Himalaya in Uttar Pradesh, India, covers an area of 21032 km^2. It once used to be extensively covered by oak forest (*Quercus* species). However, significant changes in land use pattern, brought about by man in past, have resulted in large-scale reduction, degradation and fragmentation of oak forest. Areas cleared from the oak forest are either covered by extensive chir pine (*Pinus roxburghii*) forests, barren or are under terrace cultivation. Changes in landscape leading to alteration in distribution and size of different forest types are often associated with changes in distribution and abundance of animal communities (Gilpin and Soule 1986, Scott 1991). The animal communities may experience decline in abundance as a consequence of degradation as well as reduction in their habitat. The large and medium sized animals, due to their relatively large home ranges are often first to decline in distribution and abundance. The animal communities in Kumaon Himalaya have not been explored and documented thoroughly in past and also land use changes have brought about decline and total disappearance of large and medium sized mammalian fauna from many sites in the Kumaon Himalaya (Johnsingh and Negi 1997). Considering this extensive surveys were conducted throughout the Kumaon Himalaya to document current status of large and medium sized ungulate fauna in extant oak patches. This chapter describes status, abundance and factors governing the distribution of ungulates at landscape level in the Kumaon Himalaya. The sites covered for status survey have been described in Chapter 2 under extensive study area.

4.2 METHODOLOGY

4.2.1 Data collection

The data on status, distribution and abundance of ungulate species were collected by quantification of direct and indirect evidences at each surveyed sites. During the surveys at each site, existing forest trails were monitored on daily basis in morning hours to gather data on status of different ungulate species. Since there were limited number of direct sightings of ungulates during the survey, data were also collected by quantifying pellet groups along the forest trails at each site. Pellet groups of each ungulate species were counted in 10 m radius circular plot established at 100 m intervals. Sampling plots were established on 10 m either side of trail to avoid sampling of relatively disturbed vegetation along the trails. A total of 634 plots were sampled at 19 sites. Pellet groups of different ungulate species were distinguished on the basis of shape, size and colour, which differ markedly for each species. Data on habitat parameters as well as various disturbance attributes such as cutting, lopping, and grazing were also collected at each sampling plot.

Tree species and their individuals were counted in 10 m radius circular plot for density, diversity and species richness estimation. Tree cover was measured at four points around the sampling plot using a mirror of 25 X 25 cm divided into 100 equal grids. The mirror was kept horizontally at 1.25 m above the ground level and grids covered more than 50% by tree foliage were counted and converted into percentage tree cover. Shrub species and their individuals were counted in 3 m radius circular plot. Shrub height was measured using a measuring tape and shrub cover was measured by ocular estimation using an ordinal scale of 0-5 with 0 representing no shrub cover and 5 representing maximum shrub cover.

The ground cover composition was quantified by sampling four quadrats of 0.50 x 0.50 m dimension in four different directions. The ground cover was estimated by point intercept method (Canfield 1941). A meter tape was laid on the ground in four directions and intercepting materials (herbs, grasses, rock, bare ground, withered stone, and litter) were recorded at 5 cm interval. Number of cut trees, lopped trees, cattle dung piles and evidence of fire were also recorded in 10 m radius circular plot for assessment of general disturbance in each patch.

4.2.2 Data analysis

The diversity and species richness of trees, shrubs, and grasses for each plot were calculated by Shannon-Weiner diversity Index (*H'*) and Margelefs richness index (*RI*) by using the following formulae: $H' = -\sum pi \times \log pi$ and $RI = S\text{-}1/\ln N$

Where pi is the proportion of i^{th} species in sample, S is the number of species in sample and N is the total number of individual.

The sightings of different ungulate species were used to calculate encounter rates in terms of 100 hours of observations. The number of pellet groups for each species in each plot were used to calculate pellet group density (pellet groups/ha) for each species in each plot. One way analysis of variance was used to test for significant differences in mean pellet group densities of each species among different sites following Fowler and Cohen (1986).

To investigate the factors governing distribution of ungulates at landscape level, Discriminant Function Analysis (DFA) was performed. The DFA provides an appropriate multivariate statistical technique for the separation of groups according to their characterisation by a series of attributes (Ferrer and Walker 1974). The DFA was performed on pellet groups data which were organised into a sample-habitat parameters matrix. Sample plots which were exclusive for each species were only used in the analysis. The raw data matrix had to be suitably transformed to allow for a valid analysis. This is necessary because DFA is very sensitive form of analysis designed for data containing overall variation and an equality of dispersion of group mean for each group (ungulate species) on each attributes (habitat variables). Variables were measured on different scales, with ranges from 0-1 to 1000-3200. In order to avoid the analysis being dominated by those with the large ranges, The data were transformed on 0-1 scale by dividing each variable by its own maximum score. Data were transformed on 0-1 scale to bring uniformity in the magnitude of variation each variable possessed. Each variable was further adjusted by transformation by using Natural Log and Arcsine transformation. Species pellet groups–habitat variable matrix was further subjected to Pearson Product Moment Correlation analysis (two tailed significance) to check for auto-correlation. Those variables, which were significantly correlated, were dropped from the analysis (Table 4.3). The stepwise DFA was performed on a 260 sample-13 habitat variables matrix.

4.3 RESULTS

4.3.1 Status and abundance of ungulates

During the surveys, direct and indirect evidences of six ungulate species were collected (Table 4.1). They were barking deer (*Muntiacus muntjak*), goral (*Nemorhedus goral*), sambar (*Cervus unicolor*), serow (*Capricornis sumatrensis*), Himalayan tahr (*Hemitragus jemlahicus*) and musk deer (*Moschus moschiferus*). While barking deer and goral were recorded from 15 sites, sambar was recorded from seven sites. There were no direct sightings of serow but its pellet groups were sampled at three sites. The Himalayan tahr was observed in Pindari and its pellet groups were recorded in Sunderdunga and Pindari areas also. Musk deer was not seen directly but pellets were recorded from Pindari area.

The encounter rate of barking deer was maximum in Binsar (16.04groups/100 hours) followed by Jageshwer (16.6 groups/100 hours), Maheshkhan (15.7 groups/100 hours), Gandhura (10.16 groups/100 hours), Binayak (9.5 groups/100 hours) and Pandavkholi (8.5 group/100 hours). Goral encounter rate was highest in Kunjakharak (54.5 groups/100 hours) followed by Binsar (17.81 groups/100 hours), Binayak (9.5 groups/100 hours), Maheshkhan (7.8 groups/100 hours) and Gandhura (5.08 groups/100 hours). The encounter rate of sambar in Mukteshwer and Maheshkhan was 8.69 groups/100 hours and 3.92 groups /100 hours respectively. Himalayan tahr was sighted only in Pindari, where its encounter rate was 13.3 groups/ 100 hours.

The mean pellet group density (pellet groups/ha±S.E.) of barking deer differed significantly between sites ($F_{18,\ 615}$=6.1, P<0.001) and it was highest in Binsar (88.6±16.3) followed by Jageshwer (79.16±26.9), Binayak (55.19±19.1), while no pellet groups of barking deer were found at high altitude areas such as Sunderdunga, Pindari, Munsiyari (Table 4.2). The mean pellet group density for goral differed significantly between sites ($F_{18, 615}$=5.1, P<0.001) and it was maximum in Kunjakharak (68.46±19.0) followed by Pandavkholi (16.7±5.0) and Sobla (16.7±5.2). The mean pellet group density of sambar was found to be highest in Maheshkhan (139.0±20.4) followed by Mukteshwar (116.0±30.3) and the differences between sites were significant ($F_{18, 615}$=19.6, P<0.001). Pellet groups of serow were found only at three places i.e., Sunderdunga, Pindari and Munsiyari and the mean pellet group density was highest in Sunderdunga (12.0±6.3), followed by Munsiyari (2.5±2.5) and Pindari (2.38±1.7) and the differences between sites were also significant ($F_{18, 615}$=2.7, P<0.001).

4.3.2 Factors governing distribution of ungulates

DFA is one of the most powerful techniques to discriminate between the different groups according to their habitat characterisation The first step in the analysis is the calculation of univariate *F* ratio's and *U* statistics (Wilks' Lambda). *U* statistics varies from 0-1, large values of lambda indicate that group mean do not appear to be different, while small values indicate that group mean do appear to be different. Table 4.4 provides the *U* statistics and *F* ratios for habitat variables included in DFA. Six variables, i.e., Altitude, ground cover, tree cover, tree density, shrub density and shrub cover had significant *F* values and were capable of discrimination between species. The variable with least discriminating power between species was herb richness. Table 4.5 provides values of standardised canonical discriminant function coefficients for variables included in the DFA. The

DFA produced three discriminant functions (DF's) accounting for 52.6%, 29.1% and 18.3% of the variance respectively. The DF1 represents the gradient of altitude and shrub density with shrub density decreasing with increase in altitude. The DF2 is a gradient of increasing tree density along with decreasing ground cover values while the DF3 represents the gradient of increase in shrub cover as well as tree cover.

The distribution of the species centroids in relation to three functions is provided in Figure 4.1 and 4.2. The relative position and location of species in these figures determines the extent to which each species is associated with each function. Figure 4.1a is a plot of DF1 in relation to DF2 which separates barking deer, serow and to some extent sambar. While barking deer and sambar are separated along DF2 occupying low and high tree density areas, serow occupies the extreme end of altitude gradient along DF1. Figure 4.1b is a plot between DF2 and DF3. Serow and goral are clearly associated with DF3 and DF2 respectively. Figure 4.1c is a plot between DF1 and DF3, which shows separation between barking deer, sambar, goral and serow along altitude gradient with serow occupying the extreme ends of altitude and cover gradients.

Figure 4.2 summarises the relationship of different species with habitat variables in a three dimensional plot, which can be used to explain habitat variables governing distribution at macro level for each species. The barking deer mainly occurs at lower altitudes in areas with high shrub densities, high ground cover and low tree densities and cover. The sambar occurs in low altitude areas with very high shrub and tree densities with low ground cover. The goral occupies middle altitude areas with medium shrub and tree densities, low shrub and tree cover with medium ground cover. The serow is distributed at very high altitudes in areas with high tree and shrub cover. In terms of tree and shrub cover requirements, goral occupies open forested areas followed by barking deer, sambar and serow which is found in closed canopy forests.

4.4 DISCUSSION

Out of six ungulate species recorded in the Kumaon Himalaya, three species e.g. Himalayan tahr, musk deer and serow occur in high altitude areas and therefore have restricted distribution in sites such as Pindari and Sunderdunga. The other three species e.g. barking deer, goral and sambar whose distribution overlap in low and middle altitude areas have disappeared from certain patches. Sambar seems to be the most affected species as its direct and indirect evidences could only be recorded from seven oak patches. In general, however, there were very few direct sightings of all six ungulate species in different patches, which suggests extremely low abundance for these species. While changes in land use pattern in past have drastically reduced the distribution of ungulate species, the extremely low abundance of different species within patches is due to high poaching pressure. During the surveys, poaching was found to be common throughout Kumaon including in established protected areas (Khan 1998).

The Pellet Group Count method, reviewed by Neff (1968), Overton (1971) and Putman (1984), has been used extensively for finding out habitat use, abundance and population size estimation of a number of ungulate species (e.g. Kearney and Gilbert 1976, Cairns and Telfer 1980, Bailey and Putman 1981, Rowland *et al.* 1984, Loft and Kie 1988, Mayle *et al.* 1996). Although some workers have questioned the validity of method for abundance estimation and habitat use (e.g. Van Etten and Bannett 1965, Fuller 1991), the method has been found to be efficient in terms of time and man power. It also yields valuable data on abundance and habitat use provided potential sources of errors are removed in sampling (Putman 1984). Extremely low number of direct sightings of different ungulate species in Kumaon made quantification of pellet groups absolutely necessary for generation of base line information on relative abundance of different species. The overall mean pellet group density (pellet groups/ha±S.E.) was highest for barking deer (22.6±6.0) followed by sambar (21.7±9.5), goral (8.8±3.6) and serow (0.88±0.64) and there were significant differences between sites for each species. The overall as well as site specific relative abundance values for each species are useful baseline index for future monitoring of trends in population densities.

The distribution of species in space is governed by a combination of resource gradients and several species occurring in same area tend to show differential use of such gradients. Avoidance of inter-specific competition has been hypothesised to be underlying factor responsible for differential use of resource gradients (Cody 1974, Schoener 1986). Habitat partitioning has been shown to be most common strategy of achieving ecological separation by sympatric species in different taxa (Schoener 1974). A number of workers (Ferror and Walker 1974, Hirst 1975, Dunbar 1978, Green 1987, Jenkins and Wright

1988, Wood 1989) have documented habitat partitioning as common mode of ecological separation in ungulate communities to avoid inter-specific competition. The results of discriminant function analysis in this study clearly establish that barking deer, sambar, goral and serow are separated ecologically along the altitude, density and cover gradients and therefore may not have much inter-specific competition. Altitude gradient which alone was responsible for 52% of total variability had most profound influence on species distribution at landscape level. It was expected considering the wide range of altitude which was sampled during this study. The density and cover gradient which extracted remaining variability are equally important determinants of distribution at landscape and patch level. Green (1987) studied ecological separation in Himalayan ungulates in the Kedarnath Wildlife Sanctuary and found similar differences in habitat use by musk deer (*Moschus chrysogaster*), sambar, serow and goral. These species not only showed differential habitat use pattern but also showed differences in their diets. Many workers (e.g. Johnsingh 1983, Green 1987, Khan 1996) have documented occurrence of sambar in closed canopy forests and the same has been recorded in this study. Requirement of very high tree cover by sambar may be responsible for disappearance of it from many oak patches as anthropogenic activities of local people in Kumaon are leading to loss of closed canopy oak forests. The barking deer and goral which may be expected to occur in similar habitat conditions due to similarity in body size, social organisation and vulnerability to predators show considerable differences in their habitat requirements and food habits. Barking deer, which inhabit forested valleys with high under-storey and ground cover, is a selective browser feeding on buds, tender shoots and fruits (Barrette 1977a) whereas goral, known to occur in open and steep grassy slopes, is predominantly a grazer (Green 1987). These differences between similar sized species may again be related to avoidance of competition.

The protected area coverage in the Kumaon Himalayas is low and currently there are two wildlife sanctuaries i.e. Binsar and the Askot Wildlife Sanctuary which cover an area of approximately 645 km² which is approximately 3% of the total land area of Kumaon. Both sanctuaries have very high anthropogenic pressures and one of these i.e. Binsar is just 45 km² in size. Both sanctuaries conserve only barking deer and goral leaving sambar, serow, musk deer and Himalayan tahr unprotected. In order to conserve all ungulate species the protected area coverage must be increased. Areas such as Kilbary, Binayak and Kunjakharak in Nainital and Pindari and Sunderdunga region in Almorah district have very high conservation potential and therefore should be declared as sanctuaries. Creation of these sanctuaries will ensure conservation of all six ungulate species in Kumaon Himalaya. There is also a need for placing some regulation on cutting, lopping, grazing and complete ban on poaching in remaining unprotected oak patches so that existing anthropogenic pressures may be reduced and to allow ungulate populations to increase in abundance.

Table 4.1 Direct and indirect evidences of different ungulate species recorded at surveyed sites in Kumaon Himalaya. BD= barking deer, GO= goral, SA= sambar, SE= serow, HT= Himalayan tahr, MD= musk deer, Status= += indirect evidence only, +*= direct and indirect evidences, -= no evidence

Site name	Ungulate species					
	BD	GO	SA	SE	HT	MD
Kunjakharak	+	+*	+	-	-	-
Binayak	+*	+*	+	-	-	-
Mukteshwar	+	-	+*	-	-	-
Gager	+	+	+	-	-	-
Maheshkhan	+*	+*	+*	-	-	-
Jageshwar	+*	-	-	-	-	-
Sitlakhet	-	+	-	-	-	-
Pandavkholi	+*	+	+	-	-	-
Sunderdunga	-	+	-	+	+	-
Pindari	-	+	-	+	+*	+
Gasi	+	+	-	-	-	-
Binsar	+*	+*	-	-	-	-
Gandhura	+*	+*	-	-	-	-
Daphiyadhura	+	+	-	-	-	-
Majtham	+	+	-	-	-	-
Duku	+	-	-	-	-	-
Sobla	+	+	-	-	-	-

Munsiyari	-	-	-	+	-	-
Mechh	+	+	+	-	-	-

Table 4.2 Mean pellet group density (pellet groups/ha±S.E.) of different ungulate species at surveyed sites in Kumaon Himalaya. N= number of sampling units.

		Ungulate species			
Site name	N	Barking deer	Goral	Sambar	Serow
Kunjakharak	20	22.2±11.5	68.4±19.0	25.4±11.2	00.0±0
Binayak	30	55.1±19.1	8.49±3.0	50.9±17.2	00.0±0
Mukteshwar	31	14.3±6.5	00.0±0	116±30.3	00.0±0
Gager	30	40.3±16.1	2.12±1.4	14.8±5.4	00.0±0
Maheshkhan	30	32.9±10.0	00.0±0	139±20.4	00.0±0
Jageshwar	35	79.1±26.9	00.0±0	00.0±00	00.0±0
Sitlakhet	15	00.0±0	00.0.0±00	0.0±0	00.0±0
Pandavkholi	40	34.2±11.9	16.7±5.0	64.4±10.4	00.0±0
Sunderdunga	37	00.0±0	1.82±1.2	00.0±0	12.0±6.3
Pindari	40	00.0±0	2.38±1.7	00.0±0	2.38±1.7
Gasi	40	15.9±8.0	5.57±3.5	00.0±.0	00.0±0
Binsar	60	88.6±16.3	19.6±10.7	00.0±0	00.0±0
Gandhura	31	1.02±1.0	1.03±1.0	00.0±0	00.0±0
Daphiyadhura	50	10.1±4.7	14.0±3.8	00.0±0	00.0±0
Majtham	20	11.1±4.1	9.55±4.0	00.0±0	00.0±0
Duku	40	7.96±3.7	00.0±0	00.0±0	00.0±0
Sobla	40	6.37±2.3	16.7±5.2	00.0±0	00.0±0
Munsiyari	25	00.0±0	00.0±0	00.0±.0	2.55±2.5
Mechh	20	11.1±4.7	1.59±1.5	3.18±3.1	00.0±0

Table 4.3 List of variables used in discriminant function analysis.

S.No.	Variable code	Variable	Adjustment and discarded criteria
1	ALT	Altitude (m)	Adjusted by log transformation
2	ASP	Aspect	Qualitative data, descarded
3	BG	% bare ground	Correlated with SD, discarded
4	CD	Cattle dung	Adjusted with logtransformation
5	CT	Cut trees	Corr with SD, discarded
6	FIR	Fire	Qualitative data,discarded
7	GA	% of grass cover	Corr with SD, discarded
8	GC	% groung cover	Adjusted by arcsin transformation
9	GDS	Grass species density	Corr with GC,TC, discarded
10	GDV	Grass species diversity	Corr with GC,CD, discarded
11	GP	Grass phenology	Qualitative data, discarded
12	GR	Grass richness	Corr with SD, GC, ALTI, discarded
13	GSP	Grass species	Corr with ALTI, CD, GC, HDS, discarded
14	HAB	Habitat	Qualitative data, discarded
15	HA	% of herb	Corr with HDS, SC, TC discarded
16	HDS	Herb species density	Adjusted by log transformation
17	HDV	Herb species diversity	Corr with HDS, discarded
18	HR	Herb species richness	Corr with HDS, discarded
19	LA	% of litter	Corr with GC, HDS discarded

20	LOC	Location	Qualitative data, discarded
21	LT	Lopped trees	Corr with ALTI, HDS, TC discarded
22	RA	% of rock	Corr with GC, SC, SD, TC discarded
23	SC	Shrub cover	Adjusted by arcsin transformation
24	SD	Shrub species density	Adjusted by log transformation
25	SDV	Shrub species diversity	Corr with GC, SC,SD, TD discarded
26	SH	Shrub height	Corr with ALTI, GC, HDS discarded
27	SLP	Slope	Qualitative data, discarded
28	SR	Shrub richness	Corr with GC, SC, SD, discarded
29	TC	% Tree cover	Adjusted with arcsin transformation
30	TD	Tree species density	Adjusted with log transformation
31	TDV	Tree species diversity	Corr with GC, SD, TD discarded
32	TOPO	Topography	Qualitative data, discarded
33	TR	Tree species richness	Adjusted with log transformation
34	WSA	% Weathered stone	Corr with CD, SC, SD, TC discarded

Table 4. 4 Values of Wilks' Lambda and univariate *F* ratios for variables used in DFA (3 & 256 degree of freedom).

Variables	Wilks' Lambda	*F* ratio	Significance
Altitude	.844	15.802	.000
Cattle dung	.979	.818	.145
Ground cover	.893	10.194	.000
Grass richness	.926	6.842	.000
Herb density	.970	2.654	.049
Herb richness	.985	1.300	.257
Shrub cover	.966	3.047	.029
Shrub density	.846	15.5	.000
Shrub height	.907	8.786	.000
Shrub richness	.956	3.962	.009
Tree cover	.881	11.578	.000
Tree density	.805	8.943	.000
Tree richness	.943	5.154	.002

Table 4. 5 Standardised canonical discriminant function coefficient for 6 variables from a discriminant function analysis of four ungulate species (percentage of total variance extracted by each DF is noted in each column).

Variables	DF1	DF2	DF3
	52.6%	29.1%	18.3%
Altitude	.596*	-.054	.637
Ground cover	.313	.615*	.017
Shrub cover	.309	-.588	.231*
Shrub density	-.580*	.521	.186
Tree cover	-.124	.253	.712*
Tree density	-.241	-.577*	-.098

*Variables showing largest absolute correlation with each function

Figure 4.1a Distribution of species centeroid in relation to discriminant function 1 and 2

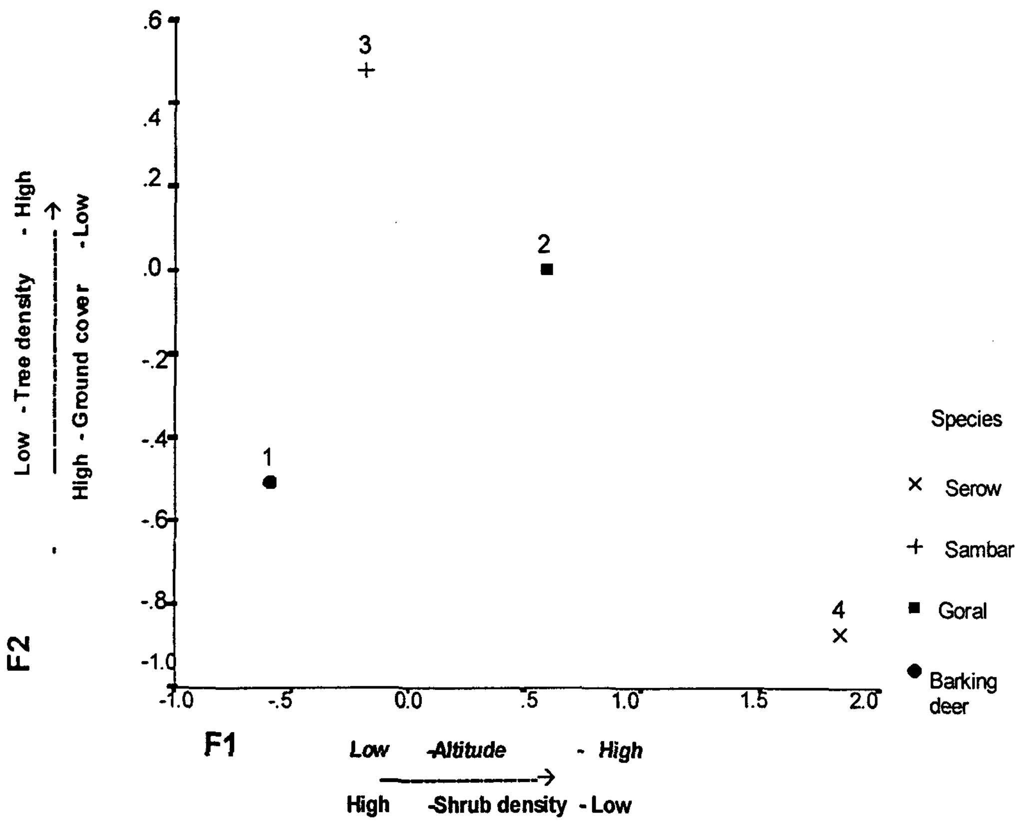


Figure 4.1b Distribution of species centeroid in relation to discriminant function 2 and 3

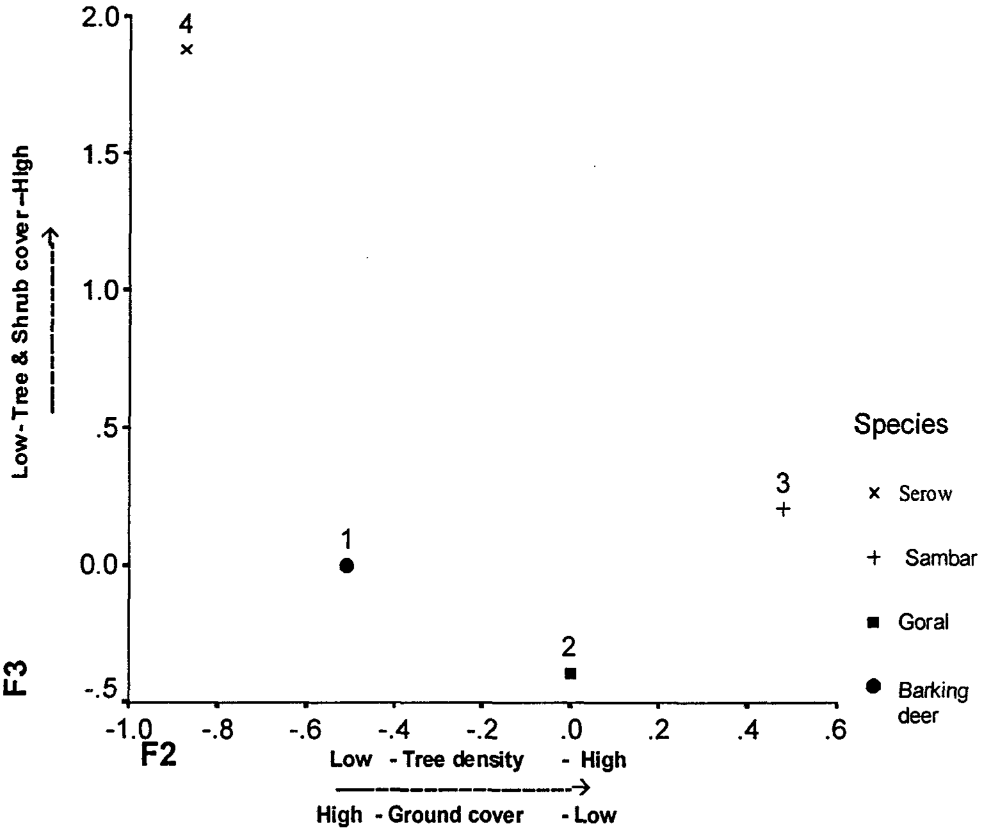


Figure 4.1c Distribution of species centeroid in relation to discriminant function 1 and 3

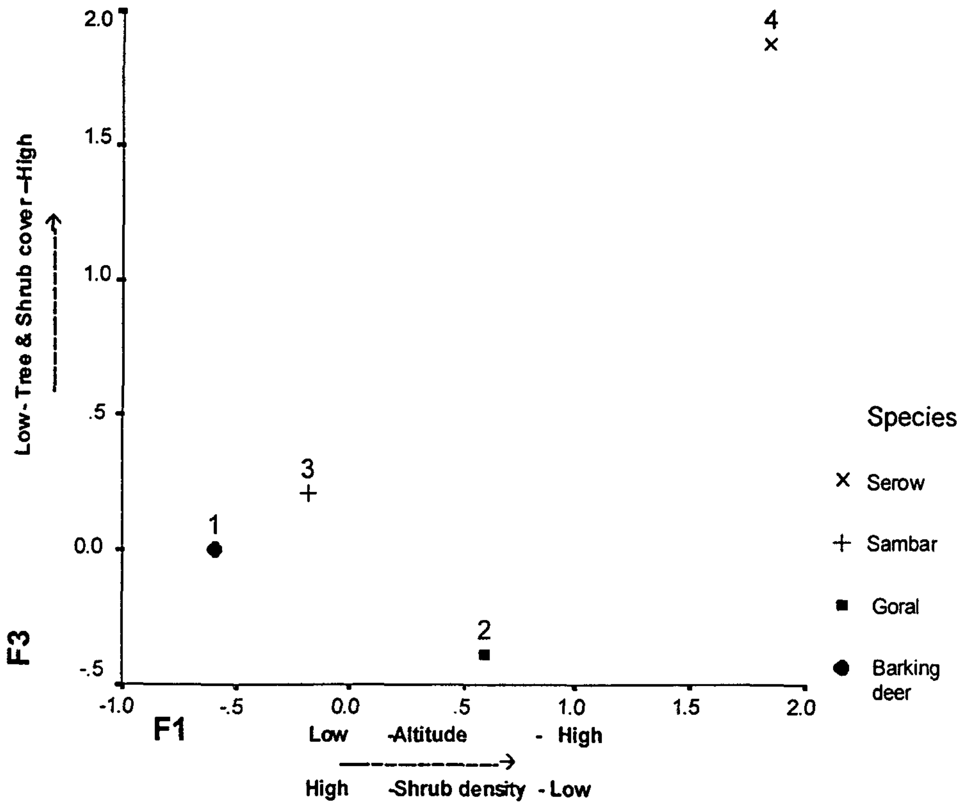
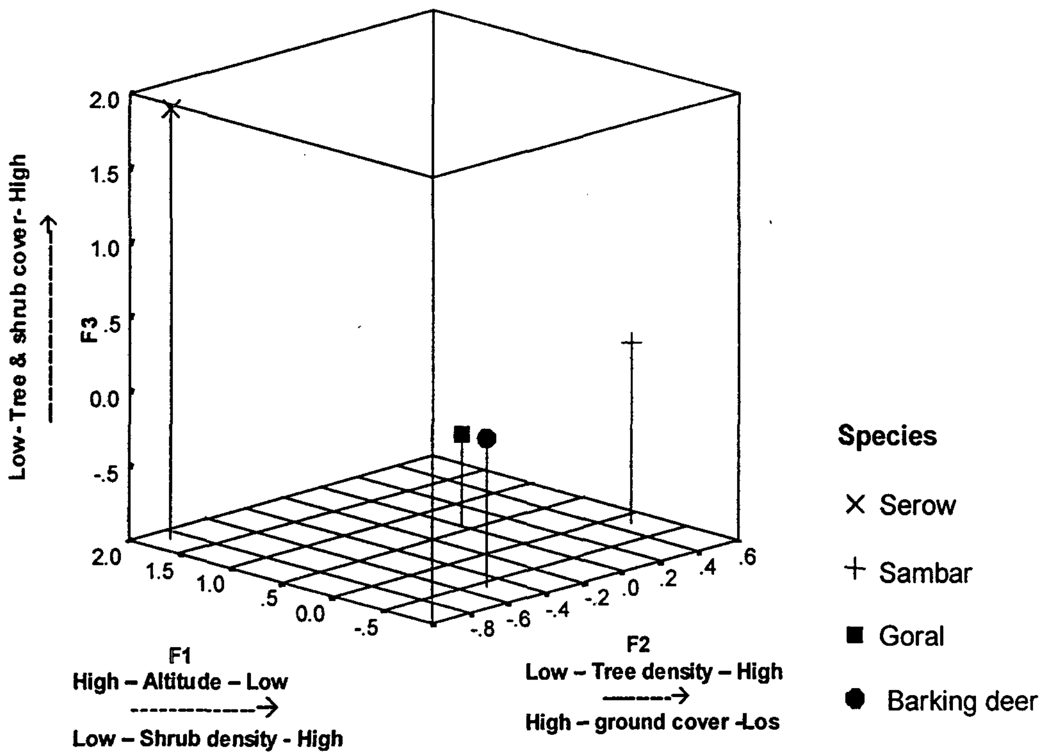


Figure 4. 2 Distribution of ungulate species according to three discriminant functions



CHAPTER 5

ABUNDANCE AND POPULATION STRUCTURE OF BARKING DEER AND GORAL IN BINSAR

5.1 INTRODUCTION

Barking deer (*Muntiacus muntjak*) is distributed over the greater part of Indo-Malayan countries and is also found in China, Formosa and Japan whereas grey goral (*Nemorhaedus goral*) is distributed from Western to Eastern Himalaya (Prater 1980). Once these species were found throughout the Himalaya, but due to habitat destruction and poaching, their populations are now fragmented and confined to many small and medium sized oak patches, and at some places they are locally threatened. The excessive dependency of local people on the oak patches for fuel wood, fodder, timber and other forest produce continue to degrade their habitat. The poaching of barking deer and goral for meat continue to pose a big threat to existing populations.

No work has been done on estimation of abundance and population structure of barking deer and goral in their distribution range. Data on abundance and population structure is vital for conservation and management of a species. In case of Binsar, barking deer and goral constitute important prey items for the thriving leopard population. Therefore changes in population size of barking deer and goral are likely to influence abundance of leopard. In absence of baseline data on abundance for both species, no suitable management strategy can be evolved by managers for predator-prey populations. Moreover the habitat in Binsar undergoes drastic changes annually due to heavy snowing, frequent summer fires, grazing by livestock and wood cutting. Both barking deer and goral may be affected due to fluctuating habitat conditions. The abundance and population structure variables are therefore most suitable tools to assess impact of habitat changes on barking deer and goral populations. This chapter provides the results of population monitoring done in Binsar.

