ECOLOGY AND CONSERVATION OF AVIAN COMMUNITIES OF MIDDLE-ALTITUDE OAK FOREST OF KUMAON HIMALAYA, UTTAR PRADESH, INDIA

SUMMARY

THESIS

SUBMITTED FOR THE DEGREE OF

Doctor of Philosophy

IN

WILDLIFE SCIENCE

BY

AISHA SULTANA

DEPARTMENT OF WILDLIFE SCIENCES

ALIGARH MUSLIM UNIVERSITY

ALIGARH (INDIA)

2002

SUMMARY

INTRODUCTION

Kumaon Himalaya experienced major changes in land use pattern and practices during the last two centuries. The size and distribution of once extensive oak forests decreased due to its exploitation and clearance for terrace cultivation leading to large-scale fragmentation. Since the fragmentation and degradation of habitats are known to have negative impact on animal communities, the changes in land use pattern in the Kumaon Himalaya may also had negative impact on status and abundance of animal communities.

The conservation of overall bird community in the Himalayas is necessary because they are considered to be the best indicator species of a good forest and it has been argued that if bird communities are protected then other communities will be protected themselves. Keeping this in mind avian community study was carried out in the five districts; Almora, Bageshwer, Champawat, Naini Tal and Pithoragarh of Kumaon Himalaya (28° 43' 55" and 30° 30' 12" N latitude and 78° 44' 30" and 80° 45' E longitude) with following objectives-

1. To estimate the status and distribution of bird community in Kumaon Himalaya.
2. To estimate the bird densities and abundance pattern in different oak patches of Kumaon Himalaya.
3. To establish the bird- habitat relationship especially in context of vertical and horizontal heterogeneity.
4. To study the foraging strategies and guild structure.

5. To find out the threats on avian community.
6. To prepare the conservation strategy for avian community of Kumaon Himalaya.

METHODOLOGY

Avian community studies were conducted from March to June 1996 and September to December 1997 in Binsar Wildlife Sanctuary (hereafter BWS); from September to December 1996 and March to July 1997 at different oak patches in Kumaon and from February to July 1998 and September to December 1998 in Vinaiyak Reserve Forest (hereafter VRF). Line transect method, point count method and species richness counting method were used for sampling birds. Parameters recorded for each bird species for point count and line transect methods included: The time of initial contact, perpendicular distance, group size, species, number and activity of bird, plant species used and its total height, vertical height at which bird was observed, strata of tree used (upper, middle, lower canopy, trunk or ground). Only perpendicular distance and number of individuals were used for estimating densities in different habitats. A total of 215 bird lists in BWS, 158 lists in different localities of Kumaon Himalaya and 308 lists in VRF were compiled by Species richness counting method.

For habitat use, data on following habitat variables were also collected: Tree density, diversity and richness, tree cover, shrub density, shrub diversity, shrub richness, ground cover, vertical heterogeneity, horizontal heterogeneity or patchiness. Vertical heterogeneity was estimated at the vegetation plots by assessing foliage on ordinal scale of low, medium and high in different height intervals within a 0.5m radius.

Data were collected on transects and point transects for foraging observations for each bird species. A minimum of five observations was made for each species. For each foraging attempt microhabitat details such as height above the ground level, substrate and species of plant on which the prey was, and foraging method were recorded.

Several threats on biodiversity values (plants and birds) were also assessed during the surveys of Kumaon. The map boundaries as well as proposed sanctuaries boundaries of Kumaon region were digitized from toposheets. The proposed sanctuary map was divided into grids of 1 x 1 km. On ground, the data on different aspects were collected for each grid and GIS analyses were performed.

ANALYSES

VEGETATION STUDIES

Densities for trees, shrubs and ground vegetation (herbs and grasses) were calculated. The diversity and richness for each vegetation layer (tree, shrub and ground vegetation) and birds in different habitats were also calculated.

Kruskal–Wallis one-way ANOVA was used to detect significant statistical differences in density, diversity and richness for all vegetation layers (tree, shrub and ground vegetation) of all the oak patches of Kumaon. Vegetation attributes such as tree density, diversity, richness; shrub density, diversity, richness; ground layer density, diversity, richness along with altitude, number of stumps, lopped trees and cattle dung were subjected to Principal Component Analysis (PCA), to ordinate 23 sites in space.

Tree species of Kumaon was classified using TWINSPAN computer program. Ordination of tree species was obtained using DECORANA computer program for DCA.

STATUS AND DISTRIBUTION

Data collected by Species richness counting method, line transect and point count methods were analysed separately to calculate bird species diversity and richness. The log normal distribution was applied for whole Kumaon to present abundance data of birds. It was applied to species abundance data in different habitat types in BWS and VRF for different seasons. The model was applied for BWS and VRF by combining both seasons and all habitat types.

The distribution was written in the form-

$S(R) = So \exp(-a^2 R^2)$

where S (R) = the number of species in the R^{th} octave (i.e. class) to the right and left of the symmetrical curve.

So = the number of species in the modal octave

$a = (2\sigma^2)^{1/2}$ = parameter related to the variance of the distribution

The analysis was performed by LOGNORM.BAS computer program by using $\log_2$.

Spatial analysis was performed on landscape level between bird diversity and habitat features. Bird diversity, tree cover and tree diversity was categorized into the ordinal scale i.e. low, medium and high. Vegetation parameters were assigned as base theme layer and bird diversity layer was overlaid on them. To examine the relationship between bird diversity and vegetation on spatial level, Spearman rank correlation was performed.

DENSITY AND ABUNDANCE PATTERN

Densities were calculated using the DISTANCE program for repeated transects. Detectability and densities were calculated for each habitat and for each season separately. 20 most abundant bird species were also selected for the density estimation for each season and 10 most abundant species for each habitat (irrespective of season) of BWS and VRF. Radius for the area was considered as the mean of all perpendicular distances of all individuals sighted at each point. Standard error and confidence intervals were also calculated for the same.

HABITAT USE

Principal Component Analysis (PCA) was performed between bird attributes and vegetation components in BWS while for VRF Whittaker's (1987) vegetation-environment plexus concept for general ecological application was used. The measurements were arranged in four-way data matrix (quadrates x vegetation physiognomy x vegetation floristic x bird attributes).

FORAGING PATTERN

The foraging specialization of each foraging dimension (height, substrate, and method) was analysed using the Shannon-Weiner Index. These values were then converted to a standardized range using the formula-

$J' = H' / H_{max}$

Where J' = specialization and H_{max} = the H' value obtained when the observations are distributed equally across all subsets of the foraging dimension.

The degree of species overlap in niche utilization for different categories recorded (i.e. foraging method, substrate and height) has been quantitatively expressed using Horn's (1966) equation-

$$R_o = R_o = \frac{\Sigma\,(x_1 + y_1) \log (x_1 + y_1) - \Sigma\, x_1 \log x_1 - \Sigma\, y_1 \log y_1}{(X+Y) \log (X+Y) - X \log X - Y \log Y}$$

Total spatial niche overlap was obtained by summing the overlap on species X of all other species-

$R_o = \Sigma\, R_o$

Mean total overlap was obtained as the average of the total niche overlap for each species-

$Rx = (\Sigma R_o) / N$

where N = the number of species

THREATS AND CONSERVATION

Tree species diversity and richness was calculated for different fire height categories and GBH classes. The Importance Value Index (IVI) for each tree species was calculated. Trees were categorized arbitrarily into six GBH classes and height of fire was categorized into eight classes. Percentage of overall dead trees and percent dead of each tree species was calculated for each fire affected patches. The Bonferroni confidence intervals were constructed to detect species-specific mortality pattern. Percent regeneration of seedlings of different tree species was calculated to assess the regeneration pattern. Top five IVI ranking dead tree species and different GBH classes were taken into account for chi-square contingency test while the same test was performed between top four IVI ranking dead tree species and different height categories.

Threat index for surveyed sites was generated by converting each threat parameter into the ordinal scale ratings of low, medium and high. The converted ratings of threats were added together and then divided by number of threat parameters to generate mean threat score for each site. The surveyed sites were categorized as low, medium and high threat areas on the basis of generated mean threat score.

For the assessment of conservation value of each surveyed site in terms of birds, a conservation index was calculated following Jarvinen and Vaisanen (1978),

$V_k = \Sigma V_{ik}$

where, V_{ik} is the conservation value of the i^{th} species in habitat k.

$$V_{is} = \frac{n_i A}{N^2_i} \delta_{is}$$

So the conservation value of each site was calculated by the following formula-

$$Vs = \Sigma V_{is}$$

Different themes (aspects) were used as layers to prepare thematic maps in terms of various threats. Spatial analysis was performed by using threat index and sets of threat parameters for the preparation of thematic maps of birds for the surveyed sites.

RESULTS

VEGETATION STUDIES

A total of 63 tree species, 56 shrub species, 90 herb species and 21 grass species were sampled in 23 oak patches of Kumaon Himalaya. TWINSPAN recognized nineteen broad habitat types in Kumaon. A total of five homogenous groups in relation to environmental variables were identified.

DCA produced the extreme diversity of tree communities from low altitude to high altitude. Its first axis was elevation gradient, which represented ecological series from low altitude, middle altitude and high altitude communities. Axis 2 reflected shrub characters and canopy cover gradient. The tree density ($ha^{-1} \pm$ S.E.) was significantly high at Gasi (995.2 ± 269.4). Shrub density was also significantly different in all oak patches and it was highest for Gager (24504.6 ± 11280.7).

The tree layer was dominated by *Rhododendron arboreum* (3861.41 / ha) for whole Kumaon while *Myrcine africana* (91299.86 / ha) dominated in shrub layer. Tree species diversity and richness was found maximum at Daphiadura. Shrub diversity and richness were highest in VRF.

STATUS AND DISTRIBUTION

Overall 270 bird species were recorded in Kumaon Himalaya. A total of 236 species, 128 species and 125 species were sampled by compiling 681 bird lists, 171 point counts and 218 monitoring of 10 transects respectively in five districts of Kumaon Himalaya.

The overall Bird species diversity (BSD) based on Species richness counting method was highest for Pithoragarh district while Bird species richness (BSR) was highest for Almora compared to Naini Tal, Bageshwer, Pithoragarh and Champawat districts. BSD and BSR were also highest for different sites in Almora district. In Naini Tal district, the maximum BSD was recorded at Kunjakharak (3.2) while minimum was for Kilbery (2.5) by Species richness counting method whereas by Point count method, the maximum BSD was recorded at Kunjakharak (2.8) and minimum BSD and BSR was recorded for VRF (1.4 & 1.7 respectively).

In Bageshwer district the maximum BSD and BSR were found in Sunderdunga (4.2 & 16.1 respectively) while minimum at Dhakuri (1.7 & 2.59) by Species richness counting method while maximum BSD and BSR were recorded by point count method at Pindari (3.2 & 3.1 respectively) and minimum at Sunderdunga (1.8 & 2.3 respectively).

In Almora district, the maximum BSD and BSR were found at Jageshwer (3.6, 10.9) and minimum at Pandavkholi (3.3, 8.2) by Species richness counting method. In Pithoragarh district, the maximum BSD was found at Daphiadhura (3.8) and maximum BSR at Duku (11.2) while minimum BSD and BSR were at Gandhura (2.8 & 4.8

respectively) by Species richness counting method. The maximum BSD and BSR were found at Majtham (3.2 & 6.4) and minimum at Duku (2.2 & 3.9) by Point count method.

Densities of avian community were found to vary greatly between sites. Highest bird density was calculated for Maheshkhan (81.53 ± 17.44) and minimum for Sobala (17.83 ± 3.23). Naini Tal district had maximum bird density.

A total of 13 octaves were formed for Kumaon. LOGNORM.BAS program gave total expected number of species 247.60 against the observed value 284 which showed that the area was well sampled in terms of birds.

The low elevation site was the most species rich zone with a total of 119 bird species. The zones 2201- 2600 and 2601-3000m were having more or less same species (91 and 94 respectively). The highest elevation zones (3401- 3800m and 3801- 4200) were having fewer species.

Significant difference in the number of individuals found at different elevations ($F = 3.465$, d.f. = 5, 359, $p < 0.005$). Bird species diversity and richness also differed significantly at different altitudes ($t = 6.09$, d.f. = 5, $p < 0.002$ and $t = 3.74$, d.f. = 5, $p < 0.013$).

DENSITY AND ABUNDANCE PATTERN

Total 99 and 91 species were identified by transect monitoring in BWS and VRF respectively, which accounted 61% and 50% of total species recorded in both the areas. Transect method proved to be reliable in sampling birds at both the intensive study site.

Binsar Wildlife Sanctuary

The overall density estimate was 12.75 ± 3.96 birds / ha for BWS. The overall bird density in different habitat types calculated by DISTANCE program was found maximum in oak habitat (18.19 /ha.) and minimum in riverine habitat (8.44 /ha). One sample t-test showed significant difference in different habitats in BWS ($t = 6.27$, d.f = 3, $p < 0.008$).

Bird density estimates at BWS varied between species and habitats. Highest densities were recorded for Black throated tit (4.76 birds / ha.). Yellow browed warbler had lowest density (0.92 birds / ha). In pine habitat the highest density was calculated for Black headed jay (1.17 birds / ha.).

Density was found more during premonsoon season than postmonsoon season. The highest density was found in oak habitat (14.85 birds / ha.) during premonsoon season while during postmonsoon season it was highest in mixed habitat (17.69 birds / ha.).

Densities were maximum in the disturbed habitats of oak and pine in both seasons. Significant difference in density values in disturbed oak habitat was observed for pre and postmonsoon seasons while it was not significant for undisturbed oak habitat.

Nine octaves were formed for BWS. The modal octave had 22 species (Maximum number of species) in the first octave. The parameters 'a' and 'So' were calculated from the LOGNORM.BAS program, where a = 0.327 & So = 22 & 17.2. It gave total expected number of species 93 against the observed value 98.

Vinaiyak reserve forest (VRF)

Overall 13.93 ± 1.41 birds / ha was calculated for VRF. The maximum density was found in mixed coniferous forest (29.15 birds / ha.). No significant difference in the densities for different habitats ($\chi^2 = 0.149$, $p > 0.05$) was observed. In mixed coniferous habitat the maximum density was calculated for Black throated tit while Rufous sibia had minimum density in this habitat.

Maximum bird density was found during postmonsoon season. No significant difference in the estimated density was observed between seasons. For both seasons, maximum density was calculated for mixed coniferous forest.

The highest density was calculated for undisturbed oak and mixed habitats during premonsoon season while during postmonsoon season the density was high in disturbed habitats.

The observed number of species (93) in VRF was less than BWS (98) but the number of octaves was more. The expected frequencies were 138.4 and 83.02 at So = 19.0 and 11.4 respectively. The best fit for these data was with a = 0.224 and So = 83.02, which gave the theoretical number of species available for observation S* = 90.

HABITAT USE

Binsar Wildlife Sanctuary (BWS)

Significant difference in bird species diversity as well as bird species richness of oak and pine habitats was observed during premonsoon season. Bird diversity and richness were highest in pine habitat during premonsoon while during postmonsoon season bird diversity was highest for riverine habitat and richness was highest in oak habitat.

Significant differences in disturbed and undisturbed habitats were observed in pine habitat during premonsoon season for bird species diversity ($t = -2.73$, $p<0.02$) in BWS. The null hypothesis was rejected because diversity and richness were found higher in disturbed habitats in both seasons.

Overall six components were extracted by PCA during premonsoon season in BWS. PC I component represented close canopy and dense forest. Multiple regression analysis showed no significant correlation between bird species diversity and component I. PC II were cattle dung, herb density, herb diversity, canopy cover and seedling density. Stepwise Regression model showed no correlation with bird species diversity but it showed positive relation with bird species richness. Component III described less disturbed and dense forest. No significant correlation was found with this component and bird species diversity and richness.

During postmonsoon season, tree density, richness, and shrub density, diversity and canopy cover as well as tree cut showed positive correlations with the first axis and bird species diversity and richness were positively correlated with this axis. II axis was positively correlated with grass density, richness and herb density. III axis was correlated with seedling density, diversity and sapling density and diversity. It represented areas with more shrub layer rather than trees and ground cover. Bird diversity was not correlated with this axis also.

Vinaiyak reserve forest

Maximum bird diversity and richness were calculated for oak habitat during both the seasons. No significant difference was observed in oak and mixed habitats in terms of bird diversity and richness. During premonsoon season, bird species richness was high as compared to postmonsoon season. Significant difference was observed in mixed habitat only in bird species richness for both seasons.

Significant differences in bird species diversity was observed in disturbed and undisturbed oak habitat for pre ($t = 2.36$, $p<0.02$) and postmonsoon seasons ($t = 16.09$, p<0.00) while in mixed habitat, it appeared only during postmonsoon season (t = 5.68, p<0.00).

During premonsoon season, PC 1 showed tree and shrub character of the habitat, which also included grass density and horizontal heterogeneity by negative sign. PC 2 had high loading for grass density, herb diversity, canopy cover (-) and insect biomass (-). Altitude, slope, tree richness and insect biomass (-) showed high loadings on PC 3. Correspondence analysis computed on the basis of plant species number revealed two floristic components. The first axis showed the indicated dispersal of plant species from high altitude to low altitude and second axis indicated the gradient of plant richness along the axis (high to low tree richness). The floristic component did not show any significant correlation with any physiognomic components. Bird species diversity and richness showed significant relationship with PC III. Axis II also showed significant correlation with bird species diversity.

During postmonsoon season, PC I explained only 20.77% variance. Tree richness and vertical diversity had high positive loadings while horizontal heterogeneity had negative loadings on PC I while PC II described low altitude forest with high canopy cover and shrub cover. PC III had high positive loadings of grass density and herb diversity and negative loading of tree richness. DECORANA revealed two floristic components. First axis contained plant abundance gradient from low to high. II axis showed gradient of cover from low to high. The first floristic component showed highly significant negative correlation with PC III.

FORAGING PATTERN

Of the total five height categories considered in the forest of Kumaon, all of them were used by 64 bird species. Total 22 species foraged on or near the ground. The main species were Kalij, Koklass, Hill partridge, White-throated laughing thrush etc. The 2-4 meter layer was least used by species, however 26 species in a very low percentage used this layer. The tree layers 4 -10m and >10m were frequently used by maximum number of species bird species.

Six substrates were recognized in Kumaon forest. Avian species in Kumaon used foliage as their maximum (36.68%) foraging substrate while they used ground as their minimum (7.47%) foraging substrate.

Based on the 16 foraging techniques used by birds, 11 major methods were possibly distinguished for the birds in Kumaon forest. At least one bird species was found predominantly using any one of the 16 foraging techniques. The major prey attack maneuvers used by birds in Kumaon forest were Canopy sallying, Leaf gleaning, Twig gleaning, Bush gleaning, Bark tearing, Wood probing, Wood gleaning, Litter search, Ground search, Ground grain gleaning and Fruit exploiting.

Among three dimensions (foraging height, foraging substrate and foraging methods), highest mean overlap for the whole avian community was found in the foraging height while lowest was in foraging method.

In foraging height dimension, the specialist bird species included ground feeding birds such as Black & Yellow grosbeak, Common myna, Hill partridge etc. 48 species were the specialists' birds in foraging substrate dimension such as Black bulbul, Black throated sunbird, Oriental dove, Jungle crow. In foraging method dimension, Black bulbul, Black-throated sunbird, Plum-headed parakeet, Black & Yellow grosbeak emerged as specialist of this dimension.

THREATS AND CONSERVATION

In the burnt forest patches, maximum mean tree species density was quantified for Jageshwer and minimum for Daphiadhura. Maximum regeneration of different tree species was observed at Daphiadhura while minimum in BWS. Tree species diversity and richness was maximum at Jageshwer while minimum diversity and richness was at BWS.

Maximum tree species mortality (48.37%) was observed for *Quercus leucotricophora* and minimum mortality (0.001%) in case of *Pyrus pashia* in BWS. In Daphiadhura, maximum mortality (38.95%) was observed for *Lyonia ovalifolia* and minimum (0.58%) for *Quercus floribunda* while in Jageshwer mortality was maximum (32.07%) for *Rhododendron arboreum* and minimum (0.94%) for *Viburnum mullaha.*

The maximum IVI was accounted for by *Quercus leucotricophora* and minimum for *Euonymus* tree species while at Daphiadhura *Quercus lanuginosa* had maximum IVI and *Myrica esculenta* had minimum IVI.

Significant difference was observed between GBH classes of dead trees in BWS. The highest mortality was found in 0-25 cm GBH class in *Viburnum mullaha* tree species and least mortality was found in >51 cm for *Lyonia ovalifolia* in BWS.

Significant difference was observed between different fire height categories in dead trees in BWS. Maximum mortality was found in >801 cm fire height category and least was found in <200 cm category. In Daphiadhura the category 801-1600 cm was most affected while in Jageshwer categories >801 cm was most affected. Significant difference ($\Sigma\chi^2 = 83.03$, d.f = 6, $P < 0.001$) was observed in the mortality of different height categories of different tree species and *Viburnum mullaha* representing the fire height category 401-800 cm was most affected and the category >800 cm was least affected in the same species.

In BWS mortality of *Rhododendron arboreum* (18.79%), *Euonymus* sp. (0%), *Symplocos theifolia* (0%) and *Toona serrata* (0%) was significantly less than expected according to availability while other species had significantly higher mortalities than expected. *Quercus lanuginosa* (18.85%) in Daphiadhura, *Pyrus pashia* (0%) and *Litsea umbrosa* (0%) in Jageshwer had significantly less mortality than expected according to availability. But *Lyonia ovalifolia* (72.42%) had significantly more mortality than expected in Jageshwer.

A total of 18 regenerating (seedlings) tree species were sampled in BWS. Maximum regeneration was accounted for by *Swida oblonga* and minimum regeneration was recorded for *Persea duthiei*. Nine and 12 regenerating (seedlings) tree species were found in Jageshwer and Daphiadhura respectively. Maximum regeneration was observed for *Quercus leucotricophora* at Jageshwer and *Quercus lanuginosa* at Daphiadhura. Minimum regeneration was observed for *Litsea umbrosa* at Jageshwer, and *Pyrus pashia* at Daphiadhura. 11 tree species at sapling stage were recorded in BWS. Maximum mortality at the sapling stage was found in *Lyonia ovalifolia*. Eight and nine tree species (saplings) were recorded from Jageshwer and Daphiadhura respectively. Maximum mortality was recorded for *Rhododendron arboreum* at Jageshwer.

The generated mean threat score for sites of Kumaon varied from 0.78 to 2.3. The sites Jilling and Sunderdunga experienced low threats while BWS, Sitlakhet, Jageshwer, Pindari, Gandhura and Munsiary experienced high threats whereas rest of the sites were in the medium threat category.

The analysis showed significant positive relationship with bird species diversity and richness with patch size and negative significant relationship with nomadic pressure and source of income. Kendall's tau_b test also showed significant positive relationships among bird species diversity and richness with patch size

VRF obtained highest conservation value in terms of birds followed by Sunderdunga (0.33), Binsar (0.21), Gandhura (0.15), Duku (0.12), Pindari (0.12) and Dhakuri (0.11).

Significant relationship was observed between bird species diversity and threat index on map. Pindari, Binsar, Sitlakhet and Jageshwer experienced high threat as well as high bird diversity except Gandhura, which had low bird diversity. The sites Sobala, Daphiadhura, Majtham, Gasi, Kunjakharak and Maheshkhan had medium threats but showed high bird diversity. The overlaying of bird diversity on the mean value of human and livestock population showed that Binsar, Jageshwer and Sitlakhet had high pressure as well as high bird diversity. The result again was not significant for anthropogenic pressure.

ECOLOGY AND CONSERVATION OF AVIAN COMMUNITIES OF MIDDLE-ALTITUDE OAK FOREST OF KUMAON HIMALAYA, UTTAR PRADESH, INDIA

THESIS

SUBMITTED FOR THE DEGREE OF

Doctor of Philosophy

IN

WILDLIFE SCIENCE

BY

AISHA SULTANA

DEPARTMENT OF WILDLIFE SCIENCES
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2002

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 **"Ecology and conservation of avian communities of middle-altitude oak forest of Kumaon Himalaya, Uttar Pradesh, India"** submitted for the award of Ph.D. degree in Wildlife Science, of the Aligarh Muslim University, Aligarh is the original work of **Aisha Sultana**. This work has been done by the candidate under my supervision.

Jamal A Khan, Ph.D.

Date: 22 April 2002

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

DEDICATED TO MY PARENTS
AND BROTHERS

CONTENTS

Page no.

ACKNOWLEDGEMENTS

I am extremely grateful to the Ministry of Environment & Forest (MOE&F), Govt. of India for providing funds to carryout this study under the Man and Biosphere Research Programme. I gratefully acknowledge Dr. Subodh K. Sharma, Director, MOE&F and Dr. (Mrs.) Chhanda Chowdhury, Joint Director, MOE&F for their guidance, vital support and continuous encouragement throughout the duration of project.

I would like to thank Chairman Prof. H.S.A. Yahya and Dr. Asad R. Rahmani, former Chairman, Department of Wildlife Sciences for providing valuable support and logistical provisions in Department. I wish to place on record my deep sense of gratitude to founder chairman and my teacher Prof. A.H. Musavi who has introduced wildlife field to me and he also created interest in the same, which compelled me to pursue my career in this field. I am grateful to my supervisor Dr. Jamal A. Khan for all help and guidance. Thanks are also due to Mr. Afifullah Khan, Senior Lecturer, Department of Wildlife Sciences, A.M.U., Aligarh, for his valuable help and guidance in field as well as in the Department throughout the compilation of the thesis. I am highly indebted to Dr. Salim Javed and Dr. Satish Kumar of the Department for their time to time help and support in data analysis.

I am highly indebted to Mr. Ashok Singh, former Chief Wildlife Warden, U.P, Dr. R.L. Singh, present Chief Wildlife Warden, UP and Chief Conservator of forest, U.P. for providing permission to carryout this study in Askot Wildlife Sanctuary, Binsar Wildlife Sanctuary and other protected forests of Kumaon. I have deep sense of appreciation for DFO's, Mr. Alok Srivastava and Mr. Rakesh Shah (Pithoragarh), Ms. Indu Sharma and Mr. Vishnu Singh (Naini Tal) and Dr. D.N. Srivastava (Almora) for providing logistic facilities and full cooperation throughout the study period. I would also like to thank Mr. K.N. Tiwari, Range Officer, Vinaiyak, Naini Tal for his time to time help and support during my stay at this place. I would like to thank Mr. P.C. Harbola, Station Incharge, IVRI, Mukteshwer who provided accommodation inside the campus during the surveys. Also, I would like to thank Director, Naini Tal Observatory for providing meteorological data.

I thank Dr. L.M.S. Palni, Director, G.B. Pant Institute of Himalayan Environment & Development, Kosi, Almora for providing library facility. I gratefully acknowledge the help and suggestions provided by Dr. S.S. Samant of this Institute who identified plant species collected from Kumaon. I am thankful to research scholars especially Dr. Nadeem, Mr. Hemant, Mr. Neeladri and Mr. Bhuvan of the G.B.Pant Institute, Kosi, Almora for their valuable help and support.

I thank Mr. Sanjay Saxena of ER & DCI, NOIDA, Gautam Buddha Nagar, for suggestions in maps preparation and GIS analyses. I thank Prof. Ali Mohammad, Chairman, Geography Department, AMU, Aligarh for giving permission to work in GIS cell. Special thanks are due to Mr. Mazhar ul Haque, Senior Programmer of this Department for all kinds of help in GIS cell and without his help this work would not have been possible. I also thank Dr. Riyaz Ahmed, Lecturer, Chemistry Department, AMU, Aligarh who provided lab facility. I thank Property Incharge, AMU, Aligarh who provided basic facilities at Ardee Estate, Ranikhet that was used as base camp during entire study period.

Thanks are also due to Mr. Qamar Qureshi of Wildlife Institute of India, Dehra Dun for his suggestions in data analysis and Mr. M. Haque, Librarian, FRI, Dehra Dun for providing library facility.

Special thanks are also due to Dr. Ekwal Imam for proof reading, discussions and every day help in many ways. His family is also acknowledged for a nice hospitality during my stay in Aligarh. I also acknowledge Dr. Subuhi Khan, Ex. Warden, Abrar Hostel, for her great help and providing permission as a guest whenever I came back from field. I am equally thankful to my friends and hostel mates Nasheed, Darakhshan, Sheeba, Sameena, Nahid and Fauzia for their help and support during my studies.

I am very grateful to Ms. Huma Waseem for proof reading of the entire thesis and moral support throughout the study. I have great appreciation for Dr. Azra Jamal for her support and sisterly attitude throughout the study period. I am also thankful to Drs. Farha Ishtiyaq, Hillol Jyoti Singha, Sunita and Sarala for moral support and encouragement during my field studies.

I thank Sangeeta, Tahmina, Shahid and Faiza, from Department of Wildlife Sciences for supporting me morally. I gratefully acknowledge the help and assistance of Mr. Jaseem Bakhsh, in field. Thanks are also due to my assistants, Mr. Ratan Ram, Mr. Ambu and Mr. Ramesh. The study would not have been possible with out their help in the difficult field conditions of Kumaon. I am also thankful to Mr. Masroor Khan, Ms. Anjum, Mr. Munis Saleem, Mr. Tanveer, Mr. Chhotey Khan, Mr. Gaffar, Mr. Umar and Mr. RamGopal, office staff of my department for their valuable help. Special thanks are also due to Ms. Nasreen, Seminar Incharge for cooperation.

Thanks due to Mr. Athar Pervez, caretaker of the Ardee Estate and Mr. S.D. Joshi, security staff for caring attitude during my stay in Ranikhet.

I would like to thank estate owners Mr. Raja Shah and Mr. Steve Lal for providing accommodation facility in Binsar Wildlife Sanctuary and Jilling respectively. I acknowledge the assistance and help of villagers who provided shelter and sometimes food in remote areas of Kumaon. Their affection for me is unforgettable.

In the last I take this opportunity to thank my husband, Mr. Shah Hussain for providing helping hand in field, analyses and full cooperation throughout the study. All my family members have been a source of support and encouragement and I grateful to all of them. I am especially grateful to my parents for being ever so supportive and appreciating what I was doing. I am dedicating this thesis to them as a token of my gratitude for all that they have done for me.

Aisha Sultana

(AISHA SULTANA)

List of Tables **Page no.**

Chapter 1

Chapter 2

Chapter 3

Chapter 6

Chapter 7

Chapter 8

List of Figures **Page No.**

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Chapter 7

Chapter 8

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The investigation of the avifauna of the Indian subcontinent began in the first half of the 19th century with three main pioneers: Edward Blyth, Brian Hodgson and Thomas Jerdon. Jerdon (1860) published a book named 'Birds of India' which summarized what was known at that time about the avifauna of much of what is now the country of India (Grimett *et al.* 1998). In the 20th century, Dr. Salim Ali, first Indian Ornithologist carried out many surveys throughout the country and published relevant literature on birds. But still there is lack of information on the ecology of bird community in India and especially in the Himalaya.

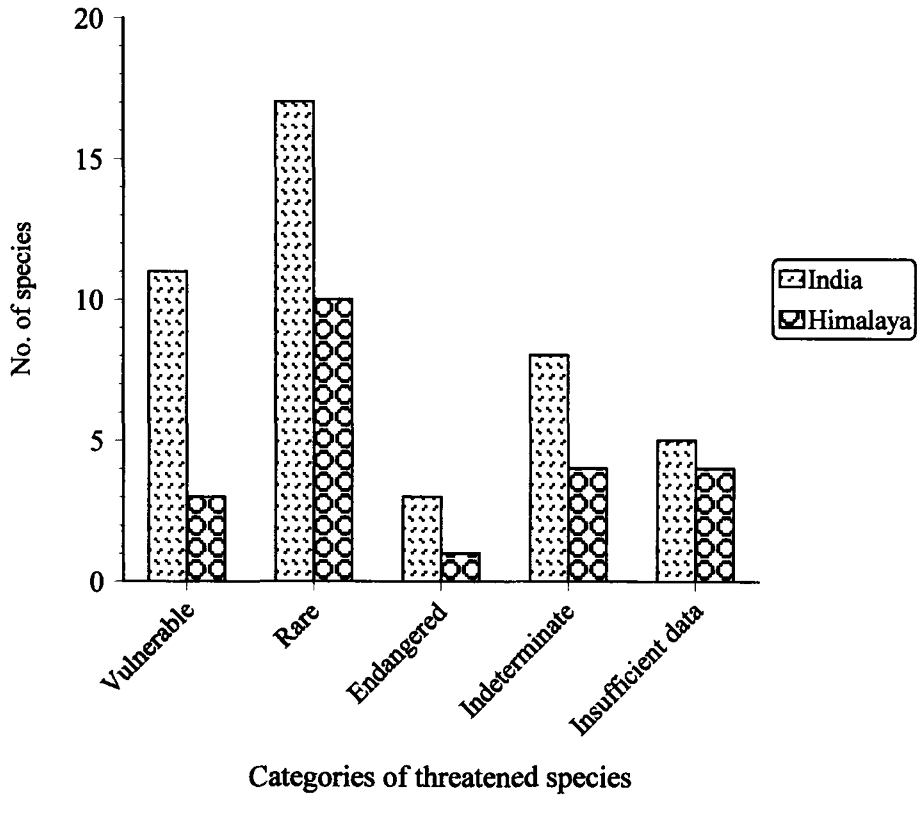
On the basis of information on birds compiled by Grimmett *et al.* (1998), I summarized data on the distribution of birds of the Himalayas. In this compilation no water birds were taken into account only terrestrial forest birds were incorporated. Out of 1290 bird species found in India, 300 bird species are found to be common in Indian Himalayas. The notable species are Grey-capped pygmy woodpecker *Dendrocopos canicapillus*, Fulvous-breasted woodpecker *Dendrocopos auriceps*, Himalayan Swiftlet *Collocalia brevirostris*, Oriental dove *Streptopelia orientalis*, Common Myna *Acridotheres tristis*, Streaked laughing thrush G*arrulax lineatus* etc. A total of 59 species are exclusively found in the Western Himalaya such as Brown-fronted woodpecker *Dendrocopos auriceps*, Variegated laughing thrush G*arrulax variegatus*, Rufous-naped tit *Parus rufonuchalis*, Spot-winged tit *Parus melanolophus*, Chukar partridge *Alectoris* *chukar*, Western Tragopan *Tragopan melanocephalus*, Himalayan snowcock *Tetraogallus himalayensis* etc. Eastern Himalaya, exclusively represents 241 bird species such as Blood pheasant *Ithaginis cruentus*, Blyth's Tragopan *Tragopan blthyii*, Chestnut-vented nuthatch *Sitta nagaensis*, Beautiful Nuthatch *Sitta formosa*, Ruby-cheeked sunbird *Anthreptes singalensis*, Scarlet-backed flowerpecker *Dicaeum cruetatum* etc. While 102 bird species are common in Kumaon-Garhwal & Eastern Himalaya, for e.g. Nepal house martin *Delichon nipalensis*, Coal tit *Parus ater*, Satyr Tragopan *Tragopan satyra*, Hill myna *Gracula religiosa*, Cutia *Cutia nepalensis*, Silver-eared mesia *Leiothrix argentauris* etc., no such species are only confined to the Kumaon Himalaya.

According to IUCN Red list of threatened animals (1994), out of 11 Vulnerable bird species three (3) are found in the Himalayas (Fig 1.1). Most of the species, which have been included in the Red Data list, are from the Himalayas. Out of three endangered bird species of India, one of them is Western Tragopan, which is found in the Himalayas. Indeterminate species are those, which were not decided to be kept in Vulnerable, Rare or Endangered categories such as Blyth's kingfisher *Alcedo hercules*, Black-breasted parrotbill *Paradoxornis flavirostris*.

1.2 LITERATURE REVIEW

The literature review on bird studies has been divided in five categories such as Bird-habitat relationship, Foraging studies, Environmental influence, Comparison of methods and Management studies.

Fig. 1.1 Number of species falling in different categories of IUCN threatened species of India and Himalayas.



1.2.1 Bird-habitat relationship

Till date the status and distribution of each and every species of the world is unknown. Many surveys and studies were conducted to know the status of birds. Crooks *et al.* (2001) have surveyed the islands of USA to know the status of birds. They have also calculated the local extinction and colonization rates of birds. While in South America, Jacobs & Walker (1999) estimated the density of birds inhabiting fragments of cloud forest in Southern Ecuador. Many checklists of birds have been published through out the world for the status and distribution of birds but the main work has been done on bird-habitat relationship.

Vegetation is the basic living component of any community. It not only serve as the base of food chains, but it also provides shelter and reproductive sites for animals within the community. Several authors (Lack, 1933, 1943; Hilden, 1965) have theorized that birds select habitats on the basis of 'sign stimuli' that convey information about ultimate factors such as food, protection and nest site availability. Root (1967) has documented areas in which given bird species appear to be associated directly with ultimate factors. Other studies have described functional and structural components of vegetation usually involving some form of symbolism denoting items considered important to the avifauna present (Weins, 1969). For example, MacArthur & MacArthur (1961) developed a technique to describe the layering of vegetation and found that by computing a foliage height diversity based upon the distribution of vegetation layers, they could predict the bird species diversity of a given community. Some authors insisted on the availability of food in the habitat preferences by birds (Connell & Orias, 1964; MacArthur, 1965; Clout & Gaze, 1984) while according to Erdelen (1984), vegetation structure is only an indicator of the availability of these primary requirements to the birds.

Stages in plant community succession have often been associated with changing bird species composition (Bond, 1957; Anderson, 1970a). A number of macrohabitat features are felt to be important to birds. Robbins (1979) indicated the importance of habitat size to maintain populations of Neotropical migrants. Increased edge is a factor that does attract species, as shown by Lay (1938) and Johnson (1947). MacArthur & MacArthur (1961) were the first to suggest that structural complexity of vegetation measured by the vertical layering of foliage in temperate forests, influences the bird species diversity positively. Later studies in temperate forests do support this (Erdelen, 1984) but studies in tropical forests have failed to prove this relationship (Pearson, 1982; Weins, 1983; Daniels, 1989). Habitat diversity or spatial heterogeneity influences the diversity of birds positively (MacArthur, 1965; Rafe *et al.* 1985; Pyrovetsi & Crivelli, 1988). The local assemblages of birds are determined by the floristic and not the physiognomy of the vegetation (Rotenberry, 1985). Larger area of a habitat tends to increase the bird species diversity (Terborgh, 1973; Galli *et al.* 1976; Martin, 1980; Blake, 1983; Woolhouse, 1983; Blake & Karr, 1984). While small habitats when compared to larger habitats of the same biotope are found to have a higher proportion of the communities consisting of abundant generalists that are often the smaller species (Terborgh *et al.* 1978; Howe, 1979; Willis, 1980; Ambuel & Temple, 1983; Nilsson, 1986).

1.2.2 Foraging studies

Foraging studies are mainly either the direct observation of feeding or feeding behaviour, or the indirect analysis such as gut analysis, faecal analysis etc. Many workers studied the pattern of foraging behavior. Studies comparing the foraging behaviour of congeners have shown the familiar pattern of resource partitioning found in warblers and tits (MacArthur, 1958; Hartley, 1953; Cody, 1974). Other studies also showed that closely related species show similar foraging strategies (Root, 1967; Fitzpatrick, 1980). In some other studies, it has been found that bird species show preferences for certain tree species and avoid others (Holmes & Robinson, 1981; Peck, 1989) as the availability of prey varies from one tree species to another (Robinson & Holmes, 1984). In other study hornbills showed preferences for tall, large trees (Datta, 1998). Time budgets suggest that birds do not spend more time in foraging during autumn and winter than during spring and summer in temperate forest (Haylock & Lill, 1988; Ford, 1989).

Foraging behaviour has been divided into guilds and guild defined as functionally related group of species (Kikawa & Anderson, 1986). Root (1967) described guild as a group of species that exploit the same class of resource in a similar way. Holmes *et al.* (1986) defined guild structure as the patterns of resource use among co-existing species and with emphasis on similarities and differences in how those species exploit resources. Recent researches have documented a mere objective analysis of the bird guild and exploration of the second level of guild grouping based on the foraging strategies (Holmes *et al.* 1979; Sabo, 1980; Holmes & Robinson, 1981; Holmes & Recher, 1986; Poulin *et al.* 1994).

The study of relationships between bird dispersed plants and fruigivorous birds in temperate regions have received attention (Snow, 1971; Thompson & Willson, 1979; Stiles, 1980; Herrera, 1984a,b; Herrera & Jordano, 1981; Jordano, 1982; Sorenson, 1981; Stapanian, 1982; Johnson *et al.* 1985). The relationship between the time of fruiting of bird dispersed plants and fruigivore diversity and abundance is basic to understand temperate bird-fruit dispersal systems.

1.2.3 Environmental influence

Ornithologists have noted changes in avian activity with time of day for decades. During the breeding season, activity and detectability of most bird species are maximum at dawn, decrease to a diurnal minimum at mid-day (Robbins & Van Velzen, 1967; 1970; Weber & Theberge, 1977; Sheilds, 1977) and increase in late afternoon (Jarvinen *et al.* 1977a). Seasonal changes were also studied by Best (1981) and Anderson *et al.* (1981). Climate is the primary environmental factor that determines the distribution patterns of all life forms. It was found in Australia that the birds reach the highest levels of diversity in the zones of maximum rainfall (Pianka & Schall, 1981). Robbins (1981) also found effect on bird diversity by temperature, wind speed, sky condition and winter condition. Some studies have also been conducted on the limitation of sampling in the rugged terrain (Oberholser, 1905; Wetmore, 1939; Murray, 1946; Tanner, 1955; Dawson, 1981).

1.2.4 Disturbance studies

Some studies have also been conducted on disturbance effect. Human activities in an ecosystem result in restructuring of its communities through a variety of means.

However, the influence differs in different ecosystems (Brash, 1987). Habitat loss and fragmentation are known as causal agents of species extinction (Leck, 1979; Brash, 1987; Whitten *et al.* 1987). Several authors studied the human disturbance on birds during the breeding season. Some authors compared samples of experimentally disturbed nests or colonies with undisturbed controls (Anderson & Keith, 1980; Cairns, 1980). A number of studies have shown the effects of disturbance on behaviour, predation rate and other factors, which are likely to affect overall reproduction (Hobson & Hallina, 1981; Verbeek, 1982; Anderson, 1988). Effect of human activities on the structure of bird communities has mainly been studied in passerines. One study found that ditching increased species diversity in salt marshes (Burger *et al.* 1982). Four studies compared bird communities in undeveloped areas and areas used as campgrounds with different degrees of developments for holiday cottages (Foin *et al.* 1977; Robertson & Flood, 1980; Clark *et al.* 1984; Blakesley & Reese, 1988). All these studies found in general a higher species diversity in disturbed habitats, which was mainly due to addition of usually common and hence opportunistic species moving in, while other species were negatively affected by developments. Other study in Tanzania (Fjeldsa, 1999) also showed the same results.

Some studies have also been conducted on the human disturbance effects outside the breeding season. Studies showed that wintering geese avoided areas close to roads for grazing (Madsen, 1985). Hunting is a less significant problem (King, 1978). Of the birds with an endangered status over the world, 67.2% are forest birds, 16.8% are scrub and grassland birds and 12.7% are wetland birds (King, 1978). Birds with larger body size are more susceptible to extinction with habitat reduction.

1.2.5 Comparison of methods for assessing bird abundance

A bird census technique that estimates the number of birds per area rather than relative abundance is desirable when the objective is to estimate the number and species of birds in a community for energetic considerations (Weins & Nussbaum, 1975), for calculating species diversity (MacArthur, 1960; MacArthur & MacArthur, 1961), or for enlightening the effects of habitat disturbances on bird population (Bock & Lynch, 1970). Since existing methods require different amounts of effort and give results of differing accuracy (Kendeigh, 1944; Emlen, 1971; Robinette *et al.* 1974; Best, 1975; Franzreb, 1976; Reynolds *et al.* 1980), the choice of a suitable technique should be based on the species of interest, the season of the year, time and personnel available, number and types of habitats to be censused, and accuracy of the density estimate that is required.

Territorial or spot mapping methods (Williams, 1936; Kendeigh, 1944) require that the census be conducted during the breeding season and involve considerable time and effort. Both factors severely restrict the number of habitats that can be sampled (Franzreb, 1976). Plots of fixed size (Fowler & McGinnes, 1973; Anderson & Shugart, 1974), whether traversed by transect or censused from a fixed point, are more easily censused since only bird occurrence needs to be noted (Reynolds *et al.* 1980). O'Meara (1981) compared the line transect and spot mapping techniques and found that density estimates for breeding species were greater from the spot mapping technique than from the transect techniques in almost all cases. However the transect apparently provided estimates for both non-breeding and breeding species, while underestimating species densities relative to the spot mapping technique. DeSante (1981) compared the mapping and circular plot method while Franzreb (1981) compared mapping and line transect methods. Edwards *et al.* (1981) compared sample plot, variable circular plot and transect methods. Fjeldsa (1999) compared species richness counting method with point count and transect and found that this is highly time efficient and secures broad area coverage.

1.2.6 Management studies

For management purpose evaluation and assessment of nature for conservation has been described and researched by several people including Ratcliffe (1971), Goldsmith (1975), Peat (1984) and Gotmark *et al.* (1986). A review of a small number of evaluation methods and an introduction to the idea that it is possible to use ecological criteria effectively to evaluate a community or a species was published in 1981 (Spellerberg, 1981) and later, wildlife conservation evaluation was reviewed by Usher and several colleagues (Usher, 1986). However, there are those who do not support the idea that an evaluation of a species or a community or natural area can be based on ecology. Naess (1986) and Norton (1987) argued that every organism has a right to live. Organisms have intrinsic vales, which they preserve them for their own sake. Helliwell (1985) felt that the term 'ecological evaluation' is an example of meaningless jargon, asserting that there can be no such things as an ecological principle in the sense of something, which says what one can or can not do.

Some studies have been conducted in relation to patch size for the management of birds. For temperate forest bird communities a general pattern appears to be that total density is negatively correlated with patch size (Oelke, 1966; Gromadzki, 1970; Helliwell, 1976; Morse, 1977; Nilsson, 1977; Martin, 1981). This correlation disappears when species preferring forest edges are excluded (Gromadzki, 1970; Morse, 1977;

Nilsson, 1977; Martin, 1981; Nilsson, 1986). However, for tropical forest islands this pattern does not exist. Here, there are either no clear density trends on larger islands (Cox & Ricklefs, 1977; Terborgh *et al.* 1978), or the total density increases with patch size, especially on smaller islands (Diamond, 1970; Willis, 1980; Wright, 1979; 1981).

An early debate within conservation biology occurred over whether species richness is maximized in one large nature reserve or several smaller ones 'SLOSS' (Single large or several small) of an equal total area (Diamond, 1975b; Simberloff & Abele, 1976; 1982; Terborgh, 1976; Terborgh & Winter, 1980). Opposing this viewpoint, other conservation biologists argue that well placed small reserves are able to include a greater variety of habitat types and more populations of rare species than one large block of the same area (Jarvinen, 1979; Simberloff & Gotelli, 1984). As suggested by Game & Peterkin (1984) and Soule & Simberloff (1986) strategy on reserve size depends on the group of species under consideration as well as the scientific circumstances.

1.2.7 Overview of bird studies in the Indian Himalayas

Studies on overall bird community in the Indian Himalayas are few. However, species specific studies have been conducted in Western and Eastern Himalayas. Other than Ali & Ripley (1987), Shankar (1995) studied the impact of shifting cultivation on bird community in Mizoram while Singh (1994) compiled a checklist of Arunachal Pradesh. Katti *et al.* (1992) conducted an ornithological survey in eastern Arunachal Pradesh. Katti (1989) studied the bird communities of lower Dachigam valley in Kashmir.

Mainly pheasants have been studied at the species level. Garson *et al.* (1992) and Kaul (1993) studied the ecology and conservation of cheer pheasant. Iqbal (1993) studied the pattern of habitat use by Kalij in the Indian Himalayas. Saklani *et al.* (1988, 1989) worked on the habitat utilization and behavioral ecology of Kalij in the Garhwal Himalaya. Sathyakumar *et al.* (1993) collected information on the ecology of Kalij and Monal in the Kedarnath Wildlife Sanctuary. Ahmed & Musavi (1993) studied the ecology of Kalij at Ranikhet in Kumaon. Asad *et al.* (1994) surveyed Limber valley to study the Western Tragopan and its habitat. Khaling (1998) studied the ecology and conservation of Satyr Tragopan in Singhalila National Park, Darjeeling. Datta (1998) studied the hornbills in Arunachal Pradesh. Pandey (1993) conducted a pheasant survey in the Upper Beas valley, Himachal Pradesh.

1.2.8 Overview of bird studies in Kumaon Himalaya

A review has been done on the past work done in Kumaon Himalaya (Table 1.1). Total 62 studies were conducted on birds of this area but these studies covered the reporting of new sightings and compiled a checklist of an area. No ecological study has been done except Sultana & Khan (1999) and Hussain *et al.* (2001).

British very well surveyed Almora & Naini Tal district in terms of bird species in 19th century. Though the reportings mainly consisted new sightings but all of them are have great importance in knowing the status of birds. Such as Gray had last sighted and reported Western Tragopan in Almora district in 1829. Out of 62 studies, 36 were held in Naini Tal, 23 in Almora and 10 in Pithoragarh (Fig. 1.2). More studies on birds have been conducted in Almora and Naini Tal districts as compared to Pithoragarh.

Table 1.1 Review of bird studies conducted in Kumaon Himalaya.

Author	Year	Area of study	Particular bird/group
Lesson, R.P.	1826	Almora	Bird community
Hardwicke, T.	1827	Almora	Cheer pheasant
Gray, J.E.	1829	Almora	Western tragopan
Griffith, E.	1829	Almora	Koklass pheasant
Gray, J.E. & T. Hardwicke	1830	Almora	Koklass pheasant
Vigors, N.A.	1830	Naini Tal	Bird community
Moore, F.	1856	Pithoragarh	Rock bunting
Irby, L.H.	1861	Almora, Naini Tal	Bird community
Brooks, W.E.	1869	Almora, Naini Tal	Bird community
Hume, A.O.	1869	Naini Tal	Bird community
Hume, A.O.	1870	Almora	Bird community
Anderson, A.	1878	Pithoragarh	Ashy prinea
Sharpe, R.B.	1890	Naini Tal	Bird community
Finn, F.	1899	Naini Tal	Finn's weaver
Walton, H.J.	1900	Almora, Pithoragarh	Bird community
Whymper, S.L.	1902a	Pithoragarh	Shortwing & Yuhina
Whymper, S.L.	1902b	Pithoragarh	Bird nesting
Osmaston, A.E.	1916	Almora, Naini Tal	Woodpeckers
Hartert, E.	1917	Naini Tal	Rallidae
Kloss, C.B.	1918	Naini Tal	Phasianidae & Eurylaemidae
Field, F.	1922	Almora	H.T. creeper
Anon.	1929	Pithoragarh	Indian black partridge
Hudson, C.	1930	Naini Tal	Bird community
Kinnear, N.B. & H. Whistler	1930	Almora	Nuthatch
Brigg's, F.S.	1931	(Ranikhet) Almora	Bird community
Whistler, H.	1931	Naini Tal	Bird community
Ali, S.	1935	Naini Tal	Finn's baya
Prater, S.H.	1940	Almora	Yellow-bellied flower pecker
Smythies, B.E.	1943	Naini Tal	Yellowheaded fantail warbler
Davis, D.	1946	Pithoragarh	Snow pigeon
Koelz, W.	1950	Naini Tal	Bird community
Abdulali, H.	1952	Naini Tal	Finn's weaver
Koelz, W.	1954	Pithoragarh	Bird community
Ali, S. & J.H. Crook	1959	Naini Tal	Finn's baya
Rao, V.U.S.	1965	Naini Tal	Bird community
Ganguli, U.	1966	Almora	Bird community
Ambedkar, V.C.	1969	Naini Tal	Finn's baya
Ambedkar, V.C.	1970	Naini Tal	Baya weaver
Ambedkar, V.C.	1972	Naini Tal	Weavers
Sridharan, E.	1974	Naini Tal	Bird community

Smetacek, V.	1975	Naini Tal	Bird community
Ghorpade, K.D.	1976	(Pindari) Almora	Bird community
Narang, M.L. & B. S. Lamba	1979	(Jageshwer) Almora	Nepal dark rosefinch
Newsome, J.	1979	Almora	Bird community
Singh, S.R. & A. Singh	1980	Naini Tal	Bird community
Rasool, T.J.	1984	(Mukteshwer) Naini Tal	Cheer pheasant
Robson, C.	1985	Naini Tal	Bird community
Jepson, P.	1987	Naini Tal	Bird community
Young, L.; P.J. Garson & R. Kaul	1987	Naini Tal	Cheer pheasant
Young, L. & R. Kaul	1987	Naini Tal	Pheasants
Yahya, H.S.A.	1990	Naini Tal	Bird community
Ahmed, A. & A.H. Musavi	1993	(Ranikhet) Almora	White-crested Kalij
Tak, P.C. & J.P. Sati	1994	Pithoragarh	Bird community
Drijvers, R.	1995	Naini Tal	Horned grebe
Tak, P.C.	1995	Kumaon	Bird community
Maheswaran, G.	1996	Naini Tal	Bird community
Robson, C.	1996	Naini Tal	Scarlet finch
Ahmed, A.	1997	Naini Tal	Bird community
Hussain, M.S.; J.A. Khan, A. Ahmed & R. Kaul	1997	Kumaon	Galliformes
Gupta, P.D.	1998	Almora	Bird community
Kazmierczak, K. & R. Singh	1998	Naini Tal	Bird community
Naoroji, R. & C. D'Silva	1998	(Ranikhet) Almora	Red kite
Sultana, A. & J.A. Khan	1999	Kumaon	Bird community
Sultana, A. & J.A. Khan	2000	Kumaon	Bird community
Hussain, M.S.; J.A. Khan & R. Kaul	2001	Kumaon	Kalij & Koklass

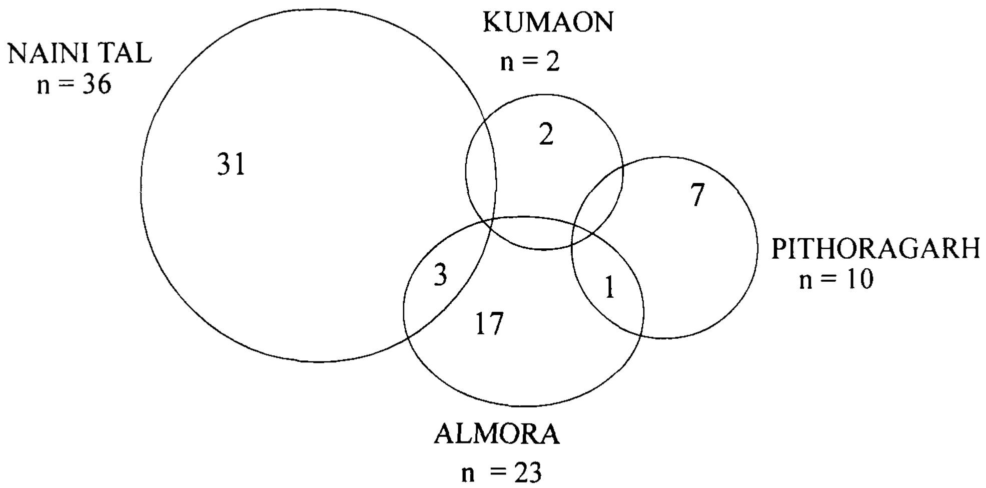


Fig. 1.2 The distribution of avian studies conducted in different districts of Kumaon.

1.3 RATIONALE

The entire Kumaon Himalaya experienced major changes in land use pattern and practices during the last two centuries. While the chir- pine forests increased in spatial coverage as a consequence of its nature of rapid spreading and large scale plantations (Singh & Singh, 1987), the size and distribution of once extensive oak forests decreased due to its exploitation and clearance for terrace cultivation leading to large scale fragmentation. The substantial increase in human population and also settlements resulted in further degradation of oak forest due to livestock grazing, burning, wood cutting, lopping and collection of other minor forest produce. Since the fragmentation and degradation of habitats are known to have negative impact on animal communities, the changes in land use pattern in the Kumaon Himalaya may also have had negative impact on status and abundance of animal communities.

The conservation of overall bird community in the Himalayas is necessary because they are considered to be the best indicator species of a good forest and it has been argued that if bird communities are protected then other communities will be protected themselves.

This thesis is an outcome of the Ministry of Environment & Forests, Govt. of India funded project under Man & Biosphere program titled "A Study of threats to Biodiversity conservation of middle altitude oak forests of Kumaon Himalaya, India". Keeping the importance of birds in relation to habitat, the study has been taken up.

The following are the main objectives of this study-

1. To estimate the status and distribution of bird community in Kumaon Himalaya.

2. To estimate the bird densities and abundance pattern in different oak patches of Kumaon Himalaya.
3. To establish the bird- habitat relationship especially in context of vertical and horizontal heterogeneity.
4. To study the foraging strategies and guild structure.
5. To find out the threats on avian community.
6. To prepare the conservation strategy for avian community of Kumaon Himalaya.

Following are the null hypotheses, which were tested in this study-

1. Avian diversity and richness is same along different elevations.
2. There is a significant difference in BSD and BSR in different seasons.
3. Disturbance has a significant effect on BSD and BSR and diversity values are less in disturbed area.
4. Bird species diversity and richness have significant positive relationship with foliage height diversity.

1.4 ORGANIZATION OF THESIS

Thesis is organized in the following way-

Chapter 1

It deals with the general introduction on birds and gives the overview of studies conducted on different aspects on bird community in the world as well as the information on the bird studies conducted in the Indian Himalayas as well as in Kumaon.

Chapter 2

This chapter describes the study area i.e. Kumaon. All the surveyed sites are described in it. Historical background of Kumaon on the aspects the forest changes and land use pattern is also described in this chapter.

Chapter 3

The overall vegetation of the study area is described in this chapter. Different communities of trees are also defined in it. GIS and spatial analyses for different vegetation parameters have been performed in this chapter. Spatial parameters are also calculated to define most fragmented oak patches of Kumaon

Chapter 4

Chapter 4 deals with the status and distribution of bird species of Kumaon. The checklist of birds of whole Kumaon is also provided in it. Bird species diversity, richness and density are also calculated and described for all sites. Species abundance model is also described for whole of Kumaon.

Chapter 5

This chapter deals with the densities and abundance pattern of different bird species in the intensive sites i.e. Binsar Wildlife Sanctuary and Vinaiyak reserve forest. Disturbance effects are also indicated on the density and diversity patterns on birds in different habitats. Overall and seasonwise abundance models for birds are calculated for both intensive sites.

Chapter 6

Chapter 6 deals with the bird species diversity (BSD) and richness (BSR) in general and in different habitat types of Binsar Wildlife Sanctuary and Vinaiyak reserve forest.

Seasonal pattern is also observed in BSD and BSR. Disturbance effects are also observed in different habitats. Bird community relationship with habitat variables is also established.

Chapter 7

In this chapter different foraging pattern of species are described. Methods, strategies and patterns of foraging activities are established. Mean niche overlap and specialist index is also calculated for selected bird species of Kumaon.

Chapter 8

This chapter deals with different threats on avian community. Conservation values are also assigned to each site in terms of avian community and high bird diversity areas are also identified. In this chapter conservation strategy is also prepared for the protection of birds and their habitat in the Kumaon Himalaya.

CHAPTER 2

STUDY AREA

2.1 INTRODUCTION

Himalayas, the major geomorphologic or tectonic division of the Indian subcontinent, constitute one of the great and young fold mountain systems in the world. It rises from 300 m to more than 8000 m above the msl. Extending from the eastern border of Pakistan to the western frontiers of Burma and having a length of about 24,000 km, and a width varying from 250 to 400km, it covers an area of about 5,00,000 km^2.

The Planning Commission (1982), Govt. of India, has divided the Himalaya lying in India into three broad regions, - the Western Himalaya consisting of the states of Jammu & Kashmir and Himachal Pradesh, the Central Himalaya consisting of 10 hill districts of Uttaranchal and the North Eastern Himalaya comprising the states of Sikkim, Manipur, Meghalaya, Tripura, Arunachal Pradesh and Mizoram and the hill areas of Assam and West Bengal. From south to north, Himalayas is divided into four geophysical divisions, the outer Himalaya, the lesser Himalaya, the Great Himalaya and the Trans Himalaya. Several thrusts such as Himalayan Front Fault (HFF), Main Boundary Thrust (MBT), Main Central Thrust (MCT) and Tons Himadri Thrust (THT) (Burrard *et al.* 1933; Kharakwal, 1951; Jalal, 1976; 1988; Valdiya, 1980; 1988) separate these longitudinal divisions from one another.

2.2 HISTORICAL BACKGROUND

Historically, Kumaon Himalaya was part of Oudh Province. Gorkhas ruled Kumaon before the British annexed the area in 1815. Thus, from 1815 to 1947 A.D., 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).

Very little is known about the agricultural condition and its development during 19th century. Kumaon from ancient times seems to have been agricultural area (Pate Ram, 1916) but practicing was a difficult job. For this, there were factors like occasional floods, hailstorms, landslides, the ravages of wild animals and a high degree of mortality among both the people and the cattle, were some of the obstacles, which made the cultivation in the hills difficult. It was observed and written by Sample (1921) during British period that sustenance was very severe, yet, agriculture flourished well till the beginning of 19th century. Great decline in agricultural practices was observed on account of the barbarous rule of Gorkhas (1790-1815 A.D). After the British took control in 1815, from 1816-1823 cultivation had increased one third and since then there was steady progress (Kennedy, 1884). The net cultivable area in the Kumaon during 1842-1846 was 10.08% of total area of Kumaon which was further increased up to 15.61% during the years 1872-1873, and it was further extended to 17.06% in the year 1886 (Mittal, 1990). The cultivable area increased up to 25.28% of the total area of Kumaon in the year 1978.

A steady increase in agricultural land was observed through out the Kumaon. This increase was due to increase in human population. The commissioner of Kumaon observed an increase of 12.8% in the agricultural production due to the policy of encouragement within twenty years from 1815-1835 (Pant, 1935). The region has recorded increase in total human population from 1,64,000 to 8,07,213 individuals (Joshi *et al.* 1983) during the years 1821-1921 and the human population further increased from 8,60,588 to 29,43,199 individuals during the years 1931-1991 (Table 2.1).

Table 2.1 Changes in the human population during 19th and 20th century in Kumaon Himalaya.

Year	Human population
1821	1,64,000
1852	3,60,011
1881	7,01,007
1911	8,49,149
1941	9,79,147
1971	19,55,281
1991	29,43,199

Industrialization, agricultural expansion and development of the area in terms of road establishment degraded the forest area. The contract arrangement for felling trees continued until the 1858 and as a consequence no conservation measures could be introduced. From 1855 to 1861, due to tremendous demand of railway sleepers, uncontrolled felling of Sal trees was attempted in the more accessible forests. The increased human population from 1,64,000 in 1821 (Atkinson, 1986) to 777,600 in 1900 (Joshi *et al.* 1983) exerted more pressure on oak forest because they provided them cheap fuel, leafage, fodder, and Sal and Deodar tree species provided wood for timber and agricultural implements. The reckless destruction of valuable forests in the quest of railway sleepers and exploitation for other human needs enhanced the national timber resource. Ramsay, the first conservator of forest, recognized the gravity of the situation and he took immediate measures to stop this wanton destruction of forests, and from this time forests progressed with vigor.

The forest department in this region was organized for the first time in 1868 with a conservator of forest as its head. For several decades forest department remained engaged more in conservation than exploitation. And this essential conservation, which was the keynote of the forest administration, then created a sufficient discontent among people of Kumaon (Pant, 1921). There was a widespread feeling of discontent and the forest policy of the government was criticized and condemned all over the area. In 1917, a fresh settlement was made which divided forests into the following categories:

a) Reserved forests (old reserves & new reserves)

b) Protected forests or civil forests

Recent assessment showed that 25.28% (Joshi *et al.* 1983) of total area of the Kumaon was under cultivation in the year 1978. Total forest cover, which was 44.3% in 1972 (Singh, 1983) of the reporting area (18631.80 km^2) of Kumaon, has increased up to 48.4% in the year 1979-80 (Joshi *et al.* 1983). The recent forest cover of Kumaon was 35.61% (Anonymous, 1991) in the year 1991. The drastic decrease in the forest cover was observed in whole of Kumaon after independence.

2.3 LOCATION AND AREA

The study was conducted in five districts; Almora, Naini Tal, Pithoragarh, Bageshwer and Champawat of Kumaon Himalaya (28° 43' 55" and 30° 30' 12" N latitude and 78° 44' 30" and 80° 45' E longitude) covering an area of 21,032 km² of Uttaranchal hills in India. Tibet bound the area in north, Nepal east Tarai region of U.P. in south. During the study period, 23 oak patches, varying in sizes at different locations of Kumaon Himalaya were covered (Fig. 2.1). Table 2.2 provides the details of sites covered during the entire study period (January 1996 to December 1998).

About 90% of the area of Kumaon is mountainous. The main ranges are aligned in NW-SE direction. The asymmetrical slopes, i.e. steeper along the southern and gentler along the northern aspects form the characteristic features of the region. The Kali Ganga, Dhauli Ganga, Gori Ganga, Saryu and Pindar form the major river system of Kumaon. Later, only Pindar, Kali and Saryu form the major river system of the region. On the basis of physiographic attributes such as absolute and relative relief, the region may be grouped into the following physiographic regions,

Himadri (Greater Himalayas)

Shiwalik and lesser Himalayas

Outer Himalayas – Tarai and bhabhar Himalayas

2.4 PHYSICAL SETTINGS

The Himadri (greater Himalayas) zone is about 50 km in width. The mean relief averages between 4800-6000 m consisting of peaks covered with snow throughout the

Fig. 2.1 Location of surveyed oak forest patches in Kumaun Himalaya.

Table 2.2 Details of different surveyed sites of Kumaon Himalaya. RF= reserve forest, POF= privately owned forest, WS= Wildlife sanctuary, CF= Community forest. * = Intensive study area

Sites	District	Area (km^2)	Status	Coordinates	
1. Kilbery	Naini Tal	16.25	RF	29°25' 24.3"N	79°2.6'24.3"E
2. Vinaiyak*	Naini Tal	15.32	RF	29°27'45.4"N	79°24'31.8"E
3. Kunjakhrarak	Naini Tal	14.50	RF	29°39' N	79°18'58.1"E
4. Maheshkhan	Naini Tal	22.00	RF	29°24'16.2"N	79°33'50.6"E
5. Gager	Naini Tal	3.25	RF	29°25'11.4"N	79°30'31.9"E
6. Mukteshwar	Naini Tal	15.75	RF	29°28'34.1"N	79°38'28.1"E
7. Jilling	Naini Tal	2.50	POF	29°22'1.6"N	79°37' E
8. Binsar WLS*	Bageshwer	11.25	WS	29°42'3.2"N	79°45' E
9. Pandavkholi	Almora	13.23	CF	29°48'19.5"N	79°27' E
10. Sitlakhet	Almora	11.25	RF	29°42'3.2"N	79°45' E
11. Jageshwer	Almora	21.00	RF	29°39'3.2"N	79°50'52.5"E
12. Gasi	Bageshwer	49.50	RF	30°04'48.4"N	80° E
13. Dhakuri	Bageshwer	32.50	RF	30°13'19.5"N	79°55'26.3"E
14. Wachham	Bageshwer	11.00	RF	30°07'25"N	79°54'37.5"E
15. Sunderdunga	Bageshwer	25.75	RF	30°13'30.3"N	79°54'18.5"E
16. Pindari	Bageshwer	21.50	CF	30°11'11.3"N	79°59'30"E
17. Daphiadhura	Pithoragarh	34.36	WS	Not available	
18. Majtham	Pithoragarh	25.00	WS	Not available	
19. Gandhura	Pithoragarh	54.00	WS	29°51'40"N	80°14'16.9"E
20. Sobala	Pithoragarh	28.12	WS	30°04'16.2"N	80°34'15"E
21. Duku	Pithoragarh	52.00	WS	30°56.3' N	80°30' E
22. Munsiary	Pithoragarh	30.50	RF	30°05'3.2"N	80°14'41.3"E
23. Mechh	Champawat	23.25	CF	29°16'16.2"N	80°12'18.8"E

year. The valley profile shows concave form with steep valley wall with rising phase of Himalayas (Singh, 1987).

The lower Himalayas with a width of 75 km is composed of massive mountainous tract. The ranges are mainly composed of highly compressed and altered rocks varying in age. The average relief of ridges in this zone ranges between 1500-2700m and the valley bottom 500-1200m. The valleys are steep. The bhabhar belt, a piedmont plain 10-15 km in width, is the immediate land composed of debris from the Himalayas. The surface streams disappear in this zone of boulders and sand.

The lake region of Kumaon has its own characteristic features. These lake basin roughly confined to a belt of approximately 25 km in length and four km in width near the outer fringes of the lesser Himalayas in Naini Tal, Bhim Tal, Naukuchiya Tal, Sat Tal, Puna Tal form a group of lakes to the east of Naini Tal and form considerably low lying lake basin. Another group of lakes; Sukha Tal, Kurpa Tal, and Saria Tal are very small in their size.

2.5 SOIL

So far, no systematic and detailed study has been made about soil of the Himalayas. The soils of this region do not form a compact block. They differ from valley to valley and slope to slope according to the different ecological condition. The humid-tropical vegetal zone (300-900m) is composed of 'alluvial soil', warm temperate-zone (900-1800m) has 'brown forest soil', and the cool temperate-zone (1800-3000m) is composed of brown deciduous soil and grey coniferous soil. Alpine zone (3000-4500m) soils are mostly granitic sandy loam. These soils are normally loamy but clay increases in the sub soil layers (Makhan, 1967). These soils are not suitable for crops other than potato cultivation and horticulture.

2.6 CLIMATE

Extreme variation in the climatic condition is observed in the entire region of Kumaon. The range of altitude of the region's mountainous topography influences its climate. Owing to its complicated relief, microclimates are of considerable importance. Valleys of the region experience hot steamy tropical climate during summer, while great ranges bear some of the highest snowfields of the world. Winds in narrow valleys and heavy fog during winter in wide valleys are conspicuous features of the weather of this region. The precipitation of every locality is directly related not only to the altitudinal zone in which it exists but also to its situation in the front ridge or the rear of the ridge or overlapping spur. When the study was conducted in the Kumaon, there were only three districts so the data on meteorological were recorded for these only (Fig. 2.2).

The monsoon starts at the end of June and ceases by the middle of September (Singh, 1987). Convention rain in the small amounts (12-25 mm) is observed every third and fourth day often in the afternoon just before the break of monsoon at higher elevation. The zone between 1200-2100m receives maximum precipitation (3267 mm), summer and winter, in both the seasons. The zone above 2400m experiences much lesser amount of summer rainfall. There are marked differences in the amount of rainfall in the front and rear of the main range. The rainfall of the region averages 370-500 mm from June to September in the front zone, and 200-250 mm in the rear (Table 2.3). In general, winter depression causes snowfall for seven to eight days in each of the three months

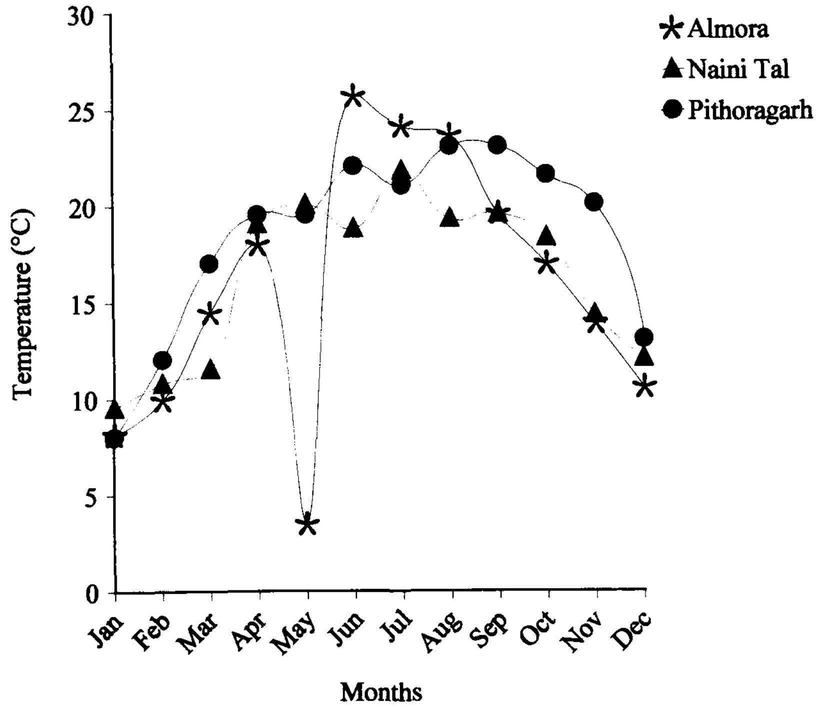


Fig. 2.2 Mean monthly variation in temperature in three districts of Kumaon Himalaya during 1998.

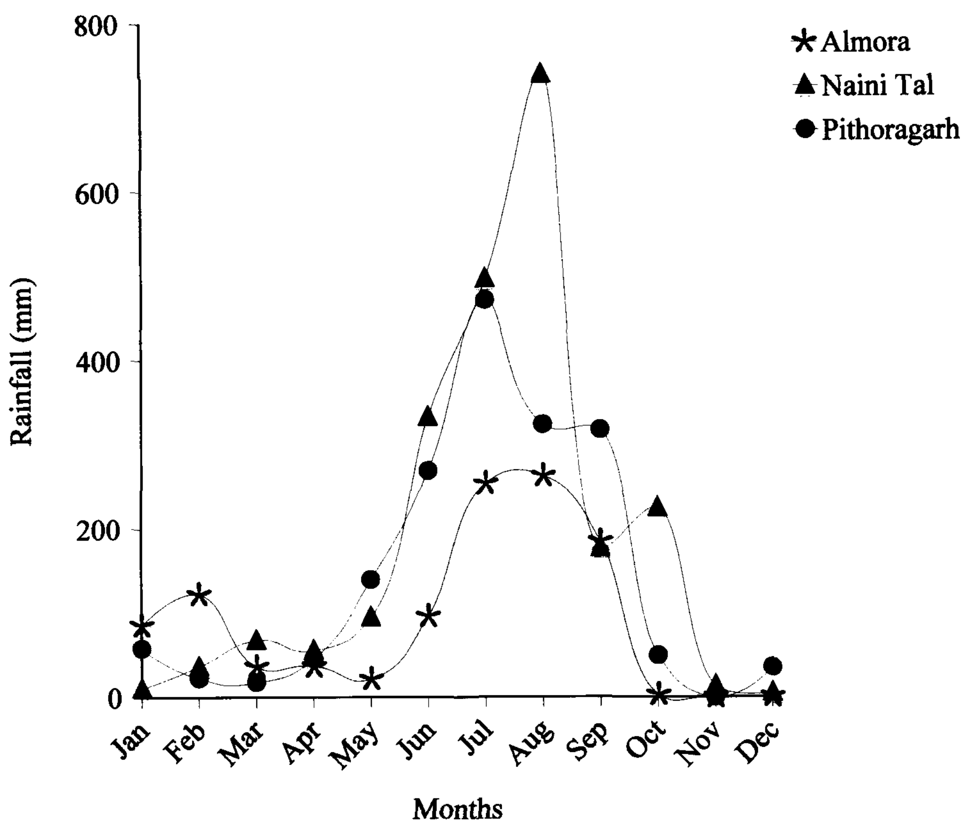


Fig. 2.3 Mean monthly variation in rainfall (mm) in three districts of Kumaon Himalaya during 1998.