5.2 METHODOLOGY

5.2.1 Data collection

Data on abundance of barking deer and goral were collected using direct and indirect methods, while data pertaining to population structure were collected through direct observations in Binsar. Data collection was done during pre-monsoon season of 1996 and 1998 and post-monsoon seasons of 1996, 1997 and 1998.

Binsar has a good network of forest trails. From the existing trails, four trails were selected for sampling. These trails passed through different habitat types and topographical features. Monitoring of the trails was carried out at down and dusk between 0600 to 0930 hours and 1700 to 1930 hours respectively. For each sighting of barking deer and goral, following data were recorded: a) trail number, b) sighting time, c) species, d) broad habitat type, e) group composition and number of individuals, f) age-sex category whenever it was possible to identify. Abundance estimation of barking deer and goral was also done through pellet group counts. As direct sightings of goral and barking deer were low and highly variable along trails, pellet groups count method was most suitable method available for relative abundance estimation. Following sampling technique was used. Three permanent transacts, each one-km in length were established in oak forest. On each transect, 20 circular plots, each of 10 m radius circular plots were permanently marked at an equal distance interval of 50 m. All the pellet groups falling in these permanent plots were cleared at the beginning of each season. The pellet groups falling in the permanent plots were counted at the end of each season. To collect pre-monsoon data, all plots were cleared during March and plots were left undisturbed for pellet group deposition for entire pre-monsoon season. These plots were visited again at the end of the pre-monsoon season and pellet groups as well as latrine sites were counted in each plot. The same procedure was repeated to collect post-monsoon data. Plots were cleared during August-September and left for accumulation of pellet groups. At the end of the post-monsoon season pellet groups were counted. Data on pellet groups deposition were collected during pre-monsoon seasons of 1996 and 1998 and post-monsoon seasons of 1996, 1997 and 1998. Data were not collected during monsoon as well as during winter due to heavy rain and snowfall respectively.

5.2.2 Data analysis

The sightings of barking deer and goral along each trail were summarised for each season. The data for morning and evening monitorings were pooled for all seasons and mean encounter rate (groups/km) for each trail was calculated for each season. Pellet group density (pellet groups/ha) was calculated separately for each species at each sampling plot using following formula:

$$\text{Pellet group density} = \frac{\text{No of pellet groups}}{\text{Area of each plot}} \times 10{,}000$$

Pellet group density was converted into animal density (individuals/km^2) by dividing the total number of pellet groups recorded on a transect with the mean defecation rate and number of days over which pellet groups were accumulated following Mayle *et al.* 1996.

$$\text{Animal density} = \frac{\text{Observed pellet group density per time period}}{\text{Defecation rate X time period}}$$

In absence of data on defecation rates of barking deer and goral, an average value of 13.5 pellet groups per day was used in density estimation considering the range of defecation rate reported in the literature varies from 12 to 15 pellet groups/ day/deer (Neff 1968).

The Kruskal-Wallis One Way ANOVA was used to test the significant differences in the mean encounter rates of barking deer and goral on different trails during different seasons. It was also used to find out differences between pellet groups density of barking deer and goral on different transacts in different seasons and during different years. The Kruskal-Wallis One Way ANOVA was also used to find out the significant difference in the mean group size of barking deer and goral on different trails and in different seasons between different years. Student *t*-test was performed to find out the differences between the animal density of barking deer and goral within and between the seasons. All statistical tests were done using computer program SPSS PC.

5.3 RESULTS

5.3.1 Encounter rates

Table 5.1 shows the encounter rates of barking deer in different seasons. During pre-monsoon 1996, encounter rate was maximum on first trail (0.296 groups/km) and minimum on fourth trail. There was significant difference in encounter rates between trails (H=4.68, $d.f.$=3, P<0.05). During post-monsoon 1996, encounter rate was maximum on second trail (0.24 groups/km) and minimum on fourth trail (0.01 groups/km) and the differences were significant (H=19.94, $d.f.$=3, P<0.001). During post-monsoon 1997, the encounter rate for barking deer was maximum on second trail (0.17 groups/km) and minimum on third trail (0.07 groups/km). However there was no significant difference in encounter rate of barking deer between trails (H=1.853, $d.f.$=3, P>0.60). During pre-monsoon 1998, the barking deer encounter rate was maximum on second trail (0.172 groups/km) and minimum on first trail (0.02 groups/km). The encounter rate of barking deer did not vary significantly between trails during pre-monsoon 1998 (H=6.28, $d.f.$=3, P>0.078). During post-monsoon 1998 also the encounter rate was maximum on second trail (0.28 groups/km) and minimum on fourth trail (0.04 groups/km) and differences were significant between trails (H=21.2, $d.f.$=3, P<0.001). The overall encounter rate of barking deer (all data combined) was 0.11 groups/km and it varied between trails. The maximum encounter rate was recorded on second trail (0.19 groups/km) and minimum on fourth trail (0.05 groups/km).

Table 5.2 shows the encounter rates for goral on different trails in different seasons. During pre-monsoon season in 1996, there were no encounters of goral on first, second and third trail and the encounter rate on fourth trail was 0.29 groups /km. During post-monsoon season of 1996, goral encounter rate was highest on third trail (0.173 groups/km) and differences between trails were significant (H=18.435, $d.f.$=3, P<0.001). During post-monsoon 1997, goral encounter rate was found to be maximum on third trail (0.19 groups/km) and the differences between the encounter rate of goral on trails were found to be significant (H=17.43, $d.f.$=3, P<0.001). During pre-monsoon 1998 the encounter rate was found to be maximum on third trail (0.30 groups/km). There were significant differences in encounter rates of goral between trails during pre-monsoon 1998 (H= 27.137, $d.f.$= 3, P<0.001). During post-monsoon 1998, the encounter rate was maximum on third trail (0.16 groups/km) and the differences between the encounter rates on different trails were not found significant (H= 5.19, $d.f.$=3, P>0.116). The overall encounter rates were also calculated for different seasons for barking deer as well as for goral. The encounter rate of barking deer was highest during post-monsoon 1998 (0.127 groups/km) while for goral the encounter rate was maximum for post-monsoon 1996 (0.112 groups/km). Kruskal-Wallis One Way ANOVA was used to compare the encounter rates between seasons i.e. pre-monsoon 1996 and 1998, post-monsoon 1996, 1997 and 1998 for barking deer and goral. There was no significant difference in encounter rates of barking deer between different seasons of different years (H=1.019, $d.f.$=4, P>0.907). There was also no significant difference in encounter rates of goral during different seasons (H= 9.19, $d.f.$= 4, P>0.06) during different years.

5.3.2 Pellet group density

Table 5.3 shows that during pre-monsoon season in 1996, barking deer pellet group density was highest on first transect (87.5 pellet groups/ha±91.7) and there was significant difference between the pellet group densities between transacts

(H=6.007, $d.f.$=2, P<0.05). During post-monsoon 1996 the pellet group density (pellet groups/ha) of barking deer was again maximum on first transect (92.3±128.9). However the differences, between pellet group density on different transacts were not significant (H=3.698, $d.f.$=2, P>0.157). During post-monsoon 1997 barking deer pellet group density was maximum on first transect (124.2 ± 156.3). However the differences between pellet group density on different transect were not significant (H=3.194, $d.f.$=2, P>0.203). During pre-monsoon 1998, pellet group density of barking deer was found to be highest on third transect (44.58±105.81). However differences in pellet group density between transacts were not significant (H=2.8, $d.f.$=2, P>0.238). The pellet group density of barking deer was maximum on third transect (36.62±38.04) during post-monsoon 1998, and the differences between pellet group density on different transect were found to be significant (H=6.503, $d.f.$= 2, P<0.03).

The data on goral pellet group densities in different seasons are provided in table 5.4. It shows that the goral pellet group density (pellet groups/ha) was maximum on first transect during pre-monsoon 1996 (36.62±92.57), post-monsoon 1997 (50.95 ±136.3), pre-monsoon season 1998 (30.25±65.6), and post-monsoon 1998 (50.9±137.8). The differences between pellet group densities on different transacts were however not significant during pre-monsoon 1996 (H=1.844, $d.f.$=2, P>0.398), post-monsoon 1997 (H=3.547, $d.f.$=2, P>0.17), pre-monsoon 1998 (H=0.07, $d.f.$=2, P>0.966) and post-monsoon 1998 (H= 2.48, $d.f.$=2, P>0.289). However during post-monsoon 1996 goral pellet group density was found maximum on fourth transect (57.32±122.35). However the differences between pellet group density on different transacts were not significant (H=3.259, $d.f.$=2, P>0.196).

When overall mean pellet group densities of barking deer and goral were calculated for each season and compared, it was found that barking deer pellet group density was maximum during post-monsoon 1997 (88.10±126.1) while goral pellet group density was maximum during post-monsoon 1998 (34.49±101.42). When five seasons in different years were compared for barking deer and goral, it was found that there was significant difference between pellet group densities of barking deer in different seasons (H=15.5, $d.f.$=4, P<0.004). However there was no significant difference between goral pellet group densities in different season (H=2.48, $d.f.$=4, P>0.383).

5.3.3 Estimation of animal density by pellet group data

Table 5.5 provides densities of barking deer and goral which were estimated using pellet groups data in different seasons for 1996 and 1998. During pre-monsoon 1996, barking deer density was found to be 5.5 individuals/km^2. While during post-monsoon 1996 barking deer density was higher (9.3 individuals/Km^2). Differences between mean animal density during pre and post-monsoon 1996 were however not significant (t=1.836, P>0.069). During 1998, the barking deer density was 3.3 individuals/km^2 in pre-monsoon and 2.6 individuals/km^2 in post-monsoon season and the difference between means was not significant (t=0.769 P>0.443). The barking deer density was compared between same seasons in different years. During pre-monsoon 1996 and 1998, barking deer density was higher in pre-monsoon 1996 (5.5 individuals/km^2) but the difference between mean was not significant (t=1.55, P>0.123). During post-monsoon seasons of 1996 and 1998, barking deer density was higher in 1996 (9.3 individuals/km^2) and the difference between mean was highly significant (t=3.655, P<0.001).

The goral density was maximum in post-monsoon season 1996 (3.7 individuals/km^2). But the difference between means was not found significant (t=1.208, P>0.229). During pre and post-monsoon 1998, the goral density was higher in post-monsoon season but difference between mean was not found significant (t=0.578, P>0.564). The mean density of goral was also compared between same seasons. The goral density was same during both pre-monsoon seasons 1996 and 1998. During post-monsoon seasons of 1996 and 1998, the goral density was higher in post-monsoon 1996 (3.7 individuals/km^2). However difference between means was not significant (t=0.645, P>0.52).

5.3.4 Group size of barking deer and goral

The group size of barking deer ranged from 1 to 3 individuals in all seasons (Fig. 5.1). The contribution of groups of one individual ranged from >71% during post-monsoon 1998 to 89% during pre-monsoon 1998 (Table 5.6). Table 5.8 shows the mean group size (group size/trail) of barking deer on different trails in pre and post-monsoon season. In general, the group size was smaller in pre-monsoon season and there was marginal increase in it during post-monsoon season. The mean group size (Mean group size±SD) was 1.22±0.415 during pre-monsoon 1996 and it was maximum on trail 2 (1.33±0.47). While in post-monsoon 1996, the overall mean group size of barking deer was 1.09±0.29 and it was maximum on trail 1 (1.125±0.33). There was no significant difference between mean group size on trails during pre-monsoon (H=1.031, $d.f.$=3, P>0.794) and post-monsoon (H=0.775, $d.f.$=2, P>0.368) season. Differences between overall mean group size values between the pre and post-monsoon seasons were also not significant (H=0.734, $d.f.$=1, P>0.392). During post-monsoon season of 1997, the overall mean group size was found to be 1±0 and it was maximum on trail 4 (1.37±0.695). The differences between trails were not significant (H=3.25, $d.f.$=3, P>0.354). The overall mean group size of barking deer in pre and post-monsoon 1998 was 1.13±0.34 and 1.34±0.59 respectively and group size was maximum on second trail in both seasons. The difference in mean group size of barking deer was not significant (H=2.079, $d.f$=1, P>0.149) between pre and post-monsoon seasons of 1998.

The group size of goral ranged from 1 to 9 individuals (Fig. 5.2). There was preponderance of groups of 3 individuals as 42% of groups were of one individual, 38% groups of two individuals, and 6% groups of 3 individuals during pre-monsoon 1996. During post-monsoon season 1996, groups of 1, 2 and 3 individuals contributed 36.5%, 34.92% and 20.6% respectively. During post-monsoon 1997, about 45%, 34% and 22% groups were of 1, 2 and 3 individuals respectively. During pre-monsoon 1998, about 45% of groups comprised of one individual while about 38% groups of two individual were observed. About 27%, 36% and 22% groups were of 1, 2 and 3 individuals respectively during the post-monsoon season of 1998 (Table 5.7). Table 5.9 provides the values of mean group size of goral in different seasons. In general the mean group size was larger in post-monsoon season as compared to pre-monsoon season during both years. The group size was smaller in pre-monsoon season and there was marginal increase in it during post-monsoon season. The mean group size was 2.3±1.51 during pre-monsoon 1996 and it was maximum on trail 3 (2.61±1.49). While in post-monsoon 1996, overall mean group size was 2.38±1.34 and it was maximum on trail 3 (2.22±1.47 group ± SD). There was no significant difference between mean group size on trails during post-monsoon (H= 0.775, $d.f.$=2, P>0.368). Differences between the pre and post-monsoon seasons of 1996 were also not significant (H=1.125, $d.f.$=1, P>0.289). During post-monsoon season 1997, the overall mean group size of goral was found to be 2.0±0 group and it was maximum on trail 3 (2.176±2.0). The difference between group size between trail was not significant (H=.674, $d.f.$=2, P>0.714). The overall mean group size of goral in pre and post-monsoon season 1998 was 2.19±1.83 and 2.34±1.4 respectively and mean group size was maximum on trail 3 (2.5±2.08) during pre-monsoon 1998 and the differences between trails were not significant (H=1.99, $d.f.$=2, P>0.368). The mean group size was maximum on second trail (3.11±1.66) during post-monsoon 1998 and the difference between the trails were not significant (H= 4.03 $d.f.$=3, P>0.258). Differences between mean group size in different seasons of 1998 were also not found significant (H=0.951, $d.f.$=1, P>0.329).

5.3.5 Population composition

Table 5.10 provides the details of individuals classified in different seasons. A total of 188 individuals of barking deer were classified for age and sex composition. Out of 188 individuals, 119 (63.29%) were adult males, 40 individuals (21.27%) were adult females and 5 individuals were (2.6%) sub-adults, 1 (0.53%) fawn and 23 individuals (12.23%) remained unidentified. The sex ratio was biased in favour of males (Table 5.11). A total of 270 goral were classified for age and sex composition. Out of 270 individuals, 106 individuals were (39.25%) adult males, 64 individuals (23.70%) were adult females, 21 individuals (7.77%) were sub adults, 4 individuals were fawns (1.4%) and 75 individuals could not be classified (27.7%). The sex ratio was biased in favour of males.

5.4 DISCUSSION

The methods of estimating size of ungulate population fall into two categories: direct and indirect. The choice of method depends on a variety of factors such as behaviour of species, terrain, man power available and the accuracy required in results. There has been rapid advancements in the field of population estimation using direct method such as line transect or more appropriately distance sampling (Burnham *et al.* 1980, Buckland *et al.* 1993). Many studies have utilised distance sampling to produce estimations of population densities for different taxa in a variety of habitats. However the distance sampling is best and robust provided the key assumptions are not violated. Under the present study which was carried out in central Himalaya, the rugged terrain of the study area and extremely low abundance of target species completely ruled out the possibility of use of distance sampling. Therefore apart from monitoring of trail, the use of indirect method was found to be ideal.

The most usual indirect method of assessing ungulate population is through faecal pellet count. The method has been used extensively to asses densities for Moose *Alces alces* L. (Cairrns and Telfer 1980, Forbs and Theberge 1993), wapiti and red deer *Cervus elaphus* (Mitchell *et al.* 1983, Roeland *et al.* 1984, Ratcliffe 1987), white tailed deer *Odocoileus virginianus* (Neff 1968, Stormer *et al.* 1977, Cairns and Telfer 1980), mule deer *Odocoileus hemionus* (Rogers *et al.* 1958, Freddy and Bowden 1983, Collins and Urness 1984), roe deer *Capreolus capreolus* (Padaiga and Marma 1979, Stains and Welch 1984, Mitchell *et al.* 1985, Lindstrom *et al.* 1994), fallow deer *Dama dama* (Bailey and Putman 1981 Stubbe and Goretzki 1991), and Axis deer *Axis axis* (Dinerstein and Dublin 1982). Most of these studies have attempted to estimate population density through defecation rate since daily defecation rates have been worked out for a number of species in captivity. However, in India, there is no base line data available on the defecation rate of majority of ungulate species including barking deer and goral. Studies on defecation rates have shown that the defecation rate varies between sex and age class within a species as well as between seasons and majority of studies conducted in north American ungulates have shown that the average daily defecation rates vary between 12 and 15 pellet groups per day per deer (Neff 1968). In absence of data on defecation rates of barking deer and goral, an average value of 13.5 pellet groups per day deer was used in density estimation. Although Dinerstein and Dublin (1982) have recorded defecation rate of axis deer to be 28 pellet groups per day per deer in the Royal Karnali-Bardia Wildlife Reserve in Nepal. However defecation rate of

28 pellet groups per day per deer based on just a single study does not provide enough justification to use these values for population estimation under the present study.

The encounter rate of barking deer was highest on second trail except for pre-monsoon season of 1996 and minimum on fourth trail. The goral encounter rates were highest on third trail in all seasons except during pre-monsoon season in 1996. Similarly the pellet group densities were consistently higher on first transect in all seasons for both species except during post-monsoon 1998 when maximum barking deer pellet group density was recorded on second transect. This suggests that areas through which trails and transacts on which maximum abundance was recorded for both species provided ideal habitat conditions. However the lack of sightings of goral on first trail shows that the habitat conditions on this trail were exclusively optimum for barking deer. In general the abundance of both species was slightly higher in post-monsoon season. However lack of significant difference showed that abundance pattern did not change either between seasons or between different years suggesting stable population densities for both species.

Barking deer emerges as a solitary animal as groups of one individual contributed more than 80% in the population. These findings are in conformity with Barrette (1977a) who recorded 64.5% of barking deer groups to be of single individual. The mean group size of barking deer was 1.17 in pre-monsoon season (all values combined) while it was 1.06 in post-monsoon season. These values are lower than the value of barking deer group size (1.41) recorded by

Barrette (1977a). On the contrary the range of group size of goral was 1 to 9 and a maximum of 45% of groups belonged to single individual only. Therefore in a relative sense goral is more gregarious than barking deer in Binsar as the average group size of goral being 2.2 (all values combined) in pre as well as post- monsoon season was higher than barking deer. Pendharkar and Goyal (1995) estimated the mean group size of goral to be 1.6 individual during summer and 1.8 individual during winter and the largest aggregation of goral was comprised of 11 individuals in the Simbalbara Sanctuary. The average group size of goral in Majhatal Harsang Wildlife Sanctuary was estimated to be 1.8 (range1-18) by Mishra and Johnsingh (1996). Therefore the average group size in Binsar is higher compared to these studies but the size of largest group of goral is smaller than the values reported by Engleman (1938), Pendharkar and Goyal (1995), Geptner *et. al.* (1989) and similar to values reported by Cavallini (1992) and Satyakumar (unpublished data cited in Pendharkar and Goyal 1995).

Small bodied ungulates have higher basal metabolic rates as compared to large bodied ungulates. This in turn forces smaller ungulates to feed on highly nutritious food items in order to meet the higher energy requirements. Since the high quality food items are short in availability compared to less nutritious food items, it has been hypothesised that small sized ungulates will occur either in very small units or will tend to be solitary. Barking deer and goral are selective feeder (see chapter on food habits) and therefore remain solitary or in small units. Pendharkar and Goyal (1995) found that mostly males occurred as solitary animals and smaller units of 2 to 3 individuals comprised of female and sub adults in goral.

Despite occurring as solitary animals, barking deer and goral differed in their food habits as barking deer fed on browse while goral fed on grass. The former utilised closed canopy habitat while latter used open canopy habitat. Both species therefore tended to have contrasting anti predator strategies. While barking deer relied more on concealment in thick under-storey, goral utilised areas with cliffs and maintained large flight distance.

The sex ratio in both species was found to be extremely biased in favour of males. A large percentage of animals could not be classified due to monomorphism in case of goral and thick under-storey in case of barking deer. Therefore any likely explanation for skewed sex ratio would not be complete. However females, due to being in larger units than solitary males are more vulnerable to poaching and it is highly probable that more females are being poached in Binsar than males making the sex ratio biased in favour of females. Poaching of barking deer and goral occurred throughout the year by local people which perhaps is the singular factor responsible for low abundance of these species in Binsar Wildlife Sanctuary.

Table 5.1 Encounter rates (groups/km±SD) of barking deer on different trails in different seasons in Binsar Wildlife Sanctuary.

Season	Trail I	Trail II	Trail III	Trail IV	Overall
Pre-Monsoon 96	0.29	0.13	0.08	0.03	0.11
Post-Monsoon 96	0.23	0.24	0.06	0.01	0.12
Post-Monsoon 97	0.12	0.17	0.07	0.08	0.11
Pre- Monsoon 98	0.02	0.14	0.12	0.08	0.09
Post-monsoon 98	0.12	0.28	0.11	0.03	0.12
Overall	0.16±0.10	0.19±.06	0.09±02	0.05±.03	0.11±.01

Table 5. 2 Encounter rates (groups/km) of the goral on different trails in different seasons in Binsar Wildlife Sanctuary.

Season	Trail I	Trail II	Trail III	Trail IV	Overall
Pre-Monsoon 96	0	0	0	0.29	0.08
Post-Monsoon 96	0	0.01	0.17	0.02	0.11
Post-Monsoon 97	0	0.06	0.19	0.08	0.09
Pre- Monsoon 98	0	0.04	0.30	0.14	0.11
Post-monsoon 98	0	0.03	0.16	0	0.04
Overall	0	0.02±0.02	0.16± 0.1	0.1± 0.1	0.08± 0.02

Table 5. 3 Mean pellet group density (pellet groups/ha±SD) of barking deer in different seasons on different transects in Binsar Wildlife Sanctuary.

Season	Transect I	Transect II	Transect III	Overall
Pre-monsoon 96	87.57±91.76	70.06±104.66	22.29±35.94	59.97±85.47
Post-monsoon 96	92.36±128.9	82.89±97.74	28.66±55.55	67.97±100.3
Post-monsoon 97	124.2±156.31	100.39±129.47	39.80±52.2	88.10±126.1
Pre-monsoon 98	44.58±105.81	39.81±58.61	14.33±34.11	32.9±73.76
Post-monsoon 98	36.62±38.04	44.73±74.87	14.33±39.61	33.49±101.42

Table 5.4 Mean pellet group density (pellet groups/ha±SD) of goral in different seasons on different transects in Binsar Wildlife Sanctuary.

Season	Transect I	Transect II	Transect III	Overall
Pre-monsoon 96	36.62± 92.57	12.74± 44.32	17.5±33.44	22.29±61.61
Post-monsoon 96	55.75± 98.56	20.7 ± 41.85	4.77 ±11.36	27.07±64.47
Post-monsoon 97	50.95±136.38	1.59± 6.9	6.36± 16.23	19.63±82.45
Pre-monsoon 98	30.25± 65.63	15.92±37.0	12.73 ±21.11	19.63±45.81
Post-monsoon 98	50.95±137.86	30.25± 97.88	22.29 ±42.84	34.49±101.42

Table 5.5 Mean density (individuals/km^2) of barking deer and goral in different seasons in Binsar Wildlife Sanctuary.

Year	Barking deer		Goral	
	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
1996	5.5	9.3	2.0	3.7
1998	3.3	2.6	2.0	2.9
Mean	4.4±1.5	5.9±4.7	2.0±0.0	3.3±0.56

Table 5. 6 Percentage of groups of barking deer in different group size category in different seasons in Binsar Wildlife Sanctuary.

Seasons	Groups size		
	1	2	3
Pre-monsoon 1996	82.1	17.8	0
Post-monsoon 1996	83.4	13.5	2.9
Post-monsoon 1997	87.5	10	2.5
Pre-monsoon 1998	89.2	10.7	0
Post-monsoon 1998	71.8	21.8	6.2

Table 5. 7 Percent of groups of goral in different group size category in different seasons in Binsar Wildlife Sanctuary.

Seasons	Groups size								
	1	2	3	4	5	6	7	8	9
Pre-monsoon 1996	42	38	6	2.0	8.0	2.0	2.0	0	2.0
Post-monsoon 1996	36.5	34.92	20.6	1.5	1.5	4.76	0	0	1.5
Post-monsoon 1997	45.16	34.9	22.58	3.22	0	0	0	0	0
Pre-monsoon 1998	45.16	38.7	0	0	9.6	3.22	0	0	0
Post-monsoon 1998	27.2	36.36	22.72	0	0	9.0	0	0	0

Table 5. 8 Mean group size±SD of barking deer on different trails in different seasons in Binsar Wildlife Sanctuary.

Season	Trail I	Trail II	Trail III	Trail IV	Overall
Pre-Monsoon 96	1.25±0.43	1.33±0.47	1.0±0	1.0±0	1.22±0.41
Post-Monsoon 96	1.12±0.33	1.11±0.32	1.0±0	1.0±0	1.09±0.29
Post-Monsoon 97	1.0±0	1.0±0	1.0±0	1.37±0.69	1.0±0
Pre- Monsoon 98	1.0±0	1.23±0.42	1.16±0.37	1±0.37	1.137±0.34
Post-monsoon 98	1.0±0	1.58±0.75	1.16±0.37	2±0	1.34±0.59

Table 5.9 Mean group size±SD of goral on different trails in different seasons in Binsar Wildlife Sanctuary.

Season	Trail I	Trail II	Trail III	Trail IV	Overall
Pre-Monsoon 96	0	0	2.61±1.49	0	2.3±1.51
Post-Monsoon 96	0	2±0	2.22±1.47	2±0	2.38±1.34
Post-Monsoon 97	0	2±0.89	2.176±2.0	2±0.63	2.0±2
Pre- Monsoon 98	0	1.25±0.43	2.5±2.08	2±1.58	2.19±1.83
Post-monsoon 98	2±0	3.11±1.6	1.9± 0.94	1.5±0.5	2.34±1.4

Table 5. 10 Age and sex composition of barking deer and goral in Binsar Wildlife Sanctuary. n = total number of individuals classified.

Species	n	Male	Female	Sub adult	Juvenile	unidentified
Barking deer	188	63.2	21.2	2.6	0.53	12.2
Goral	270	39.2	23.7	7.7	1.4	27.7

Table 5. 11 Sex ratio (adult male:100 female) in barking deer and goral in Binsar Wildlife Sanctuary.

Species	Male	Female
Barking deer	297	100
Goral	165	100

Figure 5.1 Percent distribution of groups of goral in different group size category.

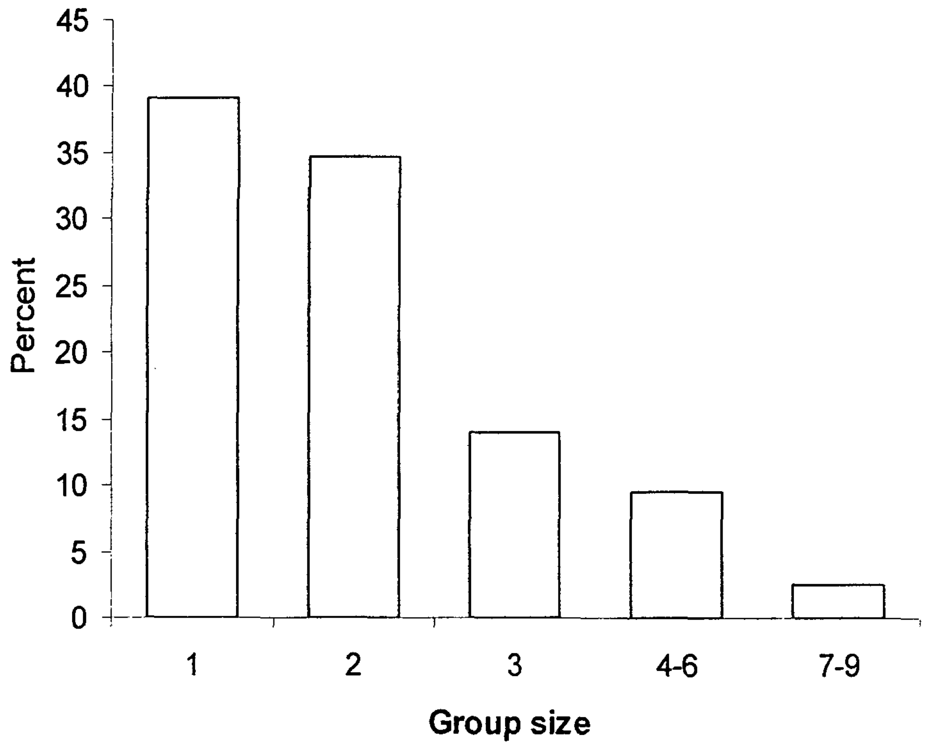
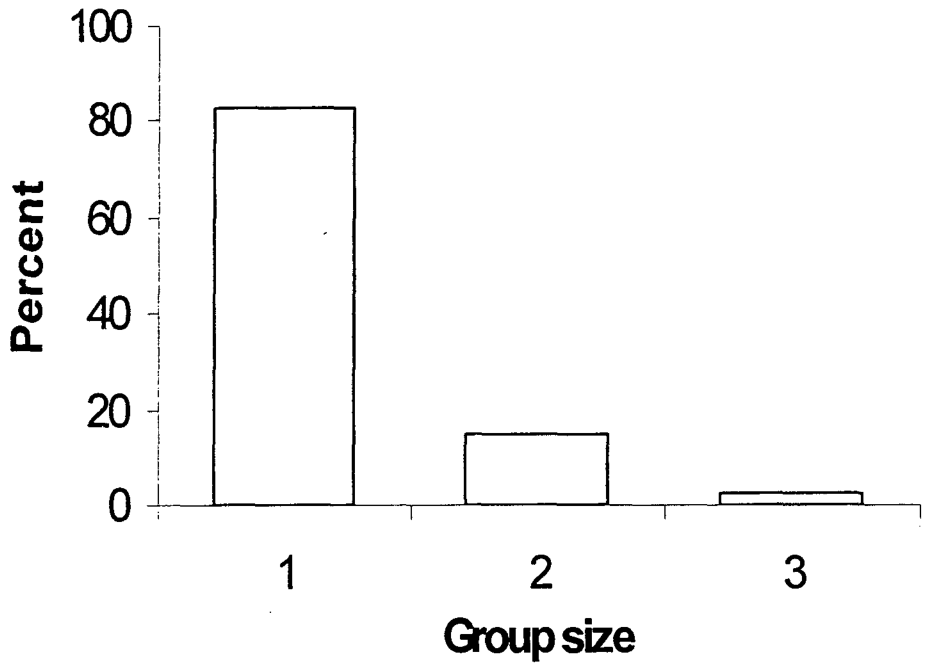


Figure 5.2 Percent distribution of groups of barking deer in different group size category.



CHAPTER 6

HABITAT USE OF BARKING DEER AND GORAL IN BINSAR

6.1 INTRODUCTION

The habitat factors influencing distribution and macro habitat use at landscape level by barking deer and goral were investigated in chapter 4. It was found that both species differed in their macro habitat use and were separated considerably in ordination space represented by discriminant function F1, F2 and F3. Significant differences existed in habitat requirements of both species and altitude played a major role in spatial segregation of both species together with habitat factors such as tree and shrub density, ground cover etc. However understanding of habitat requirement gained at landscape level may not be sufficient for managing these species in a small area like Binsar due to variety of reasons. Firstly significant differences may exist between macro and micro-habitat use of a species. Secondly the macro habitat use was investigated while carrying out the status survey which does not take into account seasonal differences which might occur in habitat use of both species. Thirdly the scale and sampling intensity would differ considerably between macro and micro-habitat investigation. The former being more broad based and extensive while the latter being very detailed and intensive. In an mountainous environment the altitude tends to play an overriding role masking influence of several key habitat features which themselves are significantly correlated with altitude. In a localised investigation such as that carried out at the Binsar, apart from altitude, it is the information on features of vegetation and topography, which may be of greater interest for managers so that suitable management strategy may be devised for management of both species.

This chapter deals with seasonal habitat use of barking deer and goral investigated in the Binsar Wildlife Sanctuary. Both direct and indirect approaches were utilised for data collection due to low number of sightings of target species.

6.2 METHODOLOGY

6.2.1 Data collection

The data on habitat use by barking deer and goral in the Binsar was collected by using direct and indirect methods from Pre-monsoon 1996 to post-monsoon 1998. Four existing forest trails in the Sanctuary were selected for the data collection. These trails were monitored in early morning (0600-0930 hours) and late evening (1600-1900 hours) when animals were most active. Morning and evening monitorings were done alternately. For each sighting of barking deer and goral on trail, we recorded data on: a) altitude, aspect, slope, and location, b) vegetation type and vegetation factors, c) disturbance factors (cutting, lopping, cattle dung and fire).