Table 2.3 Mean temperature and rainfall in different climatic zones of Kumaon Himalaya (Singh, 1987).

Climatic zone	Altitude range (meter)	Temperature (° C)		Rainfall (mm)
		Mean	Annual	(Annual mean)
Tropical zone	300-900	18.9	21.1	2860.33
Warm temperate zone	900-1800	13.9	18.9	3623.33
Cool temperate zone	1800-2400	10.3	13.9	1750.00
Cold zone	2400-3000	4.5	10.4	335.00
Alpine zone	3000-4000	3.0	4.5	-
Glacier zone	4000-4800	Ten months below zero Two months between 2.2 and 3.9		-
Perpetually frozen zone	> 4800	Cold desert-no vegetation		-

from January to March. April and May are marked by thunder and occasional hailstorms and heavy snowfall up to 3-5 m is observed from November to May (Fig. 2.3).

The microclimatic condition usually differ from valley to valley and from locality to locality according to the direction of ridges, degree of slope, sunny or shady aspects of slope, intensity of forest cover and nearness to glaciers. The region can be divided into seven broad climatic zones, primarily based on altitude (Saxena *et al.* 1985; Singh, 1987).

2.7 NATURAL VEGETATION

A major part of the region is covered with forest constituting enormous wealth. About 35.61 % area is under forest cover (Anonymous, 1991). According to Champion & Seth (1968), the vegetation of the area has been divided into four main zones. Sub tropical zone (below 1200m), extending from northwest to southeast, covers sub Himalayan tract of the region. Sal (*Shorea robusta*) is the main tree species. *Shorea* forests are seen on the Shiwalik up to an altitude of 1200m. The other associated tree species of this zone are *Largerstroemia parviflora, Dalbergia sissoo, Anogeissus latifolia, Terminalia* sp. and others. The canebrakes and bamboo brakes (*Dendrocalamus strictus*) are also found in the wet hollows and along the stream.

The temperate forests are generally found between 1050-1900m on the southern and 900-1800m on the northern slope. The chir pine (*Pinus roxburghii*) forms excellent forest at the altitude above 1200m often reaching to an altitude of more than 2000m. The under growth of Pine is very poor. Some species of deciduous forests are observed occasionally; otherwise the ground surface is covered with various species of grasses. At its upper limit, the pine may occur in association with *Quercus leucotricophora* and

Rhododendron arboreum. The Oak-Rhododendron forests in association with *Lyonia ovalifolia* are developed at an altitude above 1500m in the areas having sufficient soil moisture on the northern exposure and sheltered slopes. Oak-Rhododendron forests are densely populated and rich in epiphytes. At slightly higher elevations between 2200-2800m (sub-alpine zone) *Quercus leucotricophora* is replaced by *Quercus floribunda* with the same tree species association as those seen with the *Quercus leucotricophora* forest. At altitude above 2800m, another Oak-Coniferous forests occur, in which dominant tree species are *Quercus semecarpifolia, Abies pindrow* along with *Rhododendron arboreum, Taxus baccata, Pinus wallichiana, Euonymous tingens, Viburnum* spp., *Cupressus torulosa, Cedrus deodara* and *Betula utilis* etc.

In general, each forest cover occupies some definite locality; between 2000m and 3000m cypress is present, from 2400–3000m Deodar, from 1900-3100m blue pine and silver fir. The high level forest are usually found in the traits lying to the north of the main Himalayan ranges between 2950-3600m, covering the sub alpine and alpine zone. Above the birch and silver fir forests, a general transition from xerophytic bush land into alpine pastures. These alpine forests are found up to about 4200m and sometimes may be seen in small patches even above. The alpine pastures are the main vegetal cover on the high altitudes (Singh, 1987).

2.8 FAUNA

The Kumaon Himalaya holds rich oriental faunal composition (Mani, 1974). The area still holds some of the rare, endangered mammal and bird species. The main mammal species of the region are Musk deer *Moschus moschiferus* (endangered), Himalayan Tahr *Hemitragus jemlahicus* (suspected to be endangered), Serow *Capricornis sumatraensis* (possibly endangered), Himalayan black bear *Selenarctos thibetanus*, Goral *Nemorhaedus goral*, Barking deer *Muntiacus muntjak*, Yellow-throated martin *Martes flavigula*, Leopard *Panthera pardus* and Snow leopard *Panthera uncia* (endangered). Among birds, the area includes conspicuous species like Cheer pheasant *Catreus wallichii* (globally threatened), Satyr Tragopan *Tragopan satyra*, Monal pheasant *Lophophorus impejanus*, Koklass *Pucrasia macrolopha*, Whitecrested Kalij *Lophura leucomelana*, White-throated tit *Aegithalos niveogularis* (endangered), Pied thrush *Zoothera wardii* (endemic), White-crested laughing thrush *Garrulax leucolophus*, Red-billed chough *Pyrrhocorax pyrrhocorax*, and many species of finches, raptors, woodpeckers, laughing thrushes, tits, leaf warblers and flycatchers. Among reptiles, Python *Python molurus*, Common Indian krait *Bungarus caeruleus*, Indian cobra *Naja naja*, Rat snake *Elaphe obsoleta*, the Himalayan pit viper *Ancistrodon himalayanus*, Common Indian monitor lizard *Varanus varanus* and Common house gecko are common. Among butterflies the notable species are Indian cabbage *Pieris canidia indica*, Common sailor *Neptis hylas varmona*, Painted lady *Cynthia cardui*, Common tiger *Danaus genutia*, Great Mormon *Princeps memnon agenor*, Common Mormon *Princeps polytes romulus*, Common blue bottle *Graphium sarpedon sarpedon*, Indian tortoiseshell *Aglais cachmirensis aesis*, Paris peacock *Princeps paris paris* and Oak leaf *Kallima inachus inachus*.

CHAPTER 3

VEGETATION STUDIES

3.1 INTRODUCTION

Vegetation is one of the major geographical features of almost all parts of the earth's surface. In the major natural ecosystem, at least, it is an essential component as it attains the status of primary producer. Nevertheless, the structure of vegetation is not a mere show of the general dominance by certain species but it also exhibits local dominance by other species (Weaner & Clements, 1966).

Himalayas, the youngest mountain system of the world, constitutes an important link and/or bridge between the vegetation of the northwestern and western Asiatic-European areas, and the southern peninsular India on one hand and the eastern Malaysian and the northeastern Sino-Japanese and the northern Tibetan areas on the other (Puri *et al.* 1983). Phytogeographically, it is therefore one of the most complex areas of the Indian subcontinent. In some way they act as a bridge between the Sino-Japanese and the Irano-Turanian regions: the two most important centers of the Holarctic or extra-tropical Eurasian flora. Stearn (1960), Raven (1962) and Meusel (1971) have studied the Western Himalayan flora and vegetation from this angle.

The Himalayan Mountains from Kumaon to Kashmir are with considerable variation between the outer and the inner valleys. The vegetation is divided into altitudinal zones, such as sub-montane zone up to 1500m, a Temperate Zone from 1500 - 3300m or 3630m, and alpine zone above the snowline. The altitudinal zonation of different types of vegetation is not restricted and it has been found that geology and soils exercise a far greater influence on the distribution of vegetation than altitude or climate does (Puri *et al.* 1983). The other important feature in the Himalayas is the role of man in delimiting the vegetation zones.

Now the question arises that why should we study vegetation. The commonest examples of the use of vegetation description are in the recognition and definition of different vegetation types and plant communities, the mapping of vegetation communities and types, the study of relationships between plant species distributions and environmental controls, and the study of vegetation as a habitat for birds, mammals and insects. Information on vegetation may be required to help to solve an ecological problem: for biological conservation and management purposes, as an input to environmental impact statements, to monitor management practices or to provide the basis for prediction of possible future changes.

A useful study is applied studies where vegetation data are collected and analyzed with the aims of providing information of relevance to some ecological problems, often to do with environmental conservation and ecosystem management. The forest resources of the country are under great pressure owing to the increased demands from human and animal population resulting in degradation of forest ecosystems. This has led to poor productivity and regenerative capacity. Hence monitoring of our forest resources is of great importance (MOE&F, 1994; FAO, 1995; FAO, 1993; MOE&F, 1997). However, various other aspects related to efficient forest management through advanced tools like Geographic Information System (GIS) is minimal and not comprehensively studied at a scale required for initiation of actions (Udya Lakshmi *et al.* 1998). The collection and organization of existing scattered information with a provision to synthesize and update without much additional effort is needed for optimal resources management (Mukund Rao *et al.* 1994; Mukund Rao & Jayaraman, 1995; Rajan, 1991). Similar capabilities are possible only through use of advanced technological tools, viz. Remote Sensing (RS) and GIS (Rao, 1995; Karale, 1992).

In the proposed study, I tried to collect ground truth data of Kumaon and mapped on spatial scale and also in relation to birds. The approach used in this study was to concentrate efforts in obtaining i) assessment of flora and fauna, ii) identifying threatened areas, iii) finding the relationship between fauna and environmental data, iv) relationship between fauna and threats. In the final and concluding stage, prioritize areas for long-term conservation is suggested.

The objectives of this chapter are-

- To describe density, diversity and richness of all the three vegetation layers i.e. trees, shrubs and ground layer in all the surveyed sites of Kumaon.
- To observe correlation between vegetation attributes and altitude and also with biotic pressure.
- To describe different dominating communities of the trees of Kumaon.
- To find out the most fragmented patches with the help of GIS.
- To find out the species of special concern and also the localities having rare communities for protection.

3.2 METHODOLOGY

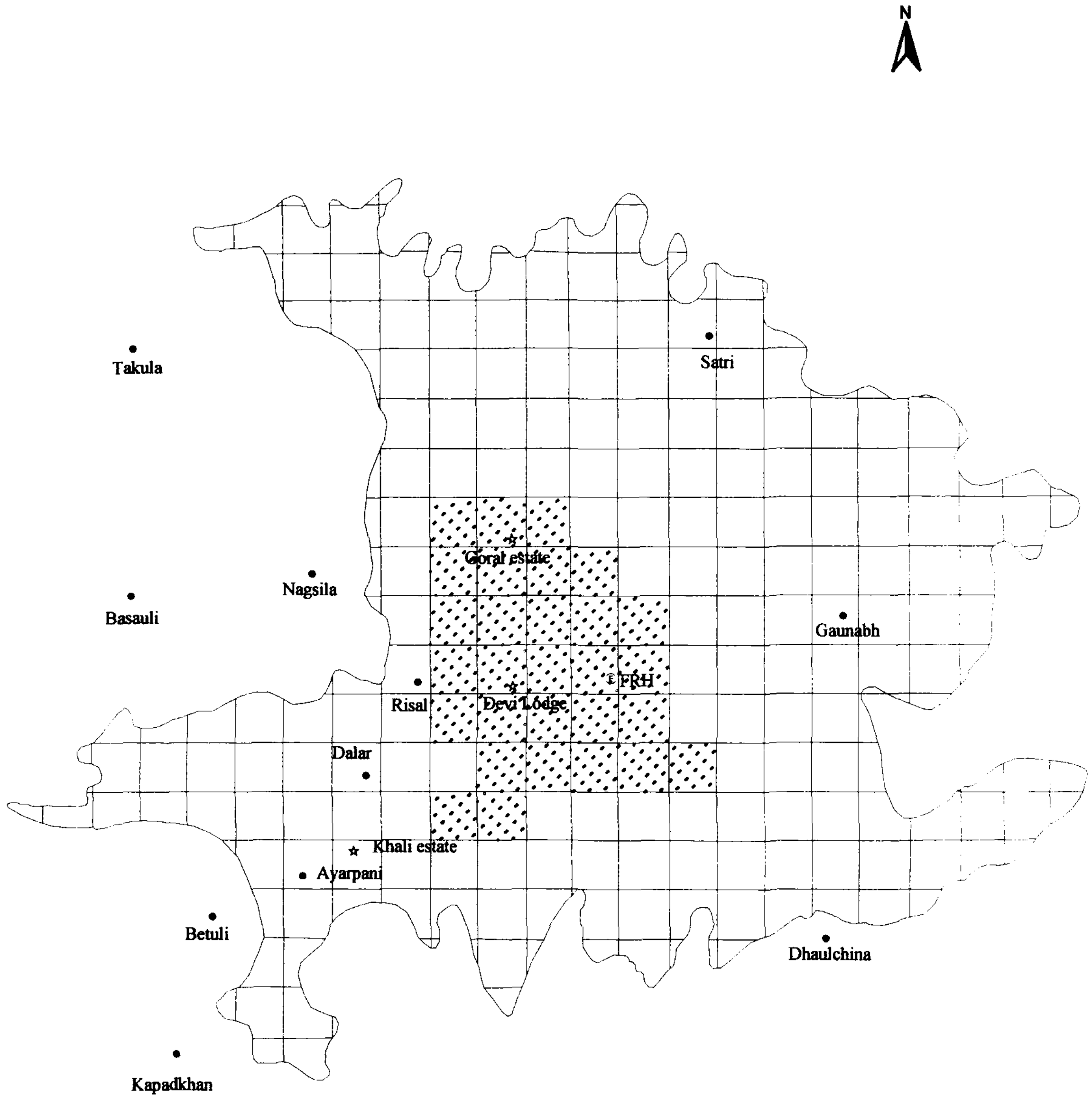
Fieldwork for this study was carried out from March 1996 to December 1998 in whole of Kumaon Himalaya. Overall 902 sampling points were established in all 23 oak patches (details in Table 3.1). Vegetation was sampled on the transects on set bearings and on the existing forest trails. The trails and transects passed through all the major habitat types at each site to allow sampling of different habitats in equal proportion. Three transects of one km each, were laid only in Binsar Wildlife Sanctuary (BWS) while trails were sampled in all oak patches including BWS (Fig. 3.1). Each transect was divided into 20 points, each 50m apart. Sampling points, each 50m apart on trails, were taken 10m inside on either side of the trail to avoid sampling the relatively disturbed vegetation along it.

Circular plot method following Dombois and Ellenberg (1974) was used for vegetation sampling. At each sampling point, a 10m radius circular plot was established. Trees of > 4m height were considered as mature trees and different species and their individuals were recorded for the estimation of density, species diversity and species richness. Shrub layer was quantified in 3m radius circular plot within the existing 10m radius sampling plot. Shrub species and their numbers were recorded for the estimation of density, diversity and species richness. Ground vegetation (herbs and grasses) was estimated in 0.5m x 0.5m quadrate at four places within the 10m radius circular plot. The species and their numbers were recorded for the estimation of density, diversity and species richness.

Tree cover was measured by using gridded mirror of 10 x 10 inches dimension, divided into 25 equal grids. The mirror was placed horizontally at 1.25m above the

Table 3.1 Distribution of sampling points in different oak patches of Kumaon Himalaya.

Oak patch	Number of sampling plots	Altitude range (m)
Kilbery	40	2085- 2240
Vinaiyak	40	2130- 2290
Kunjakharak	45	2040- 2430
Maheshkhan	40	1820- 2090
Gager	40	1860- 2220
Mukteshwer	49	1800- 2260
Jilling	20	1860- 2010
Binsar	75	1990- 2260
Pandavkholi	40	2460- 2590
Sitlakhet	15	1880- 1980
Jageshwer	26	2060- 2200
Gasi	40	2140- 2370
Dhakuri	55	2470- 2825
Wachham	50	2410- 2935
Sunderdunga	36	2560- 2780
Pindari	39	2200- 2960
Daphiadura	40	2020- 2440
Majtham	40	1595- 2250
Gandhura	50	1710- 2045
Sobala	40	2190- 2650
Duku	48	1930- 2530
Munsiary	25	2655- 2770
Mechh	10	1810- 1830



LEGEND

- Villages
- Private estates
- Forest rest house
- Area sampled

1 cm = 0.75 km

Fig. 3.1 Area sampled for biodiversity evaluation in Binsar Wildlife Sanctuary.

ground touching the body of the observer. Tree cover was measured at 5m distance from the sampling point in four different directions. Grids covered with more than 50% foliage were counted and expressed in terms of percent tree cover.

3.2.1 GIS approach

The outer boundary of Kumaon region and its districts were digitized from toposheets published by Survey of India. All the 23 oak patches were also carved from 1:50,000 scale toposheets published by the Survey of India (Reference No. 53 O/7, 53 O/10, 53N/16, 53 O/14, 53 O/11, 62 B/4, 62 B/8, 62 B/12, 62 C/1 and 62 C/3). The whole map with oak patches was digitized by Auto Cad R-14 computer software program. Outer boundary, district boundary and patch boundary were digitized as separate layers and polylines were converted into polygons by program Data Automation Kit (DAK). Each oak patch was considered as one polygon.

The area of proposed sanctuaries was also carved from 1:50,000-scale toposheet. The map was divided into grids of 1 x 1 km. On ground, the data on various aspects were collected for each grid. GIS analyses were performed by ArcView 3.1a computer software program. Data were imported through dbase file format. Thematic maps were prepared by considering some aspects such as tree cover (Fig. 3.2), tree density (Fig. 3.3), tree diversity (Fig. 3.4) and shrub diversity (Fig. 3.5). Combinations of thematic maps were also overlaid. Query analysis was performed on the map of Binsar Wildlife Sanctuary.

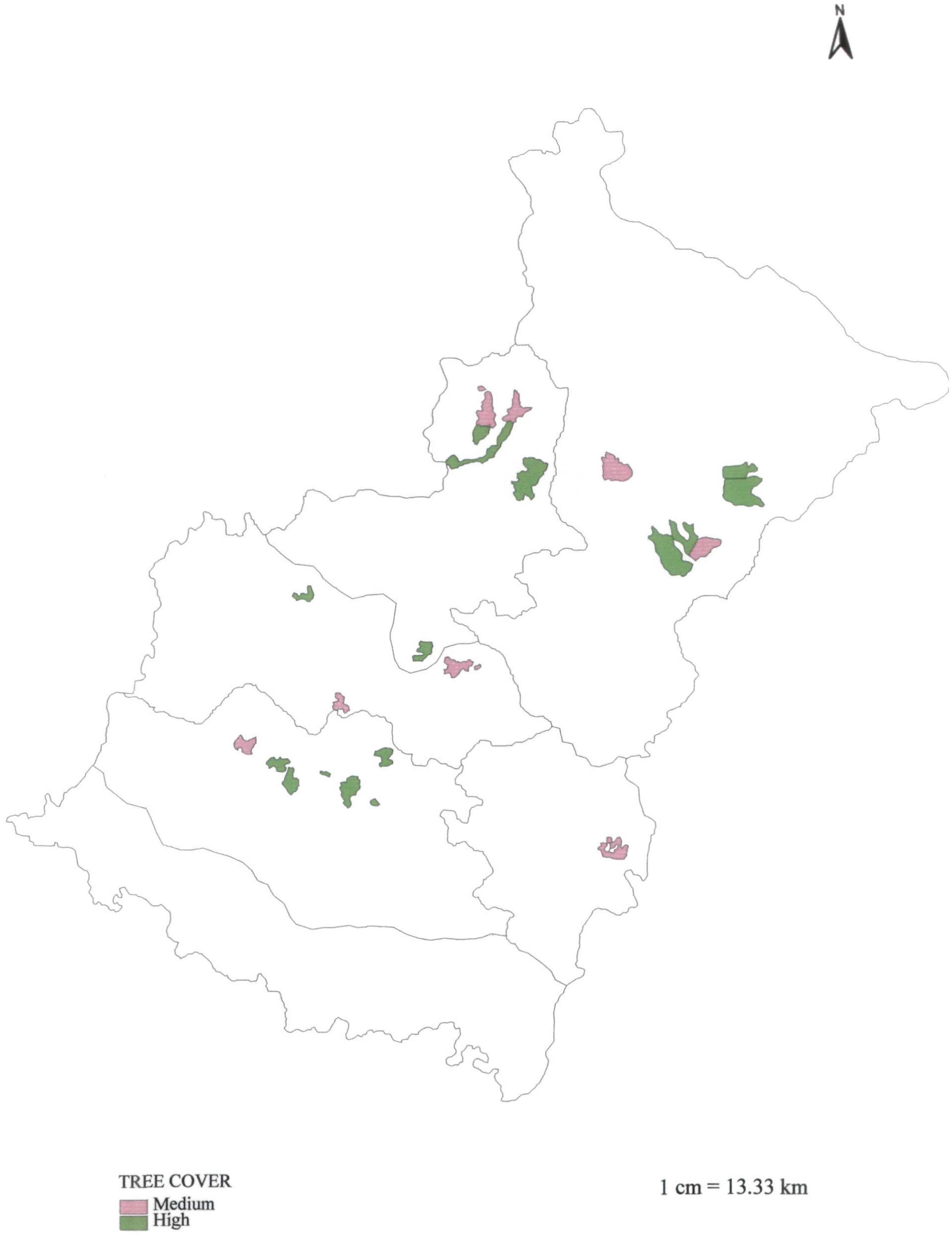


Fig. 3.2 Extent of tree cover in oak forest patches in Kumaon Himalaya.

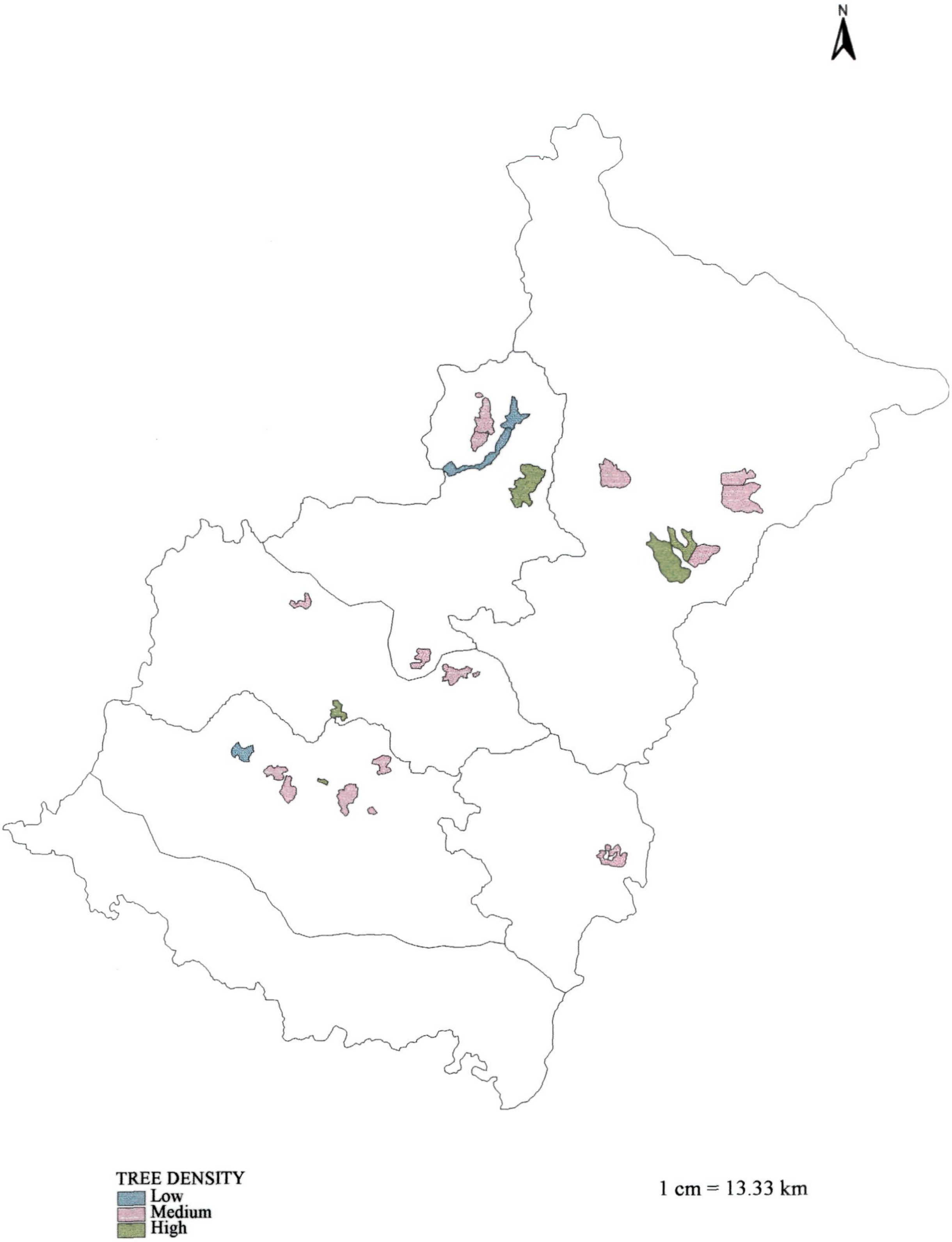


Fig. 3.3 Extent of tree density in oak forest patches in Kumaon Himalaya.

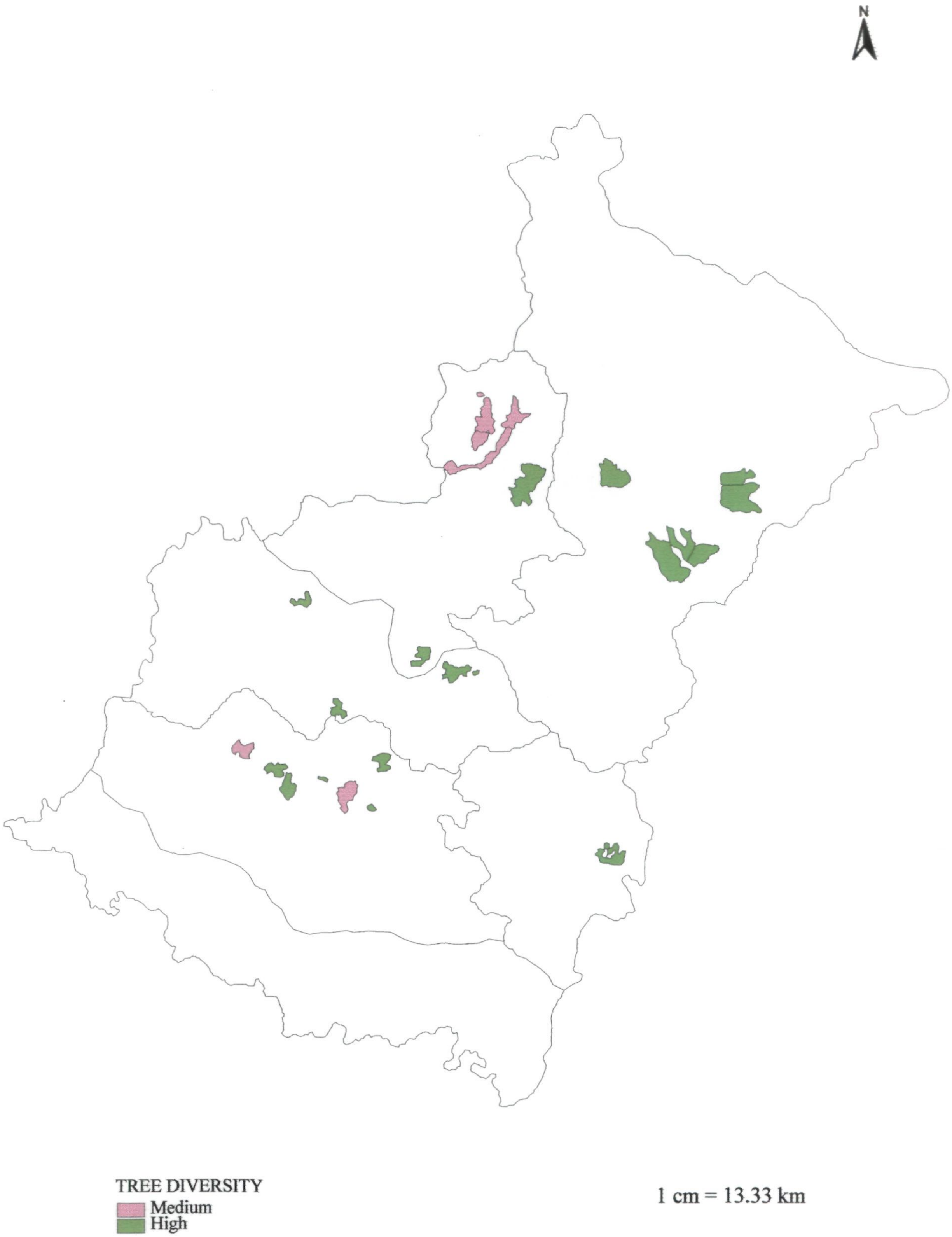


Fig. 3.4 Extent of tree diversity in oak forest patches in Kumaon Himalaya.

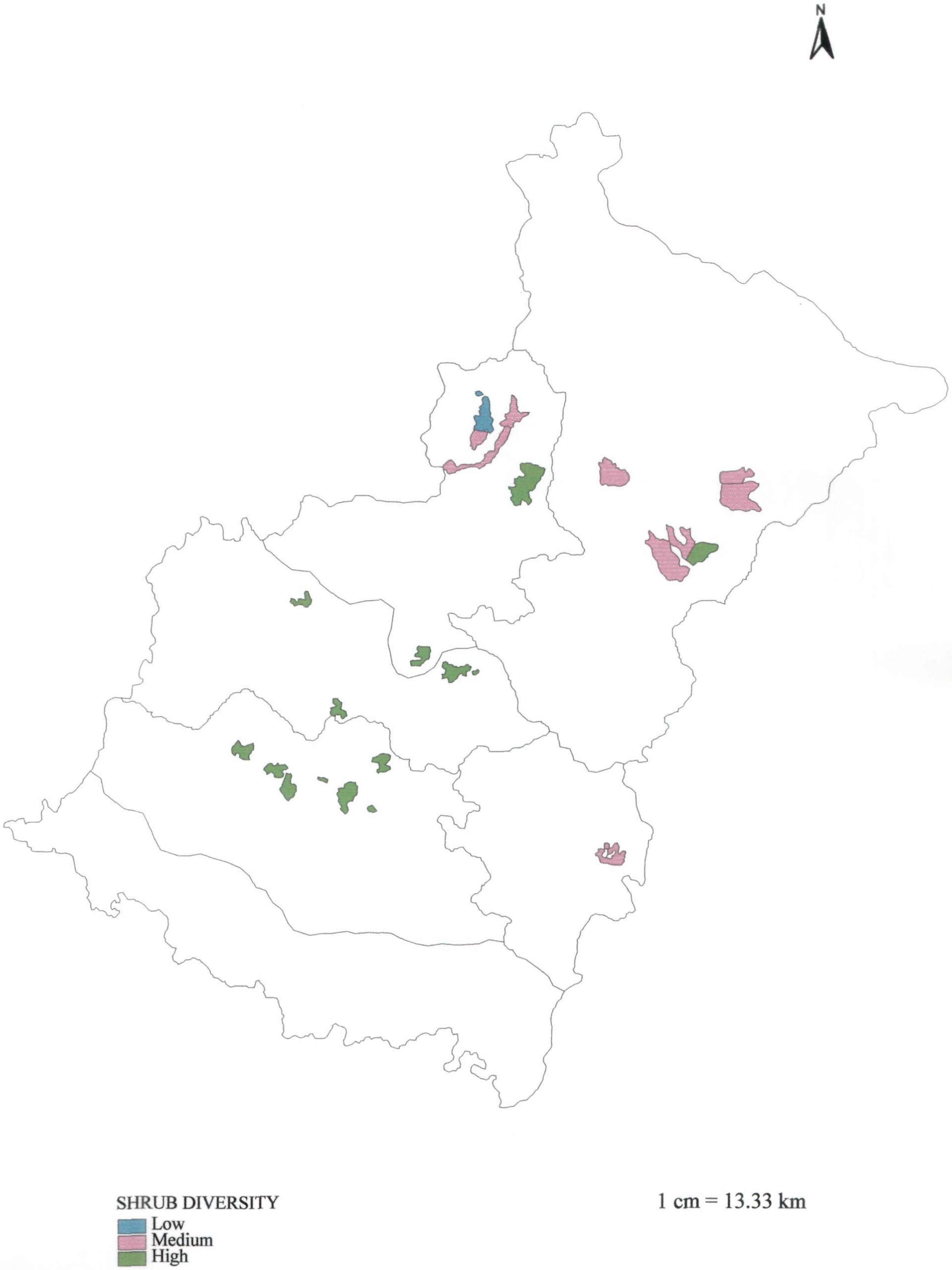


Fig. 3.5 Extent of shrub diversity in oak forest patches in Kumaon Himalaya.

3.2.2 Analyses

Densities for trees, shrubs and ground vegetation (herbs and grasses) were calculated following Greig- Smith (1983) for each sampling plot by using following formula,

Density = Number of individuals x 10,000/ Area

Tree and shrub density values were converted into hectare unit while herbs and grasses were calculated in m^2 unit. Standard error and 95% confidence interval were also calculated. The diversity for each layer (tree, shrub and ground vegetation) were calculated by using Shannon-Wiener's diversity index following Magurran (1988),

$H' = - \Sigma pi \log pi$

where pi = proportion of the i^{th} species in the sample

The species richness was calculated by using Margelef's species richness index (Magurran, 1988),

$R = S - 1 / \ln N$

where, S = number of species, N = number of individuals.

For habitat description, mean ± S.E. of density values of dominant tree species for overall Kumaon was also calculated. Kruskal–Wallis one-way ANOVA was used to detect significant statistical differences in density, diversity and richness for all vegetation layers (tree, shrub and ground vegetation) of all the oak patches of Kumaon. Further Scheff's test (Zar, 1984) was performed to find out which pair of oak patches was different. All vegetation attributes such as tree density, diversity, richness; shrub density, diversity, richness; ground layer density, diversity, richness along with altitude, number of stumps, lopped trees and cattle dung were subjected to Principal Component Analysis (PCA), to ordinate 23 sites in space.

Apart from PCA, the vegetation of Kumaon was classified on the basis of all tree species sampled by using TWINSPAN (Two-way indicator species analysis) computer program (Hill, 1979b). The data matrix was constructed in sites x species matrix by having sites in column and species in row. This analysis is the most widely used technique for polythetic divisive classification to produce two-way table of sample and species. The same data matrix was again used for ordination of species as well as sites by using computer program DECORANA for Detrended Correspondence Analysis (DCA) (Hill, 1979 a; Hill & Gauch, 1980).

Stepwise multiple regression was used to obtain regression equations for quantitative correlations between the DCA axis and dominant environmental and vegetation attributes. By incorporating the environmental factors and site parameters of sites into these multiple regression equations, quantitative environmental interpretation of sites or species is possible. A pattern or model for the community types and species distributions could be objectively established by plotting sites or species in the DCA ordination. All data matrices were standardized following Zar, (1984) to achieve the normality and reduce heteroscadesticity.

In order to see the most fragmented patches at landscape level, I used Perimeter/ area ratio index and the shape index following the formulae,

Shape index = Perimeter / 2 x $\sqrt{\pi}$ x Area

Increase in these indices will indicate the most fragmented surveyed oak patches of Kumaon.

Rarity index

A rarity index was generated to find out rare tree species of Kumaon. For the purpose two parameters were taken into account-

a) Qualitative proportion of each tree species in Kumaon (P_{QA})

$$(P_{QA}) = \frac{\text{No. of patches the concerned tree species was encountered}}{\text{Total number of patches (23)}}$$

b) Quantitative proportion of each tree species in Kumaon (P_{QI})

$$(P_{QI}) = \frac{\text{No of individuals of each tree species}}{\text{No of individuals of all the tree species where the concerned species was encountered}}$$

Rarity index for each tree species = $P_{QA} + P_{QI}$

3.3 RESULTS

A total of 63 tree species, 56 shrub species, 90 herb species and 21 grass species were sampled in 23 oak patches of Kumaon Himalaya (Appendix).

3.3.1 Habitat classification

Nineteen broad habitat types have been recognized in Kumaon. All the sites having 63 tree species were subjected to TWINSPAN analysis. A total of five homogenous groups in relation to the environmental variables were identified (Fig. 3.6 & 3.7). The left arm of the first dichotomy contained 25 species, which was further divided into two groups. First negative group consisted of four species (*Acer cappadocicum*, *Aesculus indica*, *Swida* sp. and *Betula alnoides*) characteristic of Binsar Wildlife Sanctuary. Second positive group again consisted of two homogenous groups. First group consisted *Quercus semecarpifolia* as dominant species and *Toona serrata*, *Symplocos chinensis* as co-dominant. This vegetation type was distributed at Daphiadura, Gasi and Dhakuri. Second group consisted *Abies pindrow* and *Taxus baccata* as dominant species while *Tsuga demosa*, *Betula utilis* and *Rhododendron barbatum* occurred as co-dominant species. This habitat type was found in Pindari, Sobala, Duku, Wachham, Sunderdunga and Munsiary and it represented Mixed Coniferous habitat. Further subdivisions were meaningless and did not provide any ecological information.

The right arm of the first dichotomy was having 38 tree species, which was further sub-divided into two groups. First negative group contained 21 species which had *Quercus leucotricophora*, *Quercus lanuginosa*, *Euonymus tingens*, *Quercus glauca* and *Pinus roxburghii* as dominant species and some other major tree species were *Pinus wallichiana*, *Pyrus pashia*, *Cedrus deodara*, *Cupressus torulosa*, *Myrica esculenta* and *Swida oblonga* (Table 3.2). These tree species were mainly encountered at Vinaiyak, Maheshkhan, Gager, Jilling, Majtham, Gandhura and Mechh. At Vinaiyak, *Quercus leucotricophora*, *Pinus wallichiana* and *Cedrus deodara* while at Mechh, *Quercus lanuginosa* was the dominant species. At Mukteshwer, Pandavkholi, Sitlakhet, Jageshwer, Kilbery and Kunjakharak, the dominant tree species were *Lyonia ovalifolia*, *Symplocos theifolia*, *Quercus floribunda*, *Rhododendron arboreum* and *Persea duthiei* where as *Lindera pulcherrima*, *Viburnum mullaha*, *Alnus nepalensis*, *Ilex dipyrena* and *Litsea umbrosa* were the co-dominant species (Fig. 3.8 & Table 3.2).