Tree species and their individuals were counted in 10 m radius circular plot for tree density, diversity and species richness estimation. The locations of circular plot was exactly where the animal was seen. Tree cover was measured using a mirror of 25 x 25 cm dimension divided into equal grids of 5 cm x 5 cm. The cover was estimated at four location around the plot. The mirror was kept horizontally at 1.25 m above the ground level and all grids, which were covered by >50% tree foliage were counted and converted into percent tree cover. Shrub species (including the tree seedlings and saplings) and their individuals were counted in 3 m radius circular plot. Shrub height was measured using a measuring tape and shrub cover was measured by ocular estimation using a nominal scale of 0-20%, 21-40%, 41-60%, 61-80% and >80%.

The grass and herb composition was quantified by laying four quadrates of 0.50 x 0.50m dimension at four different locations around the plot and all grass and herb species and their individuals were counted. The ground cover was estimated by point intercept method (Canfield 1941). A meter tape was laid on the ground in four directions and intercepting materials (herbs, grass, litter, bare ground, weathered stone and rock) was recorded at 5 cm interval.

Data on disturbance factors such as tree cutting, lopping, grazing and fire were also recorded at each sampling point. Number of cut trees, lopped trees and cattle dung piles were counted in 10 m radius circular plot. Fire data were recorded in terms of presence/absence of fire at each sampling plot The sampling of habitat variables around sightings of ungulates constituted the utilisation data (animal plots) for analysis purposes.

Intensive vegetation sampling was also carried on either side of the trail at every 100 m distance on all the four trails in order to collect habitat availability data. The sampling of vegetation and disturbance factors was done using the strategy described previously. A total of 80 plots were sampled for vegetation data.

Due to rugged terrain and dense vegetation, there were limited number of direct sightings of barking deer and goral. It was, therefore, decided to collect data on indirect evidences also. Presence of pellet groups is one of the indicators of habitat use by the ungulates. Three permanent transacts of one km each were established in different areas of the oak forest in order to sample the pellet groups.

Permanent circular plots of 10 m radius were established at 50 m distance interval on all three transacts. These plots were cleared before the onset of pre as well as post-monsoon seasons. Pellet groups and latrine sites were counted at the end of each season. A total of 60 plots were established along the transacts. Data on habitat parameters as well as various disturbance attributes such as cutting, lopping and grazing were also collected at each sampling plot following the same sampling strategy used for direct sightings.

6.2.2 Data analysis

The direct sighting data for barking deer and goral were organised in sample-habitat parameter matrix for each pre-monsoon and post-monsoon season in order to investigate the habitat use by both species. Direct and indirect data collected during 1996 and 1998 were pooled to prepare a single data matrix for pre and post-monsoon season. The species diversity and species richness of trees, shrubs, herbs and grasses for each plot were calculated by using Shannon-Weiner Index (H') for species diversity and Margelefs index (RI) for species richness following the formulae:

$H' = -\Sigma$ pi log pi and RI = S-1/ ln N

where pi is the proportion of i^{th} species in sample; S is the number of species in sample and N is the number of total individuals. Tree, shrub, herb and grass densities were calculated for each sampling plot and incorporated in data matrix.

To understand the habitat use by barking deer and goral, data were subjected to Principal Component Analysis (PCA). All the quantitative data in the data matrix were transformed using Log and Arcsine transformation and were standardised following Zar (1984). Factor analysis was used to reduce the dimensionality of the habitat variables and this was done for pre-monsoon and post-monsoon seasons for direct sighting data. The first two factors were used for interpretation as these explained maximum variation in the data set. Before using PCA most of the auto-correlated variables were dropped. PCA was performed using *Varimax* rotation and factor scores were saved. Extracted factors were subjected to Pearson Product Moment correlation analysis with habitat variables to find out significant correlations between habitat variables and factors. Availability and utilised plots were plotted in two dimensional space defined by PC I and PC II. All the extracted factors with *eigen* values of more than one were saved and used for the logistic regression analysis. Logistic regression was done on the random and animal centred plots.

The pellet group data for barking deer and goral were analysed by performing *t* test for mean values of different habitat variables in available and utilised plots. All statistical tests were carried out following Zar (1984) using computer statistical package SPSS. The One Way Analysis of Variance was used to test for significant differences in mean pellet group densities viz-a-viz different slope aspects, burnt/un-burnt areas etc.

6.3 RESULTS

6.3.1 Direct sighting data of barking deer and goral

The first two principal components accounted for 32.3% of variance in pre-monsoon data matrix (Table 6.1). The first factor was highly positively correlated with altitude (r= 0.77, P<0.01) and tree cover, richness and density (r = 0.46, 0.54

and 0.37, $P<0.01$) while it was negatively correlated with slope (r=-0.74, $P<0.01$) and grass cover (r=-0.59, $P<0.01$). The second factor was highly positively correlated with herb density and richness (r=0.72, 0.74, $P<0.01$). Figure 6.1 shows the distribution of utilised and available plots in relation to first and second component. The logistic regression model had an efficiency of 71.32% correct classification of random and barking deer observed plots.

During post-monsoon season the first two components accounted for 30% of variation in data matrix (Table 6.2). The Fig. 6.2 shows the distribution of available and utilised plots in relation to first and second component. The first factor is highly positively correlated with tree cover, tree density and altitude (r =0.72, 0.63 and 0.57, $P<0.01$) but negatively correlated with ground cover and grass density (r=-0.68, 0.63, $P<0.01$). Second factor was positively correlated with shrub cover, density, diversity and shrub richness (r=0.58, 0.63, 0.78 and 0.80, $P<0.01$). During post-monsoon season, barking deer preferred areas with medium to high tree cover, density, and diversity with high shrub cover, density, diversity and richness. The classification done by the logistic regression model had an efficiency of 75% of correct classification of random and barking deer centred plots.

Table 6.3 and 6.4 provides the component loading for ground PCA performed on direct sightings of goral in pre and post-monsoon season. During pre-monsoon the first two factors accounted for 36.9% of the variation in data set. The first factor was highly positively correlated with altitude, slope and shrub richness, shrub height (r=0.87, 0.90, 0.80 and 0.84, $P<0.01$). The second factor was highly positively correlated with grass cover and richness (*r* = 0.71, 0.51, *P*<0.01) but negatively correlated with tree cover (*r* = -0.63, *P*<0.01). The available and utilised plots were plotted against first and second factor (Fig. 6.3).

The figure 6.3 shows that goral prefers areas with high grass density, grass cover, steep slope with low to medium shrub density, height, shrub richness at higher altitude. The logistic regression model had an efficiency of 71% of correct classification of random and goral centred plots.

During post-monsoon season, the first two factors accounted for 29.8% of variation in habitat data (Table 6.4). The first factor was highly positively correlated with altitude (*r*=0.77, *P*<0.01) and negatively correlated with tree cover and tree density (*r*=0.72, 0.68, *P*<0.01). The second factor was highly positively correlated with gradient of herb i.e., herb density, diversity and richness (*r* = 0.74, 0.94, 0.87, *P*<0.01). The available and utilised plots were plotted against first and second factors (Fig 6.4). Figure 6.4 showed that goral utilised areas on higher altitude with low tree cover and tree density but with high herb density, diversity, and richness. The logistic regression model had an efficiency of 80% of correct classification of available and utilised plots.

6.3.2 Pellet group data of barking deer and goral

Table 6.5 provides the mean values of different habitat variables between available and utilised plots of barking deer. The mean values between available and utilised plots differed significantly viz-à-viz herb density (*t*=2.18, *P*<0.05), number of shrub species (*t*=2.61, p<0.01), tree cover (*t*= 3.72, *P*<0.001), tree diversity (*t*=2.7, *P*<0.01) and tree density (*t*=2.48, *P*<0.05). Except for herb density, other variables have significantly higher values for utilised plots. The barking deer pellet group density was negatively correlated with grass cover and number of herb species. The barking deer pellet group density was however positively correlated with Shrub richness, tree cover and tree diversity during pre-monsoon season (Table 6.7). Barking deer therefore used forested areas with high tree density, cover and diversity.

During post-monsoon season, the available and utilised plots differed with respect to percent grass cover (t= 3.60, P<0.001), shrub number (t=3.99, P<0.001), shrub cover (t=3.98, P<0.001), shrub diversity (t= 4.23, P<0.001), shrub density (t=3.67, P<0.001), shrub species (t=-5.78, P<0.001), tree number (t=3.98, P<0.001), tree cover (t=4.31, P<0.001), tree diversity (t=-4.44, P<0.001), tree density (t= -3.92, P<0.001), tree richness (t=3.78, P<0.001), tree species (t=-4.22, P<0.001), percent withered stone (t= 3.04, P<0.01). Except for percent grass cover, all other habitat variables had significantly higher values for utilised plots. The barking deer pellet group was negatively correlated grass density but it was positively correlated with shrub diversity, richness, cover, density and tree diversity, richness, cover and density (Table 6.7). This suggests that during post-monsoon season also, barking deer used areas which had high shrub density, diversity, richness, tree cover, density and diversity (Table 6.5).

Table 6.6 provides the mean values of different habitat variables for available and utilised plots of goral. During pre-monsoon season, there were significant difference between mean values of available and utilised plots viz-a-viz. herb density (t=-2.29, P<0.05) rockiness (t=-2.24, P<0.05), shrub number

(t=2.31, P<0.05) and shrub density (t=-2.35, P<0.05). The utilised plots had significantly higher values for these variables. The goral pellet group density was positively correlated with grass richness, herb cover, rockiness, shrub cover and shrub density. Goral utilised open rocky areas with good herb and shrub density. During post-monsoon season, a greater number of variables showed significant differences. The available and utilised plots differed significantly with respect to grass cover (t=5.68, P<0.001), percent herb cover (t=2.58, P<0.05), herb diversity (t=-2.07, P<0.05), litter cover (t=4.08, P<0.001), rockiness (t=2.89, P<0.01), tree number (t=2.42, P<0.05), tree diversity (t=2.04, P<0.05), tree density (t=2 48, P<0.05) and tree species (t=2.6, P<0.01).

While grass cover, percent herb, herb diversity, rockiness had significantly higher mean values for utilised plots, the values for litter cover, tree number, tree diversity, tree density and tree species were significantly higher for available plots. The goral pellet group density was positively correlated with grass cover, rockiness, shrub cover, tree diversity and slope. However it was negatively correlated with litter and tree richness (Table 6.7). This suggests that goral used open rocky areas with good grass cover and avoided areas with high litter cover. During pre-monsoon season, barking deer pellet group density was maximum on north-west facing slope (72.7±19.9 pellet groups/ha±SE) while during post-monsoon season the barking deer pellet group density was maximum on north facing slope (116.77±35.52 pellet groups/ha±SE). The difference between different aspects of slopes were not significant in both seasons ($F_{7, 112}$=1.203, P>0. 307 and $F_{7, 172}$= 2.174, P>0 .039, Table 6.8).

The goral pellet group density was maximum on West facing slope during pre-monsoon season (40.69±12.56 pellet groups/ha ±SE) while during post-monsoon season the goral pellet group density was maximum on south facing slopes (84.92±49.5 pellet groups/ha±SE). The difference between different aspects was, however, not significant ($F_{7,\ 112}$=1.17, P>0.323 and $F_{7,\ 172}$ =2.372, P>0.024) (Table 6.9)

Barking deer pellet groups were present in burnt as well as un-burnt areas. During pre as well as post-monsoon seasons pellet group density of barking deer was maximum in un-burnt area (54.42±10.39 pellet groups/ha±SE and 75.91 ±23.82 pellet groups/ha±SE respectively). However there was no significant difference between burnt and un-burnt areas ($F_{1,\ 118}$=2.249, P>0.136 & $F_{1\ 178}$ =0.375, P>0.54) (Fig. 6.5). Goral pellet group density was maximum in burnt areas (29.51±11.08 pellet groups/ha ±SE) during pre-monsoon season, while during post-monsoon season goral pellet group density was maximum in un-burnt area (47.00±12.55 pellet groups/ha ±SE). There was however, no significant difference in mean pellet group density between burnt and un-burnt patch in both seasons ($F_{1,\ 118}$=1.53 P>0.217 and $F_{1,\ 178}$=1.32 P>0.25 respectively) (Fig 6.5).

Barking deer pellet group density was found only in oak forest and mixed forest habitat. The density was maximum in oak forest habitat during pre and post-monsoon season (60.50±10.45 pellet groups/ha±SE & 80.96±10.48 pellet groups/ha±SE respectively) and differences between habitats were significant ($F_{1,\ 118}$=7.57, P<0.007 and $F_{1,\ 178}$=11.78, P<0.001) (Table 6.10). Goral pellet group density was also distributed only in oak forest and mixed forest habitat. Density was also found maximum in the oak-forest during pre as well as post-monsoon season (23.88±7.13 pellet groups/ha±SE and 35.03 ±9.20 pellet groups/ha ±SE respectively). But there were no significant differences between habitats during both seasons ($F_{1,118}$ =0.686, P>0.409 and $F_{1,178}$ =3.22, P>0.07 respectively) (Table 6.11).

6.4 DISCUSSION

The study on habitat use of barking deer and goral in Binsar Wildlife Sanctuary was carried out by direct and indirect methods. Both techniques have been used extensively by various workers (e.g. Eberhardt and Van Etten 1956, Rogers *et al.* 1958, Martinka 1968, McCaffery 1976, Short *et al.* 1977, Larson *et al.* 1978, Lyon and Jensen 1980, Green 1985, Khan 1993) to investigate the habitat use of different ungulate species in India and outside. The studies carried out so far provide substantial evidence that both approaches are equally useful in exploring the ungulate-habitat relationship provided a good sampling design is used and observer errors are reduced. Most of the workers have however, either used direct method or indirect method. The low number of sightings of barking deer and goral necessitated the need for sampling by indirect method also. Since both data sets have been analysed for this chapter, it provides an excellent opportunity for comparison of results.

The habitat factors, identified by the PCA analysis, which govern the micro habitat use of barking deer in Binsar in both seasons are mostly the one which were identified in macro habitat use. These are requirements for closed canopy, thickly wooded areas, which have diverse and thick shrub storey with diverse herb layer. This matches with the factors identified by comparison of available and utilised plots by barking deer. The only change, which is obvious, is the differences in values of habitat factors in available and utilised plots during the post-monsoon season. Not only a greater number of factors have significant difference but also the magnitude of difference is large. The major difference in case of barking deer between PCA results and that of pellet group density is the role of altitude. It again emerges as most powerful factor influencing habitat gradient associated with PC I in pre and post-monsoon season while no significant differences were found in mean altitude values in available and utilised plots. This is mainly due to a greater altitude range covered in trail sampling as compared to the line transacts used for sampling of pellet groups. In case of goral, the results of PCA and the pellet group data do not match in general. While PCA extracted the habitat factors, which succinctly identify the micro-habitat use pattern in both seasons, the mean values of habitat factors in available and utilised do not differ much for majority of habitat factors. For example only four factors showed significant differences in pre-monsoon season in available and utilised plot and except for proportion of rock, other factors (e.g. shrub density) are not known to play any significant role in governing habitat use of goral (Mishra and Johnsingh 1996). Also some of the factors which are known to be associated with ecology of goral (e.g. variables of grass layer, tree cover etc.) do not show any significant difference between available and utilised plots. In fact the mean values of most of the habitat factors in case of goral are what one may expect for barking deer. It follows that there exist major differences in habitat use of goral while it is actively feeding and the habitat it utilises for resting and bedding. The pellet group density data reflect more of the habitat use of goral for resting and bedding time. However it is merely a speculation since only one detailed study (Mishra and Johnsingh 1996) on habitat selection of goral has been carried out in Himalaya. Mishra and Johnsingh (1996) have also sampled goral population in the morning hours along trails. However Cavallini (1992) based on analysis of sightings of goral during different times of the day concluded that the day time activity pattern suggested a possible nocturnal feeding activity preceded and followed by crepuscular movement from and to resting grounds. This observation is similar to findings of Green (1987) who found goral to be equally active during day and night.

The pellet group densities recorded in different habitat types and also the direct sightings showed that both species utilised only oak and oak mixed habitat. While it is expected of barking deer to be in oak habitat (thick canopy, high shrub cover, high browse availability), the absence of goral in oak-pine and pine habitat with ample grass is surprising. The goral is known to occur and utilise pine habitat in other areas of Himalaya (Cavallini 1992, Mishra and Johnsingh 1996). The analysis of quality of food available in pine and oak habitat showed significant differences as crude protein values were considerably lower in pine habitat. This possibly is the reason why goral also utilised oak habitat only.

Similar sized species differ most in resource use traits. The pattern of habitat use in both seasons by barking deer and goral showed considerable spatial separation between the two species. The spatial separation by both species is achieved by clear preferences firstly, for terrain as barking deer utilised valleys and avoided steep areas whereas goral preferred steep, rugged and precipitous areas. Secondly both species showed preference for closed and open canopy habitats. Thirdly Goral avoided areas with thick shrub layer where as barking deer utilised such areas. The spatial separation is further strengthen by differences in diet of both species. Therefore in Binsar Wildlife Sanctuary barking deer and goral showed considerable ecological separation in resource use thereby minimising the possibility of any competition.

Avoidance of inter-specific competition has been speculated to be underlying factor responsible for differential use of resource gradients (Cody 1974, Schoener 1986) Avoidance of inter-specific competition has been speculated to be underlying factor responsible for differential use of resource gradients (Cody 1974, Schoener 1986) and habitat partitioning has been shown to be most common strategy of achieving ecological separation by sympatric species in different taxa (Schoener 1974). Ecological separation by way of differential habitat use and difference in dietary pattern has been documented in several high altitude sympatric ungulate communities (Dunbar 1978, Green 1987) as well as elsewhere ((Ferror and Walker 1974, Hirst 1975, Jenkins and Wright 1983, Wood 1989).

The barking deer pellet group densities were higher in un-burnt areas whereas the pellet group densities for goral were higher in burnt areas in pre-monsoon season only. It is expected since fires in pre-monsoon season leads to fresh grass growth. The tender shoots of grasses are high in nutrition and goral being predominantly grazer utilises these tender shoots.

Based on findings of present study, the managers of Binsar need to formulate strategies, which may create optimum habitat condition for both species. The oak patch in Binsar has to be maintained a mosaic of closed and open areas keeping in mind the needs of barking deer and goral. Extensive grazing by livestock from the nearby villages as well as grass harvesting from oak habitat in post-monsoon season is directly detrimental for the goral in terms of its food and a source of disturbance for both species. Therefore grazing and grass harvesting should not be allowed in oak forest. The fires, which are deliberate, set by graziers need to be controlled completely. Although one may argue, that it benefits the goral to some extent in pre-monsoon season, the repeated fires create conducive conditions for establishment of *Pinus roxburghii* and there is substantial evidence that pine takes advantage of fires and spread at the expanse of oak species in Kumaon. The spread of pine, no matter how slow it might be, endanger the entire oak ecosystem which is vital for survival of both sympatric ungulate species. Also the impact of fires on herb layer is not known which provides bulk of barking deer food in pre and post-monsoon season.

Table 6.1 Principal component analysis of direct sighting data of barking deer during pre-monsoon season in Binsar.

Variables	PC I	PCII	PC III	PC IV	PC V
Altitude	0. 771	-.217	-. 0068	-. 0022	.0011
Cattle dung	0.0098	.414	-.180	.326	.533
Cut trees	0.0079	.104	.135	-.163	.618
Lopped trees	-0.252	.0066	-.187	-.155	.621
Grass cover	-.592	.205	-.156	.332	-.219
Grass density	-.271	.0016	-.0053	.756	.0064
Grass richness	.0037	.0046	-.00023	.703	.121
Herb density	.0016	.724	.0098	.0099	.0057
Herb richness	.0091	.748	.0036	-.163	.139
Shrub cover	-.188	.0057	.790	-.166	-.152
Shrub density	.197	-.106	.752	.156	.205
Shrub height	.0016	.365	.509	-.351	-.280
Slope	-.747	-.301	.251	.0089	.0097
Shrub richness	.244	.209	.293	-.345	.312
Tree cover	.468	-.409	.303	-.265	-.0048
Tree density	.372	-.519	.309	-.0058	.403
Tree richness	.543	-.0081	.220	-.194	-.246

Variance explained by each component	14.4	12.27	11.54	10.49	9.5
Percent of total variance by components	14.42	26.69	38.24	48.73	58.24

Table 6. 2 Principal component analysis of direct sighting data of Barking deer during post-monsoon season in Binsar.

Variables	PC I	PCII	PC III	PC IV	PC V	PCVI
Altitude	.570	.19	-.254	-.193	-.0058	.0058
Cattle dung	-.00097	-.0074	.0015	-.794	.114	-.0088
Cut trees	.203	.0078	.00062	-.0082	.846	.0027
Lopped trees	-.267	-.0093	.0049	.0078	.0043	.696
% Grass cover	.684	-.0019	-.0011	.121	.0083	.191
Grass richness	-.369	-.009	.114	.513	.0067	-.338
Herb density	-.330	.009	.709	-.169	-.214	-.132
Herb richness	-.0024	-.0026	.928	.114	.125	.0025
% Shrub cover	-.297	.580	-.254	-.125	.009	.0039
Shrub density	.213	.636	.0089	.200	-.0038	.0054
Shrub height	.0069	.676	-.231	-.0045	.0014	.36
Slope	-.408	.108	.0052	.0097	.109	-.533
Shrub richness	.210	.800	.175	.0013	-.0018	-.150
% Tree cover	.724	.150	-.006	.216	-.00012	.0082
Tree density	.631	.120	-.214	.0092	.172	.0086
Tree richness	.468	.207	-.129	.0058	-.535	.138
Shrub diversity	.165	.786	.202	.003	.0029	-.148
Herb diversity	-.102	.0048	.952	.0034	.0083	.0024

Grass density	-.632	-.0058	.0028	.300	-.196	.00007
Variance explained by rotated component	16.2%	13.82	13.77	6.41	6.3	6.14
Percent of total variance explained	16.2	30.02	43.79	50.2	55.51	62.65

Table 6. 3 Principal component analysis of direct sighting data of Goral during pre-monsoon season in Binsar.

Variables	PC I	PCII	PC III	PC IV	PC V
Altitude	.877	.139	.00155	.0066	.0029
Cattle dung	-.139	.165	.667	.312	.0023
Cut trees	.327	-.487	.406	.0086	-.272
Lopped trees	.0035	.0022	.638	.00088	.263
Grass cover	.0007	.715	.172	-.183	-.245
Grass density	.184	.769	.239	.0043	.0013
Grass richness	-.0032	.518	-.0099	-.0034	.198
Herb density	.001	.0039	.0036	.804	.0097
Herb richness	.0082	-.165	.164	.700	.0042
Shrub cover	.310	.150	-.510	.391	.0003
Shrub density	.901	.0036	-.008	.009	-.0053
Shrub height	.806	.0084	-.126	.117	.0053
Slope	.0025	.635	.0082	.0085	.0017
Shrub richness	.559	-.410	-.0066	.0087	-.447
Tree cover	.397	-.528	-.438	-.270	.181
Tree density	.849	-.179	.00084	.0083	.0027
Tree richness	.0062	.002	.203	-.0084	.848

Variance explained by each component	21.77%	15.27	9.81	9.16	7.13
Percent of total variance by component	21.22	36.99	46.81	55.97	63.115

Table 6. 4 Principal component analysis of direct sighting data of goral during post-monsoon season in Binsar.

Variables	PC I	PCII	PC III	PC IV	PC V
Altitude	0.779	-0.133	-0.004	-0.00006	-0.001
Cattle dung	-0.0058	-0.0025	-0.0038	0.106	0.794
Cut trees	0.101	0.0098	0.0082	-0.303	0.676
Lopped trees	-0.154	0.151	-0.155	0.007	0.009
% Grass cover	-0.717	-0.130	-0.0044	-0.0032	0.002
Grass density	-0.394	-0.005	-0.124	0.567	-0.177
Grass richness	-0.145	0.0042	0.0038	0.793	-0.793
Herb density	-0.143	0.746	0.004	0.172	-0.001
Herb diversity	-0.007	0.942	0.002	-0.001	0.006
Herb richness	-0.008	0.879	0.006	-0.002	0.0053
% Shrub cover	-0.278	-0.157	0.268	-0.496	-0.0055
Shrub density	0.279	0.107	0.700	-.163	-0.155
Shrub diversity	0.004	0.008	0.899	-.001	0.009
Shrub height	-0.009	-0.292	0.593	-.413	-0.0038
Slope	-0.504	0.304	0.005	.008	0.008
Shrub richness	0.120	0.105	0.832	.127	0.005
% Tree cover	0.726	-0.161	0.211	-.153	-0.009
Tree density	0.684	-0.172	0.171	.005	0.254

Tree richness	0.501	-0.195	0.169	-.202	-0.424
Variance explained by rotated component	16.04	13.76	13.58	8.55	7.57
Percent of total variance explained	16.04	29.8	43.28	51.93	59.5

Table 6. 5 Mean values of habitat variables between available and utilised plots during pre-monsoon and post-monsoon season for barking deer in Binsar.

Variable	Pre-monsoon			Post- monsoon		
	Available	Utilised	t	Available	Utilised	t
Altitude	2222.85	2256.00	-1.466	2221.18	2253.21	-1.76
Bare ground	8.23	11.09	-1.461	6.75	6.61	0.092
Cattle dung	0.38	0.12	1.74	1.18	0.63	2.40*
Cut trees	0.002	0.002	0.29	2.12	2.42	-0.617
% grass cover	10.58	4.58	3.33	6.79	8.7	3.60***
Grass cover	23.17	7.32	4.34	31.39	23.81	2.19*
Grass diversity	0.7	0.66	0.29	0.59	0.595	-0.004
Grass density	12.58	7.84	2.83	13.80	10.57	2.005
Grass richness	0.62	18.69	-1.18	0.56	0.65	-1.104
Grass species	2.5	2.3	0.48	2.44	2.43	0.018
%Herb	6.26	5.37	0.8	8.14	7.52	0.503
herb diversity	0.59	0.57	0.183	0.54	0.53	0.112
Herb density	7.98	4.52	2.18*	5.92	5.7	0.294
Herb richness	0.64	0.66	-0.185	0.69	0.8	-1.217
Herb species	2.3	1.9	1.57	2.08	2.18	-0.54

Litter	66.43	68.34	-0.439	55.48	71.46	-4.40
Rock	5.17	4.7	0.244	9.90	6.08	1.76
Shrub number	62.11	74.78	-1.49	54.62	75.87	-3.99***
Shrub cover	27.38	13.2	-.832	31.54	44.04	-3.98***
Shrub diversity	1.57	1.61	-1.66	1.53	1.79	-4.23***
Shrub density	22.15.84	26070.7	-1.34	18762.1	26025.87	-3.67***
Shrub height	62.03	70.95	-1.31	64.02	88.32	-4.26***
Slope	46.0	42.8	0.91	44.13	45.22	-0.38
Shrub richness	1.85	2.03	-1.81	1.71	2.10	-4.63***
Shrub species	8.22	9.5	-2.61**	7.6	9.98	-5.78***
Tree number	27.4	33.9	-2.45*	26.09	34.41	-3.98***
Tree cover	63.22	78.69	-3.72***	63.02	77.84	-4.31***
Tree diversity	1.45	1.62	-2.7**	1.41	1.63	-4.44***
Tree density	877.6	1088.7	-2.48*	837.9	1102.0	-3.92***
Tree richness	1.41	1.48	-0.82	1.32	1.56	-3.78***
Tree species	5.58	6.14	-1.66	5.29	6.37	-4.22***
Lopped trees	0.00	0.00	-	-0.79	0.67	0.51
Weathered stone	2.4	1.01	1.03	2.19	0.28	3.04**

Table 6.6 Mean values of habitat variables between available and utilised plots during pre-monsoon and post-monsoon season for goral in Binsar.

Variable	Pre-monsoon			Post-monsoon		
	Available	Utilised	t	Available	Utilised	t
Altitude	2241.6	2220.35	0.802	2234.7	2243	-0.387
Bare ground	9.58	8.91	0.289	7.11	5.30	1.01
Cattle dung	0.26	0.32	-0.337	1.04	0.5	2.002
Cut trees	0.003	0.00	0.963	1.49	1.54	1.67
% grass cover	8.39	7.05	0.612	11.54	17.55	-2.25*
Grass cover	17.9	23.17	1.25	22.69	44.2	5.68***
Grass diversity	0.63	0.85	-1.45	0.567	0.686	-1.31
Grass density	10.38	11.35	-.485	11.44	14.85	-1.79
Grass richness	0.58	33.02	-1.84	0.88	0.684	-1.09
Grass species	2.25	3.07	-2.48	2.33	2.78	-1.09
% Herb	5.05	8.66	-2.87	6.10	10.70	2.58*
Herb diversity	0.54	0.71	-1.16	0.49	0.67	-2.07*
herb density	5.55	9.78	-2.29*	5.67	6.28	-.68
Herb richness	0.66	0.64	0.15	0.72	0.82	-.95
Herb species	2.13	2.35	-0.72	2.09	2.26	-.78
Litter	68.02	64.63	0.67	67.32	23.82	4.08***

Rock	3.82	8.79	-2.24*	6.35	13.63	-2.89**
Shrub number	62.14	84.64	2.31*	64.36	66.64	-.35
Shrub cover	26.97	33.75	-1.73	36.81	40.11	-8.5
Shrub diversity	1.62	1.61	0.08	1.66	1.64	0.22
Shrub density	21801.4	29961.94	-2.35*	22006.4	23148.6	-4.7
Shrub height	67.4	60.27	0.89	76.4	73.61	0.39
Slope	44.67	44.14	0.008	40.72	57.65	-5.45
Shrub richness	1.92	1.93	0.08	1.91	1.84	0.698
Shrub species	8.57	9.35	-1.34	8.79	8.61	0.334
Tree number	29.88	30.89	-0.32	31.55	25.4	2.42*
Tree cover	68.85	72.35	-0.69	72.08	64.19	1.86
Tree diversity	1.52	1.51	0.076	1.55	1.42	2.04*
Tree density	955.85	997.49	-.410	1012.7	810.7	2.48*
Tree richness	1.45	1.39	0.72	1.47	1.33	1.76
Tree species	5.84	5.71	0.34	6.00	1.81	2.6**
Lopped trees	0.00	0.00	-	0.789	0.57	0.795
Withered stone	2.32	0.187	1.36	1.37	0.94	0.565

Table 6. 7 Correlation between pellet group density of barking deer and goral with habitat variables during pre-monsoon and post-monsoon seasons in Binsar.

Habitat variables	Pre-monsoon		Post-monsoon	
	Barking deer	Goral	Barking deer	Goral
Altitude	0.178	0.09	0.27**	0.14*
Bare ground	0.07	0.03	-0.08	0.09
Cattle dung	-0.13	0.060	-0.003	-0.07
Cut trees	-0.029	-0.06	0.03	-0.02
Percent grass	-0.23*	-0.10	-0.2**	-0.008
Grass cover	-0.24**	-0.05	-0.12	0.13*
Grass diversity	0.01	0.14	-0.15*	-0.01
Grass density	-0.08	0.05	-0.23**	-0.05
Grass richness	0.05	0.23**	-0.07	-0.02
Grass species	0.03	0.22	-0.16**	-0.02
Percent herb	-0.15	0.19*	-0.12	-0.02
Herb diversity	-0.02	0.12	-0.06	0.01
Herb density	0.13	0.07	-0.14*	-0.06
Herb richness	-0.11	-0.03	0.05	0.06
Herb species	-0.18*	0.02	-0.06	0.01

Litter	0.16	-0.09	0.25**	-0.1
Rockiness	-0.06	0.32**	-0.01	0.3**
Shrub number	0.08	0.26**	0.26**	0.08
Shrub cover	0.01	0.18*	0.27**	0.17**
Shrub diversity	0.027*	0.04	0.23**	0.01
Shrub density	0.07	0.26**	0.26**	0.089
Shrub height	0.07	-0.06	0.26**	0.02
Slope	-0.12	0.11	-0.009	0.27**
Shrub richness	0.23**	0.04	0.24**	0.01
Shrub species	0.28**	0.13	0.31**	0.01
Tree number	0.11	-0.02	0.24**	-0.06
Tree cover	0.24**	0.13	0.18**	-0.04
Tree diversity	0.18	-0.04	0.24**	-0.07
Tree density	0.11	-0.01	0.23**	-0.07
Tree richness	0.06	-0.12	0.14*	-0.11
Tree species	0.12	-0.12	0.18**	-0.12
Lopped trees	-	-	-0.1	-0.07
Withered stone	-0.06	0.09	-0.1	-0.03

Table 6. 8 Barking deer pellet group density (pellet groups/ha±SE) on different aspects in pre and post-monsoon seasons in Binsar.

Aspect	Pre-monsoon	Post-monsoon
East	12.73±9.72	16.98 ±4.24
West	40.69±15.62	72.01±13.24
North	71.65±32.82	116.77±35.52
South	61.70±30.13	42.46± 20.52
North-East	26.53±17.28	21.23± 11.86
South-East	47.76±15.71	51.89± 13.50
North-West	72.79±19.91	102.36±19.34
South-West	19.10±9.35	52.01 ± 23.52

Table 6. 9 Goral pellet group density (pellet groups/ha±SE) on different aspects in pre and post-monsoon seasons in Binsar.

Aspect	Pre-monsoon	Post-monsoon
East	0.00±.00	4.24±2.89
West	40.69±12.56	29.48±10.74
North	0.00±.00	5.30±5.30
South	39.8±106.89	73.00±36.95
North-East	31.84±63.69	84.92±49.5
South-East	17.68±26.00	16.51±6.44
North-West	18.19±9.18	21.98±8.44
South-West	6.36±6.36	3.18±1.77

Table 6.10 Barking deer pellet group density (pellet groups/ha±SE) in different habitat during different seasons in Binsar.