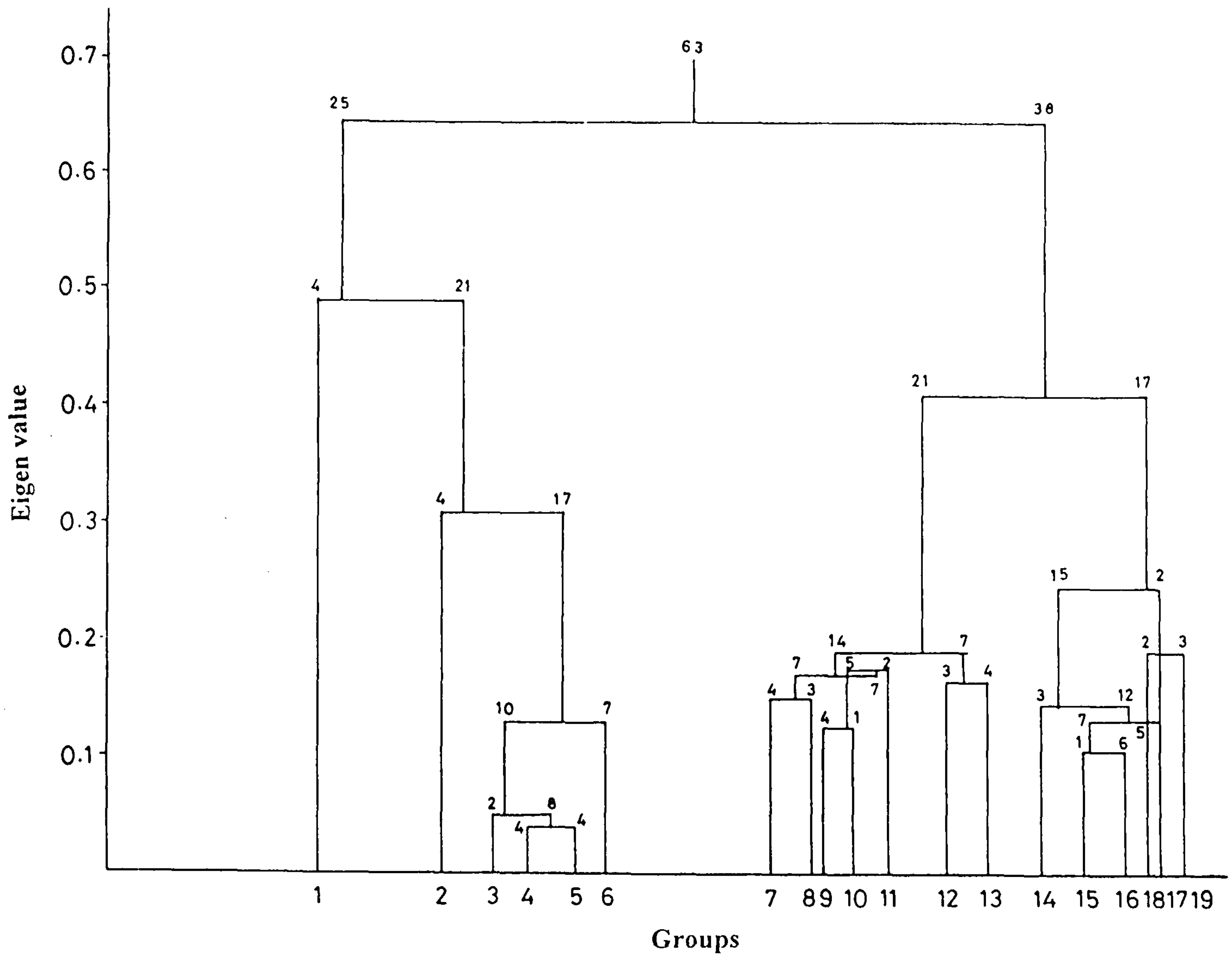


Fig 3.6 TWINSPAN classification of 63 tree species into 19 groups based on the tree species data.

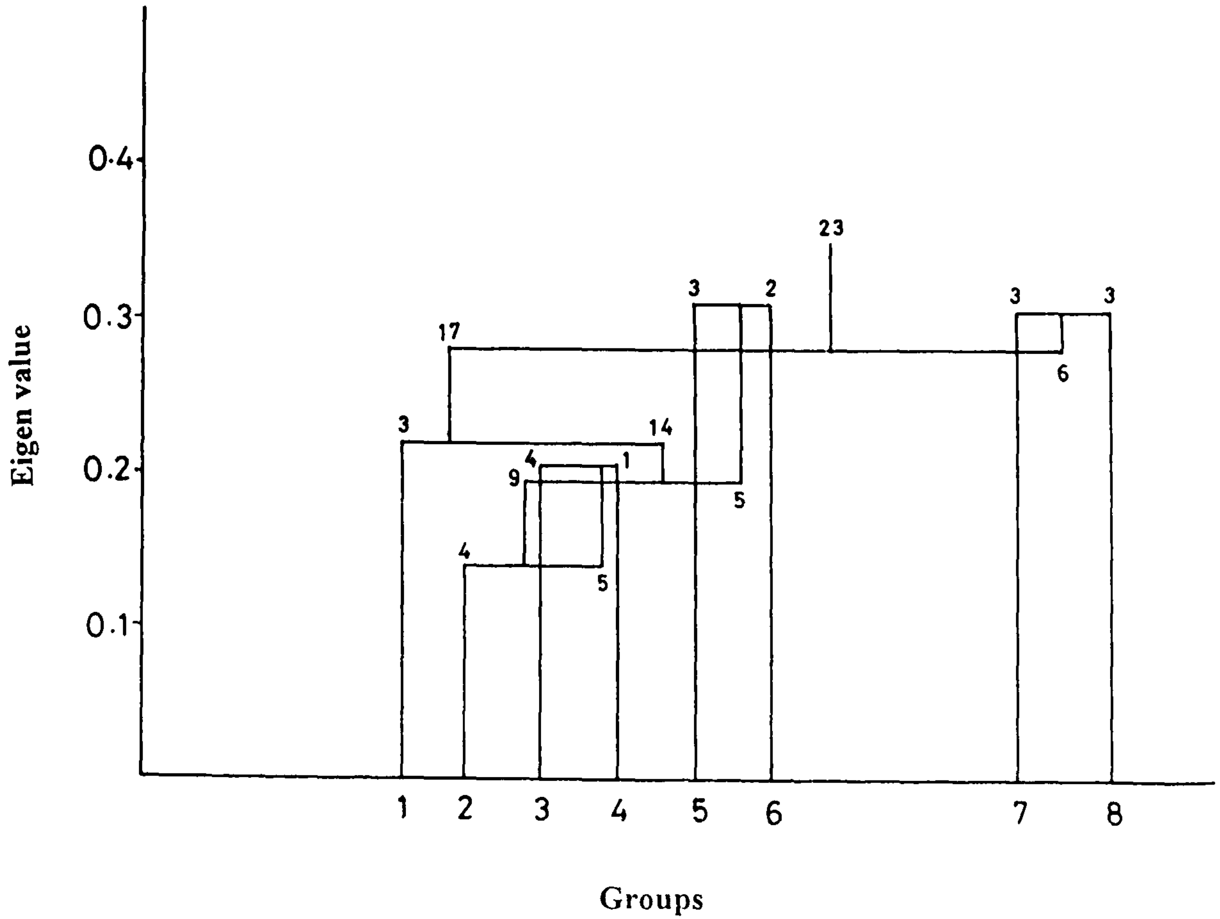


Fig 3.7 TWINSPAN classification of 23 sites into 8 groups based on the tree species data.

Fig. 3.8 Map showing distribution of the eight TWINSPAN- groups, based on tree species in Kumaon Himalaya.

Table 3.2 The vegetation communities and their characteristic tree species in Kumaon based on TWINSPAN classification. Comm. = Community

Comm.	Group No.	Sites	Tree species
1	1	Binsar WLS	*Acer caesium*, *Aesculus indica*, *Swida* sp., *Betula alnoides*
2	2	Daphiadura Gasi, Dhakuri	*Quercus semecarpifolia*, *Toona serrata*, *Dodecademia grandiflora*, *Symplocos* sp.
3	3,4,5,6	Pindari, Sobala, Duku Wachham, Sunderdunga Munsiary	*Abies pindrow, Jugulans regia, Prunus cerasoides Betula utilis*, *Rhododendron barbatum,Taxus baccata*, *Tsuga demosa*, *Pyrus vestita,Zanthoxylum armatum*, *Ficus palmata*, *Morus serrata*, *Symplocos chinensis*, *Prunus cornuta*, *Debregeasia hypoleuca*, *Acer cappadocicum*, *Fraxinus* sp., *Dendroephthoe falcata*
4	7,8,9,10,11 12,13	Vinaiyak, Maheshkhan Gager, Jilling, Majtham Gandhura, Mechh	*Cedrus deodara*, *Cupressus torulosa*, *Cassia fistula*, *Quercus lanuginosa*, *Engelhardia spicata*, *Ficus auriculata*, *Daphnephyllum*, *himalense*, *Quercus glauca,Pinus roxburghii*, *Myrica esculenta*, *Maytenus rufa*, *Benthamidia capitata*, *Phoenix humilis*, *Castanopsis*, *tribuloides,Quercus leucotricophora*, *Pyrus pashia*, *Pinus wallichiana*, *Euonymus tingens,Swida oblonga*, *Macaranga pustulata*, *Picea smithiana*
5	14,15,16,17, 18,19	Mukteshwer, Kilbery Pandavkholi, Sitlakhet Jageshwer, Kunjakharak	*Litsea umbrosa*, *Populus ciliata*, *Persea duthiei*, *Rhododendron arboreum*, *Alnus nepalensis Viburnum mullaha*, *Ilex dipyrena*, *Stranvissia naussea*,, *Meliosma dillenaeafolia*, *Rhamnus triqueter*, *Quercus floribunda,Praxinus micrantha*, *Symplocos theifolia*, *Lindera pulcherrima*, *Lyonia ovalifolia*, *Euonymus pendulus*, *Viburnum coriacieum*

3.3.2 Ordination

The matrix consisting of 23 sites and 63 tree species was subjected to Detrended Correspondence Analysis to ordinate sites as well as species while PCA was performed to ordinate only sites on the basis of some vegetation and environmental attributes. DCA produced an excellent ordination for the Kumaon data, successfully handling the extreme diversity of tree communities from low altitude to high altitude. All the sites and tree species showed meaningful distribution on axis 1 and axis 2 of DCA (Fig 3.9). The first axis 1 (eigen value = 0.389) is an elevation (low to high) gradient. It represented ecological series from low altitude, middle altitude and high altitude communities.

Pindari, Sobala, Duku, Wachham, Sunderdunga and Munsiary occupied extreme end of first axis and represented TWINSPAN group 3 (*Abies pindrow*, *Taxus baccata, Betula utilis, Tsuga demosa* etc.), to low altitude sites Mechh, Majtham, Maheshkhan, Sitlakhet, which represented TWINSPAN group 4 & 5 (*Pinus roxburghii, Quercus leucotricophora, Pyrus pashia, Quercus floribunda*).

The second axis (eigen value = 0.254) appeared to reflect the canopy cover from open to close. The species associated with open canopy were (*Quercus glauca, Quercus lanuginosa*, *Cassia fistula*, *Zanthoxylum armatum*, *Quercus semecarpifolia*) and the sites were Majtham, Gandhura, Mechh, Dhakuri and Wachham while close canopy areas were Gasi, Sobala, Duku and Pandavkholi and the associated tree species were *Quercus semecarpifolia, Toona serrata, Symplocos theifolia* (Fig. 3.10). These interpretations were largely confirmed by the results of Principal Component Analysis. The first factor (PC 1) explained 44.26% variance and emerged as an open to close canopy forest with tree density and diversity in increasing order. While second factor (PC 2) explained

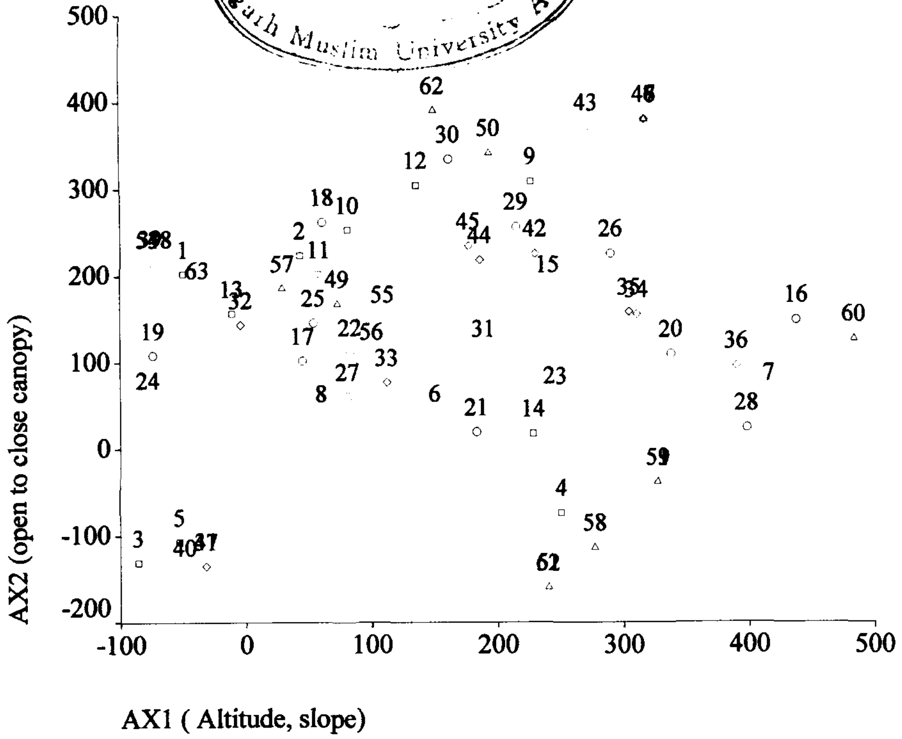


Fig. 3.9 Ordination of different tree species on two axes extracted by DECORANA

Table 3.3 List of tree species with codes used in DECORANA.

SPECIES	CODE	SPECIES	CODE	SPECIES	CODE
Quercus leucotricophora	1	*Viburnum mullaha*	22	*Dendroephthoe falcata*	43
Quercus floribunda	2	*Aesculus indica*	23	*Betula alnoides*	44
Quercus glauca	3	*Myrica esculenta*	24	*Picea smithiana*	45
Quercus semecarpifolia	4	*Cupressus torulosa*	25	*Ficus palmata*	46
Quercus lanuginosa	5	*Ilex dipyrena*	26	*Morus serrata*	47
Rhododendron arboreum	6	*Swida oblonga*	27	*Fraxinus* sp.	48
Rhododendron barbatum	7	*Betula utilis*	28	*Populas ciliata*	49
Lyonia ovalifolia	8	*Meliosma dillenaeafolia*	29	*Symplocos* sp.	50
Persea duthiei	9	*Litsea umbrosa*	30	*Symplocos chinensis*	51
Euonymus tingens	10	*Lindera pulcherrima*	31	*Pyrus vestita*	52
Euonymus pendulus	11	*Praxinus micrantha*	32	*Acer cappadocicum*	53
Symplocos theifolia	12	*Macaranga pustulata*	33	*Maytenus rufa*	54
Pyrus pashia	13	*Jugulans regia*	34	*Viburnum coriacieum*	55
Toona serrata	14	*Tsuga demosa*	35	*Rhamnus triqueter*	56
Abies pindrow	15	*Engelhardia spicata*	36	*Stranvissia naussea*	57
Taxus baccata	16	*Dodecademia grandiflora*	37	*Zanthoxylum armatum*	58
Cedrus deodara	17	*Daphnephyllum himalense*	38	*Debregeasia hypoleuca*	59
Pinus wallichiana	18	*Benthamidia capitata*	39	*Prunus cornuta*	60
Pinus roxburghii	19	*Castanopsis tribuloides*	40	*Phoenix humilis*	61
Acer caesium	20	*Ficus auriculata*	41	*Cassia fistula*	62
Alnus nepalensis	21	*Swida* sp.	42	*Prunus cerasoides*	63

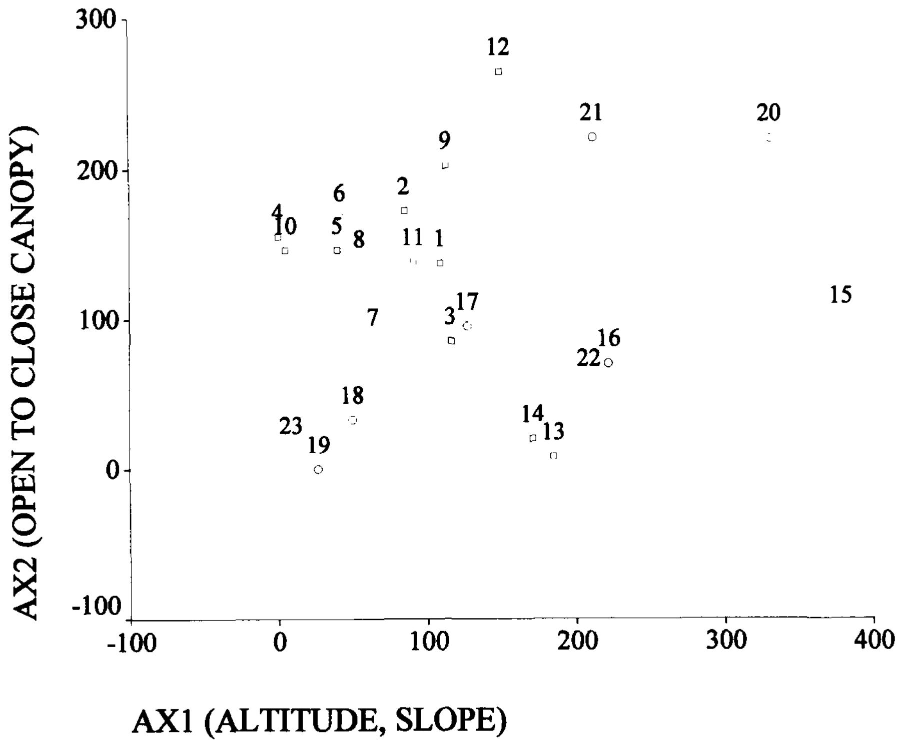


Fig. 3.10 Ordination of sites on the two axes extracted by DECORANA.

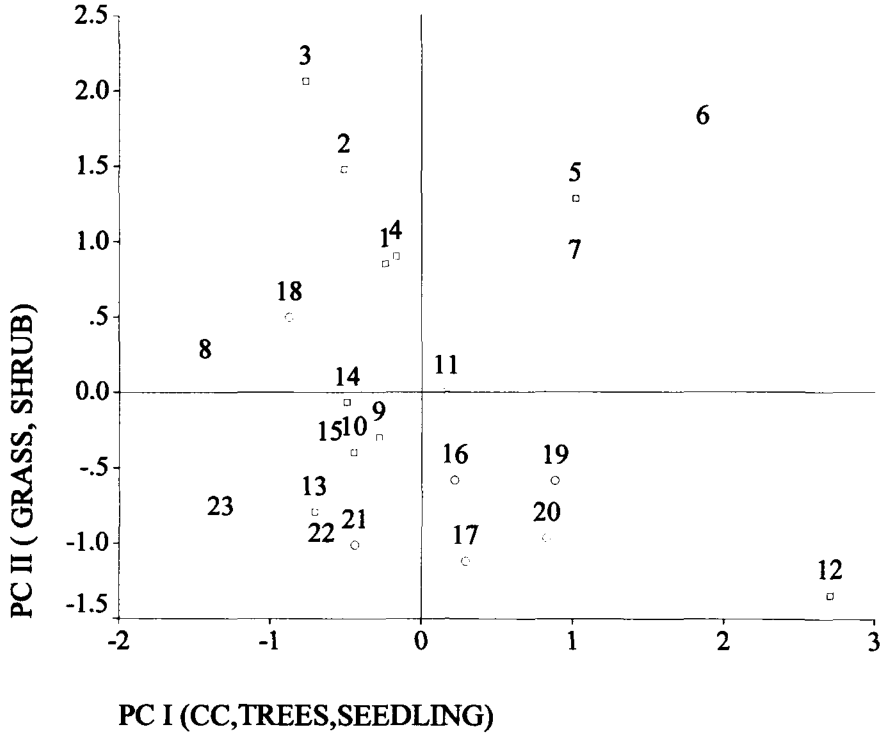


Fig. 3.11 Ordination of sites on two extracted factors from Principal Component Analysis.

18.26% variance and showed the characters of increase in shrub density and diversity. The distribution of species and sites was same on the two axis of PCA as on DCA axis (Fig. 3.11 & Table 3.3).

Multiple regression of DCA sites ordination scores with environmental and vegetation attributes provided objective, quantitative environmental interpretation for vegetation types. According to regression analysis, DCA axis 1 was significantly positively correlated with altitude (53.5% variance) and further slope also contributed cumulative 62.1% variance in the model (Table 3.4). Axis 2 again appeared to reflect shrub characters and canopy cover gradient. It was positively correlated with these two gradients (Table 3.5), which again clearly interpreted both the DCA axis for sites and species.

3.3.3 Species composition

The tree, shrub, herb and grass densities varied significantly at different sites (Table 3.6 & 3.7). The tree density was significantly high at Gasi (995.2 / ha ± 269.4), Gager (915.6 / ha ± 331.6) and Sitlakhet (815.1 / ha ± 257.3) compared to rest of the oak patches. Shrub density was also significantly different in all oak patches and it was highest for Mukteshwer (28158.2 / ha ± 10478.7), Gager (24504.6 / ha ± 11280.7), and Kunjakharak (21470.3 / ha ± 10435.9) while lowest for Mechh (6852.01 / ha ± 4068.38) and Munsiary (7353.31 / ha ± 5059.38).

Significant differences were not observed in different communities for tree density. However, tree density was maximum for *Quercus floribunda - Rhododendron arboreum* community (714.51 / ha ± 70.0) and minimum for *Abies pindrow - Betula utilis* community (492.92 / ha ± 37.53). Shrub density was also not significantly different for all communities but it was maximum for community *Quercus floribunda – Rhododendron arboreum* (16834.9 / ha ± 2863.22) and minimum for *Quercus semecarpifolia – Toona serrata* (6914.96 / ha ± 431.01) community (Table 3.8 & 3.9).

The tree layer was dominated by *Rhododendron arboreum* (3861.41 / ha) in whole of Kumaon followed by *Quercus leucotricophora* (2637.06 / ha), *Quercus floribunda* (2538.07 / ha), *Lyonia ovalifolia* (2621 / ha), *Persea duthiei* (1985.39 / ha) (Table 3.10). In Vinaiyak, *Cedrus deodara* (184.71 / ha) was dominant tree species while in Pindari *Rhododendron arboreum* (263.03 / ha) and *Debregeasia hypoleuca* (414.01 / ha) were dominant species. *Quercus floribunda* (266.72 / ha) dominated the tree layer in Binsar Wildlife Sanctuary.

The shrub layer also plays a major role in vegetation analysis. *Myrcine africana* (91299.86 / ha) was the dominant shrub species for whole Kumaon followed by *Athyrium* sp. (64645.31 / ha) and *Nerium* sp. (62405.28 / ha.) (Table 3.11). *Myrcine africana* was found to be maximum at Kunjakharak (13269.64 / ha) and Gager (12356.3 / ha) while *Rubus ellipticus* was dominant at Pindari (2830.85 / ha) and Binsar (2753.93 / ha). The other species of Rubus i.e. *Rubus biflorus* was maximum in number at Pandavkholi (3096.24 / ha), Sunderdunga (3037.27 / ha) and Pindari (2756.36 / ha). *Berberis aristata* was dominant at Jageshwer (1725.05 / ha), Kunjakharak (1430.81 / ha) and Wachham (1326.96 / ha). *Daphne papyracea* was found to be maximum at Dhakuri and Sunderdunga (4600.14 / ha), Kilbery (3132.67 / ha) and Vinaiyak (3063.07 / ha).

Table 3.4 Multiple regression analysis of Axis 1 of DCA with vegetation attributes.

Model	Variables	Correlation	R^2	F	Significance
1	Altitude	+	0.535	24.16	0.001
2	Altitude, Slope	+	0.655	19.05	0.001

Table 3.5 Multiple regression analysis of Axis 2 of DCA with vegetation attributes.

Model	Variables	Correlation	R^2	F	Significance
1	Shrub diversity	+	0.32	10.08	0.05
2	Shrub diversity, Grass richness	+	0.544	11.93	0.001
3	Shrub diversity, Grass richness, Canopy cover	+	0.635	11.01	0.001
4	Shrub diversity, Grass richness, Canopy cover, Shrub density	+	0.714	11.2	0.001

Table 3.6 Mean values of density ± S.E. and confidence limit 95% (C.I.) of quantified trees and shrubs of surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	Trees/ha	±S.E.	%C.I.	Shrub/ha	±S.E.	%C.I.
Kilbery	793.8	311.9	96.66	14092.0	6881	2132
Vinaiyak	590.8	311.9	96.65	20444.0	9351	2898
Kunjakharak	367.8	185.8	54.32	1470	10436	3049
Maheshkhan	611.3	857.4	265.7	13880	7534	2335
Gager	915.6	331.6	102.8	24505	11281	3496
Mukteshwer	765.1	275	77.01	28158	10479	2934
Jilling	774.7	305.9	134.1	19502	10034	4398
Binsar WLS	743.6	415.9	94.12	14402	10490	2374
Pandavkholi	796.2	212.7	65.92	8855	5395	1672
Sitlakhet	815.1	257.3	130.2	11836	7195	3642
Jageshwer	749	247.9	95.27	16597	8542	3284
Gasi	995.2	269.4	83.54	7776	5058	1568
Dhakuri	313.7	189.1	50.44	6449	5181	1381
Wachham	530.3	385.2	106.77	10386	7795	2160
Sunderdunga	499.3	220.4	77.0	11637	9621	3142
Pindari	326.6	107.6	33.35	12632	10843	3360
Daphiadhura	804.1	246.7	76.44	6519	4326	1340
Majtham	447.5	214.4	66.45	11421	5631	1745
Gandhura	841.6	275.4	76.33	5458	4185	1160
Sobala	582	242.4	75.13	10952	7443	2306
Duku	558.1	243.1	68.76	8616	6583	1862
Munsiary	461.2	231.2	90.64	7353	5059	1983
Mechh	486	245.8	152.35	6852	4068	2521

Table 3.7 Mean values of density ± S.E. and confidence limit 95% (C.I.) of quantified herbs and grasses of surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	Herbs/m²	±S.E.	%C.I.	Grass/m²	±S.E.	%C.I.
Kilbery	18.65	11.1	3.44	37.13	17.14	5.3
Vinaiyak	17.83	12.81	3.97	39.93	17.52	5.4
Kunjakharak	23.85	13.9	4.1	48.79	45.6	13.3
Maheshkhan	10.4	8.5	2.63	27.83	16.82	5.2
Gager	14.23	9.93	3.08	35.4	15.7	4.8
Mukteshwer	15.2	11.05	3.1	44.73	20.08	4.6
Jilling	12.71	7.95	3.49	34.11	17.02	7.46
Binsar WLS	15.88	14.08	3.19	17.68	15.69	3.5
Pandavkholi	12.4	14.07	4.36	18.78	19.5	6.0
Sitlakhet	14.57	13.51	6.84	11.03	9.27	4.69
Jageshwer	16.42	14.94	5.74	17.4	15.8	5.8
Gasi	35.48	20.77	6.44	2.2	4.4	1.4
Dhakuri	33.98	17.35	4.63	17.45	13.87	3.7
Wachham	17.93	16.72	4.63	25.78	18.36	5.1
Sunderdunga	21.16	24.61	8.04	9.31	18.7	6.1
Pindari	31.8	19.13	5.93	4.20	6.13	1.9
Daphiadhura	19.53	16.34	5.06	16.13	17.89	5.5
Majtham	20.2	14.84	4.6	33.9	18.07	5.6
Gandhura	17.6	10.71	2.97	27.08	13.31	3.7
Sobala	22.83	14.42	4.47	7.3	9.1	2.8
Duku	22.3	14.37	4.1	8.95	8.93	2.5
Munsiary	22.87	14.54	5.7	9.5	8.19	3.2
Mechh	24.74	14.17	8.7	13.03	20.41	12.6

3.3.4 Species diversity and richness

Species diversity and richness also varied significantly between the sites (Table 3.12 & 3.13). However, tree species diversity was found maximum at Daphiadura (1.53) in Askot Wildlife Sanctuary followed by Gasi (1.45), Gager (1.44) and Mukteshwer (1.43). Tree species richness was maximum at Daphiadura (1.76) and Gasi (1.44).

Shrub diversity and richness was also statistically different between the sites. It was highest in Vinaiyak (1.61 & 1.54 respectively) followed by Kilbery (1.49 & 1.49 respectively) and Mukteshwer (1.38). Shrub richness was also high at Mukteshwer (1.5).

3.3.5 Species of special conservation concern

Using the individuals of tree species sampled in whole Kumaon the generated rarity index value ranged from 0.03 to 0.40. The tree species falling between 0.03 to 0.20 range values were considered rare. *Betula utilis* (0.03), *Tsuga demosa* (0.06), *Quercus glauca* (0.06), *Pinus wallichiana* (0.09), *Taxus baccata* (0.12), *Cupressus torulosa* (0.15), *Picea smithiana* Wall. (0.16), *Abies pindrow* (0.16) and *Cedrus deodara* (0.17) were found to be rare tree species in Kumaon. Except *Quercus glauca* all the above-mentioned rare tree species were found in Pindari region only while *Pinus wallichiana*, *Cupressus torulosa, Picea smithiana* and *Betula utilis* were found in Vinaiyak reserve forest also.

On the basis of Perimeter/Area ratio and shape index, it was concluded that Gager, Jilling and Pandavkholi were the most fragmented patches and Gandhura, Dhakuri and Duku were the least fragmented patches. Increase in fragmentation denotes increase of abrupt habitat change, an ecologically undesirable influence on most species

Table 3.8 Tree species density (TDEN), shrub species density, Standard error (SE) and confidence limit (95%) in different communities based on TWINSPAN classification.

Community	TDEN	± S.E.	%C.I.	SDEN	± S.E.	%C.I.
1. *Aesculus indica*	743.6	415.9	94.12	14402	10490	2374
2. *Quercus semecarpifolia*	704.3	202.9	397.8	6915	431.01	844.7
3. *Abies pindrow*	492.9	37.5	73.5	10263	799.3	1566.6
4. *Quercus leucotricophora*	666.77	67.92	133.13	14580	2719	5329.2
5. *Quercus floribunda*	714.5	70.0	137.2	16835	2863.2	5611.8

Table 3.9 Tree species diversity (TDIV), tree species richness (TRIC), shrub diversity (SDIV) and shrub richness (SRIC) in different communities based on TWINSPAN classification.

Community	TDIV	TRIC	SDIV	SRIC
1. *Aesculus indica*	1.31	1.39	1.07	1.06
2. *Quercus semecarpifolia*	1.23	1.33	0.87	0.82
3. *Abies pindrow*	1.03	1.03	0.83	0.74
4. *Quercus leucotricophora*	1.27	1.34	1.13	1.11
5. *Quercus floribunda*	1.26	1.31	1.26	1.20

Table 3.10 Mean values of density ± S.E. and confidence limit 95% (C.I.) of major tree species of surveyed oak patches of Kumaon Himalaya during 1996-97.

Tree species	Density	± Standard error	CI (95%)
Abies pindrow	150.85	97.38	95.43
Acer caesium	76.14	35.12	18.39
Aesculus indica	47.33	19.28	10.12
Alnus nepalensis	55.94	26.59	11.37
Betula utilis	84.93	36.77	41.61
Cedrus deodara	110.54	76.74	50.13
Cupressus torulosa	112.15	37.01	32.43
Euonymus tingens	70.03	37.77	21.36
Ilex dipyrena	70.16	37.17	17.17
Juglans regia	70.52	21.82	16.16
Lindera pulcherrima	117.91	65.53	42.81
Litsea umbrosa	92.22	52.56	32.57
Lyonia ovalifolia	113.95	55.45	22.66
Myrica esculenta	86.56	33.27	18.82
Persia duthiei	110.3	92.83	42.88
Pinus roxburghii	81.54	43.97	25.98
Pinus wallichiana	92.35	60.0	52.59
Pyrus pashia	49.73	17.83	9.34
Quercus floribunda	181.29	102.26	53.56
Quercus glauca	59.14	47.28	53.50
Quercus lanuginosa	167.42	70.56	52.27
Quercus leucotricophora	138.79	93.39	41.99
Quercus semecarpifolia	108.36	45.59	29.78
Rhododendron arboreum	175.52	74.64	31.18
Swida oblonga	68.34	27.91	14.61
Swida sp.	109.56	91.38	56.63

Symplocos theifolia	129.77	107.11	66.38
Taxus baccata	150.85	97.38	95.43
Toona serrata	51.94	24.22	17.94
Tsuga demosa	93.95	24.77	34.33
Viburnum mullaha	82.34	41.12	20.14

Table 3.11 Mean values of density ± S.E. and confidence limit 95% (C.I.) of major shrub species of surveyed oak patches of Kumaon Himalaya during 1996-97

Shrub species	Density	± Standard error	CI (95%)
Argimone maxicana	2064.1	1918.3	2658.6
Urtica dioca	5017.2	7525.2	5574.69
Arundinella nepalensis	2953.9	1399.96	665.5
Athyrium sp.	3055.3	1594.7	666.3
Berberis aristata	984.6	318.7	130.2
Euphorbia prolifera	1862.1	1231.9	853.6
Cratagus sp.	1492.2	281.4	246.7
Daphne papyracea	1808.7	1190.2	486.43
Desmodium gangeticum	2020.7	1252.4	613.6
Indigofera heterantha	1667.4	959.1	455.9
Mahonia sp.	554.1	205.5	164.4
Myrcine africana	6521.4	4760.3	2493.56
Nerium sp.	3670.9	2656.2	1262.65
Polystichum sp.	1526.6	630.93	257.8
Pteridium sp.	2189.9	1687.5	721.7
Pteris cretica	3046.9	1391.5	609.88
Pyracantha crenulata	812.9	356.7	233.1
Rubus biflorus	1618.2	758.9	316.9
Rubus ellipticus	1955.0	1361.5	687.0

Table 3.12 Tree species diversity (TDIV), tree species richness (TRIC), Shrub species diversity (SDIV) and Shrub species richness (SRIC) quantified at surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	TDIV	TRIC	SDIV	SRIC
Kilbery	1.42	1.66	1.4	1.4
Vinaiyak	1.12	1.2	1.6	1.5
Kunjakharak	0.77	0.78	1.1	0.9
Maheshkhan	1.00	1.13	1.2	1.2
Gager	1.45	1.59	1.3	1.4
Mukteshwer	1.43	1.66	1.3	1.5
Jilling	1.4	1.64	1.2	1.2
Binsar WLS	1.32	1.39	1.1	1.1
Pandavkholi	1.33	1.18	1.3	1.2
Sitlakhet	1.34	1.22	1.2	1.1
Jageshwer	1.36	1.41	1.1	1.3
Gasi	1.45	1.44	1.1	1.1
Dhakuri	0.72	0.71	0.6	0.6
Wachham	0.99	0.95	0.8	0.7
Sunderdunga	0.84	0.79	0.5	0.5
Pindari	0.67	0.62	0.8	0.7
Daphiadhura	1.53	1.77	0.8	0.7
Majtham	1.17	1.27	1.2	1.1
Gandhura	1.31	1.21	0.6	0.5
Sobala	1.25	1.40	0.9	0.7
Duku	1.24	1.41	0.7	0.6
Munsiary	1.18	1.25	0.7	0.6
Mechh	1.26	1.35	0.7	0.7

Table 3.13 Herb species diversity (HDIV), herb species richness (HRIC), grass species diversity (GDIV) and grass species richness (GRIC) quantified at surveyed oak patches of Kumaon Himalaya during 1996-97.

Area	HDIV	HRIC	GDIV	GRIC
Kilbery	0.75	0.67	0.93	0.74
Vinaiyak	0.78	0.76	0.40	0.38.
Kunjakharak	0.91	0.89	2.64	0.73
Maheshkhan	0.71	0.7	1.12	0.88
Gager	0.81	0.82	1.13	0.89
Mukteshwer	0.76	0.76	1.16	0.88
Jilling	0.66	0.63	1.07	0.83
Binsar WLS	0.83	0.84	0.67	0.70
Pandavkholi	0.81	0.85	0.31	0.29
Sitlakhet	0.83	0.82	0.49	0.44
Jageshwer	0.99	1.03	0.71	0.63
Gasi	0.92	0.93	0.07	0.08
Dhakuri	0.79	0.56	0.27	0.25
Wachham	0.40	0.38	0.69	0.61
Sunderdunga	0.93	0.91	0.28	0.34
Pindari	1.02	0.88	0.24	0.24
Daphiadhura	0.76	0.74	0.26	0.34
Majtham	0.79	0.75	0.94	0.72
Gandhura	0.71	0.66	0.82	0.64
Sobala	0.61	0.55	0.38	0.41
Duku	0.72	0.62	0.27	0.26
Munsiary	0.84	0.75	0.31	0.28
Mechh	0.82	0.72	0.36	0.32

populations and communities. The correlation between these two indices of landscape ecology and abundance of birds will be discussed in Chapter 4.

3.4 DISCUSSION

The main advantage of numerical methods in evaluating representativeness is that they summarize information about the range in variation in species composition found in whole Kumaon region in an effective and meaningful way. Numerical methods make no claim to being objective as the very choice of method is a subjective decision (Birks, 1987). However, statistical significance is not enough to qualify a site for selection but biological significance is also needed as a basis for sound selection for prioritizing area.

TWINSPAN found to be a satisfactory method, to classify different tree communities of Kumaon. This polythetic divisive classification divides sites into groups on the basis of all the species information. This division was not made on the basis of presence/absence of one species, but on the basis of species composition for the entire sites. It was not possible to consider all 902 sampling plots individually, as it is out of the limit of program. So all the sampling plots for each site were pooled and one site was considered as one quadrate/sample. My main emphasis was to classify sites so it was taken on Y-axis. None of the species was found to be > 5% cover at each site. This could be a sampling error also. As suggested by Margules (1986), representativeness should be used as the first stage in selecting nature reserves. By classifying sites into groups with different species compositions, one can ensure that all these major groups are represented in the selection.

Detrended Correspondence Analysis (DCA) was applied in order to attempt to solve two problems i.e. the 'arch effect' and compression of points at the end of first axis. The first axis was divided into a number of segments and within each segment, the second axis scores are recalculated so that they have an average of zero. Though the DCA axes were clearly defined but unfortunately, the data lacked direct observation on soil moisture, which could be an important factor for the distribution of species (Rikhari *et al.* 1989).

Various studies have been conducted on vegetation of Kumaon by several workers (Saxena & Singh, 1980; Saxena & Singh, 1982; Tiwari, 1982; Tiwari & Singh, 1984; Singh *et al.* 1984; Singh & Singh, 1984; Saxena *et al.* 1985; Upreti *et al.* 1985; Tiwari & Singh, 1985; Singh & Singh, 1987; Singh *et al.* 1987; Rikhari *et al.* 1989; Adhikari *et al.* 1992; Dhar *et al.* 1997). The main aim of this study was to identify and classify the vegetation communities and also in relation with bird diversity and richness.

Species density was significantly different at all sites. It was found to be high at Gasi and Gager. Another study by Rikhari *et al.* (1989) showed that tree density was higher at Gager than what he estimated. But the diversity index value for all the sites was higher than the value reported by Saxena & Singh (1982), Tiwari (1982), Singh & Singh (1984) and Rikhari *et al.* (1989) for oak forests of different localities in Kumaon Himalaya. *Pinus roxburghii* and *Quercus semecarpifolia* are typical west Himalayan elements and are poorly represented in Nepal and further east (Ohsawa *et al.* 1986). Two other oak forests (*Quercus leucotricophora* and *Quercus floribunda*) are widely distributed in the west with higher concentration in central Himalaya (Singh & Singh, 1986). Both forests were distributed in most of the surveyed sites except at higher elevation. *Abies pindrow*, *Taxus baccata* and *Betula utilis* form the sub-alpine forest throughout the Himalayas (Dhar *et al.* 1997). *Abies pindrow* community dominated some of the patches of Askot Wildlife Sanctuary, Pindari, Wachham, Sunderdunga and Munsiary. Tree density, diversity and shrub density, diversity was low in *Abies pindrow*-*Betula utilis* forest as diversity and richness decreases at higher elevations (Singh *et al.* 1994; Rawal & Pangtey, 1994). Same results were available from other areas also (Frankel, 1977; Brithers & Spingarn, 1992; Knops *et al.* 1995). *Quercus semecarpifolia* forest was represented at Daphiadura (AWS), Gasi and Dhakuri. Tree diversity range (0.72- 1.53) was similar as recorded by Dhar *et al.* (1997) at *Quercus semecarpifolia* forest in Askot Wildlife Sanctuary (1.41) but shrub diversity range (0.6-1.1) was lower than what has been reported for Askot Wildlife Sanctuary (1.36). It showed a diversity decline in shrubs.

Forest composition (tree, shrub and ground vegetation) of whole Kumaon corresponds with the forest reported by others for the region. *Quercus leucotricophora* forest represented the elevation between 1800- 2300m (1200-2300m by Singh & Singh, 1986; 1700-2100m by Singh *et al.* 1994) while *Quercus semecarpifolia* forest was present between 2200-3000m (2400-3600m by Singh & Singh, 1986; 2366-3000m by Singh *et al.* 1994). The Shannon-Wiener (H') diversity values were also almost similar as reported by others (Singh *et al.* 1994). These values are even similar to those of temperate communities in adjacent Nepal Himalaya (Ohsawa *et al.* 1975) and elsewhere (Monk, 1967).

As reported by Dhar *et al.* (1997) that > 50% species of this region are non-native species. The area has received plant elements from adjoining regions of tropical Asia

(Indo-China and Indo-Malaya, Mani, 1974) and Indo-Gangetic plains (Spate, 1957). Though the data were not collected and analyzed by keeping native species in mind but the distribution of non-native species is known from the Himalayas (Maheshweri, 1962). However, the change in native flora because of non-native species could lead to long-term change in ecosystem processes (Ramkrishnan & Vitousek, 1989).

Human interference causes great impact on forest structure (Tyser & Worley, 1992). In Kumaon, most of the lower altitude and middle altitude oak patches are densely populated as compared to high altitude forest (see Chapter 8). So the chances of destruction of forest and invasion of non-native species are more in *Quercus leucotricophora* and *Quercus semecarpifolia* forest. Disturbances may interact in complex ways to affect species composition (Collins & Barber, 1985; Steuter *et al.* 1990; Noy-Meir, 1995). Regular fire events, heavy grazing, lopping and felling of trees cause great influence on vegetation. All the sites, where grazing was prohibited or low, were found to be having very high ground cover as compared to other sites such as Jilling and Kunjakharak.

Some tree species such as *Alnus nepalensis* is fast growing. Ohsawa (1991) considers it as a 'habitat pioneer' species as it can occupy the newly formed habitat. Similarly, the expanding *Pinus roxburghii* poses a serious threat to native oak (*Quercus leucotricophora* and *Quercus floribunda*) in whole Kumaon as it has been reported earlier also (Singh & Singh, 1987). The acidic nature of *Pinus roxburghii* does not allow any broad-leaf species to survive (Singh *et al.* 1984). All oak species are facing severe threats because they are lopped and felled for fodder and fuel purposes. This leads to reduction in seed production (Saxena & Singh, 1984). Destruction at large scale, of selected species may change plant communities. Other valuable tree species such as *Abies pindrow*, *Taxus baccata, Tsuga demosa* and *Cedrus deodara* are felled because of their timber value. This community is mainly represented in Pindari but *Abies pindrow* and *Cedrus deodara* are in good population in Vinaiyak reserve forest also. So the protection of this community is necessary.

I tried to map the actual quantified data on different oak patches of Kumaon Himalaya. Though, the interpretation of vegetation and habitat analysis through aerial photography of Kumaon has already been done (Tiwari & Singh, 1984; 1987) but the true assessment of land use pattern and habitat types through remote sensing and GIS techniques is lacking. These two tools can be used effectively in mapping, monitoring and management of natural resources. Landscape parameters are very effective in evaluating the fragmentation of patches and if they are evaluated by taking data of early years, then the habitat loss can be assessed in successive years. To identify potential areas for conservation in Kumaon, it is often necessary to complement remote sensing techniques with vegetation analyses.

CHAPTER 4

STATUS AND DISTRIBUTION OF AVIAN COMMUNITY

4.1 INTRODUCTION

Temperate forests are complex habitats that support diversified communities. Several aspects of the ecology of the birds inhabiting these forests, such as community structure (Holmes & Sturges, 1975; Keast, 1988), population dynamics (Holmes *et al.* 1986; Leck *et al.* 1988), competition (Barlow & Rice, 1977; Robinson, 1981) or habitat selection (Hespenheide, 1971; Sherry & Holmes, 1985) have been investigated.

Many birds are restricted to certain types of habitats and their distribution patterns are thought to be strongly related to various structural and floristic aspects of the vegetation (Karr, 1971; Noon, 1981; Cody, 1985; Levey, 1988; Terborgh, 1971). Consequently, a structurally complex forest rich in plant species is likely to house a greater diversity of birds species than a nearby, structurally more simple vegetation type. Relation to habitat complexity will be discussed in more detail in another chapter 'habitat use'.

All the surveyed oak patches of Kumaon Himalaya were situated on different altitude so the bird diversity and richness would be different in these oak patches. Species diversity and community composition of birds change rapidly along elevation gradients. Early works by Orians (1969) and Terborgh (1971) on elevational distribution patterns of birds in Costa Rica and Peru, respectively, stimulated later studies on the roles of biotic (competition, resource abundance, vegetation structure) and abiotic (rainfall, temperature) factors on species distribution patterns and community structure in tropical forests (Beehler, 1981; Loiselle & Blake, 1991). Decline in bird species richness with elevation is common, but important differences exist in the patterns of change among functional groups (i.e. foraging guilds, migrant status) of birds (e.g. Stiles, 1983). Decline in species richness has been attributed to decline in forest area at higher elevation, declines in abundance and size distribution of invertebrates, competition and changes in environmental conditions (Terborgh, 1971; Beehler, 1981; Janes, 1994). Local migrations of birds along elevation gradients are also an important factor structuring bird assemblages and is a critical consideration in conservation efforts (Stiles, 1988; Loiselle & Blake, 1991; Winker *et al.* 1977).

I have conducted studies on birds along different elevations, which provided an opportunity to evaluate changes in bird diversity and turnover in species composition among elevations. This study also provided an opportunity to compare patterns of species diversity and richness by three methods. While Line transect was used only at intensive sites, Point count and 'Species richness counting method' were used in surveys. Point count technique is commonly used for surveying bird populations. The major objectives of this chapter are-

- To describe avian diversity & richness in different oak patches of Kumaon Himalaya.
- To describe the abundance pattern of birds in whole Kumaon.
- To observe the distribution pattern of birds on different elevation gradients.
- To observe the similarity in different oak patches on the basis of bird species composition.

Following is the null hypothesis-

Avian diversity and richness is same along different elevations.

4.2 METHODOLOGY

4.2.1 Data collection

I conducted avian community studies from March to June 1996 and September to December 1997 in Binsar Wildlife Sanctuary (hereafter BWS); from September to December 1996 and March to July 1997 at different oak patches in Kumaon and from February to July 1998 and September to December 1998 in Vinaiyak Reserve Forest (hereafter VRF). Line transect method (Emlen, 1971), point count method (Reynolds *et al.* 1980) and species richness counting method (Mackinnon & Phillips, 1993) were used for sampling birds in oak patches of the Kumaon Himalaya. Line transect and Species richness counting methods were followed in BWS while Point count method, Line transect method and Species richness counting method were followed in VRF. For the surveys, only Point count method and Species richness counting method were employed by establishing sampling plots in different oak patches.

Point count method was applied during surveys of Kumaon and in VRF during intensive studies in the area. During surveys, birds were sampled by monitoring 121 points. Four points were monitored per day at each site for rapid assessment of birds to enhance the number of points in a limited time period (3-4 days per site). A 20 minute field time duration was spent at each point in the morning hours between 0600-1030 hrs without fixing the radius. 50 points were established in different habitats in VRF. Visits on points were scheduled so that monitoring at each began at the same time in the evening on consecutive visits. A minimum of two counts per point were scheduled during each season (premonsoon and postmonsoon) i.e. all points counted in one counting cycle prior to beginning the second cycle. One point per day began at 1600 hrs and ended at 1730 hrs.

No counts were conducted during a steady hard rain, in thick fog or in heavy wind but drizzle or a light breeze were tolerated, as they did not have any noticeable effect on bird activity in the forest interior. To ensure that there was no overlapping between observations, at least 200m distance was left between adjacent points and transects. Whether it was line transect method or point count method, following common parameters were recorded for each encounter of the bird species: The time of initial contact, perpendicular distance, group size, species, number and activity of bird, plant species used and total height, vertical height at which bird was observed, strata of tree used (upper, middle, lower canopy, trunk, ground)

Only perpendicular distance and number of individuals were used for estimating densities in different habitats. I tallied, but did not analyse birds flying over the plots (fly-overs) that were unlikely to be using the plots or area. A total of 215 bird lists in BWS, 158 lists in different localities of Kumaon Himalaya and 308 lists in VRF were compiled by Species richness counting method. Each list consisted of only 20 or 10 consecutive different bird species seen. Starting time, ending time and length covered in preparing one bird list was also recorded. None of the bird species were repeated in the same list, but the same could appear in another lists of the same habitat at the same time. This method was applied for assessing overall diversity and richness of birds of the area.

4.2.2 Analyses

4.2.2.1 *Density and diversity*

Data collected by Species richness counting method, line transect and point count methods were analyzed separately to calculate the bird species richness and diversity. Species richness was calculated by Margelef's richness index,

RI = S-1 / ln N

where, S = Total number of species, N = Total number of individuals

Species diversity was calculated by using Shannon-Weiner index (Magurran, 1988),

H' = - Σ pi ln pi where pi = proportion of individuals found in the i^{th} species

This index assumes that individuals are randomly sampled from an 'indefinitely large' population (Pielou, 1975). This index also assumes that all species are represented in the sample.

Density of birds on Point transects was estimated by the following formula,

Density/ha = Number of birds / area of the plot x 10,000

Radius for area was considered as the mean of all perpendicular distances of all individuals sighted at each point. Standard error and confidence intervals were also calculated for the same. Point counts could not be performed at Kilbery, Gandhura, Binsar, Jilling, Wachham and Dhakuri, so the density was not estimated at these places. Whereas Species richness counting method was performed at all places, so diversity and richness was estimated for all sites.

4.2.2.2 *Abundance model*

Rank / abundance plot is the only method of presenting species abundance data (May, 1975). The log normal distribution was applied to whole Kumaon.

The distribution was written in the form:

$$S(R) = So \exp(-a^2 R^2)$$

where S (R) = the number of species in the R^{th} octave (i.e. class) to the right and left of the symmetrical curve.

So = the number of species in the modal octave

$a = (2\sigma^2)^{1/2}$ = parameter related to the variance of the distribution

The analysis was performed by LOGNORM.BAS computer program and $\log_2$ was used. Each class was double of the previous class.

The number of hypothetical species available for observation was computed by using following formula-

$$S^* = 1.77 \times (So / a)$$

4.2.2.3 *Similarity in sites on the basis of presence/absence of bird species*

Cluster analysis is a classification technique that accomplishes the sorting of objects into groups or clusters based on their overall resemblance to one another. Keeping this in mind, a matrix was prepared on the presence/absence of bird species of the surveyed oak patches of Kumaon Himalaya. A Single-linkage clustering (Nearest-neighbour) method was applied on this matrix. Jaccard's similarity measure was applied in clustering. Single-linkage clustering tends to produce straggly clusters, which quickly agglomerate very dissimilar samples (Gauch, 1989), so this method is suitable to observe similarity in sites in terms of bird species in a broader aspect.

4.2.2.4 *Spatial analysis*

To understand the relationship of bird diversity and habitat features, a spatial analysis was performed on landscape level. Bird diversity was categorized into low = 0-1, medium = 1.1-2.5 and high = >2.5. Vegetation parameters such as tree cover (low = 0-25%, medium = 25-50%, high = >50%) and tree diversity (low = 0-0.5, medium = 0.51-1.00, high = >1.00) were also categorized on ordinal scale. Vegetation parameters were assigned as base theme layer and bird diversity layer was overlaid on them. To examine the relationship between bird diversity and vegetation on spatial level, Spearman rank correlation was performed on maps.

4.3 RESULTS

4.3.1 Status and abundance

Over all 270 bird species were recorded in Kumaon Himalaya (Table 4.1). A total of 236 species, 128 species and 125 species were sampled by compiling 681 bird lists, 171 point counts and 218 monitoring of 10 transects respectively in five districts of Kumaon Himalaya (Table 4.2).

4.3.2 Species diversity and richness at different sites

Table 4.3 provides values of species diversity (BSD) and species richness (BSR) for each site by different methods. The overall BSD based on data gathered by Species

Table 4.1 List of birds recorded at various oak patches in Kumaon during surveys from 1996-1998 (Alt. = Altitude, Almr = Almora, Bagwr = Bageshwer, Pigarh = Pithoragarh, Chmpt = Champawat). Rkt= Ranikhet

Species	Alt. range (in m)	Naini Tal	Almr	Bagwr	Pigarh	Chmpt
CHUKAR *Alectoris chukar*	1800	-	-	14	-	-
BLACK FRANCOLIN *Francolinus francolinus*	1600-1800	-	Rkt	8	17	-
TIBETAN PARTRIDGE *Perdix hodgsoniae*	3500-4200	-	-	16	-	-
HILL PARTRIDGE *Arborophila torqueola*	2000-2400	4	11	8,12,15	17,20-22	-
SATYR TRAGOPAN *Tragopan satyra*	2800-3100	-	-	16	-	-
KOKLASS PHEASANT *Pucrasia macrolopha*	1800-2600	2	11	8,16	17,20	-
HIMALAYAN MONAL *Lophophorus impejanus*	2600-3200	-	-	16	22	-
KALIJ PHEASANT *Lophura leucomelanos*	1800-2500	2-6	9,11	8,12,15,16	17,18,20-22	23
CHEER PHEASANT *Catreus wallichii*	2500	2	-	15	-	-
SPECKLED PICULET *Picumnus innominatus*	2200	-	-	-	21	-
BROWN-FRONTED WOODPECKER *Dendrocopos auriceps*	1800-2200	2,5,6	11,Rkt	8,15	18,20-22	23
YELLOW-CROWNED WOODPECKER *Dendrocopos mahràttensis*	2000	-	Rkt	-	-	-
RUFOUS-BELLIED WOODPECKER *Dendrocopos hyperythrus*	2100-2700	2,3,5,6	10,11	8,13	17,18,20-22	23
HIMALAYAN WOODPECKER *Dendrocopos himalayensis*	1800-2100	3,5	9, 11	8,12,15,16	17,18,20,22	23
LESSER YELLOWNAPE *Picus chlorolophus*	1800-2200	-	10	8	-	-
GREATER YELLOWNAPE *Picus flavinucha*	1700-2400	-	9	8	17,20	-
SCALY-BELLIED WOODPECKER *Picus squamatus*	1800-2400	-	10,11,Rkt	8,15	17,20,22	-
GREY-HEADED WOODPECKER *Picus canus*	1800-2500	4-6	11,Rkt	8,12,15	17,18,20,22	23
HIMALAYAN FLAMEBACK *Dinopium shorii*	1800	2	-	-	-	-
SKYLARK *Alauda arvensis*	2100	2	-	-	-	-
GREAT BARBET *Megalaima virens*	1800-2600	2,4,6	10,11	8,15,16	17,20,21	23

BLUE-THROATED BARBET *Megalaima asiatica*	2100	-	-	-	17	-
GREAT HORNBILL *Buceros bicornis*	2200	2	-	-	-	-
COMMON HOOPOE *Upupa epops*	1800-2200	-	11	8,15	20	23
INDIAN ROLLER *Coracias benghalensis*	800	-	-		Jauljivi	
RED-HEADED TROGON *Harpactes erythrocephalus*	2200	2	-		-	
WHITE-THROATED KINGFISHER *Halcyon smyrnensis*	1000	-	Salyani		-	
PIED KINGFISHER *Ceryle rudis*	1230	Bearsinghia	-		-	
CHESTNUT-HEADED BEE-EATER *Merops leschenaulti*	2100	-	-		23	
LARGE HAWK CUCKOO *Hierococcyx sparverioides*	2000-2500	2	8,11,15,16		17,22	
INDIAN CUCKOO *Cuculus micropterus*	1900-2400	2	8,12,16		18,20	
EURASIAN CUCKOO *Cuculus canorus*	1800-2400	2	8,12,15,16		22	
ROSE-RINGED PARAKEET *Psittacula krameri*	900	-	-		Baram	
SLATY-HEADED PARAKEET *Psittacula himalayana*	1800-2400	2,3	8,11		17,18,20,21	
PLUM-HEADED PARAKEET *Psittacula cyanocephala*	1800-2200	2,4,6	8-12,15,16,Rkt		17,18,20-23	
RED-BREASTED PARAKEET *Psittacula alexandri*	2300	3				
WHITE-THROATED NEEDLETAIL *Hirundapus caudacutus*	2000-2600	-	11,15,16		18,21,23	
WHITE-RUMPED NEEDLETAIL *Zoonavena sylvatica*	1800-2400	-	8,9,10,15		20,22	
ASIAN PALM SWIFT *Cypsiurus balasiensis*	2000-2500	-	8,16		20,22	
ALPINE SWIFT *Tachymarptis melba*	1900-2600	-	8,15,16		20,21	
COMMON SWIFT *Apus apus*	1800-2400	-	8		-	
FORK-TAILED SWIFT *Apus pacificus*	1900	-	Salyani		-	
COLLARED SCOPS OWL *Otus bakkamoena*	2000	-	Salyani		-	
BROWN WOOD OWL *Strix leptogrammica*	1800-2400	-	8		17	
COLLARED OWLET *Glaucidium brodiei*	1800-2500	6	8		17,20,23	
ASIAN BARRED OWLET *Glaucidium cuculoides*	2000	-	Salyani		-	
SPOTTED OWLET *Athene brama*	900	-	-		Baram	
BROWN HAWK OWL *Ninox scutulata*	2000	-	Salyani		-	
GREY NIGHTJAR *Caprimulgus indicus*	1600-2300	2,3	8,10		18,20,21,23	
LARGE-TAILED NIGHTJAR *Caprimulgus macrurus*	1700-2200	2	8		-	
ROCK PIGEON *Columba livia*	1200	-	-		Didihat	
HILL PIGEON *Columba rupestris*	2400-2700	-	12,15,16		-	
SNOW PIGEON *Columba leuconota*	2000-2600	-	16		20,21	

ORIENTAL TURTLE DOVE *Streptopelia orientalis*	1200-2500	2-6	10,11	12,15,16	17,18,20-22	23
SPOTTED DOVE *Streptopelia chinensis*	1800-2000	-	Rkt	-	17	-
EURASIAN COLLARED DOVE *Streptopelia decaocto*	1800-2400	-	9,Rkt	8	17	-
EMERALD DOVE *Chalcophaps indica*	900	-	-	-	Baram	-
WEDGE-TAILED GREEN PIGEON *Treron sphenura*	1800-2400	-	Rkt	8	17,20,21	-
WOODCOCK *Scolopax rusticola**	3000-4000	-	-	16	-	-
COMMON SNIPE *Gallinago gallinago*	1800	-	-	8	-	-
RED-WATTLED LAPWING *Vanellus indicus*	1200	-	Baserkhet	-	-	-
BLACK KITE *Milvus migrans*	1800	-	-	8	-	-
LAMMERGEIER *Gypaetus barbatus*	1800-3000	2-4	-	8,12,15,16	17,18,20-22	-
HIMALAYAN GRIFFON *Gyps himalayensis*	1800-3000	2-4,6	10,11,Rkt	8,12,15,16	17,18,20-22	23
RED-HEADED VULTURE *Sarcogyps calvus*	2000-2200	-	-	8	17,20,21	-
CRESTED SERPENT EAGLE *Spilornis cheela*	1900-2500	2-4	9,10,Rkt	8,12,15,16	17,18,20-22	-
SHIKRA *Accipiter badius*	2200	-	-	8	-	-
EURASIAN SPARROWHAWK *Accipiter nisus*	1600-2700	-	11	8,15	17,18,20-22	-
NORTHERN GOSHAWK *Accipiter gentilis*	1700-2400	-	-	8	20,22	-
BLACK EAGLE *Ictinaetus malayensis*	1800-2500	2,3	11	8,16	17,20,21	-
GOLDEN EAGLE *Aquila chrysaetos*	2300	-	-	8	-	-
BONELLI'S EAGLE *Hieraaetus fasciatus*	2000-2300	-	-	8	20	-
CHANGEABLE HAWK EAGLE *Spizaetus cirrhatus*	1700-1800	-	-	8	20,21	-
MOUNTAIN HAWK EAGLE *Spizaetus nipalensis*	2200-2400	-	-	8	17	-
COMMON KESTREL *Falco tinnunculus*	1800-2400	2	9-11	8,15	17,18,20-22	-
EURASIAN HOBBY *Falco subbuteo*	1800	-	Rkt	-	-	-
HODGSON'S HAWK EAGLE *Spizaetus nipalensis*	2200	2	-	-	-	-
ROUGHLEGGED BUZZARD *Buteo lagopus*	3500	-	-	15	-	-
BLACK STORK *Ciconia nigra*	1200	-	Baserkhet	-	-	-
LONG-TAILED BROADBILL *Psarisomus dalhousiae*	2400	2	-	-	-	-
ORANGE-BELLIED LEAFBIRD *Chloropsis hardwickii*	2300	-	-	-	18	-
GREY-BACKED SHRIKE *Lanius tephronotus*	2100-2200	-	-	8,12,15	17,20,21	-
EURASIAN JAY *Garrulus glandarius*	1800-2500	2-6	9-11,Rkt	8,12,15,16	17,18,20-22	23
BLACK-HEADED JAY *Garrulus lanceolatus*	1800-2400	2-6	9-11,Rkt	8,12,15,16	17,18,20-22	-
YELLOW-BILLED BLUE MAGPIE *Urocissa flavirostris*	2100-2600	-	9,10	12,15,16	17,18,20-22	-

RED-BILLEDBLUE MAGPIE *Urocissa erythrorhyncha*	1800-2200	2,6	10,11,Rkt	8,15	17,20,21	-
GREY TREEPIE *Dendrocitta formosae*	1800-2300	2,4	9-11	8,15	17,20	-
INDIAN TREEPIE *Dendrocitta vagabunda*	2100	-	-	16	-	-
SPOTTED NUTCRACKER *Nucifraga caryocatactes*	2800	2	-	16	-	-
RED-BILLED CHOUGH *Pyrrhocorax pyrrhocorax*	3600	-	-	16	-	-
YELLOW-BILLED CHOUGH *Pyrrhocorax graculus*	2600	-	-	15	-	-
HOUSE CROW *Corvus splendens*	1700-2000	2-6	9-11	8,16	17,18,22	23
LARGE-BILLED CROW *Corvus macrorhynchos*	1800-2800	2-6	9-11,Rkt	8,12,15,16	17,18,20-22	23
BLACK-NAPED ORIOLE *Oriolus chinensis*	2200	-	-	8	-	-
MAROON ORIOLE *Oriolus traillii*	1800-2400	-	9	8,15	17,18,20-22	23
BLACK-WINGED CUCKOOSHRIKE *Coracina melaschistos*	2100-2400	-	-	8,15,16	17,20-22	23
LARGE CUCKOO SHRIKE *Coracina novaehollandiae*	2200	2	-	-	-	-
LONG-TAILED MINIVET *Pericrocotus ethologus*	1800-2300	2-5	10,11	8,12,15,16	17,18,20,22	-
SHORT-BILLED MINIVET *Pericrocotus brevirostris*	2100	2	-	-	-	-
SCARLET MINIVET *Pericrocotus flammeus*	1800-2100	-	10,11,Rkt	8,12	17,18,20,21	-
BAR-WINGED FLYCATCHER-SHRIKE *Hemipus picatus*	2100	-	Rkt	8	-	-
YELLOW-BELLIED FANTAIL *Rhipidura hypoxantha*	2100-2500	-	10,11	15,16	17,20,21	-
WHITE-THROATED FANTAIL *Rhipidura albicollis*	1800-2400	3,6	Rkt	8	18,20,22	-
WHITE-BROWED FANTAIL *Rhipidura aureola*	2200	2	-	-	-	-
ASHY DRONGO *Dicrurus leucophaeus*	1700-2600	2	10,11	8,12,15,16	17,20,21	-
BRONZED DRONGO *Dicrurus aeneus*	1700	-	-	8	17	-
LESSER RACKET-TAILED DRONGO *Dicrurus remifer*	1800	5	-	-	-	-
SPANGLED DRONGO *Dicrurus hottentottus*	1800-2100	-	10,Rkt	8	20,21	-
BROWN DIPPER *Cinclus pallasii*	2100-2500	-	-	15,16	20	-
BLUE-CAPPED ROCK THRUSH *Monticola cinclorhynchus*	1800-2400	2	-	8,16	20	-
CHESTNUT-BELLIED ROCK THRUSH *Monticola rufiventris*	2100-2500	3	9,11	8,12,15	17,20-22	-
BLUE WHISTLING THRUSH *Myophonus caeruleus*	1800-2700	3-6	9-11,Rkt	8,12,15,16	17,18,20-22	-
PIED THRUSH *Zoothera wardii*	2200	2	-	-	-	-
ORANGE-HEADED THRUSH *Zoothera citrina*	2100	2	-	-	-	-
LONG-TAILED THRUSH *Zoothera dixoni*	2100-2300	-	-	8	-	-
SCALY THRUSH *Zoothera dauma*	2100-2400	-	-	8,15,16	17,18,20,21	-
PLAINBACKED MOUNTAIN THRUSH *Zoothera mollissima*	2300	2	-	16	-	-

LONG-BILLED THRUSH *Zoothera monticola*	2200	2	-	-	-	-
TICKELL'S THRUSH *Turdus unicolor*	2200-2400	2,6	10,11	8,15,16	20,21	-
WHITE-COLLARED BLACKBIRD *Turdus albocinctus*	2300-2800	3	-	15,16	22	-
GREY-WINGED BLACKBIRD *Turdus boulboul*	2100-2600	2,4-6	10,11,Rkt	8,15,16	17,20-22	-
CHESTNUT THRUSH *Turdus rubrocanus*	2100	2	-	-	-	-
DARK-THROATED THRUSH *Turdus ruficollis*	1800-2200	4,6	10,11,Rkt	8,16	20,21	23
MISTLE THRUSH *Turdus viscivorus*	1900-2400	3,4,6	9,Rkt	8,12,15,16	17,18,20-22	-
DARK-SIDED FLYCATCHER *Muscicapa sibirica*	1800-2300	-	9,Rkt	8,12,15,16	17,18,22	-
RUSTY-TAILED FLYCATCHER *Muscicapa ruficauda*	2500	-	-	14	-	-
SLATY-BACKED FLYCATCHER *Ficedula hodgsonii*	2200	2	-	-	-	-
RUFOUS-GORGETED FLYCATCHER *Ficedula strophiata*	1800-2100	4	Rkt	8,15,16	17,20,22	-
SNOWY-BROWED FLYCATCHER *Ficedula hyperythra*	900	-	-	-	Baram	-
LITTLE PIED FLYCATCHER *Ficedula westermanni*	1800-2000	-	Rkt	8	17,20	-
ULTRAMARINE FLYCATCHER *Ficedula superciliaris*	1800-2600	-	10,11,Rkt	8,12,15,16	17,20-22	-
SLATY BLUE FLYCATCHER *Muscicapa leucomelanura*	2500	-	-	16	-	-
VERDITER FLYCATCHER *Eumyias thalassina*	1800-2500	4-6	10,11,Rkt	8,12,15,16	17,18,20,21	23
SMALL NILTAVA *Niltava macgrigoriae*	2100-2300	4	-	8	17	-
RUFOUS-BELLIED NILTAVA *Niltava sundara*	1800-2400	3,4	9-11	8,12,15,16	17,18,20-22	23
GREY-HEADED CANARY FLYCATCHER *Culicicapa ceylonensis*	1700-2400	2,4-6	9-11,Rkt	8,12,15,16	17,18,20-22	23
INDIAN BLUE ROBIN *Luscinia brunnea*	2100-2300	-	-	-	21	23
ORANGE-FLANKED BUSH ROBIN *Tarsiger cyanurus*	2000-2400	2-5	9-11	8,12,16	17,20	-
GOLDEN BUSH ROBIN *Tarsiger chrysaeus*	2300	2	-	-	-	-
WHITE-BROWED BUSH ROBIN *Tarsiger indicus*	1800-2200	-	-	8,15	17,20-22	-
ORIENTAL MAGPIE ROBIN *Copsychus saularis*	900	-	-	-	Baram	-
BLUE-CAPPED REDSTART *Phoenicurus coeruleocephalus*	1800-2300	-	-	8,16	17,18,20	-
BLUE-FRONTED REDSTART *Phoenicurus frontalis*	1800-2200	3,5	9,10,Rkt	8,16	17,20	-
WHITE-CAPPED WATER REDSTART *Chaimarrornis leucocephalus*	1800-2500	-	11	8,15,16	17,20,21	-
PLUMBEOUS WATER REDSTART *Rhyacornis fuliginosus*	2100-2600	-	-	15,16	20	-
LITTLE FORKTAIL *Enicurus scouleri*	2100-2600	-	-	16	20	-
SLATY-BACKED FORKTAIL *Enicurus schistaceus*	2200	2	-	-	-	-
SPOTTED FORKTAIL *Enicurus maculatus*	1800-2300	4	10,Rkt	8,15	17,20,21	-
COMMON STONECHAT *Saxicola torquata*	900	-	-	Bageshwer	-	-

PIED BUSHCHAT *Saxicola caprata*	1800-2200	-	-	8,15	20	-
GREY BUSHCHAT *Saxicola ferrea*	1800-2400	4,6	9-11,Rkt	8,15	17,20-22	23
BLUE CHAT *Erithacus brunneus*	2200	2	-	-	-	-
DESERT WHEATEAR *Oenanthe deserti*	2100	-	-	8	-	-
COMMON MYNA *Acridotheres tristis*	1800-2200	2,4,6	10,11,Rkt	8,15,16	17,18,20,21	-
JUNGLE MYNA *Acridotheres fuscus*	1800-2300	-	-	8	-	23
CHESTNUT-BELLIED NUTHATCH *Sitta castanea*	1800-2000	-	-	8,15	-	-
WHITE-TAILED NUTHATCH *Sitta himalayensis*	2100-2600	2-6	9,11	8,12,15	17,18,20-22	23
EUROPEAN NUTHATCH *Sitta europaea*	2200-2400	2	-	-	-	-
WHITE-CHEEKED NUTHATCH *Sitta leucopsis*	2300-2400	2	-	15,16	-	-
VELVET-FRONTED NUTHATCH *Sitta frontalis*	2200	2	-	-	-	-
WALLCREEPER *Tichodroma muraria*	2600	-	10	-	20	-
EURASIAN TREECREEPER *Certhia familiaris*	1800-2400	3,6	-	8	17,20,22	-
BAR-TAILED TREECREEPER *Certhia himalayana*	1800-2600	2-6	9-11	8,12,15,16	17,18,20-22	23
WINTER WREN *Troglodytes troglodytes*	2100-2400	3	-	15,16	20	-
FIRE-CAPPED TIT *Cephalopyrus flammiceps*	2100-2500	-	-	8,16	17	-
RUFOUS-NAPED TIT *Parus rufonuchalis*	2200-2700	-	-	8,16	17,20	-
RUFOUS-VENTED TIT *Parus rubidiventris*	2100-2400	-	-	15,16	17,20,21	-
SPOT-WINGED TIT *Parus melanolophus*	2100-2700	2-4,6	9-11,Rkt	8,12,15,16	17,18,20-22	-
COAL TIT *Parus ater*	2200-2600	2	-	15	17,20	-
GREY-CRESTED TIT *Parus dichrous*	2200-2600	-	-	15	20,22	-
GREAT TIT *Parus major*	1800-2000	-	Rkt	8	17,20,21	-
GREEN-BACKED TIT *Parus monticolus*	1800-2500	2-6	9-11,Rkt	8,12,15,16	17,18,20-22	23
BLACK-LORED TIT *Parus xanthogenys*	1800-2600	2,3,5,6	9,10,Rkt	8,15,16	17,18,20	23
YELLOW-BROWED TIT *Sylviparus modestus*	2200	2	-	-	-	-
BLACK-THROATED TIT *Aegithalos concinnus*	1800-2500	2-6	9-11,Rkt	8,12,15,16	17,18,20-22	23
WHITE-THROATED TIT *Aegithalos niveogularis*	2000-2600	2,4,5	10,11	8	17,18,20,21	23
BARN SWALLOW *Hirundo rustica*	1800-2400	2-5	9,10	8,15	18,21	-
WIRE-TAILED SWALLOW *Hirundo smithii*	1000	-	-	-	Baram	-
NEPAL HOUSE MARTIN *Delichon nipalensis*	2100	-	-	8	-	-
GOLDCREST *Regulus regulus*	2300	3	-	-	-	-
BLACKHEADED YELLOW BULBUL *Pycnonotus melanicterus*	2300	2	-	-	-	-