Habitat	Pre-monsoon	Post-monsoon
Oak forest	60.5±10.45	80.96±10.48
Oak-scrub forest	0	0
Oak-pine forest	0	0
Pine forest	0	0
Mixed forest	18.31±5.57	27.59±6.53

Table 6. 11 Goral pellet group density (pellet groups/ha±SE) in different habitat during different seasons in Binsar.

Habitat	Pre-monsoon	Post- monsoon
Oak	23.88±7.13	35.03±9.20
Oak-scrub forest	0	0
Oak–pine forest	0	0
Pine forest	0	0
Mixed forest	15.12±4.41	11.14±3.69

Figure 6.1 Ordination of available and utilized plots of barking deer during Pre-monsoon season in Binsar Wildlife Sanctuary.

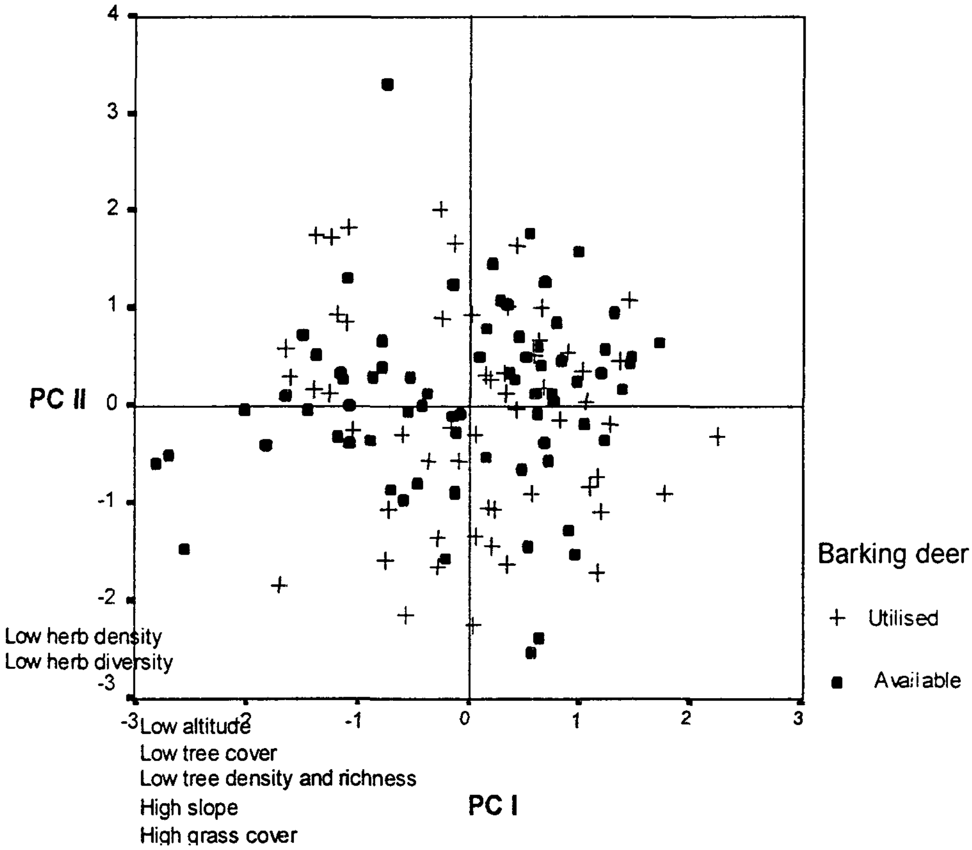
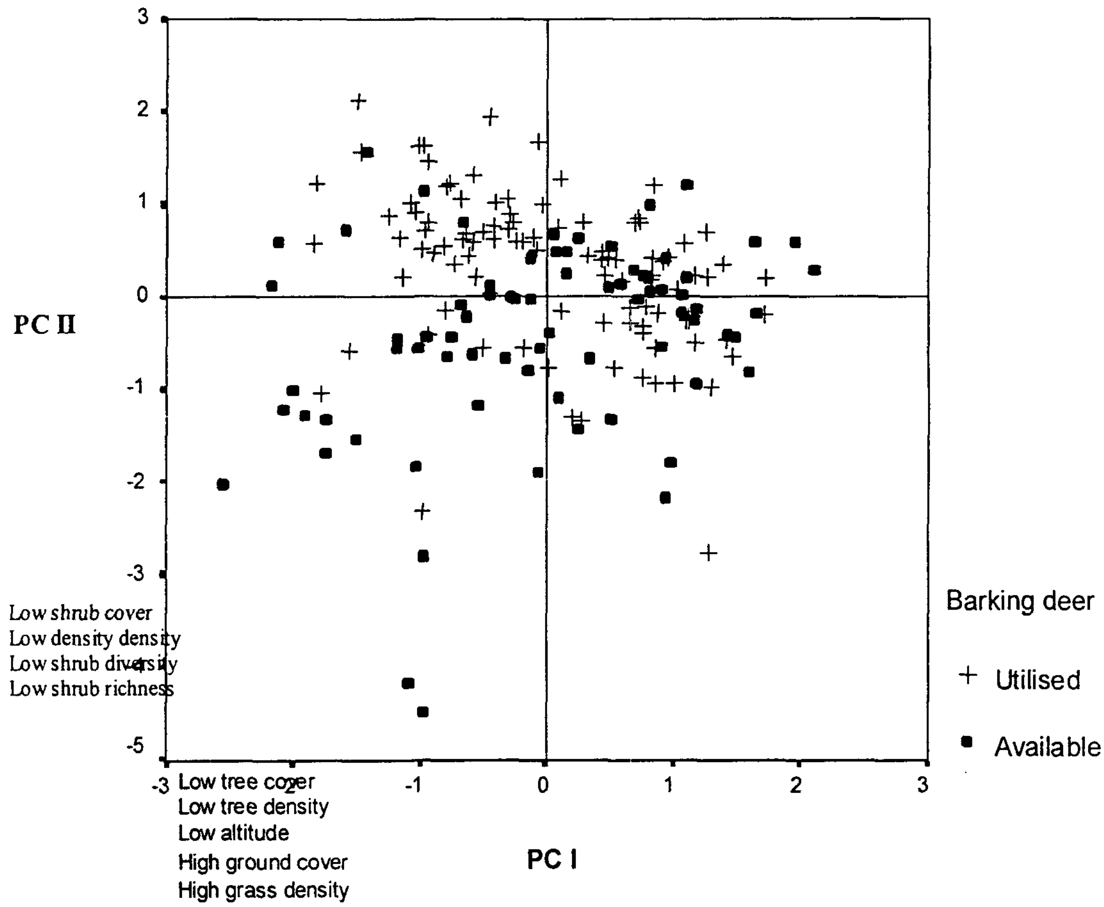


Figure 6.2 Ordination of available and utilized plots of barking deer during Post-monsoon season in Binsar Wildlife Sanctuary.



CHAPTER 7
FEEDING ECOLOGY OF BARKING DEER AND GORAL IN BINSAR

7.1 INTRODUCTION

The barking deer (*Muntiacus muntjak muntjak*) and gray goral (*Nemorhaedus goral bedfordi*) occur together throughout Himalaya up to 3000 m (Prater 1980). While barking deer is regarded morphologically primitive, more like some extinct deer species than most living ones (Barrette 1987a), the goral is also considered most primitive member of sub family Caprinae (Schaller 1977). Both species are small in size (average weight of barking deer and goral 22 to 23 kg and 25 to 30 kg respectively), solitary and elusive but occupy contrasting habitats in Himalaya. While the barking deer is distributed in closed canopy forests, the goral occupy open canopy forest with plenty of grasses.

The ecology and behaviour of both species is not well known compared to other cervids and bovids in India. While the barking deer in India has not been studied at all, it is only recently that some aspects of ecology of goral (e.g. group size and composition, habitat selection etc.) have been studied in Himalaya (Green 1987, Pendharkar and Goyal 1995, Mishra and Johnsingh 1996).

Both species have suffered a great deal in past due to habitat destruction, degradation and large scale poaching by local communities as the distribution range of these species in middle Himalaya has the maximum number of human settlements compared to lower or higher Himalaya (Singh and Singh 1986). Consequently populations of barking deer and goral are now largely confined to sanctuaries and protected reserved forests where these species need to be managed considering their overall importance as main prey species of leopard (*Panthera pardus*) and excessive dependence of local communities on their habitat. While information on different ecological and biological aspects is desirable for management, it is the data on food habits of wild ungulates which has proved to be vital for sound management in protected areas in India (e.g. Berwick 1974, Khan 1994).

This chapter presents the findings of data collected on dietary spectrum of barking deer and goral which has been gathered by analysis of faecal pellet groups since direct observations on neither barking deer nor goral were feasible due to variety of reasons.

7. 2 METHODOLOGY

7.2.1 Data collection

Data on the feeding ecology were collected by indirect method only. Permanent slides of all potential food plants were prepared for using them as reference slides following Green (1987). For preparation of reference slides, a few bits of leaves, twigs and fruits (if present) were taken from each plant. These were shredded coarsely and placed in a test tube. Concentrated nitric acid (HNO_3) and distilled water was added in the test tube in ratio of 1:3. The test tube was heated in a water bath (water at boiling point) for a minute or two. Highly coloured and tough material was boiled for a second time with fresh quantities of nitric acid and distilled water. The tube was allowed to cool down and the liquid drained off. The sample was washed repeatedly in distilled water. The sample was stained in saffarenin and it was left for two minutes to stain properly. After staining, the sample was repeatedly washed in distilled water and dehydrated by passing it through a mixture of alcohol and distilled water in the ratio of 1:3, 1:1 and 3:1. The sample was placed finally in absolute alcohol. The mounting was done in Canada Balsam and hand drawings were prepared for each plant species.

Three permanent transacts, each of one km, were established and permanent plots of 10 m radius were marked at every 50 m distance. These permanent plots were cleared at the start of pre-monsoon and post-monsoon season in 1998. Pellet groups of barking deer and goral were collected separately from each plot at the end of pre and post-monsoon season. These pellet groups were used for micro-histological studies. The pellet groups of each species from different plots were mixed thoroughly for each season. Four major samples were prepared two samples for barking deer, each for pre and post-monsoon season and two for goral, one each for pre and post-monsoon seasons.

The major faecal samples were put in a tray, shaken and tossed about several times before spreading them on tray. The entire sample was first halved and then quartered. Two opposite quarters were combined and one such combined portion was rejected. The remaining combined portion was tossed again in the same manner and spread over a tray. The sample was first halved and then quartered again. The opposite quarters were combined and one combined portion was rejected. This procedure was repeated for four times and the sample retained at the end served as starting sample for micro-histology work.

The starting sample was put in a mortar and grounded loosely so that pellets were broken up as discrete particles in coarse powder form. The grinding did not fractionate the particles but merely separated the agglomerates into single particles. Two sieves (ASTN No. 30 and 50) were placed one above the other and grounded sample was sieved. The portion of sample left on top sieve was rejected. The sieved sample was passed through the second sieve and the portion remaining on the second sieve was retained for analysis. The entire sample was first halved and then quartered. One quarter was selected as final sample and remaining three quarters were kept as reserve in case of loss of sample in subsequent processing.

The final sample was transferred in a test tube and concentrated HNO3 and distilled water was added in the test tube in the ratio of 1:3. The tube was heated in a water bath (water at boiling point) for few minutes. The solution was too dark and black. The particles were allowed to settle down and supernatant was poured off. Fresh quantities of nitric acid and distilled water were added and the sample was boiled again. In some cases a third boiling was found to be necessary. When the sample appeared to be fairly clear, the boiling was considered sufficient. The sample was allowed to cool down. More distilled water was added and the sample was shaken thoroughly. The sample was then allowed to settle down and supernatant was poured off. The sample was washed repeatedly till the nitric acid was washed off completely. The washed sample was used for preparing slides for analysis. 25 slides were prepared for each species for each season. Plant particles were identified with the help of reference slides. Each slid was thoroughly scanned under a binocular microscope using 150x magnification. A total of twenty field of views were observed for each slide. In each field of view, total number of the identified and unidentified plant species and plant fragments of each species were recorded.

In order to assess the availability of food plants in oak habitat, vegetation sampling was carried out along three line transacts which were established for quantification of pellet groups. The plants were sampled in established permanent plots. The shrub species as well as saplings and seedlings of trees up to three m were counted in three m radius circular plots at every permanent sampling point. The herb and grass species and their individuals were counted in four 0.50 x 0.50 m quadrate at every sampling points. These four quadrates and three m radius circular plots were established systematically within 10 m radius plot. Thus there were 60 plots for assessing browse availability and 240 plots for assessing availability of grasses and herbs.

The above ground biomass available to barking deer and goral in oak and pine forest ecosystem was measured by clipping 0.50 x 0.50 m quadrate in oak and pine habitat. Clipped grasses and herbs were collected in separate bags. Total 10 quadrates were clipped in each habitat type monthly. The clipped material was dried in an oven at 80°C for 24 hours and measured for its weight.

The dried grasses and herbs were used in nutritional analysis. Samples of grasses and herbs for each habitat were mixed together and grounded to make powder. This powder was sieved and final sample was prepared for the nutritional analysis. The crude protein estimation was done by the Kjeldahl method following Munro and Fleck (1969).

7.2.2 Data analysis

The information on identification of plant fragments was summarised to calculate the overall browse to grass ratios for barking deer and goral for pre and post-monsoon seasons. Since grass particles could not be identified to species level, the information on identified browse particles was further analysed to calculate the proportion of different tree, shrub and herb species in barking deer and goral diet. The proportion of each species in diet composition of each species was compared with availability of food plant species in Binsar during pre and post-monsoon season by calculating 95% Bonferroni Confidence intervals following Byers *et al.* (1984). The 95% confidence intervals were constructed by following the formulae:

$P_{ie}-Z_{\alpha/2k}\sqrt{P_{ie}(1-P_{ie})/n} \leq P_{ie} \leq P_{ie}+ Z_{\alpha/2k}\sqrt{P_{ie}(1-P_{ie})/n}$

where P_{ie} is the observed proportional utilisation of each species and $Z_{\alpha/2k}$ is the upper standard normal Table value corresponding to a probability tail area of $_{\alpha/2k}$ and n is total number of trees recorded dead. For each species its proportional availability (P_{io}) in the sample was calculated by dividing its total number (n) from that of total number of all individuals (N) sampled for all species (P_{io} = n/$\sum$N). Utilisation was significantly greater or less than availability when P_{io} lay out side the 95% confidence limits constructed for proportional mortality (P_{ie}) which was calculated by dividing number of plant fragments identified for each species (n) by the of total number of identified browse fragments (N) species (P_{ie} = n/$\sum$D). The crude protein values calculated for each months for oak and pine habitat were averaged across seasons to calculate mean crude protein values (Nitrogen x 6.25) expressed as % of dry matter. The statistical test were conducted following Fowler and Cohen (1986).

7.3 RESULTS

7.3.1 Dietary spectrum

A total of 1714 and 1389 plant particles were evaluated during pre and post-monsoon season in 1998 in order to determine the dietary spectrum of barking deer in Binsar. Based on the identification of fragments, the browse to grass ratio was 87% and 13% in pre-monsoon and 78% and 22% in post-monsoon season (Fig. 7.1) The diet of barking deer comprised of eight tree species, six shrub species and 18 herb species during pre-monsoon season whereas during post-monsoon season, eight tree, eight shrub and 19 herb species were identified. It was not possible to identify grasses at species level from plant fragments. A total of 55% and 57%

browse particles could not be identified to species level during pre and post-monsoon season. Table 7.1 provides the contribution of various species in identified browse particles. During pre-monsoon season, species, which contributed maximum in the diet, were *Indigofera heterantha* (24.5%), *Catamintha umbrosa* (19.7%), *Launea secunda* (8.5%), *Quercus leucotrichophora* (5.6%) and *Ranunculus laetus* (5.4%). During post-monsoon season the plant species which contributed maximum to the diet were *Bergenia ligulata* (11.6%), *Catamintha umbrossa* (10.2%), *Quercus leucotrichophora* (7.1%), *Flemingia strobilifera* (6.4%) and *Indigofera heterantha* (5.4%). Table 7.3 provides values of 95% Bonferroni confidence interval values for different plant species utilised by barking deer. During pre-monsoon season 20 tree, 20 shrub and 29 herb species were recorded in oak habitat. The total number of individuals recorded for these species were 3872. The proportional availability was calculated using this total value. The number of tree, shrub and herb species available and utilised by barking deer showed no significant difference (χ^2=1.9, *d.f.* =2, *P*<0.05, Fig. 7.2) in pre-monsoon season. The barking deer preferred eight plant species and avoided 5 plant species. The plant species which were utilised more than the availability were *Indigofera heterantha, Launea secunda, Galium aparina, Desmodium triguelrum, Plectranthus striatus Geranium collinum, Bergenia ligulata, and Parthenocissus himalayana*. The species, which were utilised, less than their availability were *Viburnum cotinifolium, Myrica esculenta, Daphnae papyracea, Myrsine africana* and *Desmodium elegans.* A total of four species were available but were not recorded in diet composition, whereas five species did not occur in vegetation sampling but were recorded in diet composition. One of these species *Catamintha umbrossa* made 19% contribution in barking deer diet in pre-monsoon season. There were three plant species which were neither recorded in sampling nor in diet composition. The other plant species were utilised in proportion to their availability. During post-monsoon season, a total of 18 tree, 19 shrub and 21 herb species were recorded in oak habitat and a total of 3489 individuals belonging to these species were recorded from which the proportional availability was calculated. The number of tree, shrub and herb species available and utilised did not differ significantly (χ^2= 2.65, *d.f.*=2, *P*<0.05, Fig. 7.2). The barking deer preferred and avoided six plant species in each category while rest of the species were utilised in proportion to their availability. The species which were utilised more than their availability were *Myrica esculenta, Indigofera heterantha, Thalectrum foliolossum, Launea secunda, Bergenia ligulata*, and *Flemengia strobilifera.* Plant species, which were utilised less than their availability were *Smilex vaginata, Myrsine africana, Daphnae papyracea, Rubus ellipticus, Pyrus pashia* and *Quercus floribunda.* A total of four species occurred in sampling but were not recorded in diet whereas there were eight plant species which were not recorded in sampling but were present in diet. These species also included *Catamintha umbrosssa.* Two species were neither recorded in sampling nor in the diet.

A total of 1672 and 2176 plant fragments were evaluated during pre and post-monsoon season in order to determine goral diet in Binsar. The browse to grass ratio was 12% and 88% and 3% and 97% during pre and post-monsoon season respectively. The proportion of unidentified browse was 6% and 1.5% respectively in pre and post-monsoon season. From the identified browse particles, fragments of one tree species, five shrub species and 11 herb species were identified in pre-monsoon season where as in post-monsoon season two tree species, one shrub species and six herb species were identified in the goral diet (Table 7.2). The maximum contribution in the identified browse component in goral diet was from *Myrsine africana* (26.5%), *Indigofera heterantha* (20.2%), *Daphnae papyraceae* (13.8%) and *Quercus leucotrichophora* (10.6%) in pre-monsoon season. During post-monsoon season, the proportion of *Catamintha umbrossa* was highest (44.4%) followed by *Indigofera heterantha*, *Plectranthus sp.* and *Quercus leucotrichophora*. Table 7.4 presents the values of 95% Bonferroni confidence interval for the utilised plant species. During pre-monsoon season, goral utilised 10 browse species in proportion to their availability, avoided four species and none were preferred. The browse species, which was utilised less than their availability were *Indigofera heterantha, Daphnae papyraceae, Myrsine africana* and *Launea secunda.* There were three species available but these were not recorded in diet, three species did not occur in sampling but were recorded in diet and one species neither occurred in sampling nor it was recorded in diet. During post-monsoon season goral utilised three browse species in proportion to their availability and avoided *Quercus leucotrichophora*. There were nine species, which occurred in sampling but were not utilised; four species were not recorded in sampling but these were identified in the diet and three species nether occurred in sampling nor were these recorded in diet.

Above ground biomass and its nutritional status

Figure 7.3 provides the values of above ground biomass in oak and pine habitat. The biomass was considerably lower in oak habitat compared to pine habitat in pre and post-monsoon season. The differences were significant ($P<0.05$). The above ground biomass was higher in pre-monsoon season in both habitats and the maximum biomass was in pine habitat (422 kg/ha). Figure 7.4 provides the values of crude protein (% of dry matter) assessed in different seasons. The crude protein values were significantly higher in oak habitat compared to oak-pine habitat in all seasons. The maximum crude protein values were recorded in pre-monsoon season in 1998.

7. 4 DISCUSSION

The microhisology technique first described by Baumgartner and Martin (1939) and reviewed by Holechek *et al.* (1982) is undoubtedly is the only and best technique to study the feeding ecology of small secretive species such as barking deer and goral since direct observations of feeding animals are not possible in Himalayan environment and the animals can not be sacrificed for applying the oesophageal and rumen fistula techniques. Although the microhistological analysis suffers from the problem of differential digestion as well as loss of some species during sample preparation which affects the level of accuracy and precision of results, the technique is valuable tool to find out dietary spectrum of species for which nothing is known. Holechek and Vavra (1981) have shown that the precision of microhistological analysis is a function of the number of frequency observations recorded per slide rather than the number of fields examined per slide. Though the entire microhistology work proved very time consuming and laborious, the number of frequency observations were increased substantially in order to maximise the species identification. Of the two studies which have been conducted in Himalaya to investigate the diet of goral (Green 1987, Mishra and Johnsingh 1996), only 20 frequency observations were taken per slide and only five slides were evaluated resulting in 100 frequency observations. Such sample size could be enough for describing broad grass to browse ratio. However it is too small a sample size when the objective is to identify the maximum number of species in the diet composition. It is clearly demonstrated from the data. Despite increasing the frequency observations per slide substantially, the ratio between identified and unidentified plant particles remained around approximately 50%. Therefore it can be argued that the species composition recorded by maximising the frequency observations in this study presents unbiased and fairly representative diet composition of barking deer and goral. Although some browse species certainly may have been lost in sample preparation (Rogerson *et al.* 1976) as well as remained unidentified in the sample. These were perhaps the species which were recorded as available. The proportion of such species ranged from 5.7% during pre-monsoon and post-monsoon season respectively for barking deer and 5.1% and 15.5% in pre and post-monsoon season for goral. There is another set of species which did not occur in our thorough sampling but made contribution to the barking deer and goral diet. One particular species warrants discussion. The *Catamintha umbrossa*, which did not occur in vegetation sampling during pre as well as post-monsoon season, was recorded in the diet of barking deer. Its proportion was 19.7 and 10.2% in pre and post-monsoon season suggesting a strong preference for this particular herb which either occur in low abundance in Binsar which could be the reason why it did not occur in sampling or is confined to specialised areas such as extremely moist areas in streams which were perhaps under sampled in both seasons.

The barking deer and goral are predominantly a browser and grazer in both seasons in Binsar. The grass has been found to be main food item for goral in Kedarnath Wildlife Sanctuary in different seasons (Green 1987) and also in Majhatal Harsang Wildlife Sanctuary where the proportion of grass in goral diet ranged from

92.2% in winter to 98.3% in summer season (Mishra and Johnsingh 1996). The proportion of grass under present study was estimated to be 88% in pre-monsoon (summer) and 97% in post-monsoon Season.

The barking deer for which no detailed study on feeding habits has been carried out so far has been categorised as nibbler rather than a browser or grazer feeding on energy rich fruits, tender fresh shoots etc (Barrette 1977c). The data from present study shows that the barking deer is a browser which feeds extensively on shrub and herb layer utilising a diverse range of plant species in both seasons.

Small body size which in turn results in higher basal metabolic rates per unit body weight has been suggested as the main factor, which requires small body sized mammals to be selective feeders feeding on high quality food items in available habitat. The small mammals therefore have to feed on high quality browse items rather than grasses which are comparatively low in quality. The barking deer and goral which could be regarded similar in body size however show differences not only in habitat use but differ in diet also. Similar differences in diet have been documented in Kedarnath Wildlife Sanctuary where musk deer and goral (similar in size and weight) were found to be predominantly browser and grazer (Green 1987).

The forest dwelling barking deer fits the expectation of a small mammal to be a browser but goral being predominantly a grazer does not confirm to this expectation. Rupicaprines, believed to be ancestors of Caprines, have partly evolved to exploit open habitats as compared to rich in cover and the evolution may have progressed from a primitive rainforest inhabitant of the Miocene to the modern goat and sheep (Schaller 1977, Geist 1987, Mishra and Johnsingh 1996). Having evolved in open forested areas where grasses tend to dominate the ground flora, the goral has adapted itself to be primarily a grazer. However the data collected under present study suggest that goral despite, being grazer, exploits comparatively high quality grasses as compared to low quality. The above ground biomass was significantly higher in pine forest compared to oak forest in Binsar Wildlife Sanctuary in pre as well as post-monsoon season. Yet goral avoided pine habitat in both seasons despite pine being rich in grass diversity and biomass and utilised open areas within oak forest only in Binsar. The analysis of crude protein content of above ground biomass in oak and pine habitat showed the crude protein contents to be significantly higher in oak forest compared to pine in pre and post-monsoon seasons. This perhaps could be one of the main reason why goral utilised oak forest only in Binsar and avoided pine habitat in both seasons.

Figure 7.5 provides the values of mean number of plant species of different groups in Binsar during pre and post-monsoon seasons. The mean number of seedling and sapling species (tree and shrub species both), herb species and grass species was 8.5±2.8 and 9±2.6, 2.0±1.2 and 2.3±21.8, 1.7±1.0 and 2.0±1.1 respectively during pre and post-monsoon season. There were no significant differences between the means of two seasons for each group (Z= 1.0, 0.95 and 1.6, P<0.05). This suggests that the food availability composition did not change between seasons and it is also reflected in utilisation of each specific group by barking deer, which as a whole did not differ from expected by chance. However, the expected utilisation was lower in both seasons for herb species (18 versus 14.8 in pre and 19 versus 15 in post-monsoon). However there were definite trends in utilisation of different groups at species level between seasons. At seedling and sapling level, *Indigofera heterantha* was preferred in both seasons whereas *Myrica esculenta* and

Thalectrum foliolossum were preferred in Post-monsoon season only. At herb level, *Launea secunda* was preferred in both seasons whereas six and two herb species were exclusively preferred in pre and post-monsoon seasons respectively. This suggests that dietary preferences of barking deer were more pronounced at herb level in pre-monsoon season compared to post-monsoon season. This could be due to greater availability of herb species in pre-monsoon compared to post-monsoon season (29 versus 21 species).

Table 7.1 Percent occurrence of fragments of tree, shrub and herb species within the identified browse fragments in faecal pellets of barking deer during pre-monsoon and post-monsoon season in 1998 in Binsar Wildlife Sanctuary. N= number of individual of a species sampled, n= number of plant fragment recorded in diet composition, p= percent of occurrence.

Species	Pre-monsoon			Post-monsoon		
	N	n	p	N	n	p
Trees						
Quercus floribunda	129	25	4.5	222	9	3.0
Quercus leucotrichophora	115	31	5.6	99	21	7.1
Viburnum cotinifolium	64	7	1.2	27	0	0
Euonymus tingens	8	4	0.7	6	0	0
Swida oblonga	29	17	3.0	27	6	2.0
Cornus macrophylla	0	0	0	4	4	1.3

Prunus sp.	0	3	0.5	0	2	0.6
Myrica esculenta	13	1	0.1	9	1	0.3
Pyrus pashia	49	2	0.3	151	1	0.3
Rhododendron arboreum	34	0	0	41	1	0.3
Shrubs						
Indigofera heterantha	51	135	24.5	19	16	5.4
Rubus ellipticus	130	12	2.1	136	4	1.4
Daphnae papyraceae	298	7	1.2	307	4	1.4
Rubus biflorus	28	5	0.9	33	10	3.4
Myrsine africana	845	13	2.3	686	29	9.8
Rubus paniculetus	13	0	0	14	8	2.7
Desmodium elegans	128	2	0.3	47	0	0
Thalectrum foliolossum	12	0	0	9	19	6.4
Pyracantha crenulata	9	0	0	10	1	0.3
Herbs						
Catamintha umbrossa	*0*	109	19.7	13	30	10.2

Launea secunda	87	47	8.5	0	13	4.4
Epilobium angustifolium	0	13	2.3	0	0	0
Origanum vulgare	1	4	0.7	19	5	1.7
Galium aparina	24	18	3.2	15	11	3.7
Rubia cordifolia	37	16	2.9	14	10	3.4
Ranunculus laetus	0	30	5.4	0	4	1.3
Impatiens scabrida	0	3	0.5	0	3	1.0
Desmodium triguelrum	10	5	0.9	4	5	1.7
Plectranthus striatus	23	3	0.5	0	3	1.0
Geranium collinum	8	3	0.5	0	0	0
Bergenia ligulata	5	12	2.1	1	34	11.6
Flemengia strobilifera	16	1	0.1	14	19	6.4
Viola canescens	12	1	0.1	8	2	0.6
Parthinocissus himalayana	14	16	2.9	1	2	0.6
Valeriana hardwickii	9	1	0.1	15	7	2.3
Ainsliaea aptera	2	0	0	0	3	1.0

Micromeria biflora	7	4	0.7	15	0	0
Achyranthus gossipiana	2	1	0.1	0	3	1.0
Myriactor nepalensis	0	0	0	8	1	0.3
Smilex vaginata	87	0	0	59	1	0.3
Erigeron bonasiensis	0	0	0	0	1	0.3

Table 7.2 Percent occurrence of fragments of tree, shrub and herb species within the identified browse fragments in faecal pellets of goral during pre-monsoon and post-monsoon season in 1998 in Binsar Wildlife Sanctuary. N= number of individual of a species sampled, n= number of plant fragment recorded in diet composition, p= percent of occurrence.