HIMALAYAN BULBUL *Pycnonotus leucogenys*	1800-2600	-	9-11,Rkt	8,12,15,16	17,18,20-22	23
RED-VENTED BULBUL *Pycnonotus cafer*	1800-2000	-	-	8,15	17,20	-
ASHY BULBUL *Hemixos flavala*	2300	-	-	15	-	-
MOUNTAIN BULBUL *Hypsipetes mcclellandii*	2000	7	-	-	-	-
BLACK BULBUL *Hypsipetes leucocephalus*	1800-2500	2-6	9-11,Rkt	8,12,15,16	17,18,20,21	23
STRIATED PRINIA *Prinia criniger*	1800-2100	-	-	8	22	-
ASHY PRINIA *Prinia socialis*	1000	-	-	-	Baram	-
ORIENTAL WHITE-EYE *Zosterops palpebrosus*	1800-2200	2,4-6	10,11,Rkt	8,12	17,20,21	-
CHESTNUT-HEADED TESIA *Tesia castaneocoronata*	2300	-	-	-	20	-
CHESTNUT-CROWNED BUSH WARBLER *Cettia major*	2100-2300	-	-	8	20	-
ABERRANT BUSH WARBLER *Cettia flavolivacea*	1800-2200	2	Rkt	8	20	-
GREY-SIDED BUSH WARBLER *Cettia brunnifrons*	2200	2	-	-	-	-
LARGEBILLED BUSH WARBLER *Bradypterus major*	2800	-	-	16	-	-
MOUSTACHED SEDGE WARBLER *Acrocephalus melanopogon*	2300	2	-	-	-	-
SPOTTED BUSH WARBLER *Bradypterus thoracicus*	2100-2300	-	-	8,15	-	-
PLAIN LEAF WARBLER *Phylloscopus neglectus*	1700-2000	2	-	8	-	-
TICKELL'S LEAF WARBLER *Phylloscopus affinis*	2100-2600	-	11,Rkt	8,15,16	17,20,22	-
BUFF-BARRED WARBLER *Phylloscopus pulcher*	2000-2200	-	-	8	17,20	-
ASHY-THROATED WARBLER *Phylloscopus maculipennis*	1800-2200	5	Rkt	8,15	20,22	-
HUME'S WARBLER *Phylloscopus humei*	1800-2600	2-6	9-11,Rkt	8,12,15,16	17,20-22	23
LARGE-BILLED LEAF WARBLER *Phylloscopus magnirostris*	2100-2400	3	-	8,12	17,20	-
GREENISH WARBLER *Phylloscopus trochiloides*	2100-2300	-	11	8	17,20-22	-
WESTERN CROWNED WARBLER *Phylloscopus occipitalis*	2000-2600	4	10,Rkt	8,16	20-22	-
BLYTH'S LEAF WARBLER *Phylloscopus reguloides*	1800-2400	-	11	8,12,15	17,20,21	-
YELLOWBROWED LEAF WARBLER *Phylloscopus inornatus*	2300-2500	2	-	16	-	-
BLACKBROWED LEAF WARBLER *Phylloscopus cantator*	2500	-	-	16	-	-
GOLDEN-SPECTACLED WARBLER *Seicercus burkii*	1900-2400	-	12,Rkt	8,15,16	17,21,22	-
GREY-HOODED WARBLER *Seicercus xanthoschistos*	1800-2600	2-6	9-11,Rkt	8,12,15,16	17,20,22	23
GREY CHEEKED WARBLER *Seicercus poliogenys*	2200	2	-	-	-	-
BLACK-FACED WARBLER *Abroscopus schisticeps*	1900-2500	-	-	15,16	20,21	-
WHITE-THROATED LAUGHINGTHRUSH *Garrulax albogularis*	1800-2600	2-6	9-11,Rkt	8,12,15,16	17,18,20-22	-
STRIATED LAUGHINGTHRUSH *Garrulax striatus*	1800-2700	2,4-6	11	8,12,15,16	21,22	-

WHITE-CRESTED LAUGHINGTHRUSH *Garrulax leucolophus*	2000	7	-	-	-	-
STREAKED LAUGHINGTHRUSH *Garrulax lineatus*	1800-2500	2-4,6	9-11,Rkt	8,12,15,16	17,18,20-22	23
VARIEGATED LAUGHINGTHRUSH *Garrulax variegatus*	2200-2700	2,3	-	8,15	22	-
CHESTNUT-CROWNED LAUGHINGTHRUSH *Garrulax erythrocephalus*	2300-2600	6	10	8,12,15	17,20	-
RUSTY-CHEEKED SCIMITAR BABBLER *Pomatorhinus erythrogenys*	1800-2500	6	9	8	17	-
STREAK-BREASTED SCIMITAR BABBLER *Pomatorhinus ruficollis*	1800-2400	-	-	8	20,22	-
SCALY-BREASTED WREN BABBLER *Pnoepyga albiventer*	1900-2400	-	-	8,15	-	-
SILVER-EARED MESIA *Leiothrix argentauris*	2200	-	-	8	-	-
CUTIA *Cutia nipalensis*	2100-2400	-	-	8	17,20	-
WHITE-BROWED SHRIKE BABBLER *Pteruthius flaviscapis*	2000-2300	2,5	10	8	17,18,20,21	-
BLUE-WINGED MINLA *Minla cyanouroptera*	2100-2300	4,6	-	-	-	23
CHESTNUT-TAILED MINLA *Minla strigula*	2100-2500	2,4	-	8,12,15,16	17,20-22	-
WHITE-BROWED FULVETTA *Alcippe vinipectus*	2000-2500	-	-	15,16	17,20,21	-
RUFOUS SIBIA *Heterophasia capistrata*	1800-2600	2-5	9-11,Rkt	8,12,15,16	17,18,20-22	23
WHISKERED YUHINA *Yuhina flavicollis*	1900-2700	2,4,5	11	8,15,16	17,18,20,21	23
STRIPE-THROATED YUHINA *Yuhina gularis*	2100-2600	-	-	16	17,22	-
BLACK-THROATED PARROTBILL *Paradoxornis nipalensis*	2300	-	-	-	20,21	-
LESSER WHITETHROAT *Sylvia curruca*	2100	-	-	8	-	-
YELLOW-BELLIED FLOWERPECKER *Dicaeum melanoxanthum*	2200	-	-	14	-	-
FIRE-BREASTED FLOWERPECKER *Dicaeum ignipectus*	2100-2500	-	-	8,15	18,21	-
PURPLE SUNBIRD *Nectarinia asiatica*	900	-	-	-	Baram	-
MRS GOULD'S SUNBIRD *Aethopyga gouldiae*	2100-2600	-	11	-	18,20	23
GREEN-TAILED SUNBIRD *Aethopyga nipalensis*	2000-2500	2,3,6	9,11,Rkt	8,12,15,16	17,20-22	-
BLACK-THROATED SUNBIRD *Aethopyga saturata*	2100-2200	4,6	9,10	8,15,16	17,20-22	-
CRIMSON SUNBIRD *Aethopyga siparaja*	900	-	-	-	Baram	-
FIRE-TAILED SUNBIRD *Aethopyga ignicauda*	1800-2300	-	-	11,15	-	-
HOUSE SPARROW *Passer domesticus*	1800-2000	-	10,11	8	17,20	-
RUSSET SPARROW *Passer rutilans*	2100	-	-	8	-	-
EURASIAN TREE SPARROW *Passer montanus*	1900-2200	3	10,11,Rkt	8,15	17,18,20-22	23
WHITE WAGTAIL *Motacilla alba*	2300	-	-	14	-	-
GREY WAGTAIL *Motacilla cinerea*	1800-2200	-	Rkt	8,12,15	17,20	23
PADDYFIELD PIPIT *Anthus rufulus*	2200	2	-	-	-	-

TAWNY PIPIT *Anthus campestris*	2400	2	-	16	-	-
TREE PIPIT *Anthus trivialis*	2500	-	-	16	-	-
OLIVE-BACKED PIPIT *Anthus hodgsoni*	1800-2300	-	11,Rkt	8,15,16	21	-
UPLAND PIPIT *Anthus sylvanus*	2200	2	-	-	-	-
ALPINE ACCENTOR *Prunella collaris*	2600	-	-	16	-	-
RUFOUS-BREASTED ACCENTOR *Prunella rubeculoides*	1800-2400	-	-	16	-	-
SCALY-BREASTED MUNIA *Lonchura punctulata*	2100	2	-	8	-	-
FIRE-FRONTED SERIN *Serinus pusillus*	2500	-	-	16	-	-
YELLOW-BREASTED GREENFINCH *Carduelis spinoides*	2100-2500	3	9-11	8,12,15	17,20	-
EUROPEAN GOLDFINCH *Carduelis carduelis*	2500	-	-	16	-	-
PLAIN MOUNTAIN FINCH *Leucosticte nemoricola*	2300	2	-	-	-	-
SPECTACLED FINCH *Callacanthis burtoni*	2500	-	-	15	-	-
DARK-BREASTED ROSEFINCH *Carpodacus nipalensis*	2000-2500	5	-	-	17	-
COMMON ROSEFINCH *Carpodacus erythrinus*	1800-2400	-	9-11,Rkt	8	17,20	-
PINK-BROWED ROSEFINCH *Carpodacus rodochrous*	2100-2400	5	11	8	-	-
VINACEOUS ROSEFINCH *Carpodacus vinaceus*	2100-2300	2	11	8,15,16	20,22	-
SPOT-WINGED ROSEFINCH *Carpodacus rodopeplus*	2300-2500	-	-	15,16	-	-
BROWN BULLFINCH *Pyrrhula nipalensis*	2200-2500	-	-	15,16	20	-
REDHEADED BULLFINCH *Pyrrhula erythrocephala*	2800-3000	-	-	16	-	-
BLACK-AND-YELLOW GROSBEAK *Mycerobas icterioides*	2100-2700	2	-	-	17,22	-
COLLARED GROSBEAK *Mycerobas affinis*	2500	2	-	-	-	-
SPOT-WINGED GROSBEAK *Mycerobas melanozanthos*	2400	-	-	16	-	-
CRESTED BUNTING *Melophus lathami*	1700-1900	-	-	8	20,21	-
ROCK BUNTING *Emberiza cia*	1800-2300	3	-	8,12,15	20	-
CHESTNUT-EARED BUNTING *Emberiza fucata*	2000-2400	-	-	8,15,16	17,20-22	-

See Table 2.2 and Figure 2.1 for the names and locations of the localities richness counting method were highest for Pithoragarh district while BSR was highest for Almora compared to Naini Tal, Bageshwer, Pithoragarh and Champawat districts. The values of BSD and BSR were also highest for different sites in Almora districts. In Naini Tal district, the maximum BSD was recorded at Kunjakharak (3.2) and Gager (3.2) while minimum was for Kilbery (2.5) by Species richness counting method whereas by Point count method, the maximum BSD was recorded at Kunjakharak (2.8) and Maheshkhan (2.8) while minimum BSD and BSR was recorded for Vinaiyak (1.4 & 1.7 respectively).

In Bageshwer district the maximum BSD and BSR were found in Sunderdunga (4.2 & 16.1 respectively) while minimum at Dhakuri (1.7 & 2.59) by Species richness counting method. By point count method, the maximum BSD and BSR occurred at Pindari (3.2 & 3.1 respectively) while was minimum encountered at Sunderdunga (1.8 & 2.3 respectively). The point to be noted here is that by Species richness counting method, BSD and BSR was maximum at Sunderdunga; while by point count method, it was minimum.

In Almora district, the maximum BSD and BSR was found at Jageshwer (3.6, 10.9) and minimum at Pandavkholi (3.3, 8.2) by Species richness counting method while by point count the same pattern was observed. In Pithoragarh district, the maximum BSD was found at Daphiadhura (3.8) and maximum BSR occurred at Duku (11.2) while minimum BSD and BSR was at Gandhura (2.8 & 4.8 respectively) by Species richness counting method. The maximum BSD and BSR was found at Majtham (3.2 & 6.4) and minimum at Duku (2.2 & 3.9) by Point count method.

Table 4.2 The number of species recorded at different sites of the Kumaon Himalaya by different sampling methods. SRCM = species richness counting method, PC = point count method, LT = line transect, N = number of bird lists, points or transects, NS = number of species.

Sites	SRCM		PC		LT	
	N	NS	N	NS	N	NS
Naini Tal						
Gager	3	39	4	13		
Jilling	4	51	-	-		
Kilbery	6	67	-	-		
Kunjakharak	4	39	8	22		
Maheshkhan	5	49	8	29		
Mukteshwer	4	42	8	21		
Vinaiyak*	308	180	50	89	4	91
Bageshwer						
Binsar WS*	215	163	-	-	6	99
Dhakuri	10	45	-	-		
Gasi	6	53	8	22		
Pindari	8	73	12	22		
Sunderdunga	18	108	4	7		
Wachham	4	58	-	-		
Almora						
Jageshwer	11	70	9	34		
Pandavkholi	3	44	4	15		
Sitlakhet	5	57	4	21		
Pithoragarh						
Daphiadhura	34	111	8	28		

Duku	9	86	6	16
Gandhura	6	68	-	-
Majtham	4	49	9	29
Munsiary	5	58	4	14
Sobala	31	117	12	20
Champawat				
Mechh	3	41	4	9

* = Intensive study sites

Table 4.3 Bird species diversity (BSD) and Bird species richness (BSR) by different sampling methods at different sites in the Kumaon Himalaya. SRCM = species richness counting method, PC = point count method, LT = line transect.

Site	SRCM		PC		LT	
	BSD	BSR	BSD	BSR	BSD	BSR
Naini Tal						
Gager	3.2	7.5	2.2	3.1	-	-
Jilling	2.69	4.80	-	-	-	-
Kilbery	2.57	4.77	-	-	-	-
Kunjakharak	3.2	6.8	2.8	5.1	-	-
Maheshkhan	3.1	8.4	2.8	5.8	-	-
Mukteshwer	3.1	7.3	2.4	4.3	-	-
Vinaiyak	2.7	4.5	1.4	1.7	2.3	3.0
Mean	3.1	6.9	2.3	4.0	2.3	3.0
Bageshwer						
Binsar WS	2.4	4.2	-	-	1.8	2.4
Dhakuri	1.77	2.59	-	-	-	-
Gasi	3.4	9.1	2.7	4.5	-	-
Pindari	3.9	12.2	3.2	5.1	-	-
Sunderdunga	4.2	16.1	1.8	2.3	-	-
Wachham	2.77	5.0	-	-	-	-
Mean	3.07	8.19	2.56	3.96	1.8	2.4
Almora						
Jageshwer	3.6	10.9	3.1	6.7	-	-
Pandavkholi	3.3	8.2	2.0	3.5	-	-
Sitlakhet	3.6	10.0	2.9	4.9	-	-
Mean	3.5	9.7	2.66	5.03	-	-

Pithoragarh						
Daphiadhura	3.8	10.8	2.9	6.1	-	-
Duku	3.7	11.2	2.2	3.9	-	-
Gandhura	2.79	4.8	-	-	-	-
Majtham	3.5	8.7	3.2	6.4	-	-
Munsiary	3.7	10.7	2.5	4.2	-	-
Sobala	3.7	10.4	3.0	5.1	-	-
Mean	3.54	9.51	2.73	5.08	-	-
Champawat						
Mechh	3.3	8.2	2.1	3.0	-	-
Over all mean	3.4	9.0	2.5	4.4	2.1	2.7

4.3.3 Bird densities at various sites

Bird density was calculated for all 18 oak-patches (Table 4.4). Density estimates are based exclusively on visual encounters and flying birds were not used in the analysis to minimize the possibilities of double counting of highly mobile species (Jones *et al.* 1995).

Densities / ha of avian community were found to vary greatly between sites, despite the presence of similar habitats and altitudinal ranges. Highest bird density was calculated from Maheshkhan (81.53 ± 17.44) and minimum from Sobala (17.83 ± 3.23) and Mechh (17.83 ± 4.27). Naini Tal district had maximum bird density. In Almora district, the density was highest in Jageshwer (77.0 ± 13.41) and minimum at Pandavkholi (67.52 ± 29.15). In Bageshwer district the density was highest in Gasi (66.88 ± 11.37) and minimum at Sunderdunga (17.83 ± 2.54). While in Pithoragarh district, the density was highest at Daphiadhura (54.14 ± 6.88) and minimum at Sobala (17.83 ± 3.83).

4.3.4 Distribution- Abundance model for Whole Kumaon

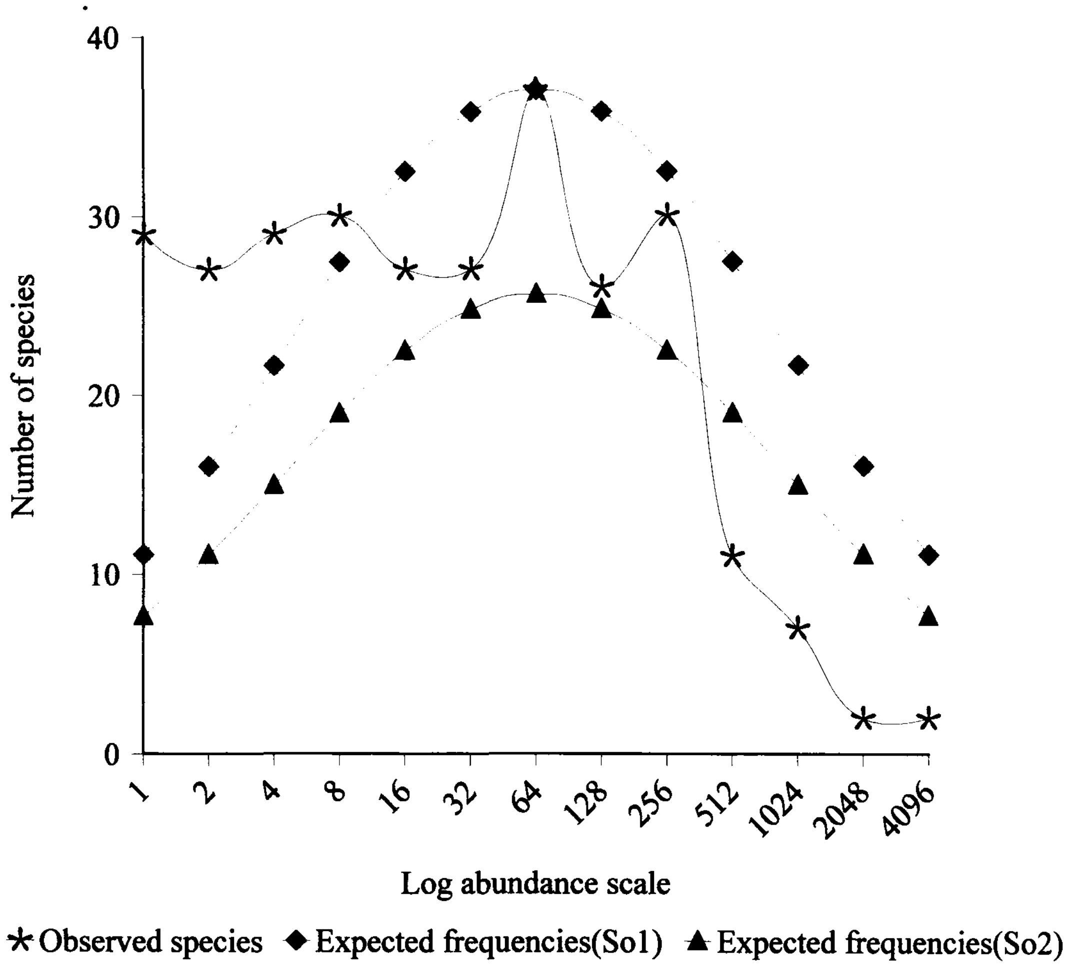
The abundance model was fitted for whole Kumaon. A total of 13 octaves were formed and the modal octave had 37 species (maximum number of species) in first octave. The parameters 'a' and 'So' were calculated from the LOGNORM.BAS program, where a = 0.183 & So = 37 & 25.6. It gave total expected number of species 247.60 against the observed value 284. It shows that the area was well sampled in terms of birds. Figure 4.1 shows the So = 25.6, a good fit to these data, which gave the theoretical number of species available for observation S* = 247.60. The log normal distribution

Table 4.4 Overall bird densities at different sites of Kumaon Himalaya.

Site name	Density/ha	Standard error	Confidence interval (95% significance)
Naini Tal			
Gager	63.69	20.0	±39.21
Kunjakharak	47.13	6.07	±11.90
Maheshkhan	81.53	17.44	±34.18
Mukteshwer	68.79	15.37	±30.14
Vinaiyak	33.76	6.38	±12.51
Total	58.98	8.37	±16.41
Bageshwer			
Gasi	66.88	11.37	±22.29
Pindari	26.75	3.55	±6.96
Sunderdunga	17.83	2.54	±4.98
Total	37.15	26.13	±29.56
Almora			
Jageshwer	77.00	13.41	±26.29
Pandavkholi	67.52	29.15	±57.13
Sitlakhet	72.61	10.88	±21.33
Total	72.37	4.74	±5.36
Pithoragarh			
Daphiadhura	54.14	6.88	±13.47
Duku	40.76	18.60	±36.47
Majtham	45.29	7.13	±13.97
Munsiary	29.30	9.15	±17.94

Sobala	17.83	3.23	±6.32
Total	37.46	14.16	±12.41
Champawat			
Mechh	17.83	4.87	±9.55
Overall	48.74	5.35	±10.50

Fig. 4.1 Abundance-distribution pattern in whole Kumaun and fitted log normal curves with a = 0.183.



showed the perfect normal bell shaped curve. The expected frequencies were 325.7 and 225.34 at So = 37 and 25.6 respectively.

4.3.5 Altitudinal distribution of birds

To observe the distribution pattern at different elevations, the altitude range was divided into six different ranges i.e. 1800m–2200m, 2201-2600, 2601-3000, 3001-3400, 3401-3800 and 3800- 4200m. The minimum altitude recorded was 1840m and maximum was 3950m at the time of bird sampling. The low elevation site was the most species rich zone with a total of 119 species. The zones 2201- 2600 and 2601-3000m were having more or less same species i.e. 91 and 94 respectively. The highest elevation i.e. 3401-3800m and 3801- 4200m were having fewer species.

I used only bird species that occurred in mature forests for comparison of bird species diversity and composition among elevations because these birds are of particular conservation concern. Birds of only summer season were analyzed due to the low probability of recording latitudinal migrant species as well as raptors and night birds.

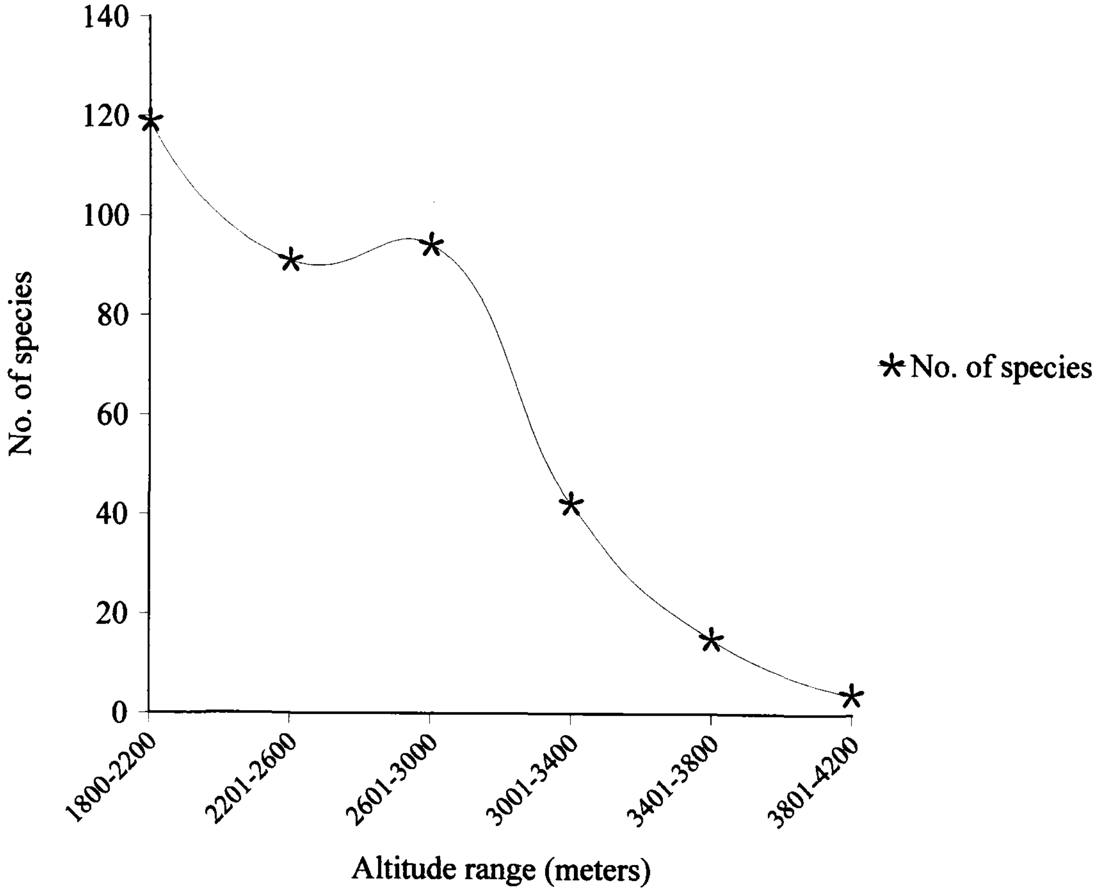
One-way ANOVA showed significant difference in the number of individuals found at different elevations ($F = 3.465$, d.f. = 5, 359, $p < 0.005$) and Tukey's multiple comparison test further clarified that the exact difference occurred between the elevation ranges 1800m–2200m and 3001-3400m (Table 4.5).

χ^2 test also showed significant difference in the number of species recorded at different elevations ($\chi^2 = 182.2$, d.f. = 5, $p < 0.000$). I recorded significantly more total individuals and species during Point counts and Species richness counting method at low elevations than at higher elevations (Fig. 4.2). Bird species diversity and richness also

Table 4.5 Mean ± 95% C.I. of individuals, bird species diversity (BSD) and bird species richness (BSR) recorded at different altitude in Kumaon Himalaya.

Altitude range	Mean	95% C.I.	BSD	BSR
1800m – 2200m	15.14	4.18	3.96	15.74
2201m – 2600m	13.79	5.84	3.47	12.59
2601m – 3000m	11.28	3.53	3.81	13.34
3001m – 3400m	5.11	2.40	3.05	7.63
3401m – 3800m	15.93	18.36	1.54	2.55
3801m – 4200m	1.25	0.48	1.33	1.86

Fig 4.2 The curve showing the trend of occurence of species at different altitude in Kumaon Himalaya.



differed significantly at different altitudes ($t = 6.09$, d.f. = 5, $p < 0.002$ and $t = 3.74$, d.f. = 5, $p < 0.013$).

All these results suggested rejecting the null hypothesis that avian species diversity and richness was same along different elevations.

4.3.6 Similarity in sites

Bird species composition (presence / absence) of 23 surveyed sites was subjected to cluster analysis (Fig. 4.3), which classified 23 sites in four clusters. The first, second, third and fourth clusters comprised of Binsar Wildlife Sanctuary to Pindari, Kunjakharak to Sitlakhet, Wachham to Munsiyari and Majtham to Mechh respectively. Binsar Wildlife Sanctuary, Vinaiyak and Sunderdunga were having common species such as Scaly thrush, Red-headed vulture, Maroon oriole etc. Kunjakharak, Pandavkholi, Gasi, Maheshkhan, Mukteshwer, Gagar, Duku etc. formed separate cluster by having a different set of combination of species such as Black bulbul, Blue-whistling thrush, Bar-tailed tree creeper, Jungle crow, White-throated laughing thrush.

Wachham, Munsiyari, Sobala and Daphiadhura were having Himalayan bulbul, White-tailed nuthatch, Yellow-billed blue magpie and Ultramarine flycatcher. Whereas another group of cluster, Majtham, Mechh and Dhakuri had 11 common species combination such as Himalayan griffon, Whiskered yuhina, Streaked laughing thrush etc. Species combination does not mean here that these species did not occur anywhere else; however the presence of distinct common species in the combination led to form the clusters.

Rescaled Distance Cluster Combine

```
                    0         5        10        15        20        25
SITES         Num   +---------+---------+---------+---------+---------+
BINSAR          1   -+-------------------------+
VINAIYAK       14   -+                         +-----------+
SUNDERDUNGA     9   ---------------------------+           +-+
PINDARI        10   ---------------------------------------+ I
KUNJAKHARAK     2   ---------------------------------+---+   I
PANDAVKHOLI    17   ---------------------------------+   I   I
GASI           12   ---------------------------+---+     I   +---+
MAHESHKHAN     16   ---------------------------+   +-+   +---+   I
MUKTESHWER     13   -------------------------------+ +---+   I   I
GAGAR          15   ---------------------------------+   I   I   I
DUKU            3   -----------------------------+-----+ I   I   I
JAGESHWER      11   -----------------------------+     I I   I   I
JILLING        19   -----------------------------+---+ +-+   I   I
GANDHURA       20   -----------------------------+   +-+     I   I
KILBERY        21   ---------------------------------+ I     I   I
SITLAKHET      18   -----------------------------------+     I   +-+
WACCHAM        22   -----------------------------------------+   I I
SOBALA          4   ---------------------------------------+-----+ +-+
DAPHIADHURA     6   ---------------------------------------+     I I I
MUNSIARI        5   ---------------------------------------------+ I I
MAJTHAM         8   -----------------------------------------------+ I
DHAKURI        23   -------------------------------------------------+
MECHH           7   -------------------------------------------------+
```

Fig.4.3 Dendrogram of different sites using Single Linkage Cluster analysis.

4.3.7 Spatial relationship

Overlaying bird diversity layer on different habitat attribute theme layers showed distinct results. Spearman rank correlation did not show any significant relationship in bird diversity layer and any vegetation and threat layer. But map indicated that after categorization of tree cover and tree diversity, none of the patches showed low category. Maheshkhan, Binsar, Gasi, Sobala and Daphiadhura were the patches where tree cover was high as well as bird diversity (Fig. 4.4). Kilbery, Jilling and Gandhura had high tree cover but low bird diversity while Kunjakharak, Sitlakhet, Jageshwer and Majtham had medium tree cover but high bird diversity. Sunderdunga, Wachham, Dhakuri, Pindari, Maheshkhan and Kunjakharak had medium tree diversity but high bird diversity found only on later three patches. Gasi, Sobala, Daphiadhura, Majtham, Binsar, Jageshwer and Sitlakhet had high tree diversity as well as high bird diversity (Fig. 4.5).

Although the detailed advanced analyses had been performed on the habitat parameters in relation to bird diversity values in the chapter 'Habitat use' but only to have a quick look on the relationship of these parameters, spatial analysis has been performed on maps.

4.4 DISCUSSION

During the period of this study, 270 bird species were recorded in the Kumaon Himalaya. No other ecological study of the avifauna in the Kumaon Himalaya has been conducted till date. Only bird lists by other workers have been compiled on a few days survey in different districts such as in 19th century Atkinson (1882) documented >600 bird species from Western Himalaya, which included Kumaon also. Later, Whymper (1902) recorded nests of seven species between 4000-5000 ft in Kumaon. Hudson (1930) documented 124 bird species occurring on seven hills around Naini Tal between 6000 ft to 8500ft altitude range and Briggs (1931) documented 83 bird species in Ranikhet forest.

The study designed, and described here is simple and highly time efficient and could therefore be useful in view of the logistical realities of studies in temperate forests. It should be emphasized that the principal advantage is not only sub listing but the approach of recording birds continuously while walking randomly through the forest. Species richness counting method is highly time efficient (compared with point count and line transect) and secures a broad coverage of the study area. The sub listing is in conflict with standard statistics for species richness estimation (e.g. Magurran, 1988) but could be a practical guideline for those who otherwise provide only a total list of birds seen. The length of sub lists needs to modify according to the circumstances, e.g. 10-species lists in species poor areas (see Poulsen *et al.* 1997). During survey of Kumaon, both 20- species list and 10-species list were compiled according to conditions of patch.

Another method, which was adopted, was Point count (Reynolds *et al.* 1980). The accumulation of species must increase with time and becomes constant when all the species that use the area have been detected. The gain rate of species in the Pindari and Sobala regions (these patches have been taken for example as maximum point counts were conducted at these places during survey in 1997) was such that after 10 minutes, I recorded about 75% of all species that I eventually detected in 20 minutes (Fig. 4.6). This percentage is nearly identical to that obtained during the breeding season by Hamel (1984), and is similar to what Scott and Ramsey (1981) reported for birds from two

Fig. 4.4 Bird species diversity in relation to tree cover in Kumaon Himalaya.

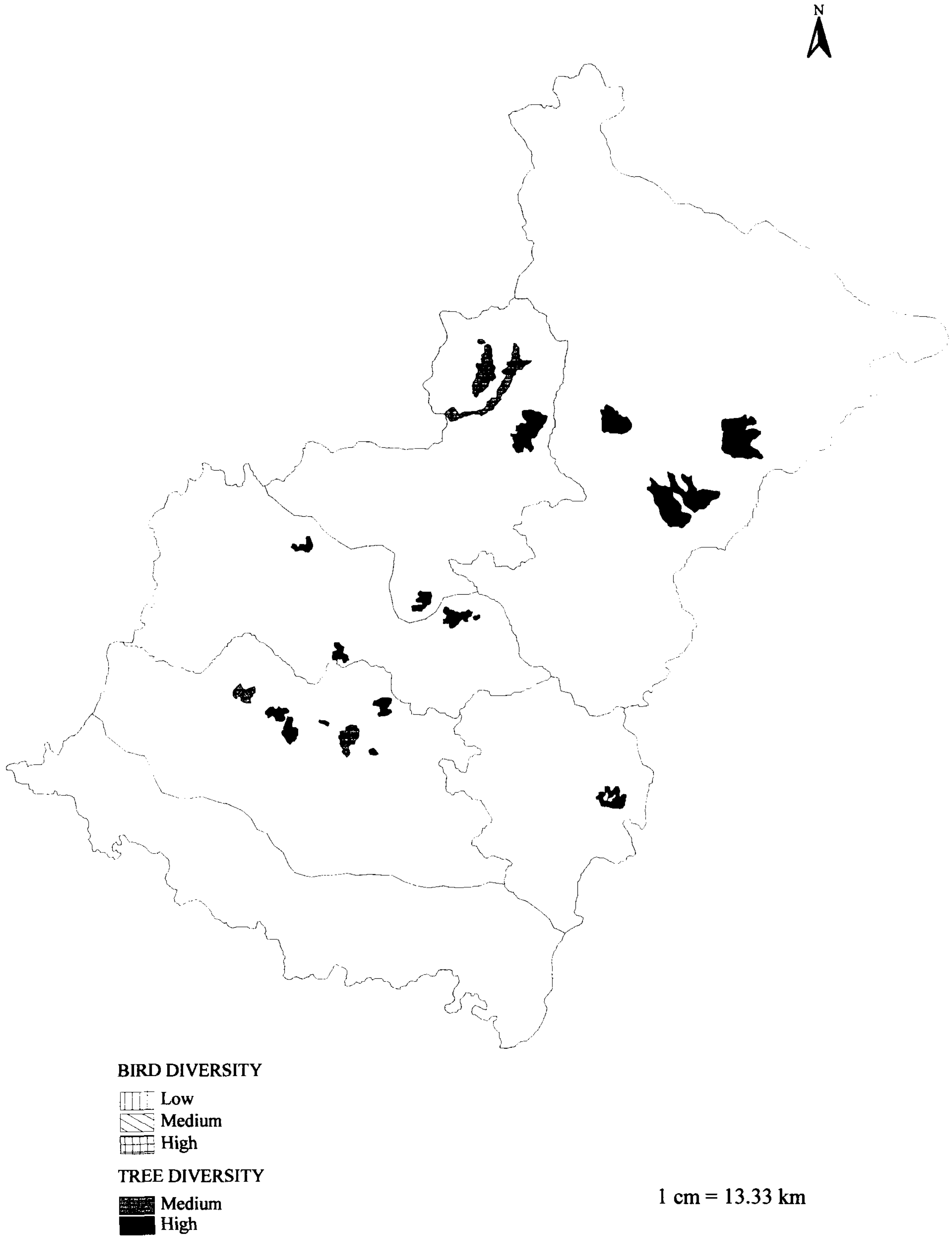


Fig. 4.5 Bird species diversity in relation to tree diversity in Kumaon Himalaya.

Hawaiian forests and the same percentage was recorded by Hutto *et al.* (1986) in Western Mexico, where after 10-12 minutes they recorded 75-80% of bird species that were inevitably recorded in 20-32 minutes. No matter what the count duration, it is important to realize that counts taken from within a single habitat type but based on unequal durations are not directly comparable because of the relationship between number of detections and time (Fig 4.6).

I found the suggestion by Morrison *et al.* (1981) that 4-6 stations are adequate for the complete census of an area to be unsatisfactory. In Kumaon, where less point counts were conducted, the bird species diversity and richness was less estimated compared to the bird species diversity and richness estimated by Species richness counting method for the same area. In Pindari and Sobala regions, more point counts were conducted so the bird diversity and richness was close to the diversity values, estimated by Species richness counting method. An alternative suggestion that 28 – 30 points give reasonable estimates of diversity and richness (Reynolds *et al.* 1980; Blondel *et al.* 1981) and Hamel (1984) also detected 80% of the species after 36 (24%) of 150 variable radius counts. No sampling technique is free of biases or effective for all groups, and a combination of techniques is most useful in many cases (Terborgh *et al.* 1990).