Species	Pre-monsoon			Post-monsoon		
	N	n	p	N	n	p
Trees						
Quercus leucotrichophora	115	10	0.59	99	4	0.18
Swida oblonga	29	0	0	27	1	0.04
Shrubs						
Indigofera heterantha	51	19	1.13	19	6	0.27
Rubus ellipticus	130	3	0.179	136	0	0
Daphnae papyraceae	298	13	0.77	307	0	0
Myrsine africana	845	25	1.49	686	0	0
Rubus paniculetus	13	1	0.05	14	0	0

Herbs						
Catamintha umbrossa	0	2	0.11	0	16	0.73
Coriaria nepalensis	0	5	0.29	0	0	0
Launea secunda	87	3	0.17	0	1	0.04
Epilobium angustifolium	0	3	0.17	0	0	0
Origanum vulgare	1	1	0.11	19	0	0
Galium aperina	24	2	0.11	15	0	0
Impatiens scabrida	0	0	0	0	1	0.04
Plectranthus striatus	23	2	0.11	0	5	0.11
Bergenia ligulata	5	1	0.05	1	0	0
Flemingia strobilifera	16	1	0.05	14	0	0
Viola canescens	12	0	0	8	2	0.09
Parthinocissus himalayana	14	0	0	1	1	0.04
Valeriana hardwickii	9	1	0.05	15	0	0
Ainsliaea aptera	2	2	0.11	0	0	0

Table 7.3 95% Boneferroni confidence limits for available (P_{io}), and utilised proportion of different browse species (P_{ie}) in barking deer diet in pre and post-monsoon seasons in Binsar Wildlife Sanctuary. 0= utilised in proportion to availability, += utilised significantly greater than availability, - = utilised significantly less than availability, * = species available but not recorded in diet composition, **= species not recorded in sampling but recorded in diet composition, *= species neither recorded in sampling nor recorded in diet composition.**

Species	Pre-monsoon				Post-monsoon			
	P_{io}	P_{ie}	95% Bonferoni C.L. for P_{ie}	Rating	P_{io}	P_{ie}	95% Bonferoni C.L. for P_{ie}	Rating
Trees								
Quercus floribunda	0.033	0.045	$0.0167 \leq Pi \leq 0.0733$	0	0.063	0.03	$0.0203 \leq Pi \leq 0.0397$	-
Quercus leucotrichophora	0.029	0.056	$0.0247 \leq Pi \leq 0.0873$	0	0.028	0.071	$0.0243 \leq Pi \leq 0.1177$	0

Viburnum cotinifolium	0.016	0.012	-0.0247≤Pi≤0.138	-	0.0077	-	-	*
Euonymus tingens	0.002	0.007	-0.0044≤Pi≤0.01836	0	0.0017	-	-	*
Swida oblonga	0.007	0.03	0.007≤Pi≤0.053	0	0.0077	0.02	-0.005≤Pi≤0.045	0
Cornus macrophylla	--	--	---	***	0.0012	0.013	-0.008≤Pi≤0.034	0
Prunus sp.	--	0.005	0.002≤Pi≤0.008	**	--	0.006	-0.0081≤Pi≤0.0201	**
Myrica esculenta	0.003	0.001	0.0003≤Pi≤0.0023	-	0.0026	0.003	0.0069≤Pi≤0.0129	+
Pyrus pashia	0.0127	0.003	-0.0044≤Pi≤0.304	0	0.043	0.003	0.0069≤Pi≤0.0129	-
Rhododendron arborum	0.008	--	---	*	0.0118	0.003	0.0069≤Pi≤0.0129	0
Shrubs								
Indigofera heterantha	0.013	0.245	0.1864≤Pi≤0.304	+	0.0054	0.054	0.013≤Pi≤0.095	+
Rubus ellipticus	0.033	0.021	0.0015≤Pi≤0.405	0	0.039	0.014	-0.007≤Pi≤0.035	-
Daphnae papyracea	0.076	0.012	-0.0028≤Pi≤0.0268	-	0.088	0.014	-0.0071≤Pi≤0.035	-
Rubus biflorus	0.007	0.009	-0.0038≤Pi≤0.0218	0	0.0095	0.034	0.0011≤Pi≤0.0669	0
Myrsine africana	0.218	0.023	0.003≤Pi≤0.043	-	0.1966	0.098	0.044≤Pi≤0.152	-
Rubus paniculatus	0.003	--	---	*	0.0004	0.027	-0.002≤Pi≤0.056	0

Desmodium elegens	0.033	0.0135	-0.004≤Pi≤0.0104	-	0.0135	--	---	*
Thalectrum foliolossum	0.003	--	---	*	0.0026	0.064	0.0501≤Pi≤0.0779	+
Pyracantha crenulata	0.0023	--	---	*	0.0028	0.003	-0.0069≤Pi≤0.0129	0
Herbs								
Catamintha umbrossa	--	0.197	0.143≤Pi≤0.251	**	0.0037	--	0.047≤Pi≤0.157	**
Launea secunda	0.0225	0.085	0.047≤Pi≤0.123	+	0	0.044	0.0324≤Pi≤0.0556	+
Epilobium angustifolium	0	0.023	0.003≤Pi≤0.043	**	--	--	-	***
Origanum vulgare	0.003	0.007	-0.0044≤Pi≤0.0183	0	0.0054	0.017	-0.0065≤Pi≤0.0405	0
Galium aparina	0.006	0.032	0.012≤Pi≤0.34	+	0.0043	0.037	0.003≤Pi≤0.071	0
Rubia cordifolia	0.009	0.029	0.007≤Pi≤0.051	0	0.004	0.034	0.001≤Pi≤0.0669	0
Ranunculus laetus	--	0.54	0.0232≤Pi≤0.0848	**	--	0.013	-0.008≤Pi≤0.034	**
Impatiens scabrida	--	0.050	0.0203≤Pi≤0.079	**	--	0.01	-0.008≤Pi≤0.028	**
Desmodium trigualrum	0.002	0.090	0.051≤Pi≤0.129	+	0.0011	0.017	-0.0065≤Pi≤0.0405	0
Plectranthus striatus	0.0059	0.050	0.021≤Pi≤0.079	+	--	0.01	0.008≤Pi≤0.028	**
Geranium collinum	0.002	0.050	0.0203≤Pi≤0.0797	+	--	--	---	***

Bergenia ligulata	0.0013	0.021	0.0015≤Pi≤0.405	+	0.0002	0.116	0.058≤Pi≤0.174	+
Flemingia strobilifera	0.004	0.001	0.0003≤Pi≤0.00234	-	0.004	0.064	0.0501≤Pi≤0.0779	+
Viola canescens	0.003	0.001	0.0003≤Pi≤0.00234	-	0.0023	0.006	-0.0081≤Pi≤0.0201	0
Parthinocissus himalayana	0.003	0.029	0.0219≤Pi≤0.0361	+	0.0002	0.006	-0.0081≤Pi≤0.00201	0
Valeriana hardwickii	0.0023	0.01	-0.0035≤Pi≤0.0235	0	0.0043	0.023	0.0145≤Pi≤0.0315	+
Ainsliaea aptera	0.0005	--	---	*	--	0.01	-0.008≤Pi≤0.028	**
Micromeria biflora	0.0018	0.007	-0.0043≤Pi≤0.01836	0	0.0043	0	0.00≤Pi≤0.00	*
Achyranthus gossipiana	0.0005	0.001	0.00034≤Pi≤0.00234	0	--	0.01	-0.008≤Pi≤0.0281	**
Myriactor nepalensis	--	--	---	***	0.0023	0.003	-0.0069≤Pi≤0.029	0
Smilex vaginata	0.0225	--	0.00≤Pi≤0.00	*	0.0169	0.003	-0.0069≤Pi≤0.0129	-
Erigeron bonariensis	--	--	---	***	--	0.003	-0.0069≤Pi≤0.0129	**

Table 7.4 95% Boneferroni confidence limits for available (P_{io}), and utilised proportion of different browse species (P_{ie}) in goral diet in pre and post-monsoon seasons in Binsar Wildlife Sanctuary. 0= utilised in proportion to availability, + = utilised significantly greater than availability, - = utilised significantly less than availability, * = species available but not recorded in diet composition, ** = species not recorded in sampling but recorded in diet composition, * = species neither recorded in sampling nor recorded in diet composition.**

Species	Pre-monsoon				Post-monsoon			
	P_{io}	P_{ie}	95% Bonferoni C.L. for P_{ie}	Rating	P_{io}	P_{ie}	95% Bonferoni C.L. for P_{ie}	Rating
Trees								
Quercus leucotrichophora	0.029	0.0059	-0.0177≤Pi≤0.0295	0	0.0284	0.0018	-0.0192≤Pi≤0.0228	-
Swida oblonga	0.0075	--	---	*	0.0077	0.004	-0.0307≤Pi≤0.0316	0
Shrubs								
Indigofera heterantha	0.0132	0.0113	-0.0212≤Pi≤0.0144	-	0.0054	0.0027	-0.0228≤Pi≤0.0282	0

Rubus ellipticus	0.0336	0.0017	0.0017≤*Pi*≤0.0144	0	0.0389	--	---	*
Daphnae papyracea	0.0769	0.007	-0.0187 ≤Pi≤-0.0187	-	0.0879	--	---	*
Myrsine africana	0.2182	0.0149	0.0025≤Pi≤0.0273	-	0.1966	--	---	*
Rubus paniculatus	0.0034	0.0005	-0.2071≤Pi≤0.2171	0	0.004	--	---	*
Herbs								
Catamintha umbrossa	--	0.0011	-0.009≤Pi≤0.0113	**	--	0.0073	-0.0349≤Pi≤0.0492	**
Coriaria nepalensis	--	0.0029	-0.027≤Pi≤0.0328	**	--	--	---	***
Launea secunda	0.023	0.0017	-0.011≤Pi≤0.0144	-	--	0.0004	-0.0307≤Pi≤0.0316	**
Epilobium angustifolium	--	0.0017	-0.011≤*Pi*≤0.0144	**	--	--	---	***
Origanum vulgare	0.0003	0.0011	-0.0091≤Pi≤0.0113	0	0.0054	--	---	*
Galium aperina	0.0062	0.0011	-0.0091≤Pi≤0.0113	0	0.0043	--	---	*
Impatiens scabrida	--	--	---	***	--	0.04	-0.0307≤Pi≤0.0316	**
Plectranthus striatus	0.0059	0.0011	-0.0091≤Pi≤0.0113	0	--	0.0011	-0.0152≤Pi≤0.0174	**
Bergenia ligulata	0.0013	0.0005	-0.0064≤Pi≤0.0074	0	0.0002	--	---	*
Flemingia strobilifera	0.0041	0.0005	-0.0064≤Pi≤0.0074	0	0.004	--	---	*

Viola canescens	0.003	--	---	*	0.0023	0.0009	$-0.0139 \leq Pi \leq 0.01568$	0
Parthinocissus himalayana	0.0036	--	---	*	0.0002	0.0004	$-0.0307 \leq Pi \leq 0.0316$	0
Valeriana hardwickii	0.0023	0.0005	$-0.0064 \leq Pi \leq 0.0074$	0	0.0043	--	---	*
Ainsliaea aptera	0.0005	0.0011	$-0.0091 \leq Pi \leq 0.0113$	0	--	--	---	***

Figure 7.1 Proportion of browse and grass during pre and post-monsoon season in diet of barking deer and goral.

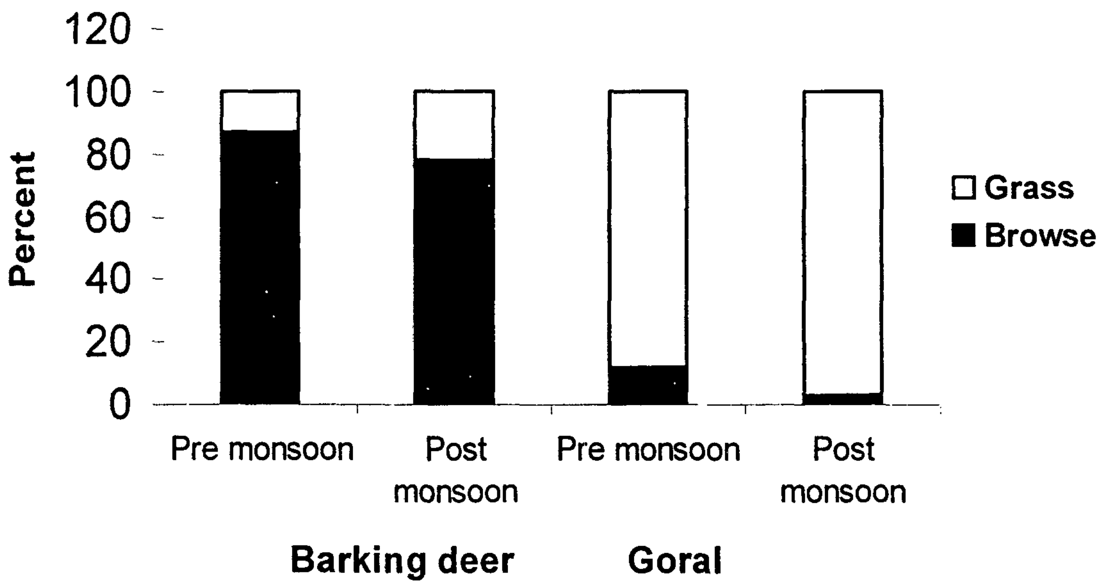


Figure 7.2 Observed and expected utilisation of tree, shrub and herb species in barking deer diet during pre and post-monsoon season in Binsar

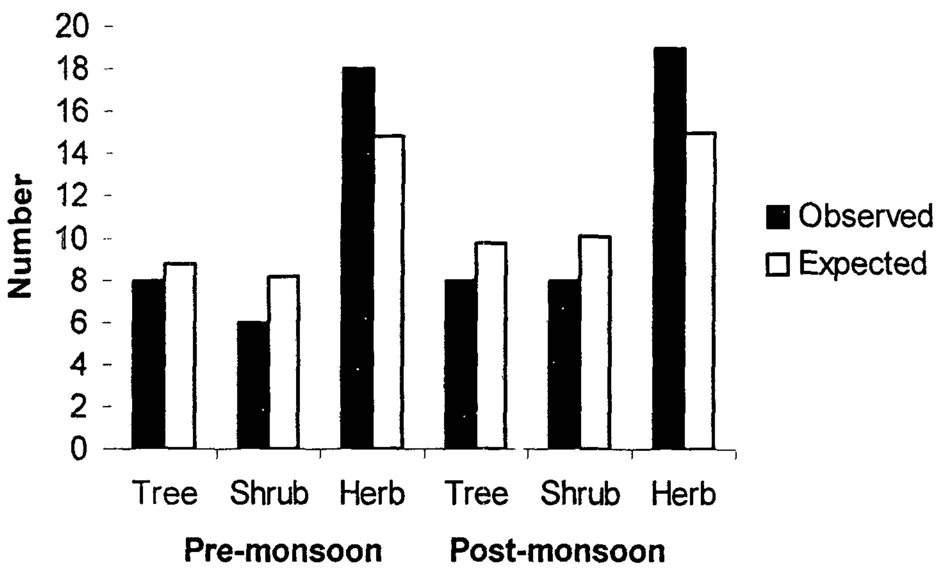


Figure 7.3 Availability of above ground biomass in oak and oak-pine habitat in Binsar

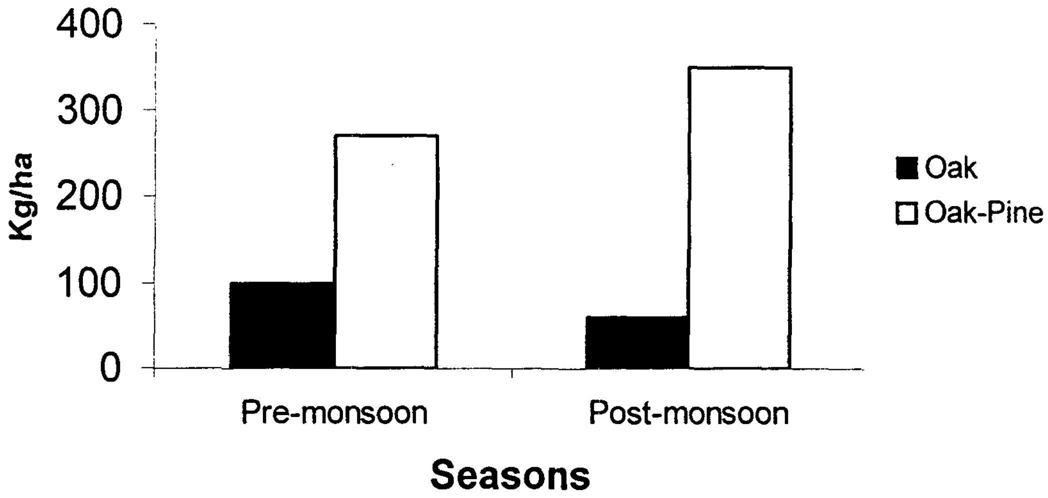


Figure 7.4 The crude protein content (% dry matter) in above ground vegetation in oak and pine habitat

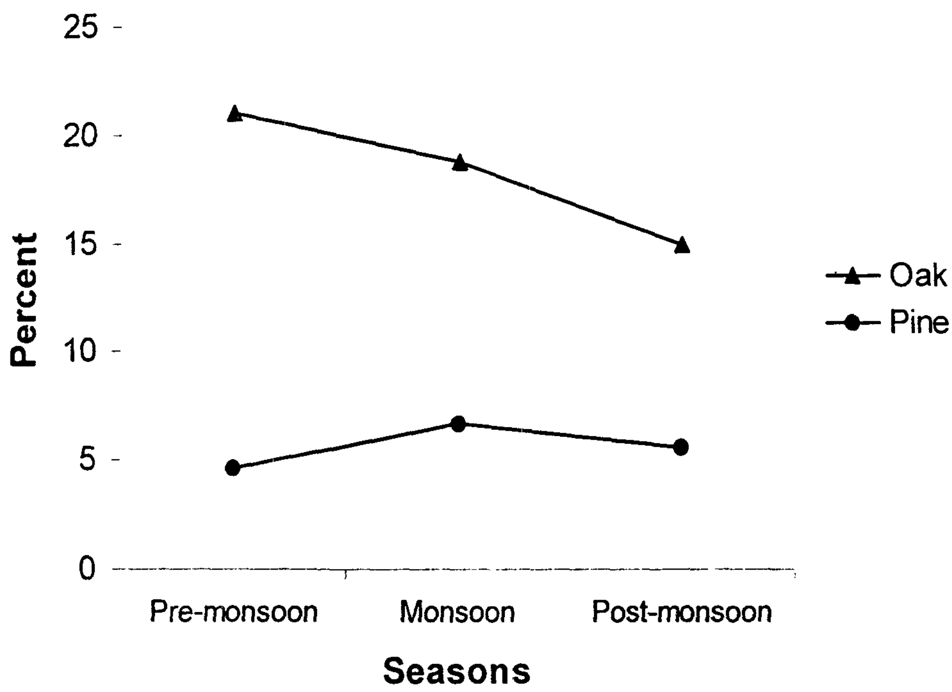
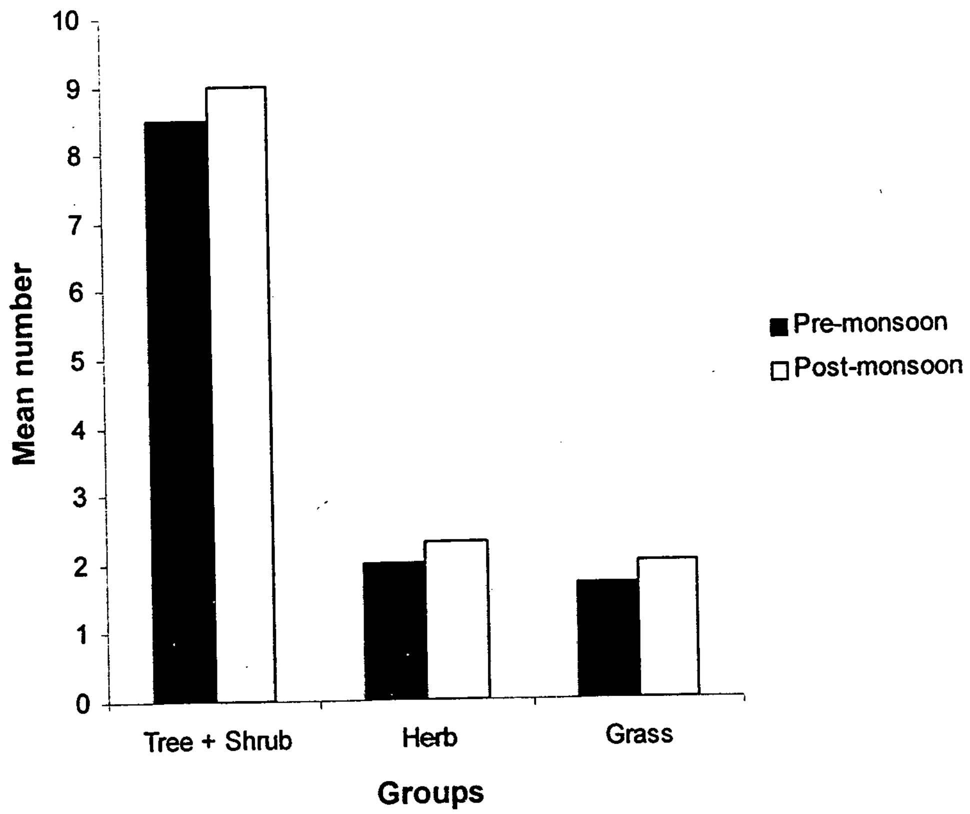


Figure 7.5 Mean number of species per plot for different groups during pre and Post-monsoon seasons in oak habitat



CHAPTER 8

THREATS ASSESSMENT IN KUMAON AND BINSAR

8.1 INTRODUCTION

Large-scale exploitation and clearance of forest for commercial, industrial and agricultural purposes in Kumaon has led to changes in land use pattern and practices resulting in loss of forest cover and forest fragmentation. The unprecedented increase in human and cattle populations simultaneously led to unsustainable exploitation of forest resources and resulted in high dependency on forested areas. The extant patches of oak forests including the two protected areas in Kumaon have large cattle and human populations dependent on resources of these patches in terms of fodder, fuel wood and timber requirements. High dependency of local people on resources of extant oak patches poses severe threats to ungulate community and their long term conservation.

The barking deer (*Muntiacus muntjak*), goral (*Nemorhaedus goral*), sambar (*Cervus unicolar*), serow (*Capricornis sumatransis*), Himalayan tahr (*Hemitragus jemlahicus*) and musk deer (*Moschus moschiferous*) which once used to be abundant in the oak forest, have been badly affected due to changes in land use pattern and dependency of local people. There has been decline in abundance of several ungulate species and several of them now occur in low abundance in extant patches (Chapter 4 and 5). The different ungulate species in Kumaon are the main prey species for the large predators such as tigers and leopards. Though the tiger, which was historically abundant in lower and middle altitudes, has become locally extinct due to variety of reasons, leopards still survive in most of the oak patches. It is therefore essential that the ungulate populations thrive in sizeable numbers to sustain the leopard populations. In order to evolve a suitable conservation strategy for ungulate populations, it is imperative that the current threats to these species and their habitats are assessed. This chapter deals with identification as well as quantitative assessment of major threats to oak patches in Kumaon Himalaya.

8.2 METHODOLOGY

8.2.1 Data collection

Data on various threat parameters were collected during the general survey of extant oak patches carried out in pre and post-monsoon seasons of 1996 using a variety of sampling techniques. A questionnaire survey was conducted around each surveyed oak patch and data on (i) number of villages, (ii) human population around the oak patch, (iii) number of livestock in each village, and (iv) percent land area under cultivation were collected. In each patch, 10 m radius circular plots were established randomly to assess the cutting, lopping, grazing and incidences of fires. Number of cut, lopped trees and cattle dung piles were counted within the sampling plot. Presence/absence of fire and damage caused by it were also noted on ordinal scale.

To evaluate the effect of forest fire on woody vegetation, sampling was carried out in a burnt oak patch of Binsar and data were collected in 100 randomly located sampling points. Data collection was carried out during post-monsoon 1996 and pre-monsoon 1998. To quantify the impact of forest fires on tree species, a 10 m radius circular plot was established at each sampling point and trees falling in it were identified to species and their numbers were enumerated. Girth at breast height (GBH) was recorded for each tree. The status (in terms of dead or alive) of each individual tree after the fire was also recorded.

To understand the effect of forest fire on the regeneration of tree species, sapling and seedlings were also enumerated in a 3 m radius circular plot laid in the centre of the plot used for sampling tree species. Plants up to the height of 0.5 m were classified as seedlings and above 0.5 m in height and less than 30 cm in GBH were considered as saplings.

8.2.2 Data analysis

All threat variables assessed in and around each oak patch were converted on ordinal scale of 1 to 4 where 1 represented low threat and 4 represented highest value of a threat parameter. For each site, number of cut trees, lopped and cattle dung piles were added together to calculate mean values for these parameters. These mean values were ranked on ordinal scale of 1 to 4 for each site. Ordinal scores for different threat parameter at different sites were added together to calculate a mean threat score for each site. Plant densities were calculated using the following formula:

$$\text{Density} = \frac{\text{Number of individual}}{\text{Area}} \times 10{,}000$$

The species diversity of tree, shrub, herb and grass layer was calculated by using Shannon-Weiner index:

$H' = - \sum pi \times \log pi$

Species richness for tree, shrub, herb and grass layer was calculated by Marglef's index:

$$RI = \frac{(S-1)}{\ln N}$$

The percent mortality in tree layer caused by fire was calculated for various tree species and different girth class categories. Simultaneous 95% Bonferroni confidence intervals was calculated following Byers *et al.* (1984) to find out the significant difference in mortality among various tree species and girth class categories. The formula for calculating 95% Bonferroni confidence interval is as follows:

$$P_{ie}-Z_{\alpha/2k}\sqrt{P_{ie}(1-P_{ie})/n} \le P_{ie} \le P_{ie}+ Z_{\alpha/2k}\sqrt{P_{ie}(1-P_{ie})/n}$$

Where P_{ie} is the observed proportional mortality in each species and $Z_{\alpha/2k}$ is the upper standard normal table value corresponding to a probability tail area of $_{\alpha/2k}$ and n is total number of trees recorded dead. For each species, its proportional availability (P_{io}) in the sample was calculated by dividing its total number (n) from that of total number of all individuals (N) sampled for all species ($P_{io} = n/\sum N$). Mortality was significantly greater or less than expected when P_{io} lay out side the 95% confidence limits constructed for proportional mortality (P_{ie}) which was calculated by dividing number of individuals found dead (d) by the of total number of dead individuals (*D*) of all species ($P_{ie}= d/\sum D$).

To find out the regeneration pattern, percentage of saplings and seedlings were calculated for post-monsoon 1996 and pre-monsoon 1998. Shannon-Wiener index of diversity ($H=-\sum pi \times \log pi$) was used to calculate the diversity of saplings and seedlings during 1996 and 1998. The t-test was used to find out significant difference between mean number of seedlings and saplings for each species between 1996 and 1998 in burnt oak patches.

8.3 RESULTS

8.3.1 Threat factors at surveyed patches

Table 8.1 provides data on threat factors at different sites. Mean tree cut (no. of trees/plot) was found to be highest at Mukteshwer (7.3±1.3), followed by Sunderdhunga (7.3±0.66). Mean Tree cutting was lowest at Kunjakharak (1.3±0.36). Mean tree lopping (no. of trees /plot) was maximum at Pandavkholi (8.1±1.3), followed by Sitlakhet (7.8±1.8) while lowest lopping was recorded at Pindari and Binayak (0.01±0.1). Maximum mean number of cattle dung was recorded from Gandhura (3.7±0.59), followed by Maheshkhan (3.2±0.79) while no cattle dung was recorded from Pindari, Gasi and Daphiyadhura. Effect of fire was found to be maximum at Pandavkholi followed by Daphiyadhura, Gager and Binsar. Human population around the oak patches was found to be maximum at Mechh (20000), followed by Gager (10450). Livestock population was found to be maximum at Mechh (25000) followed by Binayak (12000) while it was lowest in Binsar Wildlife Sanctuary. Maximum number of villages around the oak patches were recorded from Jageshwer (51), followed by Munsiyari (37), while minimum number of villages were found around the oak patch of Pindari (1).

Table 8.2 provides the combined values of threat factors for each site. Jageshwer, Gager, Sitlakhet, Mukteshwer and Munsiyari were found to be the most threatened sites as values of threat index were found to be maximum (3.571, 3.14, 3.0, 3.0 and 3.0 respectively). Least threatened sites were found to be Duku (1.428), Pindari (1.571), Binsar (1.71), Sobla (1.875), Gasi and Majtham (2.0).

8. 3. 2 Threat factors in Binsar Wildlife Sanctuary

Identified threats to the forest of Binsar Wildlife Sanctuary were excessive dependency of the locals for the fuel wood, fodder, timber, extraction of other minor forest produce and plant mortality due to fires. A total of 141 *Mawas* (house holds) were identified in ten surveyed villages of Binsar Wildlife Sanctuary and all are totally dependent on the resources of Binsar Wildlife Sanctuary.

8.3.2.1 Fuel wood collection

Villagers are totally dependent on the existing forest of Binsar for fuel wood. They fulfil their requirements of fuel wood from this sanctuary only. Survey for the fuel wood was based on the requirements of ten identified villages inside the sanctuary. All villages including Binsar were found to be utilising approximately 3525 kg of fuel wood/day. Requirement of fuel wood of each *Mawas* was found to be 25 kg/day. Villagers of the distant villages are mostly using pine wood, while villagers including from Binsar near the oak forest are using oak wood. All the villagers prefer the *Quercus* species as the fuel wood followed other species used by villagers are *Rhododendron arboreum, Viburnum, Swida, Alnus* and Pinus.

8.3.2.2 Fodder and *Arundinaria* extraction

Each household owns a cattle population. The cattle populations are also dependent on oak patch of Binsar for grazing. The villagers prefer oak leaves, grasses and herbs for fodder. Oak leaves are considered to be the best fodder for miltching cattle. The collection of oak leaves starts from November and it lasts till March. According to the ten surveyed villages, villagers collect approximately 4230 kg oak leaves/ day.

For cattle grazing people from nearby villages move up to core zone area, while people from distant villages reach up to the periphery of the oak forest. Collection of grasses and herbs starts from April and lasts till September. Each head load of grass weighs 20 kg. Overall 2820 kg/day grasses and herbs are being extracted out for the cattle by all ten villages. Green grasses are available only in September and collection of dry grasses starts in October and November for the winter season as it becomes difficult to collect grass after the snowfall. Frequency of collection of grass and herbs becomes low in July and August due to heavy rain. *Arundinaria sp.* or bamboo grass, grow mainly in oak forest as under-story. Some of the villagers collect these grasses to make basket as this is one of the partial sources of income. Extraction of the *Arundinaria* starts from

October and lasts till March, as this is the season when grass gets mature and hardens and is also available in large quantities.

8.3.2.3 Timber

Villagers depend on Binsar for their timber requirements. They are granted permits or legal rights from forest department through Gram Pradhan. The forest Department used to allot some trees to the Gram Pradhan who distributed timber to the villagers according to their requirements. For timber they were being allowed to cut only pinewood however, since March 1997 this practice has stopped in the sanctuary. Hence villagers have resorted to cutting pine trees illegally.

8.3.2.4 Medicinal plants extraction

Not much pressure is there on Binsar as far as medicinal plant extraction is concerned. The main reason is the lack of knowledge about the medicinal plants. Very few and old people know about the traditional medicinal plants. They do not want to share their knowledge of medicinal plants with the outsiders.

8.3.2.5 Pine seed and *Rhododendron* flower extraction

Children of the age group of 14-20, expert in climbing on the trees, collect the pine cone for the collection of the seeds. They sell these edible seeds in the market and the cost varies from Rs120 to 160/kg. It is a partial source of income. To collect one kg of pine seed they spend at least 3-4 days. Rhododendron flowers are used for squash, few villagers collect them for their own consumption.

8.3.2.6 Poaching

Poaching is one of the major threats to Binsar. Locals are involved in poaching. They kill barking deer, goral and pheasant such as kaleej, koklas, common hill partridge and black partridge. Occasionally people from nearby town also come to Binsar for hunting of mammals and pheasants for their own consumption.

8.3.2.7 Tourism

Heavy tourism pressure in and around Binsar causes disturbance to animals and their habitat. Figure 8.1 shows that the tourism pressure is high during April, May, and June in summer and during October and November in the winter. Heavy tourism pressure coincides with the breeding period of the birds in summer season and this is a potential source of disturbance.

8.3.2.8 Plant mortality due to forest fires

8.3.2.8.1 Mortality in tree species

Table 8. 3 provides the data on tree mortality. A total of 1944 trees belonging to 16 different species were sampled, of which 677 (34.8%) trees were found dead due to fire. Percent tree mortality was highest in *Cedrus deodara* (100%), *Swida oblonga* (83.3%), *Vibumum cotinifolium* (80.6%) and *Stranvaesia nussia* (61.5%). The relative percent mortality was however, highest in *Quercus leucotrichophora* (16.9%), followed by *Lyonia ovalifolia* (6.0%), *Rhododendron arboreum* (5.1%) and *Vibumum cotinifolium* (2.5%). The Individual tree mortality differed between different species and it was significantly higher than expected in *Viburnum cotinifolium* and *Comus macrophyla* whereas it was significantly less than

expected in *Rhododendron arboreum* and *Lyonia ovalifolia.* The mortality in rest of the species was in proportion to their availability. The overall tree mortality differed significantly between different girth classes (Fig. 8.2). It was maximum in girth class ≤50 cm (21.35%) which was significantly higher than expected. The mortality was significantly lower than expected in girth classes ranging between 51 and 200 cm while no mortality was not recorded in >200 cm girth class.

Table 8.4 provides mortality ratings among various girth classes in seven selected species. The mortality was significantly higher then expected in *Quercus leucotrichophora* in girth classes ≤ 50 cm and 151-200 cm., while it was lower then expected in girth class 101-150 cm. Mortality in *Rhododendron arboreum* was significantly higher then expected in girth class ≤ 50 cm while it was significantly lower than expected in girth classes 101-150 cm and 151-200 cm. In case of *Lyonia ovalifolia,* mortality was higher then expected in girth classes ≤50 cm and 151-200 cm whereas it was less then expected in 51-100 cm. Tree mortality in various girth classes of *Swida oblonga, Viburnum cotinifolium, Pinus roxburghii* and *Quercus floribunda* was in proportion to the availability.

8.3.2.8.2 Saplings

Table 8. 5 provides number of saplings of different species, their percentage and diversity values during 1996 and 1998. A total of 155 saplings of different tree species were recorded during 1996 which increased to 382 in 1998. Correspondingly the diversity of saplings also increased marginally from 0.59 in 1996 to 0.65 in 1998. Only *Swida oblonga, Lyonia ovalifolia* and *Quercus*

leucotrichophora had more than 10 individuals. There were changes in the proportion of saplings of various tree species between 1996 and 1998. There was a significant increase in the proportion of saplings of *Lyonia ovalifolia* from 23.8% to 30.6% (t=4.7, $d.f.$=198, P<0.001) and *Quercus leucotrichophora* from 7.09% to 16.4% (t=3.3, df=198, P<0.001) while there was a significant reduction in the proportion of *Swida oblonga* from 60% to 40% (t=2.2, $d.f$=198, P<0.025). Changes in the proportion of saplings of other species were not significant.

8.3.2.8.3 Seedlings

A total of 465 seedlings belonging to 17 species and 601 seedlings belonging to 13 tree species were recorded during 1996 and 1998 (Table 8.6). 30.7% of seedlings belonged to *Swida oblonga*, followed by *Quercus leucotrichophora* (28.6%), *Rhododendron arboreum* (10.75%) and *Lyonia* ovalifolia (9.03%) during 1996, while during 1998 maximum number of seedlings found were of *Quercus leucotrichophora* (36.1%), followed by *Swida oblonga* (21.6%), *Rhododendron arboreum* (11.14%) and *Viburnum cotinifolium* (8.32%). *Quercus* species (*leucotrichophora* and *floribunda*) showed increase in their proportion from 1996 to 1998, but the increase was significant for *Quercus leucotrichophora* only (t=3.152, $d.f.$ =198, P<0.002). Similarly proportions of *Rhododendron arboreum* and *Viburnum mullaha* increased from 1996 to 1998 but the increase was significant for *Viburnum mullaha* only (t=-3.710, $d.f.$=198, P<0.001). The proportion *of Swida oblonga, Lyonia ovalifolia* and *Pinus roxburghii* decreased from 1996 to 1998 but the differences were not significant statistically (P>0.05).

8.4 DISCUSSION

8.4.1 General threats in Kumaon

A management plan oriented towards long-term stability and maintenance of biodiversity in Kumaon is urgently needed. Dependency of the local people on small oak patches should be reduced by providing them alternatives for the fuel wood, fodder and timber. While it is impossible for humans to completely recreate the pre-existing vegetation, tree planting can help re-establish protective vegetation and accelerate the natural succession that will eventually restore a rich community of plants and animals in the area. Environmental awareness should be created as well as locals should be motivated to do the plantation in the surrounding areas. Preventive measurements should be taken to protect oak forest from forest fires, for which, fire line should be made before the fire season.

Poaching of wildlife is by far the biggest threat to mammals in the Kumaon Himalaya. The nature and magnitude of this illegal activity varies from poaching for personal consumption to organised poaching for commercial purpose.