Difference in bird species diversity and richness in different oak patches of the Kumaon Himalaya was probably due to a number of factors, including floristic and structural changes in the vegetation along the elevational gradient. Both general observations and different methods confirmed that, as predicted, the more structurally diverse forest at low elevation contains the greatest number of species. In other forests elsewhere, changes in species composition along elevational gradients have been

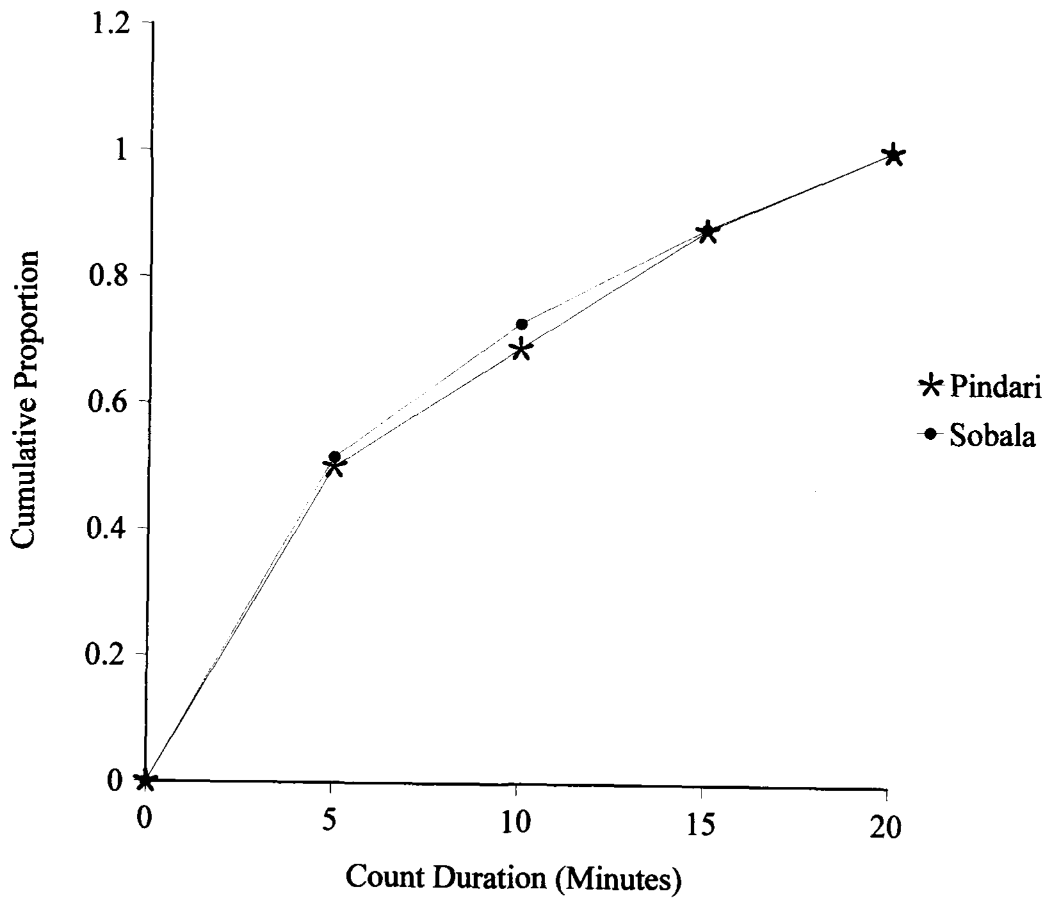


Fig 4.6 Relationship between the proportion of the total number of bird species detected in 20 minutes and the duration of the point count. Data were derived from 12 20- min point counts conducted in the Pindari and Sobala region.

explained by several factors, including competition, resource availability, habitat specialization, historical events, landuse changes (Terborgh, 1971; 1977; Beehler, 1981; Bell, 1984; Loiselle & Blake, 1991; Janes, 1994; Repasky & Schluter, 1994; Blake & Loiselle, 2000). In the study area, a combination of such factors is likely to be important in explaining the presence or absence of different species along the elevational gradient.

Decline in species number with elevation has been reported for many types of organisms (Rosenzweig, 1995), although peak species richness often is not found at the lowest elevation. Bird species diversity changed a little from 2200m- 3000m in Kumaon Himalaya, but diversity was highest at 1800m – 2200m and 2600m – 3000m. Despite the similar number of species at 2200m – 2600m and 2600m – 3000m, species composition changed substantially. Species richness was lower at 3600m – 4200m, with few species shared with sites at lower elevations. These data indicate that turnover in species composition occurs over relatively short distances in species composition. All the 23 sites were situated far from each other but the groups formed, were the most similar in terms of species number and composition (Fig 4.3). One factor for the similarity of sites was the similar species composition and another factor may be similar sites occupying almost similar altitudinal ranges. Majtham, Mechh and Dhakuri were similar sites in terms of species composition, which might be due to the reason that the areas were sampled on the same altitude ranges. Other sites such as Kunjakharak, Pandavkholi, Gasi, Maheshkhan, Mukteshwer, Gager etc. were also having similar species composition and situated on the same altitude.

Changes in community composition from one elevation to the next reflect many factors that affect the distributional patterns of individual species. Such factors may operate over various temporal and spatial scales. Many changes in species composition with elevation reflect changes in the types of resources present. Insectivorous species, for example, generally are less important at higher elevations (Terborgh, 1971). Some insectivorous groups that are particularly common and important components of lowland avifauna, are rare or absent at higher elevations. Mostly omnivorous birds were found at higher elevations, so they are not selective feeders for e.g. Yellow-billed Chough, Monal pheasant, Satyr Tragopan etc.

Knowing the status and distribution of species is very important. Conservation efforts are focused on regions or sites that support threatened, endemic or rare species. Thus, knowledge of the distribution pattern of threatened species can be an argument for protection of different areas (Wege & Long, 1995). In my study area, Pindari and Sunderdunga have a long range of altitudes and many threatened species were common there, illustrating the need to protect forest along all elevation gradients. The Vinaiyak area showed similar species composition with Pindari and Sunderdunga, so there is a need to protect this area also. Binsar Wildlife Sanctuary is already a protected area, another similar site of the same cluster.

CHAPTER 5

AVIAN DENSITY AND ABUNDANCE PATTERN

5.1 INTRODUCTION

The ornithological literature contains few serious attempts to determine total species population; the few cases are of very rare or isolated populations, usually both. Because of the lack of systematic information on the ecology of avian community of Kumaon Himalaya, the surveys and intensive study can provide important insights into the ecology of avian community. Since J.T.Emlen (1971) popularized the variable-width line transect method for estimating bird densities in large tracts of habitat, thousands of transects have been walked and millions of bird detections have been recorded.

During the study in Kumaon, line transect method was employed at intensive study areas while circular plot method (Reynolds *et al.* 1980) was used during surveys in different oak patches. Of the methods available for censusing birds, the variable circular plot technique is one of the newest. A modification of J.T.Emlen's (1971) line transect method, this technique was developed to allow the observer to census from fixed points. This method is reported to offer distinct advantages for surveying large geographical areas, for comparing different habitats, and for working in rugged and remote terrain (Scott & Ramsey, 1981a) and it is also applicable in all habitats. Keeping in mind that it being the first ecological study conducted on avian community in Kumaon Himalaya, both methods were employed to generate densities of birds.

5.2 METHODOLOGY

Methodology was divided into two portions i.e. data collection in the field and analyses.

5.2.1 Data collection

Censuses were conducted from March - June 1996 and September- December 1997 in Binsar Wildlife Sanctuary (hereafter BWS), from September- December 1996 and March - July 1997 surveys in Kumaon and from February- July 1998 & September- December 1998 in Vinaiyak Reserve Forest (hereafter VRF). Line transect method (Emlen, 1971) was followed in BWS while both Point transect method (Reynolds *et al.* 1980) and Line transect method were followed in VRF. For the surveys, only Point transect method was employed.

Birds were sampled in stratified random manner. The first step in the sample stratification procedure was to determine the number of strata to sample. For this study, two different approaches were used, each to accommodate criteria established by each forest. Four habitat groups (Oak forest, Pine forest, Mixed forest & Riverine) were identified as strata in the BWS and two habitat groups (Pure Oak forest & Mixed coniferous forest) or strata in the VRF (Table 5.1).

The next step was to determine how many samples would be required within each stratum. Because I had no estimate of the variance for data in Kumaon Himalaya, I used data gathered previously in other parts of India and abroad. It was found that the variances of several bird parameters in different habitat strata were similar (Hanowski *et al.* 1990). Consequently, samples were allocated optimally and proportionally to strata.

Table 5.1 Details of total monitoring of transects in different habitat types in Binsar Wildlife Sanctuary and Vinaiyak.

Habitat	Premonsoon		Postmonsoon	
	No.	Monitoring	No.	Monitoring
Binsar Sanctuary	1996		1997	
Oak habitat	2	18	2	20
Pine habitat	2	18	2	20
Mixed habitat	1	9	1	10
Riverine habitat	1	9	1	10
Vinaiyak	1998		1998	
Oak habitat	2	50	2	32
Mixed coniferous	2	50	2	32

Transects were marked out through selected habitat and each transect length was 500 meters marked at 50 meter intervals for future reference. In each habitat, two transects were established each in disturbed and undisturbed area to compare pattern and population estimates in both areas except in Mixed and Riverine habitats of BWS.

One transect per day was walked regularly between 0600 hrs and 0930 hrs to minimize the effects of time of day on bird detectibility (e.g. see Poulsen, 1993; Poulsen & Krabbe, 1998). The transects were monitored in a rotation manner. All transects in disturbed habitats were monitored first and then all undisturbed transects. Censuses were conducted by slowly walking the transects in succession and recording all birds detected by visual observation. Progression along transects was continous with stops only to observe and listen. Point count method was also applied in VRF. The methodology adopted for this particular method has been discussed in chapter 4.

Following parameters were recorded with the encounter of each bird species-

- The time of initial contact
- Perpendicular distance
- Group size
- Species and number
- Activity of bird
- Plant species used and total height
- Vertical height at which bird was observed
- Strata of tree used (upper, middle, lower canopy, trunk, ground)

5.2.2 Analyses

5.2.2.1 *Density estimation*

Densities were calculated using the DISTANCE programs (Laake *et al.* 1993) for repeated transects. Detectability and densities were calculated for each habitat and for each season separately because of differences in visibility between the habitats (Table 5.2).

The general estimator of density is

$$D = n\, f(o) / 2L$$

where, n = no. of observed objects, f (o) = value of probability density function (pdf) at zero, L = total length of transect line (s).

Different detection functions used in this study were the following-

i. The hazard- rate detection function is modelled as-

$$g(x) = 1 - \exp[-(x/\sigma)^{-b}]$$

where g (x) = the probability of detection of an object at a distance x from the line or point, b = shape parameter, σ = scale parameter

ii. The Negative-exponential detection function is modelled as-

$$g(x) = \exp\{-x/\lambda)$$

where x = the distance of a detected bird from the line, λ = parameter in the estimated probability function

iii. The Half / normal detection function is modelled as –

$$g(y) = \exp(-y^2/2a^2)$$

where y = the distance of a detected bird from the line, a = parameter in the estimated probability function

Table 5.2 Mean unobstructed visibility within different habitats.

Habitat	Mean	Standard Error
Binsar WS		
Oak	10.59	1.96
Pine	9.08	1.52
Mixed	6.54	1.37
Riverine	6.03	1
Vinaiyak		
Mixed	33.2	7.72
Oak	30.4	7

The total length of the transect used was, transect length multiplied by monitoring of the same transect. In many surveys, it is convenient to take the perpendicular distance data only in intervals, instead of measuring and recording the exact distance for each individual (Burnham *et al.* 1981). For this study, perpendicular distance was divided into four intervals i.e.-

1 = 0-5 meters

2 = 5.1- 10 meters

3 = 10.1 – 15 meters

4 = 15.1 – 20 meters

All the individuals, falling in these intervals, were counted. By doing this, the ungrouped data was converted into grouped data.

To analyse seasonal changes in bird species composition at intensive sites, the number of bird species detected on all transects and point counts were pooled for each season i.e. premonsoon (March- July) and postmonsoon (September- December). Rest of the months were not sampled because of inaccessibility of areas due to heavy rainfall and snowfall.

20 most abundant bird species were also selected for the density estimation for each season and 10 most abundant species for each habitat (irrespective of season) of Binsar Wildlife Sanctuary and Vinaiyak Reserve Forest.

Density of birds on Point transects was estimated by the following formula-

Density/ha = Number of birds / area of the plot x 10,000

Radius for the area was considered as the mean of all perpendicular distances of all individuals sighted at each point. Standard error and confidence intervals were also calculated for the same.

5.2.2.2 *Abundance model*

The log normal distribution was applied to species abundance data in different habitat types in BWS and VRF for different seasons. The model was applied for BWS and VRF by combining both seasons and all habitat types.

The distribution was written in the form:

$S(R) = So \exp(-a^2 R^2)$

where S (R) = the number of species in the R^{th} octave (i.e. class) to the right and left of the symmetrical curve.

So = the number of species in the modal octave

$a = (2\sigma^2)^{1/2}$ = parameter related to the variance of the distribution

5.3 RESULTS

A total of 99 and 91 species were identified by transect monitoring in BWS and VRF respectively, which is 61% and 50% of total species recorded in both the areas. Transect method proved to be reliable in sampling of birds in BWS and VRF (Fig 5.1 & 5.2).

Fig. 5.1 The cumulative numbers of species recorded per monitoring of transect in different habitats of Binsar Wildlife Sanctuary.

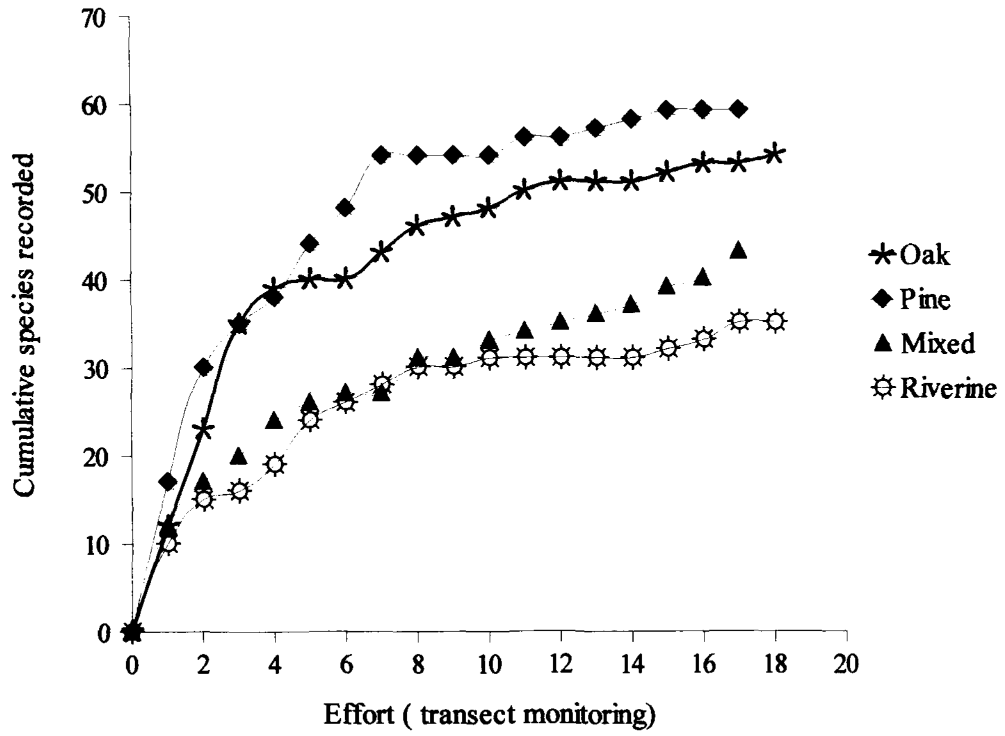
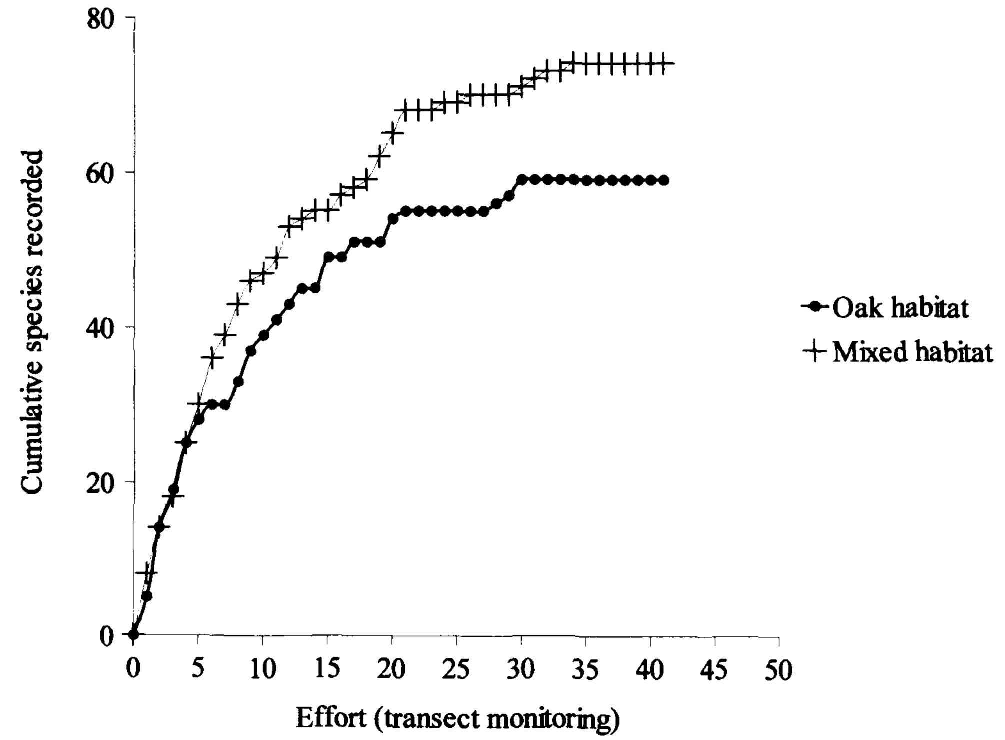


Fig. 5.2 The cumulative numbers of species recorded per monitoring of transect in different habitats of Vinaiyak Reserve Forest.



5.3.1 *Density pattern in Binsar Wildlife Sanctuary*

The overall estimated density was 12.75 ± 3.96 birds / ha for BWS. A few new species were being added to the total for most habitats as transect effort increased at the end of the study (Fig. 5.1). Also several other nocturnal or difficult to detect species such as Brown-wood owl, Indian nightjar, Jungle nightjar were recorded only by Species richness counting method. This suggests that all habitats were under sampled to some degree. However, the slow rate of addition of new species for increased transects effort in all habitats except riverine forests suggests that the majority of species were recorded (Fig 5.1).

5.3.1.1 *Density pattern in different habitat types*

The overall bird density in different habitat types was calculated by DISTANCE program and it was found that irrespective of seasons the maximum density occurred in oak habitat (18.19 / ha) (Table 5.3). The minimum density was observed in riverine habitat i.e. 8.44 / ha. It has very narrow confidence limits. One sample t-test showed significant difference in different habitats in BWS ($t = 6.27$, d.f. = 3, $p < 0.008$).

Bird density estimates at BWS varied widely between species (Table 5.4) and in different habitats. Highest densities were recorded for Black-throated tit (4.76 birds / ha), White-throated laughing thrush (3.22 birds / ha), Green-backed tit and Grey-hooded warbler (2.15 birds / ha) in oak habitat (Table 5.4). Half-normal cosine model was selected by DISTANCE because most of the sightings have fallen between two intervals. Yellow-browed warbler had the lowest density calculated (0.92 birds / ha). In

Table 5.3 Overall bird density in different habitat types of Binsar Wildlife Sanctuary. The best model Hazard/cosine was selected by "DISTANCE" program.

Habitat	Density/ha	% coefficient of variation	Confidence interval (95% significance)
Oak	18.19	4.04	16.81 -19.69
Pine	11.65	4.14	10.74 -12.63
Mixed	12.62	4.47	11.56 -13.77
Riverine	8.44	5.26	7.61 -9.36

Table 5.4 Overall bird density in oak habitat of Binsar Wildlife Sanctuary. The best model Half-normal / cosine was selected by "DISTANCE" program.

Species	Density/ha	% coefficient of variation	C.I. (95%)
Black-throated tit	4.76	13.99	3.62-6.25
White-throated laughing thrush	3.22	15.72	2.37-4.38
Green-backed tit	2.15	18.07	1.51-3.05
Grey-hooded warbler	2.15	18.07	1.51-3.05
Oriental dove	1.58	20.27	1.07-2.35
White-throated nuthatch	1.38	21.42	0.91-2.09
Eurasian jay	1.33	21.75	0.87-2.02
Chestnut-tailed minla	1.28	22.10	0.83-1.96
Spot-winged tit	1.07	23.76	0.67-1.70
Yellow-browed warbler	0.92	25.37	0.56-1.50

pine habitat the highest density was calculated for Black-headed jay (1.17 birds / ha), Green-backed tit (0.966 birds / ha) and Oriental dove (0.92 birds / ha) (Table 5.5).

The model selected for mixed and riverine habitat was Hazard / cosine. In mixed and riverine habitat the White-throated laughing thrush had maximum density calculated i.e. 2.45 birds / ha and 0.923 birds / ha respectively (Table 5.6 & 5.7). The other species which possessed maximum calculated density in mixed habitat were Oriental dove (0.988 birds / ha) and Green-backed tit (0.859 birds / ha) while in riverine habitat the maximum density was calculated for Spotted forktail (0.852 birds / ha) and Oriental dove (0.67 birds / ha). Three of these (the laughing thrush, dove and forktail) are conspicuous species, more likely to be recorded than small and solitary birds. Less frequently recorded birds would probably occur at lower densities than this, but where there are few records DISTANCE cannot calculate detection functions. So, the densities were calculated only for 10 most abundant species found in particular habitat or area.

5.3.1.2 *Density pattern in different seasons*

The seasonal pattern was also calculated and two seasons i.e. premonsoon season and postmonsoon season were sampled. Density was found more during premonsoon season (3.3 birds / ha) than postmonsoon season (Table 5.8). The two sample Kolmogorov- Smirnov Z test showed no significant difference between two seasons ($Z = 1.06$, $p > 0.05$).

Bird density was also calculated for different habitat types for different seasons (Table 5.9). One sample t-test showed significant difference in densities calculated for different habitats during premonsoon season ($t = 14.33$, d.f. = 3, $p < 0.001$) while it was not

Table 5.5 Overall bird density in pine habitat of Binsar Wildlife Sanctuary. The best model Hazard-cosine was selected by "DISTANCE" program.

Species	Density/ha	% coefficient of variation	C.I. (95%)
Oriental dove	0.92	16.75	0.66-1.27
Slaty-headed parakeet	0.57	20.75	0.38-0.86
Mistle thrush	0.64	19.69	0.43-0.94
Bar-tailed tree creeper	0.74	18.52	0.51-1.05
Long-tailed minivet	0.71	18.79	0.49-1.02
Black-headed jay	1.17	15.05	0.87-1.57
Green-backed tit	0.96	16.39	0.70-1.32
Brown-fronted woodpecker	0.59	20.38	0.40-0.88
Ashy drongo	0.39	24.88	0.24-0.63
Black-throated tit	0.48	22.51	0.31-0.74

Table 5.6 Overall bird density in mixed habitat type of Binsar Wildlife Sanctuary. The best model Hazard-cosine was selected by "DISTANCE" program.

Species	Density/ha	% coefficient of variation	C.I. (95%)
White-throated laughing thrush	2.45	14.55	1.84-3.25
Oriental dove	0.98	21.70	0.64-1.50
Green-backed tit	0.85	23.16	0.54-1.34
Black-throated tit	0.68	25.71	0.41-1.12
Black bulbul	0.68	25.71	0.41-1.12
Ultramarine flycatcher	0.55	28.38	0.32-0.96
Himalayan woodpecker	0.55	28.38	0.32-0.96
White-tailed nuthatch	0.55	28.38	0.32-0.96
Grey-hooded warbler	0.51	29.49	0.29-0.90
Verditer flycatcher	0.34	35.86	0.17-0.68

Table 5.7 Overall bird density in riverine habitat type of Binsar Wildlife Sanctuary. The best model Hazard-cosine was selected by "DISTANCE" program.

Species	Density/ha	% coefficient of variation	C.I. (95%)
White-throated laughing thrush	0.92	19.69	0.62-1.35
Spotted forktail	0.85	20.49	0.57-1.26
Oriental dove	0.67	23.01	0.43-1.05
Grey-winged black bird	0.53	25.88	0.32-0.87
Yellow-browed warbler	0.53	25.88	0.32-0.87
Grey-headed canary flycatcher	0.39	30.20	0.22-0.69
Blue-whistling thrush	0.35	31.67	0.19-0.65
Rufous sibia	0.31	33.28	0.16-0.60
White-crested kalij	0.28	35.40	0.14-0.55
Rufous-bellied niltava	0.28	35.40	0.14-0.55

Table 5.8 Overall bird density in different seasons of Binsar wildlife sanctuary. The best model Hazard/cosine was selected by "DISTANCE" program.

Season	Density/ha	% coefficient of variation	C.I. (95%)
Pre monsoon 96	3.13	3.15	2.94 - 3.33
Post monsoon 97	1.75	4.28	1.61 - 1.91

Table 5.9 Overall bird density in different habitat types of Binsar Wildlife Sanctuary in different seasons. The best model Hazard/cosine was selected by "DISTANCE" program.

Habitat	Density/ha	% coefficient of variation	C.I. (95%)
Pre-monsoon			
Oak	14.85	3.29	13.92 - 15.84
Pine	10.59	5.05	9.59 - 11.70
Mixed	13.85	7.58	11.94 - 16.06
Riverine	12.91	7.82	11.08 - 15.05
Post- monsoon			
Oak	8.21	5.87	7.32 - 9.21
Pine	3.77	8.86	3.17 - 4.49
Mixed	17.69	10.06	14.53 - 21.53
Riverine	5.48	16.51	3.97 - 7.56

significant during postmonsoon season ($t = 2.83$, d.f. = 3, $p > 0.056$). The highest density was found in oak habitat (14.85 birds / ha) during premonsoon season while during postmonsoon season it was highest in mixed habitat (17.69 birds / ha). Pine habitat consisted low densities during pre as well as post monsoon seasons (10.59 & 3.77 birds / ha respectively). Independent samples t-test showed no significant difference in the densities calculated for pre and post monsoon season ($t = 1.31$, d.f. = 6, $p > 0.056$).

Bird densities were also calculated for 20 most abundant species occurring during premonsoon and postmonsoon season. In BWS, Oriental dove (0.23 birds / ha) had maximum density in premonsoon season (Table 5.10) while White-throated laughing thrush (0.45 birds / ha) had maximum density in postmonsoon season. Mistle thrush (0.049 birds / ha), Black bulbul (0.049 birds / ha) and Brown-fronted woodpecker (0.049 birds / ha) had minimum density during premonsoon season while Jungle crow (0.039 birds / ha) and Black bulbul (0.034 birds / ha) had minimum density during postmonsoon season (Table 5.11). The best model Hazard / cosine was selected for premonsoon season by DISTANCE program while Negative exponential / cosine was selected for postmonsoon season. Both of them were having minimum Akaike's Information Criteria (AIC) values for their respective seasons.

5.3.1.3 *Effect of disturbance on density pattern*

Densities were maximum in disturbed habitats for both oak and pine in both seasons (Table 5.12). There was no significant difference in bird density in disturbed and undisturbed oak habitat ($\chi^2 = 0.334$, $p > 0.05$) as well as in pine habitat ($\chi^2 = 1.16$, $p > 0.05$) during premonsoon season. Significant difference was obtained for disturbed and

Table 5.10 Density of 20 most abundant bird species of Binsar Wildlife Sanctuary in premonsoon season 1996. The best model Hazard/cosine was selected by "DISTANCE" program. CV = coefficient of variation, CI = confidence interval.

Species	Density	% CV	95% CI
Oriental dove	0.23	9.79	0.19-0.29
White-throated laughing thrush	0.14	12.89	0.10-0.17
Black-throated tit	0.11	14.00	0.08-0.14
Grey-hooded warbler	0.09	15.15	0.07-0.12
Green-backed tit	0.08	16.24	0.06-0.11
Gray-winged black bird	0.08	16.24	0.06-0.11
Ultramarine flycatcher	0.08	16.24	0.06-0.11
Spot-winged tit	0.07	17.62	0.05-0.10
Long-tailed minivet	0.07	17.62	0.05-0.1
Grey-headed canary flycatcher	0.06	18.16	0.04-0.09
Rufous sibia	0.06	18.77	0.04-0.09
Bar-tailed tree creeper	0.06	19.09	0.04-0.08
Himalayan woodpecker	0.06	19.4	0.04-0.08
Black-headed jay	0.05	19.44	0.04-0.28
Yellow-browed warbler	0.05	20.18	0.03-0.08
White-crested Kalij	0.05	20.18	0.03-0.08
Mistle thrush	0.05	20.59	0.03-0.07
Black bulbul	0.05	20.59	0.03-0.07
Brown-fronted woodpecker	0.04	20.59	0.03-0.07

Table 5.11 Density of 20 most abundant bird species of Binsar Wildlife Sanctuary in postmonsoon season 1997. The best model Negative exponential/cosine was selected by "DISTANCE" program. CV = coefficient of variation, CI= confidence interval.

Species	Density	% CV	95% CI
White-throated laughing thrush	0.46	13.48	0.35-0.59
Black-throated tit	0.40	14.02	0.31-0.53
Green-backed tit	0.36	14.56	0.27-0.47
Black-headed jay	0.15	19.89	0.10-0.23
Yellow-browed warbler	0.15	19.89	0.10-0.22
White-tailed nuthatch	0.12	21.75	0.08-0.19
Eurasian Jay	0.11	22.13	0.07-0.18
Bar-tailed tree creeper	0.11	22.53	0.07-0.18
Chestnut-tailed minla	0.11	22.53	0.07-0.17
Grey-hooded warbler	0.08	26.42	0.05-0.13
Black-lored tit	0.07	27.2	0.04-0.13
Red-billed blue magpie	0.06	30.11	0.03-0.11
Mistle thrush	0.05	31.34	0.03-0.1
Blue-whistling thrush	0.05	31.34	0.03-0.1
Brown-fronted woodpecker	0.05	31.34	0.03-0.09
Spot-winged tit	0.05	31.44	0.03-0.10
Himalayan woodpecker	0.05	32.53	0.03-0.10
Spotted forktail	0.04	34.41	0.02-0.09
Jungle crow	0.04	36.37	0.02-0.08
Black bulbul	0.03	38.75	0.02-0.07

Table 5.12 Overall bird density in disturbed and undisturbed areas of Binsar wildlife sanctuary in different seasons. The best model Hazard/cosine was selected by "DISTANCE" program.

Habitat	Density/ha	% coefficient of variation	C.I. (95%)
Premonsoon			
Oak-disturbed	13.20	7.74	11.34 – 15.36
Oak–undisturbed	10.39	8.65	8.77 – 12.30
Pine–disturbed	17.60	6.81	15.41 – 20.11
Pine–undisturbed	11.76	8.17	10.02 – 13.80
Postmonsoon			
Oak–disturbed	33.43	7.61	28.81 – 38.80
Oak–undisturbed	13.27	10.87	10.73 – 16.41
Pine–disturbed	16.23	10.46	13.23 – 19.91
Pine–undisturbed	4.71	18.82	3.26 - 6.78

undisturbed areas of oak ($\chi^2 = 8.73$, $p < 0.05$) and pine habitats ($\chi^2 = 6.32$, $p < 0.05$) during postmonsoon season.

Chi- square test showed significant difference in density values in disturbed areas of oak habitat during pre and postmonsoon seasons ($\chi^2 = 8.77$, $p < 0.05$) while it was not significant in undisturbed areas ($\chi^2 = 0.35$, $p > 0.05$). No significant difference was observed in density in disturbed and undisturbed areas of pine habitat in pre and post seasons ($\chi^2 = 0.05$, $p > 0.05$ & $\chi^2 = 3.01$, $p > 0.05$ respectively).

Table 5.13 showed the species specifically found in disturbed and undisturbed areas of oak habitat by combining both seasons. Only 13 species were found in oak disturbed area while three species were specific to undisturbed oak habitat. Cutia and Streak-breasted scimitar babbler were sighted only once in disturbed area.

Seven species each in disturbed and undisturbed areas of pine habitat were specifically sighted (Table 5.14). Rufous-throated partridge is a rare bird and it was sighted only once in undisturbed pine habitat. Woodpeckers were very well acquainted with disturbed areas and were sighted many times.

5.3.2 Density pattern in Vinaiyak reserve forest

A total of 91 species were recorded by transect monitoring in VRF and overall density calculated was 13.93 ± 1.41 birds / ha. Fig. 5.2 shows that after 30 monitorings the asymptote reached for both oak and mixed coniferous forest. Oak forest comprised less species than mixed forest in fixed monitorings.

Table 5.13 List of species specific to disturbed and undisturbed areas of oak habitat in BWS during pre and postmonsoon seasons.

Disturbed	Undisturbed
Hill partridge	Dark-grey bush chat
Grey-faced warbler	Fire-breasted flowerpecker
Golden mountain thrush	Striated laughing thrush
Maroon oriole	
Cutia	
Green-tailed sunbird	
Plain leaf warbler	
Streak-breasted scimitar babbler	
Rufous-tailed flycatcher	
Tickle's leaf warbler	
Variegated laughing thrush	
White-collared black bird	
White-throated tit	

Table 5.14 List of species specific to disturbed and undisturbed areas of pine habitat in BWS during pre and postmonsoon seasons.

Disturbed	Undisturbed
Blue-capped rock thrush	Blyth's leaf warbler
Grey-headed woodpecker	Changeable hawk eagle
Streak-throated woodpecker	Hair-crested drongo
Rufous-bellied accentor	Long-tailed thrush
Smaller grey cuckoo shrike	Lesser white throat
Eurasian tree creeper	Rufous-throated partridge
Tree pipit	White-throated fantail flycatcher

5.3.2.1 *Density pattern in different habitat types*

The maximum density was found in mixed coniferous forest (29.15 birds / ha) (Table 5.15). χ^2 test showed no significant difference in density calculated in different habitats ($\chi^2 = 0.149$, $p > 0.05$). The confidence limit was very narrow. The densities of 10 most abundant species found in oak and mixed coniferous habitat irrespective of season were also calculated. For oak habitat the DISTANCE program chose half normal / cosine model. The tits i.e. Black-throated tit, Spot-winged tit and Green-backed tit dominated this particular habitat (4.16 birds / ha, 3.81 birds / ha and 2.30 birds / ha respectively). The Black-headed jay (0.95 birds / ha) and Bar-tailed tree creeper (1.09 birds / ha) had minimum density among 10 most abundant species (Table 5.16).

In mixed coniferous habitat the maximum density was of Black-throated tit (3.95 birds / ha), Spot-winged tit (3.70 birds / ha) and White-throated laughing thrush (2.98 birds / ha) (Table 5.17). While the Rufous sibia (1.07 birds / ha), White-tailed nuthatch (1.07 birds / ha) and Bar-tailed tree creeper (1.05 birds / ha) had the minimum density in this habitat. Sibia and creeper had minimum density in both habitats by having more in oak habitat comparatively.

5.3.2.2 *Density pattern in different seasons*

Data were pooled into two seasons, premonsoon season and postmonsoon season, to find out the seasonal differences in the total number of birds. Maximum density was found during postmonsoon season (7.31 birds per ha.) (Table 5.18). It may be due to encounter of more juveniles and sub adult birds after breeding season i.e. premonsoon season. χ^2 test showed no significant difference in density estimated for both seasons ($\chi^2 = 0.068$, $p > 0.05$).

Table 5.15 Overall bird density in different habitat types of Vinaiyak reserve forest. The best model Hazard/cosine was selected by "DISTANCE" program.

Habitat	Density/ha	% coefficient of variation	C.I. (95%)
Oak	26.26	0.50	26.01 –26.52
Mixed	29.15	1.31	28.41 –29.90

Table 5.16 Density of 10 most abundant bird species of Vinaiyak reserve forest in oak habitat. The best model Half - normal/cosine was selected by "DISTANCE" program. CV = coefficient of variation, CI= confidence interval.

Species	Density	% CV	95% CI
Black-throated tit	4.16	15.43	3.08-5.62
Spot-winged tit	3.81	15.53	2.81-5.15
Green-backed tit	2.30	16.24	1.67-3.15
Grey-hooded warbler	2.15	16.36	1.56-2.96
Yellow-browed warbler	1.93	16.57	1.39-2.66
Rufous sibia	1.70	16.84	1.23-2.37
Eurasian jay	1.51	17.13	1.08-2.10
White-tailed nuthatch	1.21	17.76	0.85-1.71
Bar-tailed tree creeper	1.09	18.08	0.76-1.55
Black-headed jay	0.95	18.59	0.66-1.35

Table 5.17 Density of 10 most abundant bird species of Vinaiyak reserve forest in mixed coniferous habitat. The best model Hazard/cosine was selected by "DISTANCE" program. CV = coefficient of variation, CI= confidence interval.

Species	Density	% CV	95% CI
White-throated laughing thrush	2.98	6.41	2.63-3.38
Yellow-browed warbler	1.71	8.35	1.45-2.01
Black-throated tit	3.95	5.62	3.54-4.42
Oriental dove	1.32	9.46	1.09-1.58
Spot-winged tit	3.70	5.79	3.31-4.15
Grey-hooded warbler	1.76	8.22	1.50-2.07
Green-backed tit	1.65	8.49	1.39-1.95
Rufous sibia	1.07	10.44	0.87-1.32
White-tailed nuthatch	1.07	10.44	0.87-1.32
Bar-tailed tree creeper	1.05	10.55	0.85-1.29

Table 5.18 Overall bird density in different seasons of Vinaiyak reserve forest. The best model Hazard/cosine was selected by "DISTANCE" program.

Season	Density/ha	% coefficient of variation	C.I. (95%)
Premonsoon 98	6.34	2.13	6.08 – 6.61
Postmonsoon 98	7.31	2.41	6.97 – 7.66

Table 5.19 Overall bird density in different habitat types of Vinaiyak reserve forest in different seasons. The best model Hazard/cosine was selected by "DISTANCE" program.

Season	Density/ha	% coefficient of variation	C.I. (95%)
Pre monsoon			
Oak	11.85	2.97	11.18 – 12.57
Mixed coniferous	14.05	2.76	13.31 – 14.83
Post monsoon			
Oak	14.85	3.29	13.92 – 15.84
Mixed coniferous	14.98	3.27	14.05 – 15.97

Density was calculated for different habitat types for different seasons also (Table 5.19). In both seasons, the maximum density was calculated for mixed coniferous forest (pre =14.05 birds / ha, post = 14.98 birds / ha). However χ^2 test showed no significant difference in both seasons across habitat types i.e. during premonsoon season ($\chi^2 = 1.023$, $p > 0.05$) and postmonsoon season ($\chi^2 = 0.0005$, $p > 0.05$).