The worst affected parts are either the interior region of the hills near glaciers or the areas adjoining the plains. However, the nature of poaching differs at both places in terms of species and magnitude. A high poaching pressure was noticed in the outer belt of the Kumaon Himalaya encompassing areas between Ramnagar, Ranikhet and Bhawali. In this forest stretch, poaching is mostly by visitors from Rampur, Moradabad, Barelli, and nearby areas.

There are people who collaborate with poachers by providing logistic help and offering their services as guides. Poaching of tigers and leopards take place in forest areas outside Corbett Tiger reserve (CTR). All commercial poachers of tigers and leopards either operate from Ramnagar, Bhatroch Khan or Ranikhet. Poaching activities are carried out on the north-eastern boundary of CTR, towards Betalghat. The road connecting Ramnagar and Khairna bridge through Betalghat is frequently used by the poachers. They come out into the plains either via Khairna or Ranikhet, as the forest Department maintains a strict vigil on the roads leading to the plains from Ramnagar. The road from Ramnagar to Khairna does not have any effective forest check post and is, therefore, a safe escape route.

There is also high poaching pressure in the forests adjacent to Bhowali, Mukteshwer, Gager and Mahesh Khan (Nainital district), Sitlakhet (Almora district), and Champawat, Lohaghat and Purnagiri areas (Pithoragarh district). Sambar, barking deer and goral species are subject to extensive poaching here. There is not much wildlife left in and around Jageshwer, probably due to poaching in the past, and due to high current human and cattle population pressure. Most of the oak forests around Jageshwer are subjected to heavy grazing, lopping and cutting. Very little indirect evidence were found for any of the ungulates species. However the area has a comparatively good population of leopard. Due to low ungulate densities, the leopard resort to preying on goats, sheep, and at time even attacking humans.

The conflict between man and leopard is most intense in Jageshwer area. In 1996, two leopard were poisoned near Vriadh Jagehwer by the locals under the guidance of poachers. Two dead langoors were poisoned and left as bait in the forest for the leopards.

The most vulnerable areas for organised poaching are the northern fringes of the Kumaon Himalaya. It is reported that organised gangs come even from Tibet and Nepal via the old trade route, and indulge in large scale hunting around the Sunderdhunga, Pindari, Kafni and Milam glaciers. Poaching in these areas is mainly targeted at the musk deer, snow leopard, Himalayan black bear and leopard. All of them fetch handsome returns in the national and international markets. A witness who managed to escape the bullets of poachers spoke about a group of about 50 people camping near Kathalia. The group remained in the area for about 20 days and killed several musk deer. These hunts are during the winter as animals come down to the lower altitudes, and therefore, become easy targets.

The villagers living south of the glacier also find poaching of musk deer, the Himalayan black bear and the leopard easy and lucrative. The locals of Khati and Jatoli villagers are involved in commercial poaching of these animals. Khati is the centre of all these activities. Areas near Sunderdhunga, Pindari and Kafni glaciers are excellent markets for procuring musk pods, leopard skin, serow head and other animal parts. The villagers have contacts with the local dealers in Bageshwer as also outside Kumaon. Large scale poaching of animals also goes on for their meat.

People regularly kill Serow, Goral, and barking deer for their own consumption, beside of course for money they receive by selling skins.

During the summer of 1997 alone, villagers killed 10-12 Himalayan black bears. Sobla in the Askot Wildlife Sanctuary, being close to Nepal, helps poachers in smuggling wildlife trophies, skins, musk pods across the border. Poaching pressure in Pithoragarh district is very high towards the Askot Wildlife Sanctuary as two international boundaries i.e. Nepal and Tibet meet in this area which happens to be the old route for the trade.

Illegal hunting has already wiped out a number of species from certain areas of Kumaon e.g. serow (*Capricornis sumatraensis)* from china peak of Nainital (Young and Kaul 1987) and from Binsar Wildlife Sanctuary (according to the villagers serow was last seen in 1990). Thus the illegal hunting in Kumaon is very common and many homes in the mountain areas possess a gun. With the increasing cost of the cartridge, villagers are resorting to the muzzleloaders and making their own lead shot.

8.4.2 Impact of fire

The fire in Binsar caused heavy mortality in mature trees as 34% of trees were found dead. This is attributed to the high intensity of fire and topography of the area. Trees on slopes are more susceptible, as fire sweeping through slopes can burn a tree at various elevations. Smaller trees on slopes usually get engulfed even by ground fire and have low chances of survival. The resistance of trees to fire varies greatly among different species, depending upon tree size, physiological condition, site quality and season of burning (Kalabokidis and Wakimoto 1992). The ability of forest Forbes and trees to survive fires varies considerably and is determined by features such as thickness and moisture contents of the bark. Martin (1998) suggested that bark thickness may be the single attribute that best characterises a species adaptation to fire. It follows that smaller individuals are at greater risk of mortality due to their thin bark as compared to larger individuals. A significantly higher overall mortality in <50 cm girth class was recorded during present study. *Viburnum cotinifolium* and *Swida oblonga* suffered high level of mortality (>80%) since majority of individuals were in <50 cm girth class. *Lyonia ovalifolia* which had >68% individuals in <50 cm girth class, however, suffered significantly lower mortality than expected as there were 96 individuals in girth class 51-100 cm out of which 15 were only dead. *Rhododendron arboreum* which suffered 19% mortality stands out as the most fire resistant species as compared to *Quercus* spp. and *Pinus roxburghii* (38% mortality in each species) the latter species being regarded as most fire resistant.

The fire changes the environment of forest floor from litter layer to clear soil, rich in readily available minerals. It also changes vertical structure of forest due to opening up of canopy allowing more solar radiation to penetrate the forest floor and thereby increasing soil temperature. These conditions enhance establishment and growth of tree seedlings (Van Cleve and Viereck 1981, Chapin *et al.* 1988). The combined density of seedlings and saplings in burnt patch was 2295 and 3477 individuals/ha during 1996 and 1998 respectively.

These values are very low compared to average density (mean±95% confidence limit) of seedlings and saplings recorded at 18 oak sites (7042±2364) distributed across Kumaon Himalaya (chapter 3). The density of saplings and seedlings ranged from 2050 in Kunjakharak to 20406 individuals/ha at Mukteshwar. The former being highly disturbed and latter being perhaps least disturbed. The density in burnt oak patch is also lower than the density of saplings and seedlings in un-burnt oak patch of Binsar where the density was found to be 4639 individuals/ha. This suggests that fire did not enhance the regeneration of seedlings and saplings, as one would expect. The diversity values at seedling and sapling level are also within the range of diversity values, which were recorded at 18 sites. This suggests that fire also did not promote a greater diversity of regenerating tree species in burnt oak patch.

The tree layer composition in sampled stand is numerically dominated by *Quercus leucotrichophora* (44%), *Rhododendron arboreum* (24%) and *Lyonia ovalifolia* (17%). Other species which have >1% contribution in tree layer are *Pinus roxburghii* (4%), *Viburnum cotinifolium* (3%) and *Quercus floribunda* (1.3%). The post fire regeneration pattern of these species, though numerically not same as in tree layer, does not indicate any major change in species composition as there were 36% seedlings of *Quercus leucotrichophora*, 11.1% seedlings of *Rhododendron arboreum*, 6.15% seedlings of *Lyonia ovalifolia,* 8.3% seedlings of *Viburnum cotinifolium* and 2.6% seedlings of *Quercus floribunda* as compared to 4.6% seedlings of *Pinus roxburghii*. The immediate post fire regeneration pattern of different species therefore do not provide any substantial evidence that *Pinus roxburghii* has any better regeneration after fire in comparison to other species. In fact except for *Lyonia ovalifolia*, seedlings of other species have shown definite increase from 1996 to 1998. On the contrary the contribution of *Pinus roxburghii* has decreased although not statistically. The data, however, points to a more important role which fire may play for *Pinus roxburghii*. Presence of 78 individuals of *Pinus roxburghii* in tree layer within oak forest conclusively indicate past encroachment and colonisation by this species in pure oak forest. There is complete absence of *Pinus roxburghii* in saplings and under-storey. The seedlings were recorded only after one year of fire. Does this mean that it is fire, which is essential for *Pinus roxburghii* to regenerate and establish? It seems this is the case with *Pinus roxburghii*. Otherwise *Pinus roxburghii*, after having established itself in tree layer, should have been regenerating like other species and had individuals at saplings and under-storey level. Unfortunately no precise records of disturbances including incidences of fires are available at beat/compartment level for Binsar with the forest department. Such records, otherwise, could have provided more substance to above observation in absence of experimental research in Himalaya. The other species which is of interest is *Swida oblonga* which has shown remarkable regeneration capacity after the fire as there were 21% seedlings in 1998 despite the fact that its overall contribution in tree layer is only 0.9%. The species composition at sapling stage shows dominance of *Swida oblonga* (40%), *Lyonia* *ovalifolia* (31%), *Quercus leucotrichophora* (16%) and *Viburnum cotinifolium* (4.1%). Though the composition is not as per the tree layer or seedling layer in terms of contribution of *Quercus* species, there is complete absence of *Pinus roxburghii* and a very low contribution of *Rhododendron arboreum* (1.5%). It is, therefore clear that after fire, *Pinus roxburghii* has not shown vigorous regeneration to pose a major threat to *Quercus* spp. which have substantial representation in seedling and sapling stage. However in the long run *Rhododendron arboreum* is expected to loose its dominance in tree layer due to poor representation at sapling stage and moderate regeneration (11%) after fire. *Swida oblonga* is expected to gain in upper canopy due to its excellent regeneration as well as very high representation at sapling stage. *Lyonia ovalifolia* having 17% contribution in tree layer may maintain its dominance due to high abundance at sapling stage but it may ultimately loose out to other species due to its poor regeneration in the long run. Many of the observations pertaining to seedling and sapling layers may require a reassessment after suitable time interval (5-10 years). It is essential that changes in this particular oak stand in Binsar are tracked in future viz-a-viz survival of regenerating *Pinus roxburghii* seedlings.

Table 8. 1 Mean number of cut trees, lopped trees, cattle dung piles per plot, human population, livestock population and number of villages in and around surveyed oak patches in Kumaon Himalaya.

Site name	Cut trees	Lopped trees	Cattle dung	Human population	Livestock Population	No. of Villages	%Area under cultivation
Binayak	1.9±.52	0.10±.10	0.80±.25	4000	12000	12	25
Binsar	2.4±.47	0.95±.22	1.15±.23	1250	760	10	30
Daphiyadhura	2.3±.44	0.94±.24	0.00 ±.00	1336	2500	28	60
Duku	1.4±.32	0.002±.002	0.43±.17	400	5000	2	40
Gager	5.5±1.1	02.8±.98	1.83±.69	10450	10200	4	60
Gandhura	4.2±.9	1.8±.46	3.7±.59	1250	1545	24	50
Gasi	0.25±.1	0.00±.00	0.00±.0.00	1120	8680	6	08
Jageshwer	6.7±.87	3.1±.71	0.88±.27	8800	10200	51	50
Kunjakharak	1.3±.36	1.5±.44	2.6±.65	1500	2740	3	50
Maheshkhan	4.9±.75	0.77±.56	3.2±.79	1785	2675	4	50
Majtham	2.3±.47	3.1±.49	1.04±.24	725	2300	3	30
Mechh	1.5±.38	0.50±.18	1.6±.63	20000	25000	13	50
Mukteshwer	7.3±1.3	1.9±.88	1.06±.36	6200	8800	16	50
Munsiyari	1.6±.46	3.7±.86	2.2 ±.63	2500	3500	37	30
Pandavkholi	5.1±1.2	8.1±1.3	0.20±.11	455	1100	3	50
Pindari	0.0±0.0	0.01±.01	0.00±.00	1100	1500	1	40
Sitlakhet	5.6±1.1	7.8±1.8	1.67±.51	4500	10000	11	20
Sobla	2.3±32	0.23±.009	0.63±.15	950	4500	8	50
Sunderdunga	7.3±.66	1.0±.37	0.001±.001	1845	7500	8	05

Table 8.2 Combined average values of all threat variables for each surveyed patch.

Site	Mean threat score
Jageshwer	3.5
Gager	3.1
Sitlakhet	3.0
Mukteshwer	3.0
Munsiyari	3.0
Gandhura	2.8
Mechh	2.7
Maheshkhan	2.7
Binayak	2.2
Pandavkholi	2.2
Kunjakharak	2.2
Daphiyadhura	2.1
Sunderdunga	2.1
Majtham	2.0
Gasi	2.0
Sobla	1.8
Binsar	1.7

Pindari	1.5
Duku	1.4

Table 8. 3. Proportion available (*Pio*), proportion dead (*Pie*) and 95% Bonferroni confidence limits for different plant species in Binsar. 0 = Mortality proportional to availability, - = Significantly lower mortality. + = Significantly higher mortality

Tree species	Total trees	*Pio*	Dead trees	*Pie*	% dead trees	Relative % dead trees	Confidence limits for *Pie*	Mortality rating
Quercus leucotrichophora	853	0.438	329	0.485	38.5	16.9	$0.42929 \leq p \leq 0.54070$	0
Rhododendron arboreum	515	0.244	100	0.147	19.4	5.1	$0.10753 \leq p \leq 0.18646$	-
Lyonia ovalifolia	342	0.175	118	0.277	34.5	6.0	$-0.0029 \leq p \leq 0.0123$	-
Pinus roxburghii	78	0.04	30	0.044	38.4	1.5	$0.0361 \leq p \leq 0.05188$	0
Viburnum cotinifolium	62	0.03	50	0.073	80.6	2.5	$0.04401 \leq p \leq 0.10199$	+
Quercus floribunda	26	0.013	10	0.014	38.4	0.5	$0.001 \leq p \leq 0.027$	0
Swida oblonga	18	0.009	15	0.022	83.3	0.7	$0.0057 \leq p \leq 0.0383$	0
Alnus nepalensis	15	0.007	6	0.008	40.0	0.30	$-0.0016 \leq p \leq 0.0192$	0
Stranvaesia nussia	13	0.006	8	0.011	61.5	0.41	$-0.0004 \leq p \leq 0.0238$	0
Myrica esculenta	9	0.004	3	0.004	33.3	0.15	$0.00303 \leq p \leq 0.011034$	0

Cedrus deodara	6	0.003	6	0.008	100	0.30	$-0.0019 \leq p \leq 0.0179$	0
Cornus macrophyla	2	0.001	1	0.0047	50	0.50	$0.2272 \leq p \leq 0.3268$	+
Pyrus pashia	2	0.001	1	0.004	50	0.05	$-0.00292 \leq p \leq 0.01232$	0
Toona serrata	1	0.005	0	0	0	0	0	
Symplocos thifolia	1	0.005	0	0	0	0	0	
Euonymus tingens	1	0.0005	0	0	0	0	0	
Total	1944		677					

Table 8.4 Proportion available (*Pio*) proportion dead (*Pie*) and 95% Bonferroni confidence limits for six dominant tree species in different girth classes during post-monsoon 1996. 0 = Mortality proportional to availability, - = Significantly lower mortality. + = Significantly higher mortality.

Girth Class	Total trees	*Pio*	Dead trees	*Pie*	Confidence limits for *Pie*	Mortality rating
Quercus leucotrichophora						
<50	302	0.35	185	0.56	$0.512 \leq P \leq 0.607$	+
51-100	372	0.43	112	0.34	$0.275 \leq P \leq 0.465$	0
101-150	145	0.16	30	0.09	$0.051 \leq P \leq 0.129$	-
151-200	23	0.026	2	0.06	$0.027 \leq P \leq 0.090$	+
>200	11	0.01	0	0.00	0	0
Rhododendron arboreum						
<50	127	0.24	56	0.56	$0.436 \leq P \leq 0.684$	+
51-100	174	0.30	38	0.38	$0.258 \leq P \leq 0.501$	0
101-150	145	0.25	5	0.05	$-0.004 \leq P \leq 0.104$	-
151-200	41	0.07	1	0.01	$-0.014 \leq P \leq 0.0337$	-
>200	28	0.04	0	0.00	0	0
Swida oblonga						
<50	15	0.83	12	0.80	$-0.625 \leq P \leq 0.975$	0

51-100	2	0.11	2	0.13	-0.087≤P≤.0.347	0
101-150	1	0.05	1	0.06	-0.093≤P≤0.213	0
151-200	0	0.00	0	0	0	0
>200	0	0.00	0	0	0	0
Lyonia ovalifolia						
<50	234	0.68	99	0.83	0.743≤P≤0.916	+
51-100	96	0.28	15	0.127	0.051≤P≤0.203	-
101-150	11	0.032	3	0.025	-0.010≤P≤0.060	0
151-200	1	0.0029	1	0.084	0.020≤P≤0.147	+
>200	0	0	0	0	0	0
Viburnum cotinifolium						
<50	47	0.75	32	0.74	0.585≤P≤0.895	0
51-100	13	0.209	12	0.24	0.090≤P≤0.390	0
101-150	2	0.032	1	0.02	-0.029≤P≤ 0.069	0
151-200	0	0	0	0.00	0	0
>200	0	0	0	0.00	0	0
Pinus roxburghii						
<50	20	0.26	12	0.40	0.180≤P≤0.62	0
51-100	30	0.39	13	0.43	0.205≤P≤0.655	0
101-150	19	0.25	03	0.16	-0.007≤P≤0.377	0
151-200	07	0.09	0	0.00	0	0
>200	0	0	0	0.00	0	0

Quercus floribunda

<50	09	0.346	5	0.5	0.341≤P≤0.658	0
51-100	16	0.615	5	0.5	0.341≤P≤0.658	0
101-150	01	0.038	0	0.0	0	0
151-200	00	0.00	0	0.0	0	0
>200	00	0.00	0	0.0	0	0

Table 8. 5 Number of tree species saplings and their percentages during 1996 and 1998. N= Number of saplings, - = Decrease in proportion, + = increase in proportion.

Tree species	Post-monsoon 1996		Pre-monsoon 1998		
	N	%	N	%	
Swida oblonga	93	60.0	155	40.5	-
Lyonia ovalifolia	37	23.8	117	30.6	+
Quercus leucotrichophora	11	7.09	63	16.4	+
Alnus nepalensis	4	2.58	2	0.52	-
Euonymus tingens	4	2.58	2	0.52	-
Lindera pulcherrima	2	1.29	1	0.26	-
Myrica esculenta	2	1.29	6	1.57	-
Pyrus pashia	1	0.64	9	2.3	+
Viburnum mullaha	1	0.64	16	4.18	+
Litsea umbrosa	0	0	5	1.3	+
Rhododendron arboreum	0	0	6	1.5	+
Total	155		382		
Diversity	0.597		0.653		

Table 8.6 Number of tree species seedlings and their percentages during 1996& 1998. N= number of seedlings, - = decrease in proportion, + = increase in proportion.

Tree seedling	Post-monsoon 1996		Pre-monsoon 1998		
	N	%	N	%	
Swida oblonga	143	30.75	130	21.6	-
Quercus leucotrichophora	133	28.6	217	36.1	+
Rhododendron arboreum	50	10.75	67	11.14	+
Lyonia ovalifolia	42	9.03	37	6.15	-
Pinus roxburghii	39	8.38	28	4.6	-
Euonymus species	13	2.79	0	0	-
Myrica esculenta	10	2.15	5	0.83	-
Lindera pulcherrima	7	1.5	4	0.66	-
Viburnum mullaha	7	1.5	50	8.32	+
Starvessia nussia	5	1.07	0	0	-
Quercus floribunda	4	0.86	16	2.6	+
Toona serrata	3	0.64	0	0	-
Alnus nepalensis	3	0.64	0	0	-
Persea duthiei	2	0.43	0	0	-
Albezzia chinensis	2	0.43	0	0	-
UN10	1	0.21	0	0	-
Litsea umbrosa	1	0.21	11	1.8	+
Pyrus pashia	0	0	17	2.8	+
Pyrus sp	0	0	18	2.9	+

Viburnum cotinifolium	0	0	1	0.16
Total	465		601	
Diversity	0.835		0.836	

Figure 8.1 Tourism pressure in Binsar Wildlife Sanctuary.

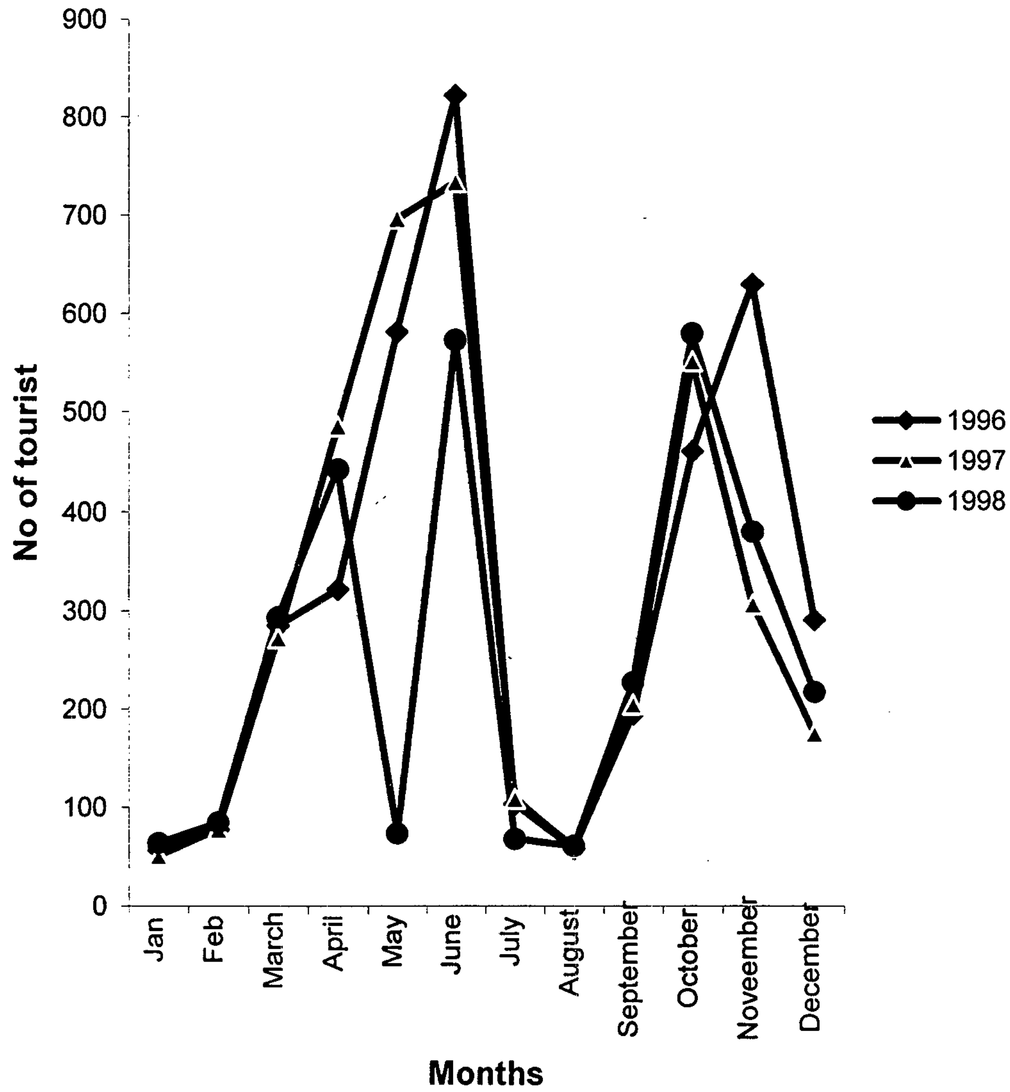


Figure 8.2 pattern of mortality in different girth class of trees.

CHAPTER 9

CONSERVATION STRATEGY

9. CONSERVATION STRATEGY

9.1 Protected area coverage and management of oak patches

The barking deer, sambar, goral, serow, Himalayan tahr and musk deer in Kumaon Himalayas are important elements of biodiversity of Himalayan landscape and some of these species are major prey item for endangered leopard which is distributed widely throughout much of the area. Therefore the conservation of these is of paramount importance. The Kumaon Himalaya, particularly the middle-altitude oak forests and higher altitude coniferous forests, has a very low protected area coverage. Currently only two sanctuaries Binsar Wildlife Sanctuary and Askot Wildlife Sanctuary covering an area of approximately 700 km^2 (3.4% of total area) exist in Kumaon. There is, therefore, a need to create more protected areas in the Kumaon Himalaya in order to conserve the different ungulate species and their predators. Hussain *et al.* (1997) have suggested creation of two protected areas in Nainital and Almora districts. The protected area in Nainital district will include Kilbury, Binayak and Kunjakharak areas, which have excellent populations of leopard, barking deer, goral and Sambar. These areas still have low human and livestock population. The protected area recommended in Almora district include Pindari and Sunderdunga reserve forest which apart from serow (*Capricornis sumatraensis*) and Himalayan tahr (*Hemitragus jemlahicus*) will conserve the highly endangered musk deer (*Moschus moschiferus*) and Himalayan black bear (*Selenarctos thibetanus*).

Apart from declaration of two protected areas, it is also recommended that the managers must evolve the guideline for conservation of patches of oak forest outside the protected areas. These patches are under tremendous lopping, livestock and poaching pressure, and the ungulate community is under heavy poaching pressure which need to be regulated. The lopping of the oak trees to provide fodder to livestock has assumed alarming proportions throughout the Kumaon Himalaya. This threaten the very existence of oak species and hence of all faunal elements inhabiting in these forests. Sound eco-development planning should be done to provide alternatives of fuel, fodder and timber to the people staying inside the protected areas in order to reduce the dependency on resources of Protected Areas. The dependency of local people on the resources of protected areas has often given rise to conflict between the local communities and the wildlife managers. The clash between the dependency of local people and the conservation interest of the protected area has been more counterproductive than to achieve conservation of biodiversity through protected area coverage. It has been long recognised that in developing world where the protected areas have high dependency of local people, the conservation of biological diversity is possible if the interests of local communities are taken care of. Also increase in conservation awareness of local people is of fundamental importance for long term conservation of protected area values. However in India the protected area managers have ignored the importance of conservation education and eco-development (a term synonymous with removal of dependency of local communities by providing alternatives) activities until recently. It is time that government should take initiative for the constructive and sustainable conservation of biodiversity. If the managers take the eco-development activities as part of routine management of protected areas, these should be with a thorough understanding of nature, magnitude and level of dependency and also keep the interest of the locals in view. This is possible if the locals are involved willingly. To preserve the Himalayan ecosystem and sustainable conservation it is necessary that government and the locals should have similarity in views.

9.2 Reduction in dependency of local people outside protected areas

Following are some recommendation to reduce the dependency on the oak patches in Kumaon Himalaya which are not included in protected areas.

9.2.1 Fuel and energy conservation

In rural India, fuelwood is the main source of energy for domestic use and fuelwood extraction is one of the major dependence of local people on oak forests. Fuelwood use can be reduced by promoting use of improved *chulhas* (stoves), which can easily reduce at least 40-50% consumption of fuel wood, promoting afforestation, and improving and democratising forest management which has already started under the Joint Forest Management Schemes. The government should promote villagers to use LPG cylinders and it can be made available to them on subsidised rate. The Ministry of Non Conventional Energy Sources should provide solar panels as well as solar cookers under the government sponsored eco-development schemes.

9.2.2 Fodder

No solution of hill problems is possible until the large cattle population is reduced. The problem of excessive livestock grazing is widespread in entire Kumaon and all patches surveyed under this study suffer from livestock grazing and excessive lopping of oak species. Excessive dependency for fodder has to be reduced in the long run if oak patches and the biodiversity these contain have to be conserved by replacing cattle population by good cattle breeds, providing fodder on subsidised rates and pasture land development.

9.2.3 Reforestation

Planting trees is one alternative for rehabilitating land and it could be a good solution to fulfill the timber requirements of local people. The plant species selected for reforestation should be indigenous, fast growing and should be compatible with land use of each area.

9.2.4 Environmental awareness

Environmental awareness is the most effective way to reduce conflict between local people and conservation interest in Kumaon. Environment awareness campaign should start at the school level and must involve women from villages as they are worst affected by depletion in forest resources in Himalaya.

REFERENCES

Adhikari, B. S., M. Joshi, H. C. Rikhari and Y. S. Rawat (1992). Cluster analysis (Dendrogram) of high altitude (2150-2500m) forest vegetation around glacier in Kumaon Himalayas. *J. Enviorn. Biol.* 13: 101-105.

Aisha Sultana and J. A. Khan (2000). Birds of oak forest in the Kumaon Himalyas, Uttar Pradesh, India. *Forktail* 16: 131-146.

Aisha Sultana and J. A. khan (1999). Avian community in the Kumaon Hiamalaya, India- a preliminary study. *Intl. J. Ecol. Environ. Sci.* 25: 167-176.

Anonymus (1994). Biodiversity in the Western Ghats. An Information Kit. WWF -India.

Atkinson, E. T. (1882). *Gazetteer of the Himalayan District of North–West Provinces of India.* Vol. X , Govt. India. Press, Allahabad.

Babu, C. R. (1977). *Herbaceous flora of Dehradun.* CSIR, New Delhi.

Bailey, R. E. and R. J. Putman (1981). Estimation of fallow deer (*Dama dama*) populations from faecal accumulation. *J. Appl. Ecol.* 18: 697-702.

Barrette, C. (1977a). Some aspects of the behaviour of muntjacs in Wilapattu National Park. *Mammalia 41*: 1-34.

Baumgartner, L. L. and A. C. Martin (1939). Plant histology as an aid in squirrel food habit studies. *J. Wildl. Manage.* 3: 266-268.

Berwick, S. H. (1974). *The Community of Wild Ruminants in Gir Forest.* Ph.D. thesis, Yale University, USA. 226 pp.

Briggs, F. S. (1931). Birds observed in the neighbourhood of Ranikhet. *J. Bombay Nat. Hist. Soc.* 34:821-827.

Buckland, S. T., D. R. Anderson., K. P. Burnham and J. L. Laake (1993). *Distance Sampling: Estimating Abundance of Biological Population.* Chapman & Hall, London.

Burnham, K. P., D. R. Anderson and J. L. Laake (1980). *Estimation of Density from Line Transect Sampling of Biological Population.* Wildlife Monograph No. 72, The Wildlife Society, U.S.A. 202 pp.

Byers, C. R., R. K. Steinhorst and P. R. Krousman (1984). Clarification of a technique for analysis of utilisation-availability data. *J. Wildl. Manage.* 48:1050-1053.

Cairns, A. L. and E. S. Telfer (1980). Habitat use by four sympatric ungulates in Boreal mixed forest. *J. Wildl. Manage.* 44: 849-857.

Canfield, R. (1941). Application of the line intercept method in sampling range vegetation. *J. Forestry* 39: 388-394.

Cavallini, P. (1992). Survey of goral *Nemorhaedus goral* (Hardwicke) in Himachal Pradesh. *J. Bombay Nat. Hist. Soc.* 89: 302-307.

Champion, H. G. and S. K. Seth (1968). *A Revised Survey of the Forest Types of India.* Government of India Publication. Delhi. 404 pp.

Chapin FS III, N. Fercher, K. Kielland, K. R. Everett and A. E. Linkin (1988). Productivity and nutrient cycling of Alaskan Tundra. Enhancement by flowering Soil Water. *Ecology* 69: 693-702.

Cody, M. L. (1974). *Competition and the Structure of Bird Communities.* Princeton University Press, Princeton, New Jersey.

Collins, W. B. and P.J. Urness (1981). Habitat preference of mule deer as rated by pellet group distribution. *J. Wildl. Manage.* 45: 969-972.

Dhar U., R. S. Rawal and S. S. Samant (1997). Structural diversity and representativeness of forest vegetation in a protected area of Kumaon Himalayas, India: Implication for conservation. *Biol. Conserv* 6: 1045-1062.

Dinerstein, E. and H. T. Dublin (1982). Daily defecation rate of captive axis deer *J. Wildl. Manage.* 46: 833-835.

Dunbar, R. I. M. (1978). Competition and nitch separation in a high altitude herbivore community in Ethiopia. *E. Afr. Wildl. J.* 16: 183-199.

Duthie, J. F. (1906). Catalogue of plants of Kumaon and of the adjacent portion of Garhwal and Tibet based on the collection Strachey and Winterbottom during the year 1846-1849. London.

Eberhardt, L. and R. C. Vanetten (1956). Evaluation of the pellet group count as a deer census method. *J. Wildl. Manage.* 20: 70-74.

Engelmann, C. (1938). Verber die Grossanger Szetschwan, Sikong and Osttibet.Zeitschrift fur Saugetierkunde 13: 76.

Ferrar, A. A. and B. H. Walker (1974). An analysis of herbivore/ habitat relationship in the Kyle National Park, Rhodesia. *J.S. Afr. Wildl. Manage. Assoc.* 4: 137-147.

Fowler, J. and L. Cohen (1986). *Statistics for Ornithologist.* BTO Guide No. 22. British Trust of Ornithology. Hertfordshire.175 pp.

Forbes, G. J. and J. B. Theberge (1993). Multiple landscape scale and winter distribution of moose (*Alces alces*) in a forest ecotone. *Can. Field-Nat.* 107: 201-207.

Freddy, D. J. and D. C. Bowden (1983). Sampling mule deer pellet group densities in Juniper pinyon woodland. *J. Wildl. Manage.* 47: 476-484.

Fuller, T. K. (1991). Do pellet count index white-tailed deer numbers and population change. *J. Wildl. Manage.* 55: 393-396.

Geist, V. (1987). On the evolution of Caprinae. Pp 3-40 *In: Biology and Management of Capricornis and Related Mountain Antelopes.* Soma, H. (Ed.), Croom Helm, USA.

Geptner, V. G., A. A. Nasimovic and A. G. Bonnidov (eds.) (1989). *Mammals of the Soviet Union.* Brill Publisher, London, UK. 1: 1-939.

Gilpin, N. E. and M. E. Soule (1986). Minimum viable population. Process of species extinction. Pp 19-34, *In: Conservation Biology, the Science of Scarcity and Diversity,* Soule, M.E. (Ed.). Sinauer Associates. Inc. Publishers.

Green, M. J. B. (1987). Ecological seperation in Himalayan ungulates. *J. Zool. Lond* (B) 1: 693-719.

Green, M. J. B. (1985). *Aspects of the Ecology of Himalayan Musk Deer.* Ph.D. dissertation, University of Cambridge. 280 pp.

Guha, R. (1994). *Social Ecology.* Oxford University Press, New Delhi, India.

Gupta, R. K. (1968*).* *Flora Nainitalensis.* New Delhi. 489 pp.

Gupta, R. K. and J. S. Singh (1962). Succession of vegetation types in the Tons Valley of the Garhwal Himalayas. *Indian For.* 88: 290-295.

Hajra, P. K. and R. R. Rao (1990). Distribution of vegetation types in North West Himalaya with brief remarks on phytogeography and floral resource conservation. *Proc. Indian. Acad. Sci.* 100: 263-277.

Hirst, S. M. (1975). *Ungulate Habitat Relationship in a South African Woodland/ Savana Ecosystem.* Wildlife Monograph No. 44, The Wildlife Society, Washington D.C. 60 pp.

Holechek, J. L. and M. Vavra (1981). The effect of slide and frequency observation number on the precision of microhistological analysis. *J. Range Manage.* 34 : 337-338.

Holechek, J. L., M. Vavra and R. D. Pieper (1982). Botanical composition determination of range herbivore diets: a review. *J. Range Manage.* 35:309-315.

Hudson, C. (1930). A list of some birds of the seven hills of Nainital, UP. *J. Bombay Nat. Hist. Soc.* 34: 821-827.

Hussain, M. S., Aisha Sultana and J. A. Khan (2000). *A Study of Threats to Biodiversity Conservation of Middle Altitude Oak Forests in Kumaon Himalayas.* Final Technical Report, Department of Wildlife Sciences. A. M. U., Aligarh, 227 pp.

Hussain, M. S., J. A. Khan, A. Ahmed and R. Kaul (1997). Status and conservation of galliforms in the Kumaon Himalaya, Utter Pradesh, India. *Intl, J. Ecol. Environ. Sci.* 23: 409-417.

Jenkins, K. J. and R. G. Wright (1988). Resource partitioning and competition among cervids in the northern rocky mountains. *J. Appl. Ecol.* 25:11-24.

Jim Corbett (1989). *Man Eater of Kumaon.* Oxford University Press, New Delhi 214 pp.

Johnsingh, A. J. T. (1983). Large mammalian prey-predators in Bandipur. *J. Bombay Nat. Hist. Soc. 80*: 1-57.

Johnsingh, A. J. T and A. S. Negi (1997). Chowgarh hills, Where Tigers once prowled. WII Newsletter 4: 1-4.

Kalbokidis, K. D. and R. H. Wakimoto (1992). Prescribed burning in un-even aged stand management of Ponderosa pine/ Douglas Fir forest. *J. Environ. Manage.* 34:221-235.

Kay, S. (1993). Factors affecting severity of deer browsing damage within coppiced woodland in the south of England. *Biol. Conserv.* 63: 217-222.

Kearney, S. R. and F. F. Gilbert (1976). Habitat use by white-tailed deer and moose on symapatric range. *J. Wildl. Manage.* 40: 645-657.

Khan, J. A. (1996). Factor governing habitat occupance of Ungulate in Gir Lion Sanctuary, Gujarat, India. *Intl. J. Ecol. Environ. Sci.* 22: 73-83

Khan, J. A. (1993). *Ungulate Habitat Relationship in Gir Forest Ecosystem and its Management Implications.* Unpublished Ph.D. Thesis, Aligarh Muslim University. Aligarh. U.P. India. 185 pp.

Khan, J. A. (1994). Food habits of ungulates in dry tropical forets of Gir Lion Sanctuary, Gujarat, India. *Acta Theriol.* 39:185-193.

Larson, T. J., O. J. Rongstad and C. Terbil (1978). Movement and habitat use of white tailed deer in South Central Wisconsin. *J. Wildl. Manage.* 52: 644-648.

Lindstrom, E. R., H. Anderson, P. Angelstam, G. Cederuland, B. Hornfeldt, L. Jaderberg, P. A. Lemnell, B. Martinsson, K. Skold, J. E. Swenson (1994). Disease reveals the predator: Sarcoptic Mange, red fox predation and prey population. *Ecology* 75: 1042-1049.

Loft, E. R. and J. G. Kie (1988). Comparison of pellet-group and radio triangulation methods for assessing deer habitat use. *J. Wildl. Manage. 52*: 524-527.

Lyon, L. J. and C. E. Jensen (1980). Management implication of elk and deer use of clear cuts in Montana. *J. Wildl. Manage.* 44: 352-362.

Martinka, C. J. (1968). Habitat relationship of white tailed deer and mule deer in North Montana. *J. Wildl. Manage.* 32: 558-565.

Martin, W. H. (1989). The role and history of fire in the Daniel Boone National Forest. US Forest Service, Daniel Boone National Forest, Winchester, KY.

Mayle, B. A., J. Deney, G. Lazarus, A. J. Peace and D. E. Smith (1996). Fallow deer *(Dama dama L.)* Defecation rate and its use in determining population size. *Suppl. Ric. Biol. Selvaggina.* XXV: 63-78.

McCaffery, K. R. (1976). Deer trail counts as an index to population and habitat use. *J. Wildl. Manage.* 40: 308-316.

McIntoch, R. P. (1967). An index of diversity and the relation of certain concepts to diversity. *Ecology* 48: 392-404.

Mishra, C. and A. J. T. Jhonsingh (1996). On habitat selection by the goral *Nemorhaedus goral* bedfordi (Bovidae, Artiodactyla). *J. Zool. Lond.* 240: 573-580.

Mitchell B., J. J. Rowe, P. Patcliff and M. Hinge (1985). Defecation frequency in Roe deer (*Capreolus capreolus*) in relation to the accumulation rates of faecal deposits. *J. Zool. Lond.* (A). 207: 1-7.

Mitchell, B., D. McCowan and D. Campbell (1983). Faecal deposition as indicator of site used by red deer. *A. Rep. Inst. Terr. Ecol.* 1982: 85-87.

Mittal, A. K. (1990). Some aspects of economic history of Kumaon under the British rule. *In: Himalayas: Past and Present.* Joshi *et al.* (Eds.). Almora Book Depot. Almora.

Munro, H. N. and A. Fleck (1969). Analysis of tissues and body fluids for nitrogenous constituents. Pp 423-525 *In: Mammalian Protein Metabolism.* Munro, H.N. (Ed.). Academic Press, New York.

Neff, D. J. (1968). The pellet group count technique for big game trend, census and distribution : A review. *J. Wildl. Manage.* 32: 597-614.

Norusis, M. J. (1990) SPSS/PC +4.0 *Base Manual- Statistical Data Analysis* SPSS Inc.

Orus Ilyas, J. A. Khan and A. Khan (1998). Status distribution and conservation of deer population of oak forest in Kumaon Himalayas. India. Proceedings, 4th International deer biology congress, Kaposvar, Hungary. 18-24.

Orus Ilyas (1998). *People and the Protected Areas: A Case Study of Binsar Wildlife Sanctuary.* WWF-India. New Delhi.

Osmaston, A. E. (1926). *A Flora for Kumaon.* International Book Distributors, Dehradun. 605 pp.

Overton, W. S. (1971). Estimating the numbers of animals in wildlife populations. Pp 403-455, *In: Wildlife Management Techniques.* Giles, R.H. Jr. (Ed.), The Wildlife Society, Washington, D.C.

Ozenda, I. (1954). La temperature facteur de repartition de la vegetation en montagne. *Coll. CNTS sur les regions ecologiques du globe.* Pp. 295-312.

Padaiga, V. I. and B. B. Marma (1979). Census of roe deer by a pellet group count. *Soviet J. Ecol.* 10: 355-357.

Pangtey, Y. P. S. and S. S. Samant (1988). Observation on the threatened, rare and endangered flowering plants and ferns in the flora of Kumaon Himalayas. *Adv. For. Res. India* 3: 65-74.

Pangtey, Y. P. S., B. S. Kalakoti and G. S. Rawat (1988). Contribution of the flora of Pithoragarh district (Kumaon Himalayas). *Him. Res. Dev.* 7: 24-46.

Pangtey, Y. P. S., R. S. Rawal, N. S. Bankoti and S. S. Samant (1990). Phenology of climber of Kumaon in Central Himalaya. *Proc. Indian. Nat. Sci. Acad. B* 60: 557-564.

Pendharker, A. P. and S. P. Goyal (1995). Group size and composition of the grey goral in Sembelbara Sanctuary and Darpur reserved forest, India. *J. Mamm.,* 76: 906-911.

Prater, S. H. (1980). *The Book of Indian Animals.* Bombay History Natural Society, Oxford University Press.

Polunin O. and A. Slainton (1994). *Flowers of the Himalaya.* Oxford University Press, Delhi. 580 pp.

Putman, R. J. (1984). Facts from faeces. *Mammal Rev.* 14: 79-97.

Ralhan, P. K., A. K. Saxena, and J. S. Singh (1982). Analysis of forest vegetation at and around Nainital in Kumaon Himalayas. *Proc. Indian Nat. Sci. Acad. B* 48: 121-137.

Ratcliffe, P. R. (1987). *The Management of Red Deer in the Commercial Forests of Scotland in Relation to Population Dynamics and Habitat Changes.* Ph.D. Thesis. University of London.

Rawal, R. S. and Y. P. S. Pangtey (1991). Distribution and phenology of climbers of Kumaon in central Himalaya, India. *Vegetatio* 97: 77-87

Rawal, R. S. and Y. P. S. Pangtey (1994). High altitude forest in a part of Kumaon, Central Himalaya. *Proc. Indian. Nat. Sci. Acad. B* 60: 557-564.

Rawal, R. S. and Y. P. S. Pangtey (1994). Altitudinal zonation of high altitude forest in Kumaon Central Himalayas, India. *Indian J. Forestry.* 17: 332-344.

Rawat, Y. S. and J. S. Singh (1988). Structure and function of oak forests in Central Himalya I. Dry matter Dynamics. *Ann. Bot.* 62: 397-411.

Reiners, W. A. (1967). Relationships between vegetation strata in the pine barrens of Central Long Island. New York. *Bull. Torrey. Bot. Club* 94: 87-99.

Rikhari, H. C., R. Chandra and S. P. Singh (1989). Pattern of species distribution and community character along a moisture gradient with in an oak zone of Kumaon Himalaya. *Proc. Indian Nat. Sci. Acad. B* 55: 431-438.

Rodgers, W. A., H. S. Panwar and V. B. Mathur (2000). *Wildlife Protected Area Network in India: A Review* (Executive summary). Wildlife Institute of India, Dehradun.

Rodgers, G., O. Julander and W. L. Robinette (1958). Pellet group counts for deer census and range use index. *J. Wildl. Manage.* 22 : 193-199.

Rogerson, S. J., E. J. Stevens and J. G. Hughes (1976). An improved preparation technique for identification of plant cuticle in animal faeces. *N. Z. J. Bot.* 14:117-119.

Rowland, M. M., G. C. White and E. M. Karlen (1984). Use of pellet-groups plots to measure trends in deer and elk populations. *Wildl. Soc. Bull.* 12 : 147-155.

Sahni, K. C. (1982). Himalayan flora and physiography: A study in contrast. *In*: *The Vegetation Wealth of the Himalayas*. G. S. Paliwal (Ed.). Puja publishers, Delhi.

Samant, S. S. and Y. P. S. Pangtey (1991a). New record of some ferns for Kumaon Himalayas (Western Himalayas). *J. Bombay Nat. Hist. Soc.* 87: 173-174.

Samant, S. S. and Y. P. S. Pangtey (1991b). Rediscovery of some rare ferns from Kumaon Himalaya. *J. Bombay Nat. Hist. Soc.* 87: 333-334.

Saxena, A. K. and J. S. Singh (1982). A phytosociological analysis of woody plant species in forest communities of a part of Kumaon Himalaya. *Vegetatio* 50: 3-22

Saxena, A. K., T. Pandey and J. S. Singh (1985). Altitudinal variation in the vegetation of Kumaon Himalayas. Pp. 43-66. *In: Perspectives in Environmental Botany.* D.N. Rao, *et al.* (Eds.) Print House, Lucknow.

Saxena, A. K., S. P. Singh and J. S. Singh (1985). Population structure of forest of Kumaon Himalaya. Implication for management. *J. Environ. Manage.* 19: 307-324.

Schaller, G. B. (1977). *Mountain Monarch: Wild Goats and Sheep of the Himalayas.* Chicago University Press, USA.

Schoener, T. W. (1974). Competition and the form of habitat shift. *Theor. Pop. Biol.* 6: 256-307.

Schoener, T. W. (1986). Resource partitioning. Pp 91-126, *In: Community Ecology-Patterns and Process.* Anderson, D. and J. Kikkawa (Eds.) Blackwell, Oxford.

Scott, K. R. (1991). Effect of habitat fragmentation on midwestern raptors. Midwest Raptor Management Symposium and Workshop. Natural Wildlife Foundation. Washington, D.C.

Singh, S. P. and J. S. Singh (1986). Structure and function of the Central Himalayan oak forests. *Proc. Indian Acad. Sci. (Plant Sci.),* 96:159-189.

Short, H. L., W. Evans and E. L. Boeker (1977). The use of natural and modified pinyon pine-Juniper woodlands by deer and elk . *J. Wildl. Manage.* 41: 543-559.

Singh, J. S. (1985). *Environmental Regeneration in Himalaya: Concept and Strategy.* CHEA and Gyanodaya Prakashan, Nainital.

Singh, J. S. and S. P. Singh (1984). *An Integrated Ecological Study of Eastern Kumaon Himalayas with Emphasis on Natural Resources.* Vol. 1-3. Final Report (HCS/DST/187/176), Kumaon University, Nainital.

Singh, J. S. and S. P. Singh (1987). Forest vegetation of the Himalaya. *Bot. Rev.* 53: 80-192.

Singh, R. S., P. K. Ralhan and S. P. Singh (1987). Phytosociology and population structure of mixed oak conifer forest in a part of Kumaon Himalaya. *Environ. Eco.* 5: 475-487.

Singh, J. S., S. P. Singh, A. K. Saxena, and Y. S. Rawat, (1984). The forest vegetation of Silent Valley, India. *In*: *The Tropical Rain Forest: Ecology and Management*. A.C. Chadwick and S.L. Sutton (Eds.). Leeds Philosophical and Literary Society, U.K.

Singh, R. S., P. K. Rahlan and S. P. Singh (1987). Phytosociological and population structure of mixed oak conifer forest in a part of Kumaon Himalaya. *Environ. Ecol.* 5: 475-487.

Singh, J. S. and S. P. Singh, (1986). Structure and function of central Himalayan oak forest. *Proc. Indian Acad. Sci.* (*Plant Sci.*) 147: 250-260.

Staines, B. W. and D. Welch (1984). Habitat selection and impact of red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) in a sitka spruce plantation. *Proc. R. Soc. Edenburgh Sect. B.* 82: 303-319.

Strachey, R. (1974). *Catalogue of Kumaon Plants.* M/S Periodical Experts, New Delhi.

Stormer, F. A., T. W. Hoekstra, C. M. White and C. M. Kirkpatrick (1977). Frequency distribution of deer pellet groups in southern Indiana. *J. Wildl. Manage.* 41: 779-782.

Stubbe, C. and J. Goretzki (1991). The significance of the defecation rate of the fallow deer in determining population density. Z. Jagdwiss. 37: 273-277.

Tahmina Shafiq, S. Javed and J. A. Khan (1997). Bird community structure of middle altitude oak forest in Kumaon Himalayas, India: A preliminary Investigation. *Intl. J. Ecol. Environ. Sci.* 23: 389-400.

Tak, P. C. (1995) Aves. Pp169-200, In: *Himalayan Ecosystem Series: Fauna of Western Himalaya, Part I, Uttar Pradesh.* Director (Ed.), Zoological Survey of India, Calcutta.

Tewari, J. C. (1982). *Vegetation Analysis along Altitudinal Gradient Around Nainital.* Ph.D. Thesis, Kumaon University, Nainital.

Tewari, J. C. and S. P. Singh (1985). Analysis of woody vegetation in a mixed oak forest of Kumaon Himalayas. *Proc. Indian. Nat. Sci. Acad.* 51 B: 332-347.

Upreti, N., J. C. Tewari and S. P. Singh (1985). The oak forests of Kumaon Himalaya (India): Composition, diversity and regeneration: *Mountain Res. Dev.* 5: 163-174.

Van Cleve, K. and L. A. Viereck (1981). Forest succession in relation to nutrient cycling in the boreal forests of Alasks. Pp 185-211, *In: Forest Succession: Concept and Application.* West, D.C. *et al.* (Eds). Springer, New York.

Van Etten, R. C. and C. L. Bennett, Jr. (1965). Some sources of errors in using pellet-group counts for censusing deer. *J.Wildl. Manage. 29:* 723-729.

Whittaker, R. H. (1967). Vegetation of the great smokey mountains. *Ecol. Monog.* 26: 1-80.

Whittaker, R. H. (1967). Gradient analysis of vegetation. *Biol. Rev.* 42 207-264.

Whittaker, R. H. (1972). Evolution and measurement of species diversity. *Taxon*, 21: 213-251.

Wood, A. K. (1989). Comparative distribution and habitat use by antelope and mule deer. *J. Mamm. 70:* 335-340.

Young, L. and R. Kaul (1987). Conservation of Himalayan pheasant in Kumaun. Pp 684-691 *In: Western Himalaya: Environment, Problem and Development,2.* Y.P.S. Pangtey and S.C. Joshi (Eds.) Gyanodaya Prakashan, Nainital.

Zar, J. H. (1984). *Biostatistical Analysis.* Prentic-Hall, N.J. 718 pp.

APPENDIX I a & b

LIST OF FAUNA AND FLORA OF BINSAR

Appendix-Ia. List of birds and mammals of Binsar Wildlife Sanctuary.

Common name	Scientific name
Birds	
Family: Accipitridae	
1. Pariah kite	*Milvus migrans govinda*
2. Shikra	*Accipter badius*
3. Sparrow hawk	*Accipiter nisus melaschistos*
4. Upland buzzard	*Buteo hemilasius*
5. Eastern steppe eagle	*Aquila rapax nipalensis*
6. Bonelli's eagle	*Hieraaetus fasciatus*
7. Golden eagle	*Aquila chrysaetos*
8. Black eagle	*Ichtinaetus malayensis*
9. Himalayan greyheaded fishing eagle	*Ichthyophaga nana*
10. King vulture	*Sarcogyps calvus*
11. Himalayan griffon	*Gyps himalayensis*
12. Egyptian vulture	*Neophron percnopterus*
13. Bearded vulture	*Gypaetus barbatus*
14. Creasted serpent eagle	*Spilomis cheela*
Family: Falconidae	
15. Shaheen falcon	*Falcoperegrinus peregrinator*
16. Kestrel	*Falco tinnunculus*
Family: Phasianidae	
17. Chukar partridge	*Alectoris chukar*
18. Black partridge	*Francolinus francolinus*
19. Common hill partridge	*Arborophila torqueola*
20. Kaleej pheasant	*Lophura leucomelana*
21. Koklas pheasant	*Pucrasia macrolopha*
Family: Columbidae	
22. Wedgetailed green pigeon	*Treron sphenura*
23. Yellowlegged green pigeon	*Treron phoenicoptera*
24. Wood pegion	*Columba palumbus*
25. Rufous turtle dove	*Streptopelia orientalis*
26. Indian ring dove	*Streptopelia decaocta*
27. Spotted dove	*Streplopelia chinensis*
Family: Psittacidae	
28. Blossomheaded parakeet	*Psittacula cyanocephala*
29. Slatyheaded parakeet	*Psittacula himalayana*
Family: Cuculidae	
30. Large hawk-cuckoo	*Cuculus sparverioides*
31. Indian cuckoo	*Cumulus micropterus*

32. The cuckoo	*Cuculus canorus*
Family: Strigidae	
33. Collared pigmy owlet	*Glaucidium brodici*
34. Barred owlet	*Glaucidium cuculoides*
35. Brown wood owl	*Strix leptogrammica*
Family: Caprimulgidae	
36. Indian jungle nightjar	*Caprimulgus indicus*
37. Longtailed nightjar	*Caprimulgus macrurus*
Family: Apopidae	
38. Whitethroated spintail swift	*Chaetura caudacuta*
39. Large whiterumped swift	*Apus pacificus*
Family: Alcedinidae	
40. Common kingfisher	*Alcedo atthis*
41. White breasted kingfisher	*Halcyon smyrnensis*
Family: Upupidae	
42. Hoopoe	*Upupa epops*
Family: Capitonidae	
43. Great hill barbet	*Megalaima virens*
Family: Picidae	
44. Scalybellied green woodpecker	*Picus squamatus*
46. Blacknaped green woodpecker	*Picus canus*
47. Large yellownaped woodpecker	*Picus flavinucha*
48. Small yellownaped woodpecker	*Picus chlorolophus*
49. Lesser goldenbacked woodpecker	*Dinopium benghalense*
50. Rufousbellied woodpecker	*Hypopicus hyperythrus*
51. Himalayan pied woodpecker	*Picoides himalayensis*
52. Brownfronted pied woodpecker	*Picoides auriceps*
Family: Hirundinidae	
53. Nepal house marten	*Delichon nipalensis*
Family: Oriolidae	
54. Golden oriole	*Oriolus oriolus*
55. Slenderbilled black oriole	*Oriolus chinensis tenuirostris*
56. Maroon oriole	*Oriolus traillii*
Family: Dicruridae	
57. Black drongo	*Dicrurus adsimilis*
58. Ashy drongo	*Dicrurus leucophaeus*
59. Bronzed drongo	*Dicrurus aeneus*
60. Haircreasted drongo	*Dicrurus hottentottus*
Family: Sturnidae	
61. Common myna	*Acridotheres tristis*
62. Jungle myna	*Acridotheres fuscus*
63. Hill myna	*Gracula religiosa*
Family: Corvidae	
64. Jay	*Garrulus glandarius*

65. Blackthroated jay	*Garrulus lanceolatus*
66. Redbilled blue Magpie	*Cissa erythrorhyncha*
67. Himalayan tree pie	*Dendrocitta formosae*
68. House crow	*Corvus splendens*
69. Jungle crow	*Corvus macrorhynchos*
Family: Campephagidae	
70. Pied flycatcher shrike	*Hemipus picatus*
71. Smaller grey cuckoo-shrike	*Coracina melaschistos*
72. Longtailed minivet	*Pericrocotus ethologus*
Family: Pycnonotidae	
73. Whitecheeked bulbul	*Pycnonotus leucogenys*
74. Redvented bulbul	*Pycnonotus cafer*
75. Black bulbul	*Hypsipetes medagascariensis*
Family: Muscicapidae	
Sub Family: Timaliinae	
76. Scalybreasted wren babbler	*Pnoepyga albiventer*
77. Whitethroated -laughing thrush	*Garrulax albogularis*
78. Striated laughing thrush	*Garrulax striatus*
79. Streaked laughing thrush	*Garrulax lineatus*
80. Redheaded laughing thrush	*Garrulax erythrocephalus*
81. Redwinged shrike babbler	*Pteruthius flaviscapis*
82. Barthroated siva	*Minla strigula*
83. Yellownaped yuhina	*Yuhina flavicollis*
84. Blackcapped sibia	*Heterophasia capistrata*
Sub family: Muscicapinae	
85. Sooty flycatcher	*Muscicapa sibirica*
86. Rufoustailed flycatcher	*Muscicapa ruficauda*
87. Little pied flycatcher	*Muscicapa westermanni*
88. Rufousbellied Niltava	*Muscicapa sundara*
89. Whitebrowed blue flycatcher	*Muscicapa superciliaris*
90. Verditer flycatcher	*Muscicapa thalassina*
91. Greyheaded flycatcher	*Culicicapa ceylonensis*
92. Whitethroated fantail flycatcher	*Rhipidura albicollis*
Sub family: Sylviinae	
93. Aberrant bush warbler	*Cettia flavolivacea*
94. Spotted bush warbler	*Bradypterus thoracicus*
95. Plain leaf warbler	*Phylloscopus negiectus*
96. Tickell's leaf warbler	*Phylloscopus affinis*
97. Orangebarred leaf warbler	*Phylloscopus cantator*
98. Yellowbrowed leaf warbler	*Phylloscopus pulcher*
99. Greyfaced leaf warbler	*Phylloscopus maculipennis*
100. Largebilled leaf warbler	*Phylloscopus magnirostris*

101. Dull green warbler	*Phylloscopus magnirostris*
102. Blackbrowed leaf warbler	*Phylloscopus cantator*
103. Greyheaded flycatcher warbler	*Seicercus xanthoschistos*
104. Blackfaced flycatcher warbler	*Abroscopus schistieeps*
105. Gold crest	*Regulus regulus*
Sub family: Turdinae	
106. Blue chat	*Erithacus brunneus*
107. Magpie robin	*Copsychus saularis*
108. Orange flanked bush robin	*Erithacus cyanurus*
109. Blueheaded redstart	*Phoenicurus caeruleocephalus*
110. Black redstart	*P. ochruros phoenicuroides*
111. Bluefronted redstart	*Phoenicurus frontalis*
112. Little forktail	*Enicurus scouleri*
113. Spotted forktail	*Enicurus maculatus*
114. Pied bush chat	*Saxicola capraata*
115. Desert wheatear	*Oenanthe deserti*
116. Whitecapped redstart	*Chaimarromis leucocephalus*
117. Chestnutbellied rock thrush	*Monticola rufiventris*
118. Blue rock thrush	*Monticola salitarius*
119. Blue whistling thrush	*Myiophonus caeruleus*
120. Plainbacked mountain thrush	*Zoothera mollissima*
121. Longtailed mountain thrush	*Zoothera dixoni*
122. Golden mountain thrush	*Zoothera dauma*
123. Large brown thrush	*Zoothera monticola*
124. Tickell's thrush	*Turdus unicolor*
125. Whitecollard black bird	*Turdus albocinctus*
126. Greywinged black bird	*Turdus boulboul*
127. Greyheaded thrush	*Turdus rubrocanus*
128. Blackthroated thrush	*Turdus ruficollis atrogularis*
129. Mistle thrush	*Turdus viscivorus*
Family: Prunellidae	
130. Alpine accentor	*Prunella collaris*
131. Robin accentor	*Prunella rubeculoides*
132. Rufous breasted accentor	*Prunella strophiata*
Family: Paridae	
133. Grey tit	*Parus major*
134. Greenbacked tit	*Parus monticolus*
135. Creasted black tit	*Paras melanolophus*
136. Black tit	*Parus rufonuchalis*
137. Yellowcheeked tit	*Parus xanthogenys*
138. Firecapped tit	*Cephalopyrus flammiceps*
139. Redheaded tit	*Aegithalos coucinnus*

140. Whitethroated tit	*Aegithalos niveogularis*
Family: Sittidae	
141. Whitetailed nuthatch	*Sitta himalayensis*
Family: Certhiidae	
142. Tree creeper	*Certhia familiaris*
143. Himalayan tree creeper	*Certhia himalayana*
Family:: Motacillidae	
144. Paddy field pipit	*Anthus novaeseelandiae*
145. Yellow wagtail	*Motacilla flava*
146. Grey wagtail	*Motacilla cinerea*
147. Pied wagtail	*Motacilla alba*
Family: Dicaeidae	
148. Firebreasted flowerpecker	*Dicaeum ignipectus*
Family: Nectariniidae	
149. Nepal yellowbacked sunbird	*Aethopyga nepalensis*
150. Blackbreasted sunbird	*Aethopyga saturata*
Family: Zesteropidae	
151. White eye	Zosterops palpebrosa
Family: Ploceidae	
Sub family: Passerinae	
152. House sparrow	*Paser domesticus*
153. Tree sparrow	*Passer montanus*
154. Cinnamon tree sparrow	*Passer rutilans*
Sub family: Estrildinae	
155. Whitethroated munia	*Lanchura malabaricay*
156. Spotted munia	*Lonchura punctulata*
Family: Fringillidae	
Sub family: Fringillinae	
157. Himalayan green finch	*Carduclis spinoides*
158. Hodgson's mountain finch	*Leucosticte nemoricola*
159. Common rose finch	*Carpodacus erythrinus*
160. Pink browed rose finch	*Carpodacus rhodochrous*
161. Vinaceous rosefinch	*Carpodacus vinaceus*
162. Redmantled rose finch	*Carpodacus rhochlamys*
163. Brown bullfinch	*Pyrrhula nipalensis*
164. Redheaded bullfinch	*Pyrrhula erythrocephala*
Family: Emberizidae	
165. Rock bunting	*Emberiza cia*
166. Crested bunting	*Melophus lathami*

Mammals

1. Rhesus macaque	*Macaca mulata*
2. Common Langur	*Presbytis entellus*

3. Leopard	*Panthera pardus*
4. Jackal	*Canis aureus*
5. Himalayan Yellow Throated Marten	*Martes flavigula*
6. Kashmir flying squirrel	*Hylopetes fimbriatus*
7. Indian porcupine	*Hystrix indica*
8. Rufous tailed hare	*Lepus nigricollis ruficaudatus*
9. Goral	*Nemorhaedus goral*
10. Barking deer	*Muntiacus muntjak*
11. Indian Wild pig	*Sus scrofa*

Appendix-1b. List of the plants of the Binsar Wildlife Sanctuary.

Species name
Trees
1. *Acer oblongum*
2. *Aesculus indica*
3. *Albizia chinensis*
4. *Albizia julibrissin*
5. *Alnus nepalensis*
6. *Carpinus viminea*
7. *Cedrus deodara*
8. *Cornus macrophylla*
9. *Cornus oblonga*
10. *Coruopteris foetida*
11. *Cupressus torulosa*
12. *Euonymus sp*
13. *Euonymus tingens*
14. *Ficus auriculata*
15. *Ficus religiosa*
16. *Fraxinus micrantha*
17. *Ilex dipyrena*
18. *Juglans regia*
19. *Lindera pulcherrima*
20. *Litsea umbrossa*
21. *Lyonia ovalifolia*
22. *Malus sikkimensis*
23. *Marsdenia lusida*
24. *Maytenus rufa*
25. *Myrica esculenta*
26. *Persea duthiei*
27. *Pinus roxburghii*
28. *Populus ciliata*
29. *Prunus cornuta*
30. *Pyrus malus*
31. *Pyrus pashia*
32. *Quercus floribunda*
33. *Quercus glauca*
34. *Quercus leucotrichophora*
35. *Rhododendron arboreum*
36. *Sorbus microphylla*
37. *Toona serrata*
38. *Viburnum cotinifolium*
39. *Viburnum mullaha*

40. *Zanthoxylum acanthopodium*

Shrub

1. *Agave angustifolium*
2. *Berberis aristata*
3. *Berberis asiatica*
4. *Bergenia ligulata*
5. *Boenninghausenia albiflora*
6. *Cinnamonum tomala*
7. *Cirsium verutum*
8. *Cotrastigma oblectum*
9. *Daphnae papyracea*
10. *Daphnae retusa*
11. *Desmodium elegans*
12. *Desmodium giganatum*
13. *Hydrocatil asiatica*
14. *Indigofera dosua*
15. *Indigofera heterantha*
16. *Myrsine africana*
17. *Opuntia monacantha*
18. *Osyris species*
19. *Pelia scripta*
20. *Pyracantha crenulata*
21. *Randia tetrasperma*
22. *Rubus biflorus*
23. *Rubus ellipticus*
24. *Rubus paniculatus*
25. *Solidago virgaaurea*
26. *Spiraea canescens*
27. *Thalictrum foliolosum*

Ferns

28. *Athyrium species*
29. *Diopteris species*
30. *Erigeron canadensis*
31 *Pteris critica*
32. *Pteridium aquilinum*
343. *Polystichum*

Herbs

1. *Achyranthus aspera*
2. *Aechmanthera gossypina*
3. *Agrimonya pilosa*
4. *Ajuga paniflora*
5. *Ainsliaea aptera*
6. *Aloe barbadensis*
7. *Amaranthus spinosus*

8. *Anaphalis triplinervis*
9. *Anemone vitifolia*
10. *Anethum sowa*
11. *Arisaema erubescens*
12. *Arisaema tortuosum*
13. *Artemisia vulgaris*
14. *Asparagus racemosus*
15. *Aster species*
16. *Atropa belladonna*
17. *Bergenia sp*
18. *Cannabis sativa*
19. *Catamintha umbrossa*
20. *Centella asiatica*
21. *Cerastium cerastioides*
22. *Cirsium verutum*
23. *Conyza striata*
24. *Cynoglossum zeylanicum*
25. *Desmodium triguelrum*
26. *Dipsacus mitis*
27. *Epilobium angustifolium*
28. *Epipactus heleborine*
29. *Erigeron bonasiensis*
30. *Flemingia strobilifera*
31. *Frageria daltoniana*
32. *Frageria nubicola*
33. *Galium aparina*
34. *Geranium nepalensis*
35. *Gladiolus species*
36. *Gnaphalium hypoleucum*
37. *Hedychium spicatum*
38. *Heracleum candicans*
39. *Launea secunda*
40. *Medera nepalensis*
41. *Micromeria biflora*
42. *Ocimum sanctum*
43. *Onychium contigucum*
44. *Orchis latifolia*
45. *Origanum majorana*
46. *Origanum vulgare*
47. *Oxalis acetosella*
48. *Paeonia emodi*
49. *Parthenocissus himalayana*
50. *Pedalium murex*
51. *Phaseolus vulgaris*

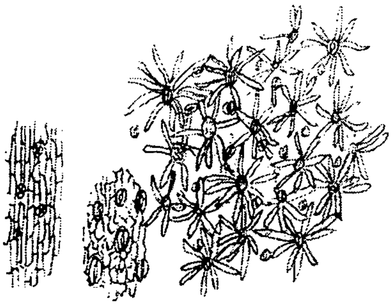
52. *Plectranthus striatus*
53. *Potentilla fulgens*
54. *Ranunculus diffusus*
55. *Ranunculus laetus*
56. *Roscoea procera*
57. *Rousfia species*
58. *Rubia cordifolia*
59. *Salvia species*
60. *Sanchus oleraceus*
61. *Smilex vaginata*
62. *Solanum nigrum*
63. *Solanum xanthocarpum*
64. *Swertia angustifolia*
65. *Swertia chirayita*
66. *Tegetus minor*
67. *Thymus serpyllum*
68. *Trachyspermum ammi*
69. *Trifolium indicum*
70. *Trigonella emodi*
71. *Urtica dioca*
72. *Valeriana hardwickii*

Grasses

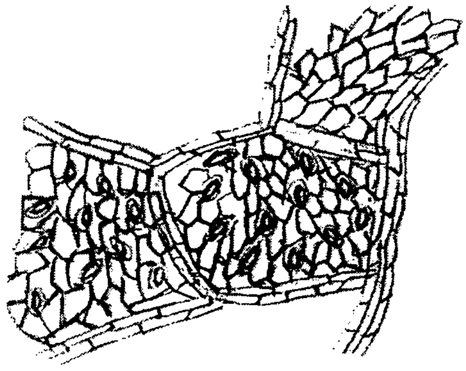
1. *Apluda mutica*
2. *Arthraxon needus*
3. *Arundinella nepalensis*
4. *Arundinaria species*
5. *Bothriochola intermedia*
6. *Bothriochola pertusa*
7. *Bromus hemalensis*
8. *Cyanodon dactylum*
9. *Chrysopogon gryllus*
10. *Cyanotis vega*
11. *Carex cruciata*
12. *Eragrostis unioloides*
13. *Erianthus rufipilus*
14. *Imperata cylindrica*
15. *Mondo intermedius*
16. *Poa annua*
17. *Setaria glauca*
18. *Themeda anathera*
19. *Thamnocalamus facloneri*

APPENDIX II

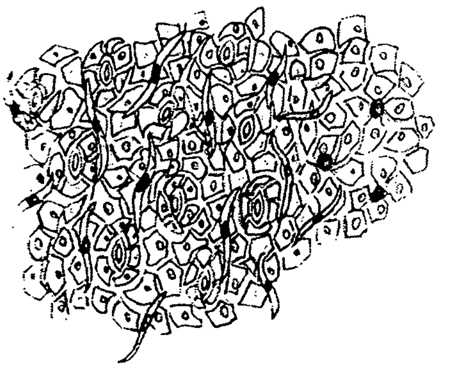
PLANT REFERENCES USED IN MICROHISTOLOGY ANALYSIS



Quercus leucotrichophora



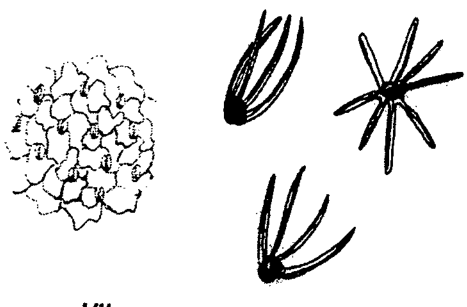
Lindera pulcherima



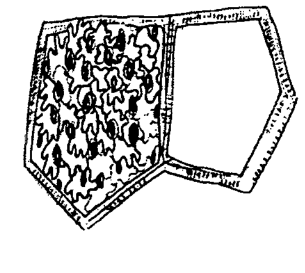
Swida oblonga

Swida oblonga

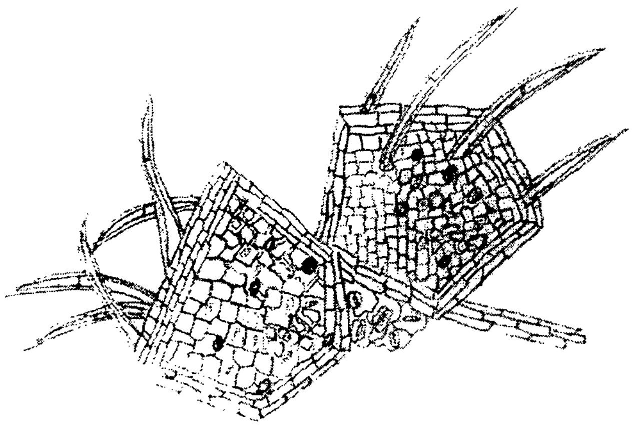
Prunus sp



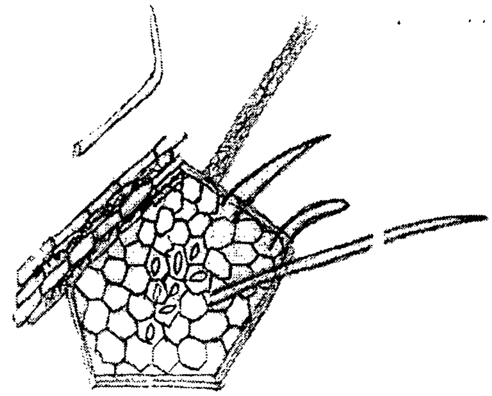
Viburnum sp.



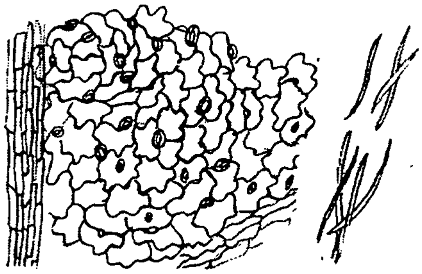
Symplocos theifolia



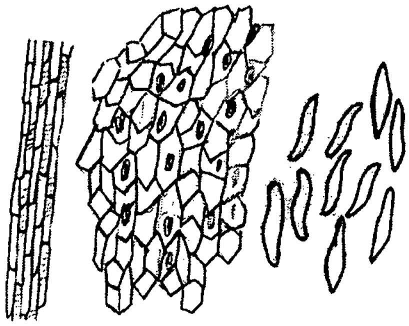
Myrica esculenta



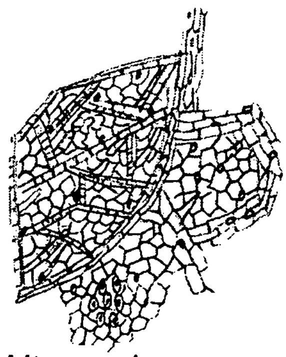
Alnus nepalensis



Smilex vaginata

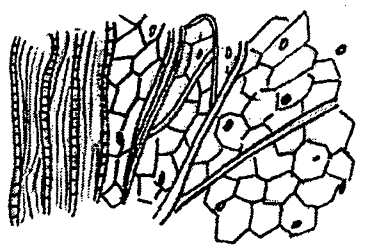


Valeriana hardwickii

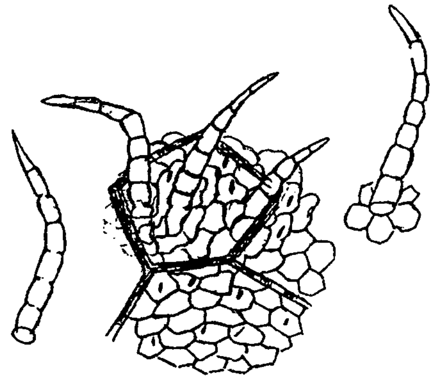


Litsea umbrosa

Cornus oblonga

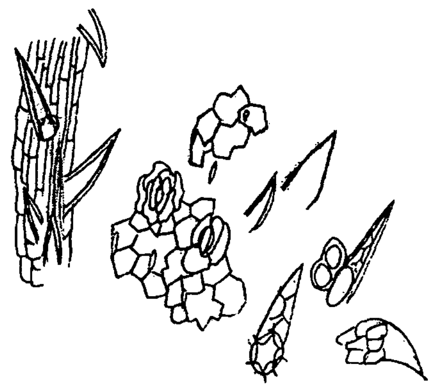


Trigonella sp

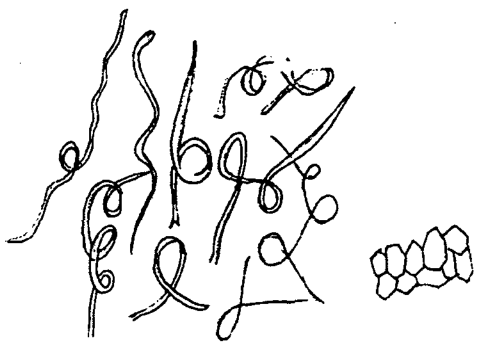


Impatiens scabrida

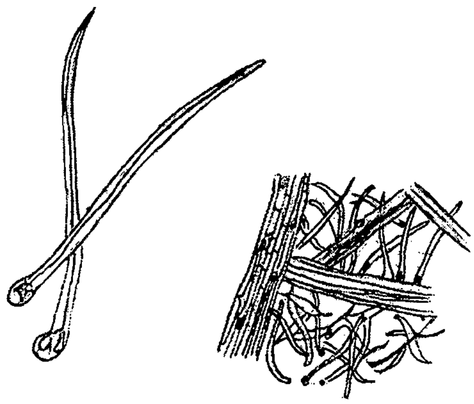
Flemingia strobilifera



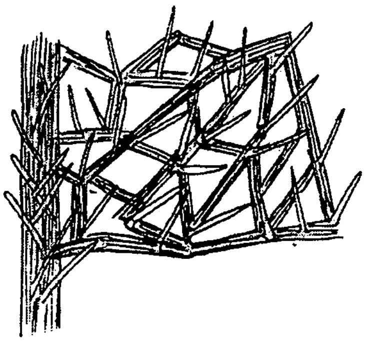
Rubia tetrasperma



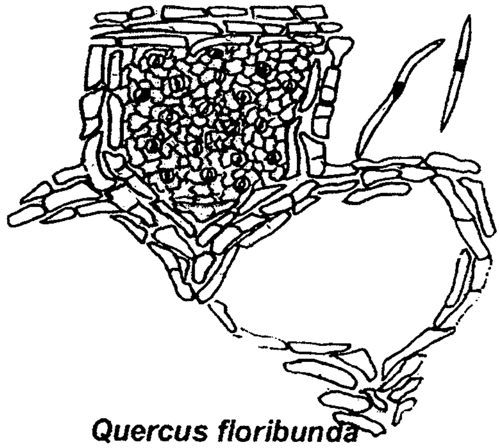
Rubus paniculatus



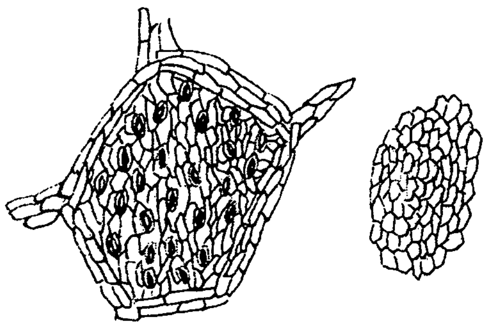
Rubus ellipticus



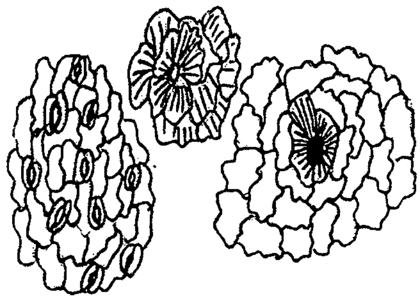
Bauhinia sp.



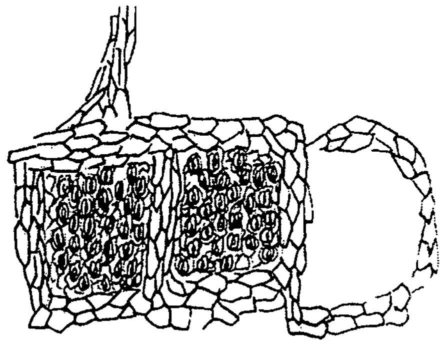
Quercus floribunda



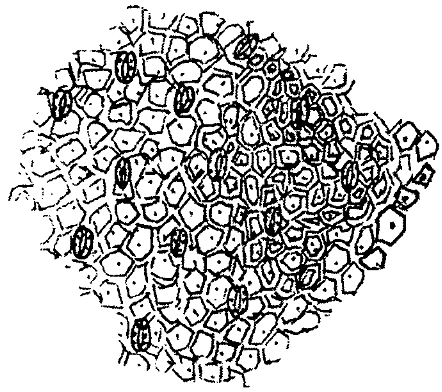
Pyrus pashia



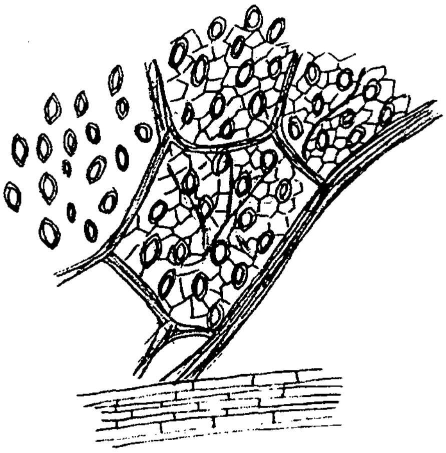
Maytenus rufa



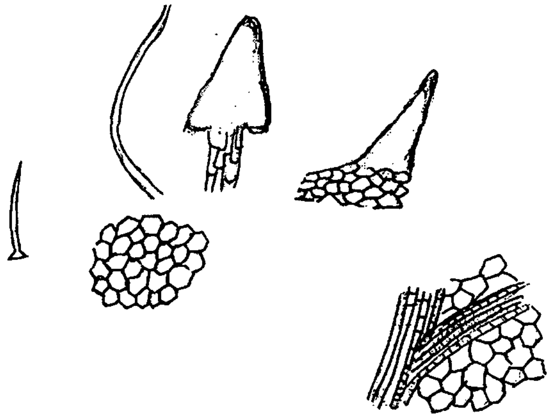
Rhododendron arborium



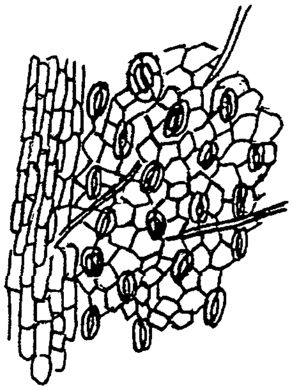
Euonymus tingens



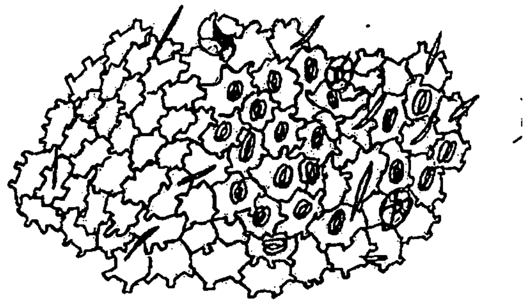
Pyracantha cranulata



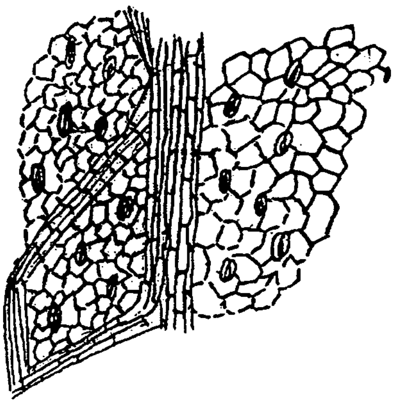
Rubus biflorus



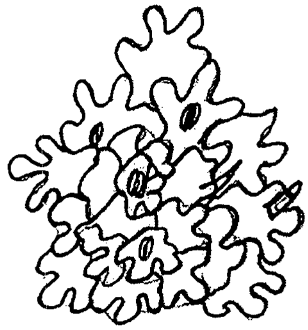
Daphne papyracea



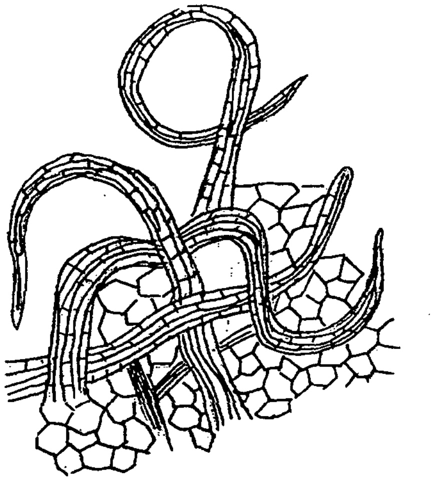
Myrsine africana



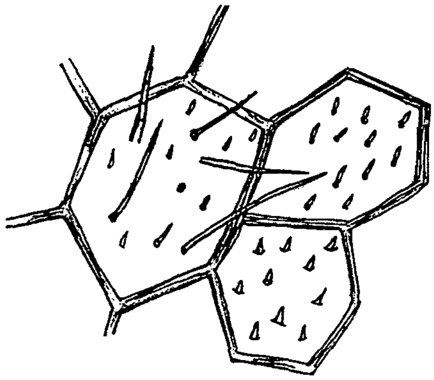
Berberis asiatica



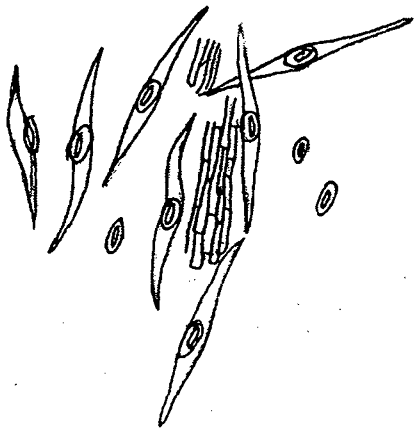
Ainselia aptera



Bergenia sp

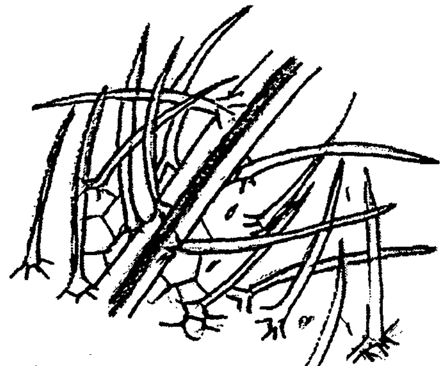


Desmodium triguetrum

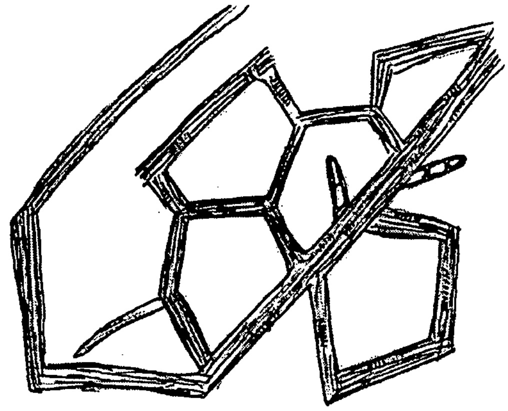


Indigofera dosua

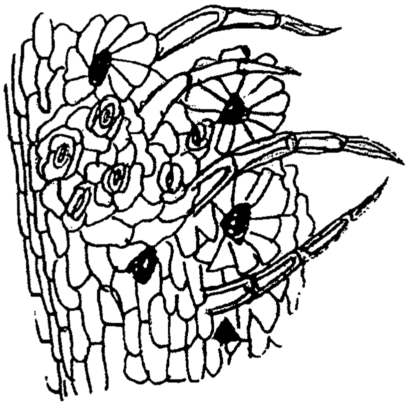
Micromeria biflora



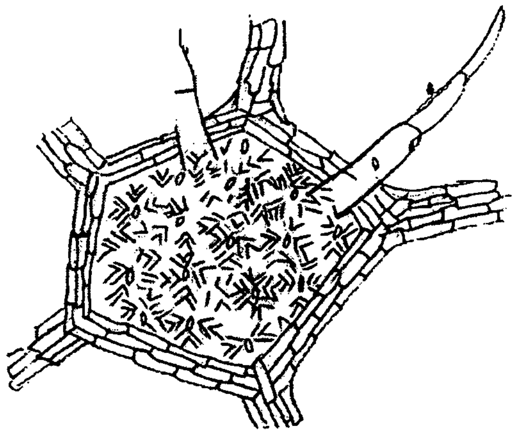
Geranium collianum



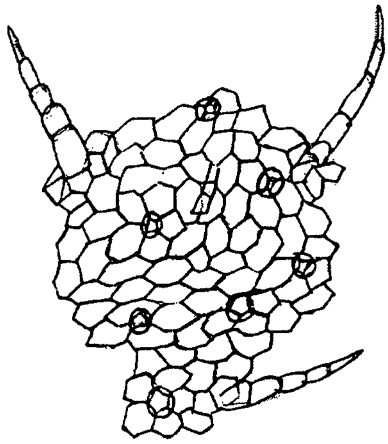
Thalictrium foliolosum



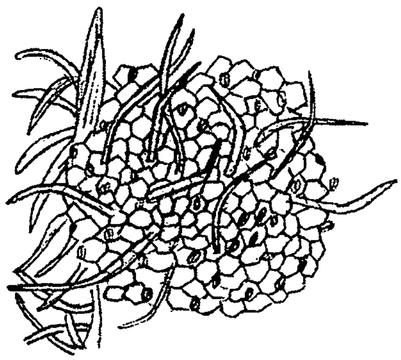
Origanum vulgare



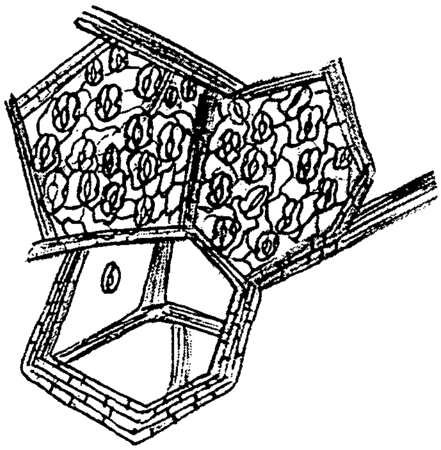
Parthinocissus sp



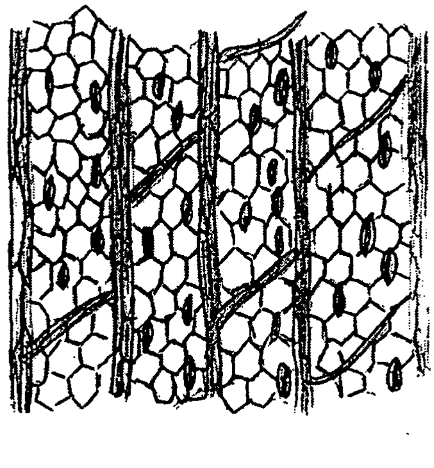
Aster sp



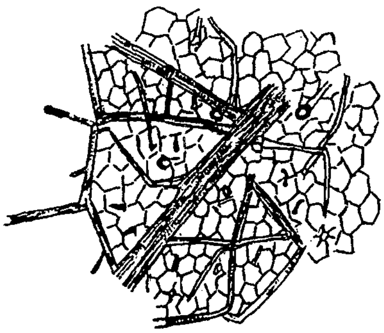
Galium aparina



Mahonia nepalensis

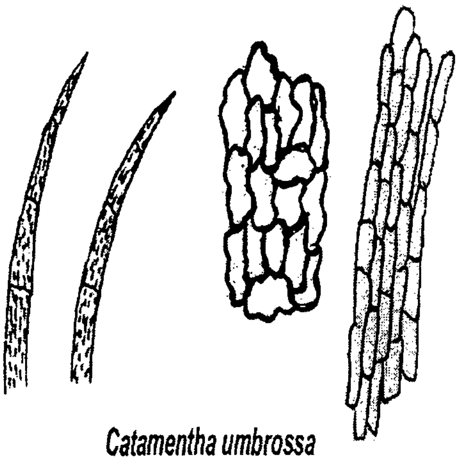


Hedychium sp.

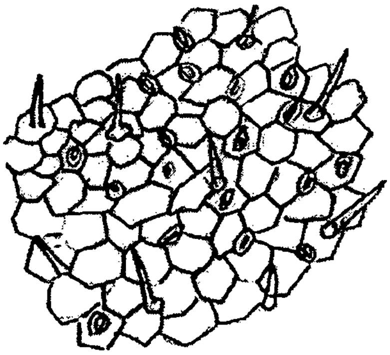


Desmodium elegans

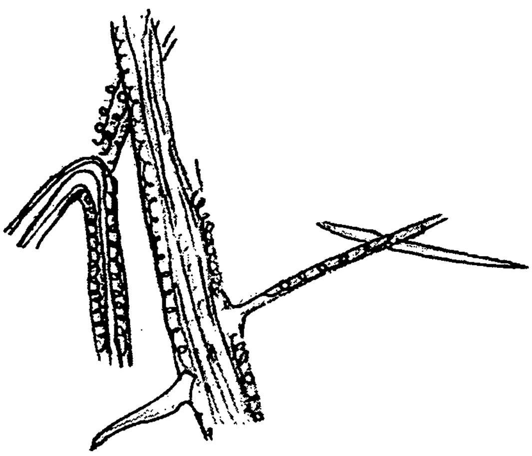
Epilobium angustifolium



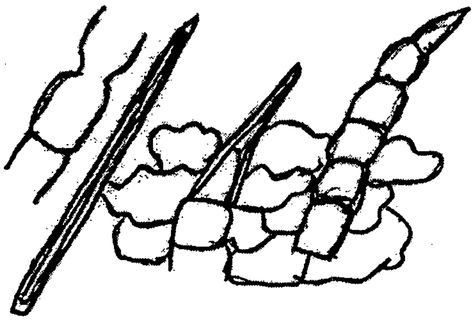
Catamentha umbrossa



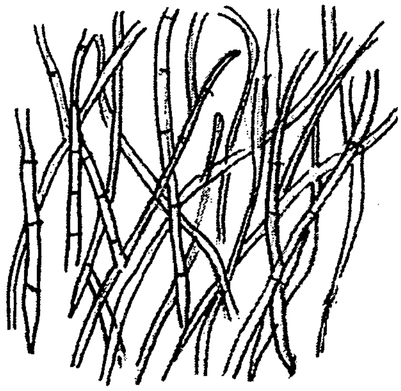
Hypericum sp



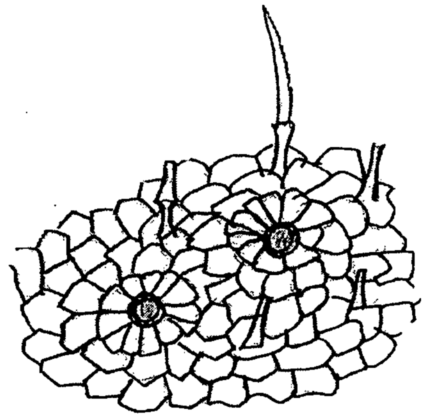
Plectranthus coerla



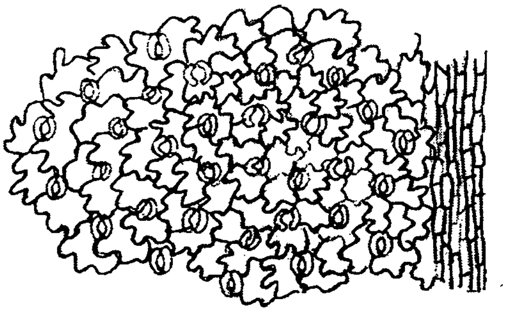
Plectranthus striatus



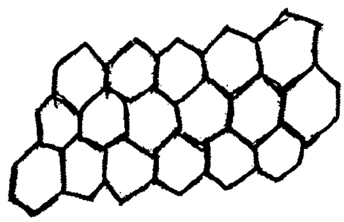
Potentila sp



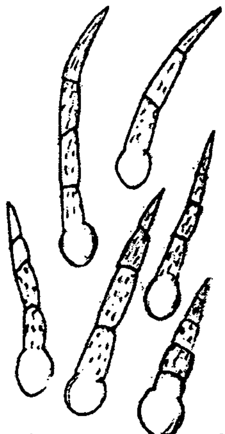
Achyranthus sp



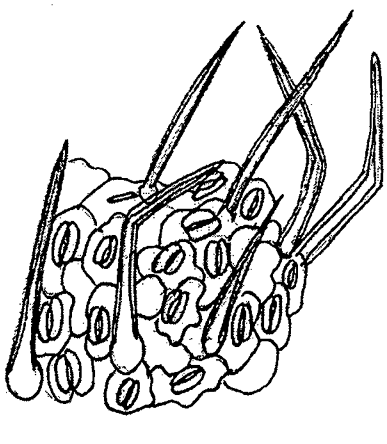
Hidra sp



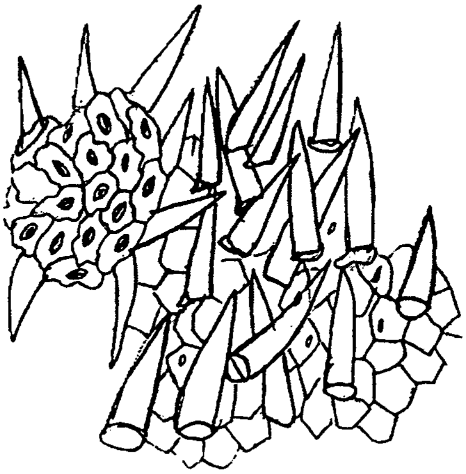
Epipatis sp



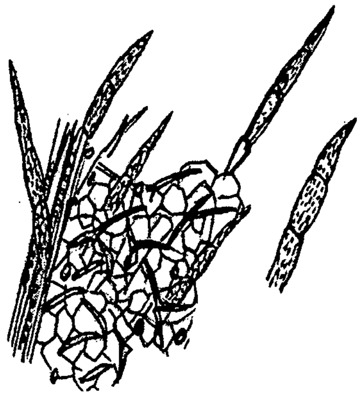
Myriactor nepalensis



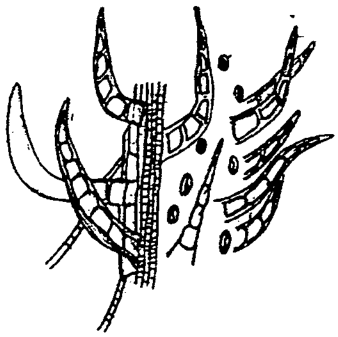
Ranunculus lactus



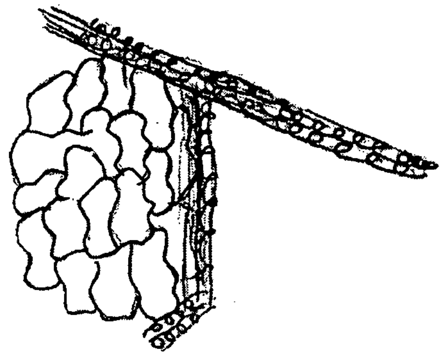
Viola canescens



Launea secunda



Erigeron bonariensis



Ainselia aptera

APPENDIX III

Appendix III. List of the plants and their code used in the ordination of the tree species in tree species density. UN = unidentified species

PCA-Code	*Species*
1.	*Quercus leucotrichophora*
2.	*Quercus semecarpifolia*
3.	*Quercus floribunda*
4.	*Rhododendron arboreum*
5.	*Viburnum sp*
6.	*Ilex dipyrena*
7.	*Lyonia ovalifolia*
8.	*Cedrus deodara*
9.	*Acer oblongum*
10.	*Litsea umbrosa*
11.	*Pinus wallichiana*
12.	*Pinus roxburghii*
13.	*Taxus bacata*
14.	*Simplocos thifolia*
15.	*Persea duthiei*
16.	*Aesculus indica*
17.	*Tsuga dumosa*
18.	*Euonymus tingens*
19.	*Euonymus* sp
20.	UN2
21.	*Swida oblonga*
22.	*Myrica esculenta*
23.	*Malus* sp
24.	*Pyrus melus*
25.	UN3
26.	*Holoptilia integrifolia*
27.	*Eucalyptus sp.*
28.	*Pyrus sp.*
29.	*Quercus glauca*
30.	*Rhododendron barbatum*
31.	*Alnus nepalensis*
32.	UN4
33.	*Lindera pulchrrima*
34.	*Populus ciliata*
35.	UN6
36.	UN7
37.	UN8
38.	*Swida sp*

39. *Vibumum mullaha*
40. *Cassia sp*
41. *Toona serrata*
42. *Prunus* sp
43. *Juglans regia*
44. *Betula utilis*
45. *Hippophae salicifolia*
46. *Prunus comuta*
47. *Stranvaesia nussia*
48. *UN9*
49. Un5
50. *Maytenus rufa*
51. *Albizia lebbek*
52. *Pyrus pashia*
53. *Quercus lanata*
54. *Quercus lamellosa*
55. *Cuprosus torulosa*
56. UN10
57. UN11
58. UN14
59. UN13
60. *Vibumum cotinifolium*
61. UN15
62. *Alnus sp*
63. UN1
64. UN12
65. *Tsuga dumosa*
66. UN16