The density of 20 most abundant bird species was calculated for each season. During premonsoon '98, the Spot-winged tit (0.73 birds / ha.), Black-throated tit (0.70 birds / ha) and Grey-hooded warbler (0.55 birds / ha) had maximum density (Table 5.20) while Yellow-breasted green finch (0.047 birds / ha), Rufous-bellied niltava (0.54 birds / ha) and White-cheeked nuthatch (0.054 birds / ha) had minimum density. The model selected was Hazard / cosine by DISTANCE. Again in postmonsoon both tits i.e. Black-throated tit (1.48 birds / ha) and Spot-winged tit (1.23 birds / ha) had maximum density even more than premonsoon season. Blue-whistling thrush (0.76 birds / ha), Himalayan woodpecker (0.10 birds / ha) and Verditer flycatcher (0.109 birds / ha) had minimum density among 20 most abundant bird species during postmonsoon season (Table 5.21).

5.3.2.3 *Effect of disturbance on density pattern*

Disturbance has a great effect on bird community structure. Keeping this in mind, I calculated densities for disturbed and undisturbed areas of each habitat for each season. In Vinaiyak reserve forest the highest density was estimated in undisturbed areas of both habitats during premonsoon season (oak = 23.61 birds / ha, mixed = 30.07 birds / ha) (Table 5.22). While during postmonsoon season the density was high in disturbed areas of both habitats (oak = 43.40 birds / ha; mixed = 41.04 birds / ha). χ^2 test

Table 5.20 Density of 20 most abundant bird species of Vinaiyak reserve forest in premonsoon season 1998. CV = coefficient of variation, CI= confidence interval.

Species	Density	% CV	95% CI
Spot-winged tit	0.73	5.62	0.66-0.82
Black-throated tit	0.71	5.71	0.63-0.79
Grey-hooded warbler	0.55	6.49	0.48-0.62
Yellow-browed warbler	0.37	7.83	0.32-0.44
White-throated laughing thrush	0.35	8.06	0.3-0.41
Green-backed tit	0.34	8.19	0.29-0.4
Rufous sibia	0.34	8.24	0.29-0.4
Eurasian jay	0.29	8.93	0.24-0.34
Oriental dove	0.28	9.00	0.24-0.34
Grey-headed canary flycatcher	0.23	9.92	0.19-0.28
Bar-tailed tree creeper	0.23	10.02	0.19-0.28
White-tailed nuthatch	0.22	10.23	0.18-0.27
Gray-winged black bird	0.15	12.52	0.11-0.19
Verditer flycatcher	0.13	13.15	0.1-0.17
White-browed shrike babbler	0.11	14.16	0.07-0.15
Black-headed jay	0.10	15.09	0.07-0.13
Orange-flanked bush robin	0.08	17.52	0.05-0.11
Rufous-bellied niltava	0.05	20.42	0.04-0.08
White-cheeked nuthatch	0.05	20.42	0.04-0.08
Yellow-breasted green finch	0.05	21.83	0.03-0.07

Table 5.21 Density of 20 most abundant bird species of Vinaiyak reserve forest in postmonsoon season 1998. CV = coefficient of variation, CI= confidence interval.

Species	Density	% CV	95% CI
Black-throated tit	1.48	5.71	1.32-1.65
Spot-winged tit	1.23	6.19	1.09-1.39
Green-backed tit	0.71	7.95	0.61-0.83
Yellow-browed warbler	0.55	8.93	0.46-0.66
White-throated laughing thrush	0.52	9.17	0.44-0.63
White-tailed nuthatch	0.38	10.73	0.31-0.47
Eurasian jay	0.32	11.50	0.26-0.41
Grey-hooded warbler	0.33	11.50	0.26-0.41
Rufous sibia	0.32	11.65	0.25-0.40
Bar-tailed tree creeper	0.32	11.72	0.25-0.39
Black-headed jay	0.27	12.66	0.21-0.34
Oriental dove	0.22	13.88	0.17-0.29
Red-breasted parakeet	0.19	15.04	0.14-0.25
Yellow-breasted green finch	0.17	15.75	0.13-0.24
Gray-winged black bird	0.15	17.02	0.11-0.21
Black-lored tit	0.14	17.79	0.1-0.19
White-throated tit	0.13	18.37	0.09-0.18
Verditer flycatcher	0.11	19.71	0.07-0.16
Himalayan woodpecker	0.10	20.51	0.07-0.15
Blue-whistling thrush	0.08	23.66	0.05-0.13

Table 5.22 Overall bird density in disturbed (D) and undisturbed (UD) areas of Vinaiyak reserve forest in different seasons. The best model Hazard/cosine was selected by "DISTANCE" program.

Species	Density/ha	% coefficient of variation	C.I. (95%)
Pre monsoon			
Oak-D	22.62	4.06	20.88 – 24.49
Oak–UD	23.61	3.98	21.83 – 25.51
Mixed coniferous–D	24.70	3.89	22.88 – 26.65
Mixed coniferous-UD	30.07	3.53	28.06 – 32.23
Post monsoon			
Oak-D	43.40	4.37	39.83–47.28
Oak–UD	24.72	5.55	22.17–27.56
Mixed coniferous–D	41.04	4.47	37.60–44.81
Mixed coniferous-UD	27.67	5.28	24.95–30.69

showed varied results in disturbed and undisturbed areas of oak and mixed habitats in different seasons. It showed no significant difference in both areas of different habitats during premonsoon season (oak $\chi^2 = 0.02$, $p > 0.05$; mixed $\chi^2 = 0.526$, $p > 0.06$). While there was significant difference in disturbed and undisturbed areas of oak habitat during postmonsoon season ($\chi^2 = 5.12$, $p < 0.05$) but again it was not significant for mixed forest ($\chi^2 = 2.6$, $p > 0.05$).

The disturbed oak forest contained five species (Table 5.23). The area had some ubiquitous species such as Ashy drongo, Black bulbul, Blue-whistling thrush, Rufous sibia, Chestnut-bellied rock thrush, Grey-winged black bird, Black-lored tit, Whiskered yuhina. The commonest species in the disturbed zone was the Spotted-bush warbler, which was particularly abundant at edges with many short bushes followed by Common myna, Hair-crested drongo and White-collared black bird. The undisturbed oak habitat contained 10 species. The common species were Red-billed blue magpie, Dark-gray bush chat, Dark-sided flycatcher and Slaty-headed parakeet.

The mixed forest, which was more heterogenous habitat, had more species than oak habitat. Total six species were sampled in disturbed areas. Coal tit was the commonest species followed by Hill partridge, Rufous-gorgeted flycatcher and Chestnut-crowned laughing thrush. In undisturbed areas, total eight species were recorded. Some ubiquitous species were Black & Yellow grosbeak, Chestnut-bellied nuthatch, Gold crest, Yellow-breasted green finch, Mountain bulbul, White-cheeked nuthatch (Table 5.24). The commonest species was White-capped water redstart, which was followed by Indian blue robin, Rufous-naped tit, Large cuckoo-shrike, which were feeding in flocks or pairs at high canopies throughout the forest. A large proportion of the birds participated in mixed

Table 5.23 List of species specific to disturbed and undisturbed areas of oak habitat in Vinaiyak reserve forest during pre and postmonsoon season.

Disturbed	Undisturbed
Common Myna	Crested serpent eagle
Hair-crested drongo	Dark-grey bush chat
Himalayan flameback	Grey wagtail
Spotted bush warbler	Golden bush robin
White-collared black bird	Maroon oriole
	Red-billed blue magpie
	Dark-sided flycatcher
	Slaty-headed parakeet
	Lesser yellow nape
	Tickle's thrush

Table 5.24 List of species specific to disturbed and undisturbed areas of mixed habitat in Vinaiyak reserve forest during pre and postmonsoon season.

Disturbed	Undisturbed
Blue-winged minla	Indian blue robin
Coal tit	Rufous-naped tit
Hill partridge	Kestrel
Rufous-gorgeted flycatcher	Long-billed thrush
Plain-backed thrush	Large cuckoo shrike
Chestnut-crowned laughing thrush	Large hawk cuckoo
	White-capped water red start
	Wedge-tailed green pigeon

feeding parties, which were mainly of two types either species rich assemblies around a pair of Ashy drongo, or a relatively smaller number of species following noisy parties of tits and warblers.

5.3.3 Fitting Distribution - Abundance model

When a large sample of animal species abundance is drawn from an ecological community, the data can be summarized in a variety of ways to help and examine relationships between abundance and the number of species having that abundance. The majority of communities studied by ecologists displayed a log normal pattern of species abundance (Sugihara, 1980). The log normal model was used to describe the abundance pattern in different habitat types in different seasons in intensively studied sites.

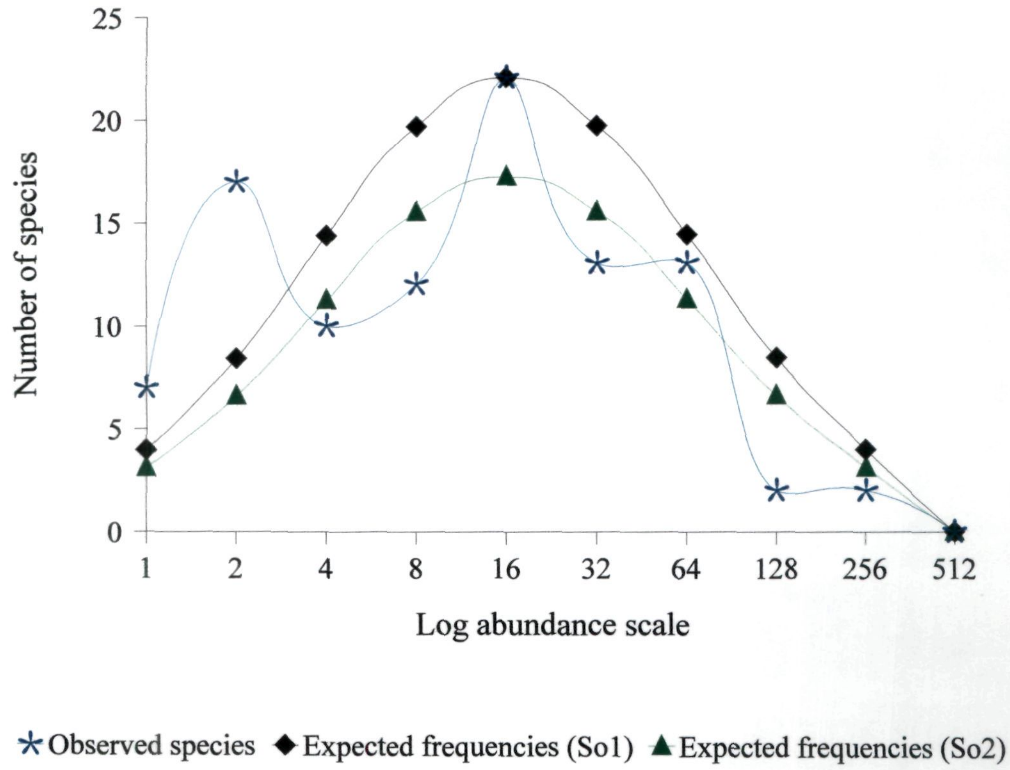
5.3.3.1 *Distribution- Abundance model for Binsar wildlife sanctuary*

The abundance model was fitted for whole of Binsar and in different habitat types in different seasons. For whole of Binsar, total nine octaves formed. The modal octave has 22 species (Maximum number of species) in the first octave. The parameters 'a' and 'So' were calculated from the LOGNORM.BAS program, where a = 0.327 & So = 22 & 17.2. It gave total expected number of species 93 against the observed value 98 (Table 5.25). It showed that the area was well sampled in terms of birds. Fig. 5.3 shows the So = 17.2, a good fit to these data. The total area under the log normal curve represents the theoretical number of species available for observation, S*, the total number of species in the community (Magurran, 1988). The log normal distribution is a symmetrical 'normal' bell shaped curve. If, however the data to which the curve is to be fitted is derived from a finite

Table 5.25 The Estimated frequencies and the observed species by fitting log normal model in different habitat types in premonsoon season in Binsar wildlife sanctuary. a = parameter, obs. = observed number of species , S(o) = observed number of species in the modal octave, S (R) = observed number of species in the octave, S* = theoretical number of species available for observation, χ^2 = goodness of fit test.

Habitat	BWS	Oak	Pine	Mixed	Riverine
a	0.327	0.184	0.263	0.343	0.235
obs.	98	50	53	32	30
So_1	22	14	12	8	8
S (R)	114.8	64.22	45.84	34.99	32.17
S*	119.08	135	80.76	41.3	60.25
χ^2	23.81	8.54	19.37	5.89	2.87
So_2	17.2	10.3	15	6.3	7.6
S (R)	90.06	47.21	57.3	27.55	30.56
S*	93.10	99.08	100.95	32.51	57.24
χ^2	26.47	7.53	14.95	7.9	2.89

Fig 5.3 Abundance- distribution pattern in whole BWS and fitted log normal curves with a = 0.327.



sample, the left hand portion of the curve (representing the rare and consequently unsampled species) will be obscured (Ludwig & Reynolds, 1988).

5.3.3.1.1 *Distribution- Abundance model for Premonsoon season*

The abundance-distribution model was fitted in different habitat types and season wise. Log normal curve for the oak habitat with 50 observed species was best fitted with a = 0.184 and an expected number of species 47 at So = 10.3. The number of species expected with this model was 99, suggesting that a good number of species around 49 remained unobserved (Fig. 5.4).

For Pine habitat the curve was best fitted with a = 0.263 and an expected number of species 45 at So = 12. The number of species expected with this model was 81. The observed number of species for this habitat was 53 (Fig. 5.5). The fitted curve in Fig 5.6 showed that there is good coverage as the fitted curve has more area on the left side than on the right side, suggesting that there were very few rare species which were not sampled in Mixed habitat. With the observed species 32, the best fit to the distribution of birds was at a = 0.343, So = 6.3 with expected 27.5 species. The total number of species in the community S*, 33 (at So = 6.3) was also very close to the observed number of species.

In Riverine habitat, more species were left for sampling. It might be due to less transect effort. The right hand curve was more prominent which clearly indicated that a good number of species i.e. 27 were left unsampled (Fig. 5.7). At parameter a = 0.235, So = 7.6, with observed value 30, the expected number of species was 30.56. This was the good fit as the expected number of species in the community at these data were 57.24 (Table 5.25).

Fig 5.4 Abundance-distribution pattern in oak forest in BWS during pre monsoon season and fitted log normal curves with a= 0.184.

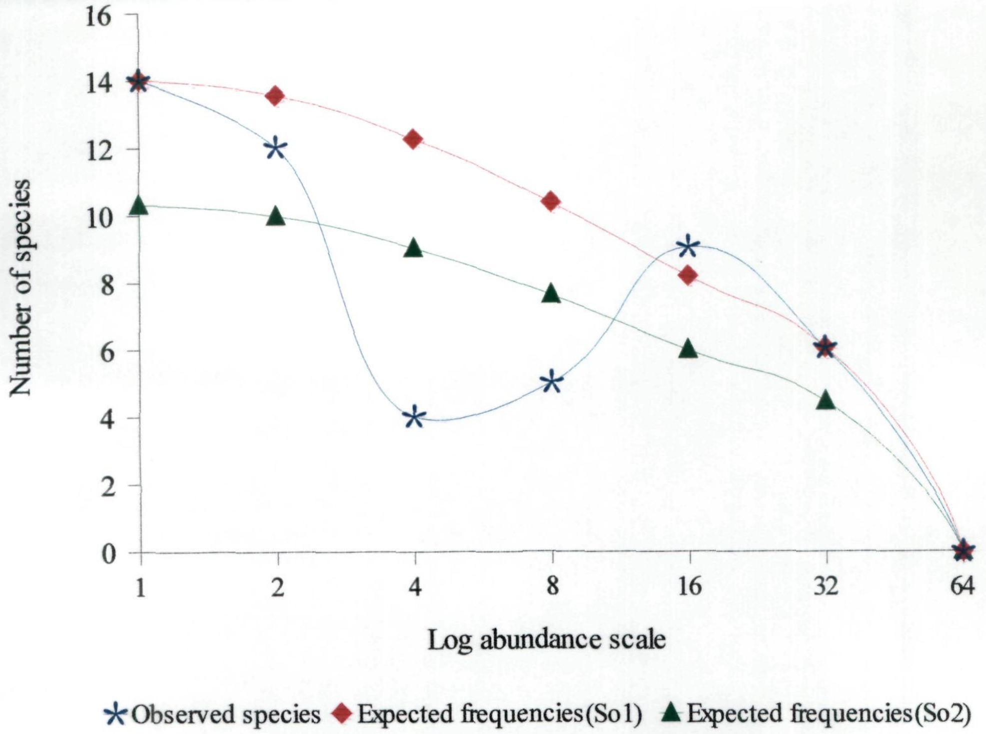


Fig 5.5 Abundance-distribution pattern in pine habitat in BWS during pre monsoon season and fitted log normal curves with a =0.263.

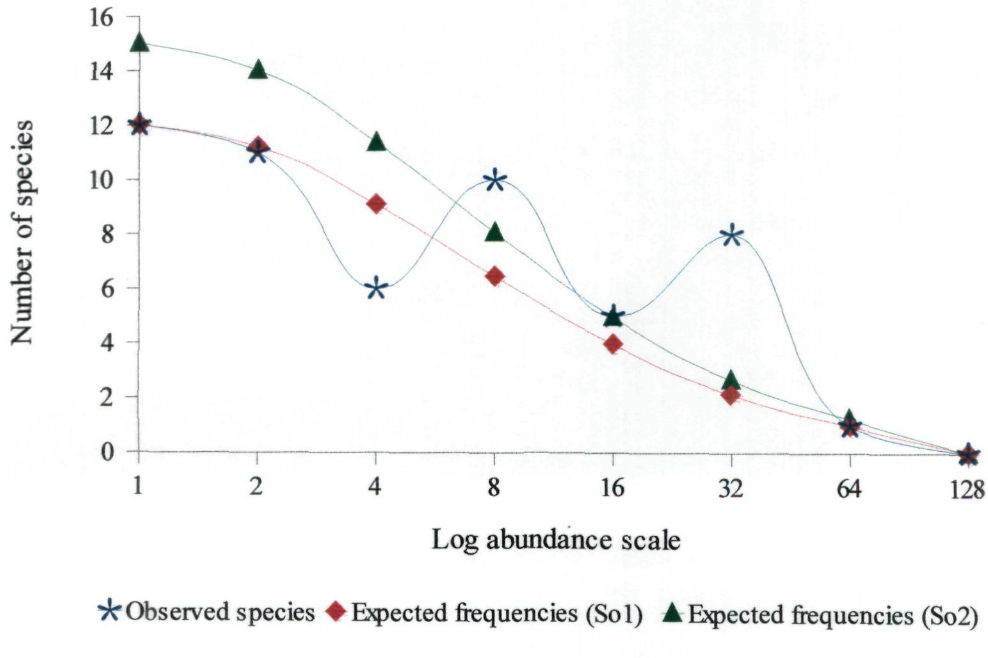


Fig. 5.6 Abundance- distribution pattern in mixed habitat in BWS during pre monsoon season and fitted log normal curves with a = 0.343.

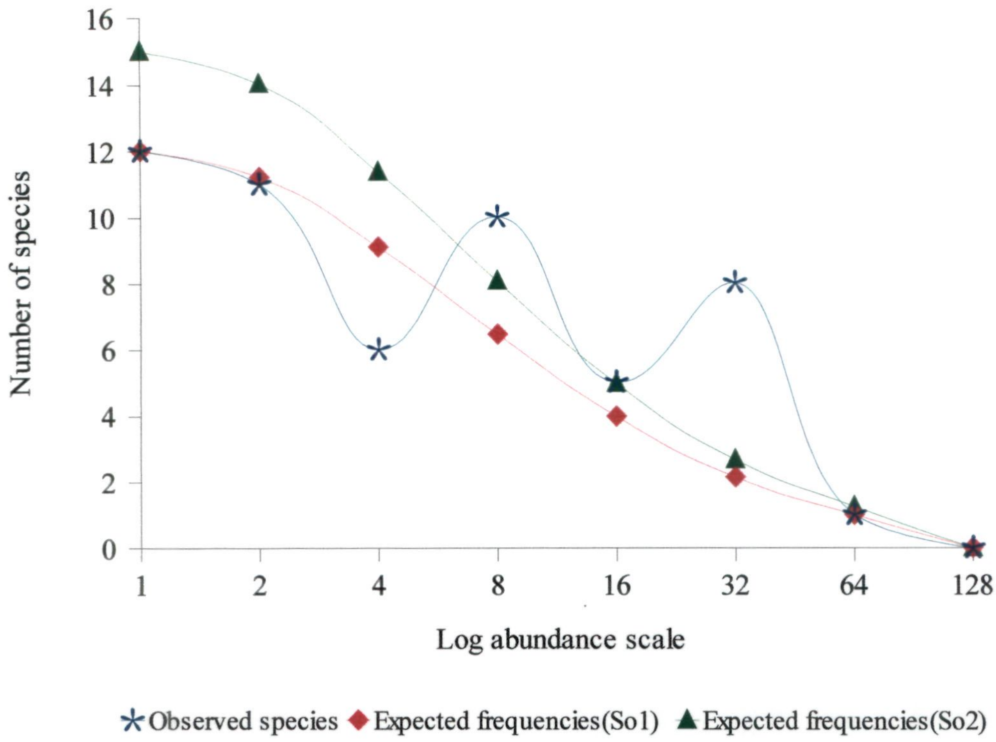
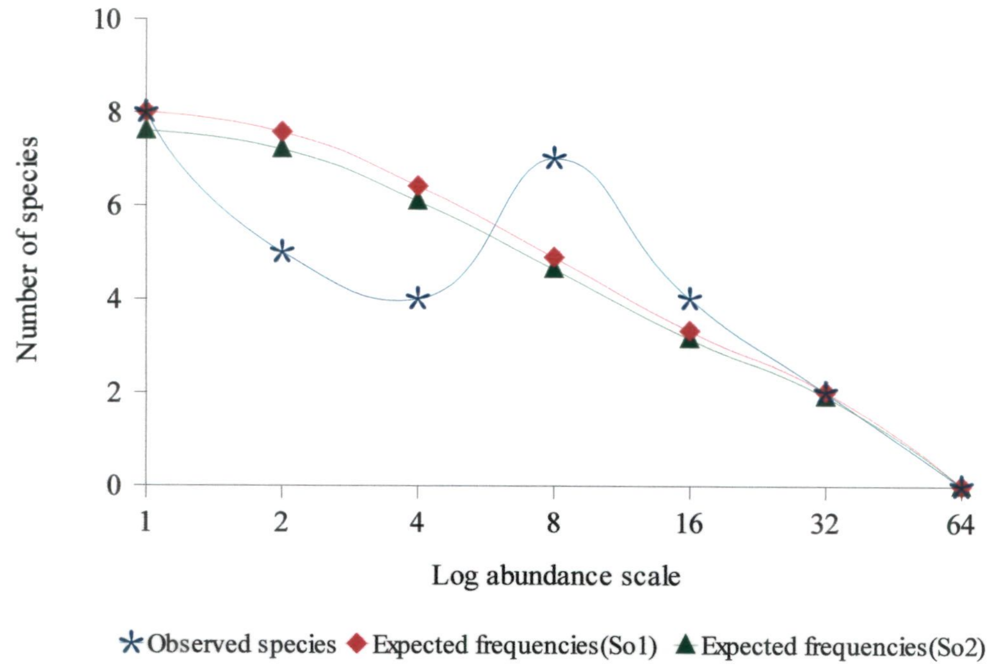


Fig. 5.7 Abundance- distribution pattern in riverine habitat in BWS during pre monsoon and fitted log normal curves with a = 0.235.



5.3.3.1.2 *Distribution- Abundance model for Postmonsoon season*

During postmonsoon season, the transect monitoring effort was slightly more than premonsoon season. In oak habitat the total number of observed species was 25, which was close to the number of species at So = 4.4 and a = 0.16 (Table 5.26, Fig 5.8). The estimate of the expected species S* which provided total species of the area included 23 more species than the observed.

For Pine habitat the log normal curve was approaching to normal distribution (Fig. 5.9). The second set of parameter estimate i.e. a = 0.29, So = 7.4 was a good fit to the data which gave expected frequency 20.84, very near to the observed species. The total number of species available for observation S* was 26.85 (Table 5.26).

The log normal curve was more visible towards right hand side not showing the normal distribution of birds (Fig. 5.10) in Mixed habitat during postmonsoon season. The parameter a = 0.247 with So = 6.7, was found to be good fit to these data. The estimate of expected frequencies with So = 9 & 6.7 were found to be 36.06 & 26.84 respectively. The theoretical number of species available for observation S* were used by So = 6.7 (Table 5.26), which was 23 species more than observed. The same pattern was observed in Riverine habitat also. The number of observed species was less than what was observed in premonsoon. Considering the second equation at So = 3.5 as the best fit, there were 18 species that were theoretical available for observation. While at So = 6, the expected species in the community were 32 (Table 5.26 & Fig. 5.11).

Table 5.26 The Estimated frequencies and the observed species by fitting log normal model in different habitat types in postmonsoon season in Binsar wildlife sanctuary. a = parameter, obs = observed number of species , S(o) = observed number of species in the modal octave, S (R) = observed number of species in the octave, S* = theoretical number of species available for observation, χ^2 = goodness of fit test.

Habitat	Oak	Pine	Mixed	Riverine
a	0.160	0.290	0.247	0.335
obs.	25	19	12	25
So_1	5	7	9	6
S (R)	26.29	33.15	36.06	18.37
S*	55.31	42.7	64.49	31.70
χ^2	4.71	12.58	6.14	5.94
So_2	4.4	4.4	6.7	3.5
S (R)	23.13	20.84	26.84	10.71
S*	48.67	26.85	48.01	18.49
χ^2	5.43	10.63	3.82	6.56

Fig. 5.8 Abundance-distribution pattern in oak habitat in BWS during post monsoon and fitted log normal curves with a = 0.16.

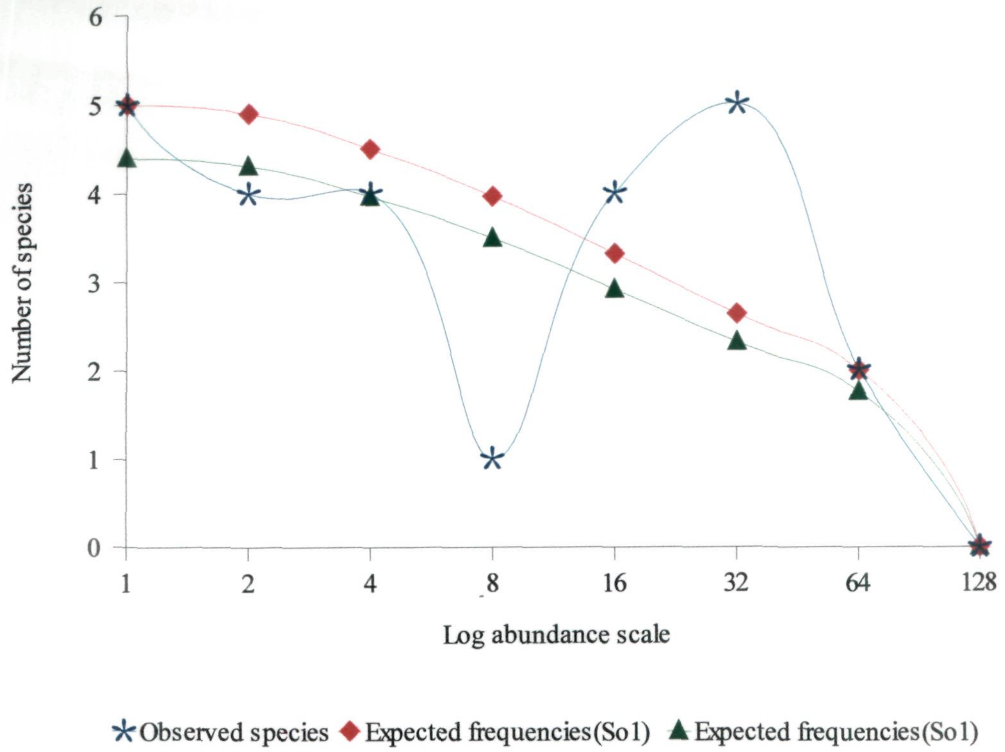


Fig. 5.9 Abundance-distribution pattern in pine habitat in BWS during post monsoon and fitted log normal curves with a = 0.29.

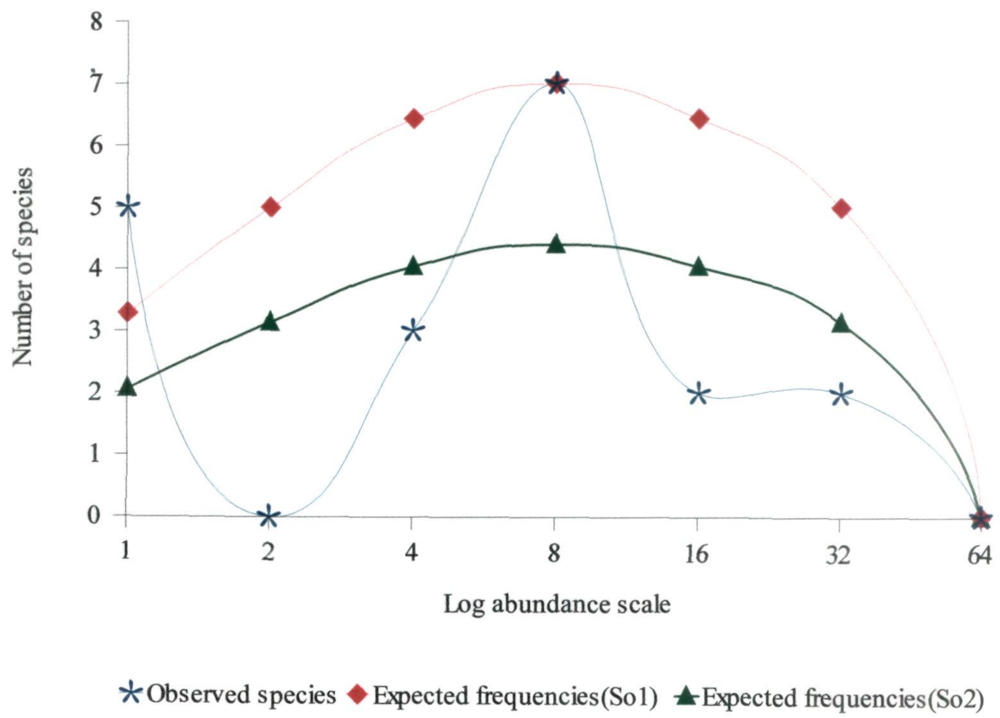


Fig. 5.10 Abundance-distribution pattern in mixed habitat in BWS during post monsoon and fitted log normal curves with a= 0.247.

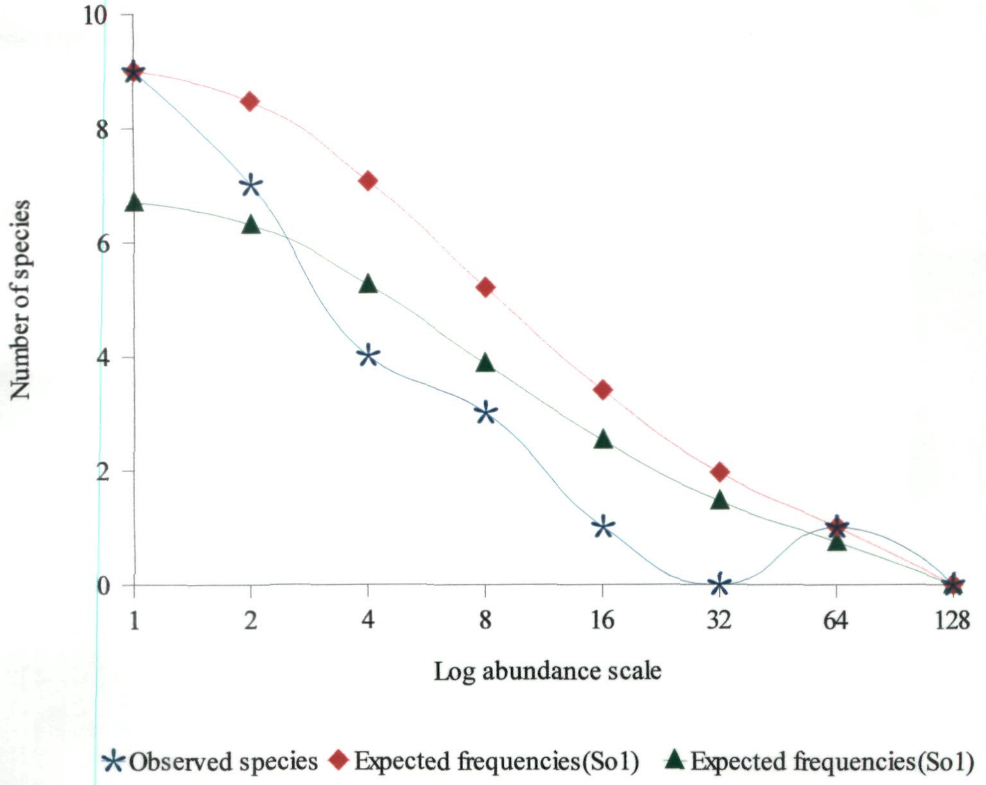
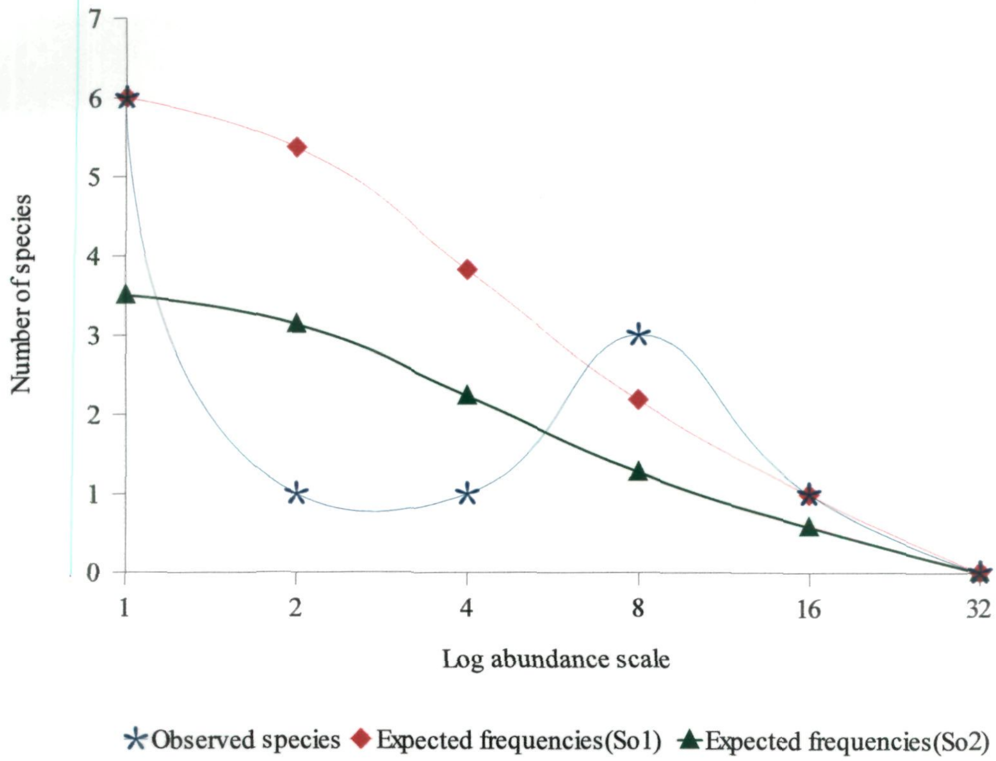


Fig. 5.11 Abundance-distribution pattern in riverine habitat in BWS during post monsoon and fitted log normal curves with a = 0.335.



5.3.3.2 *Distribution – Abundance model for Vinaiyak reserve forest*

At Vinaiyak reserve forest, the fitted curve approached towards normal distribution (Fig. 5.12). The observed number of species (93) was less than Binsar Wildlife Sanctuary (98) but the number of octaves were more than there. The expected frequencies were 138.4 and 83.02 at So = 19.0 and 11.4 respectively. The best fit for these data was with a = 0.224 and So = 83.02, which gave the theoretical number of species available for observation S* = 90 (Table 5.27).

5.3.3.2.1 *Distribution- Abundance model for Premonsoon season*

During premonsoon season, the observed number of species in Oak habitat was 61. The log normal curve showed (Fig. 5.13) more area under right hand side than the left. It means that some rare species were left unsampled in this habitat. The expected frequencies were 94.31 and 59.36 species at So = 17 and 10.7 respectively. Considering the second equation as a best fit at So = 10.7 & a = 0.293, the theoretical number of species available for observation was 64, which was very near to the observed number of species (61) (Table 5.27).

The Mixed habitat (67) had more species than oak habitat but the curve was less normally distributed (Fig. 5.14). A total of 67 species were observed and the number that was expected as shown by the model was 81 at So = 13.0 and 68 at So = 10.9 (Table 5.27), which was more than what was observed. The total number of species that could occur in the community was 111 using the second model with So = 10.9. A good number of species 44 were left unsampled.

Table 5.27 The Estimated frequencies and the observed species by fitting log normal model in different habitat types in premonsoon season in Vinaiyak reserve forest. a = parameter, obs = observed number of species , S(o) = observed number of species in the modal octave, S (R) = observed number of species in the octave, S* = theoretical number of species available for observation, χ^2 = goodness of fit test.

Habitat	**VRF**	**Oak**	**Mixed**
a	0.224	0.293	0.173
obs.	93	61	67
So_1	19	17	13
S (R)	138.4	94.31	81.33
S*	150.13	102.69	133
χ^2	36.62	21.22	4.15
So_2	11.4	10.7	10.9
S (R)	83.02	59.36	68.19
S*	90.08	64.63	111.52
χ^2	24.34	14.92	1.96

Fig 5.12 Abundance- distribution pattern in whole Vinaiyak and fitted log normal curves with a = 0.224.

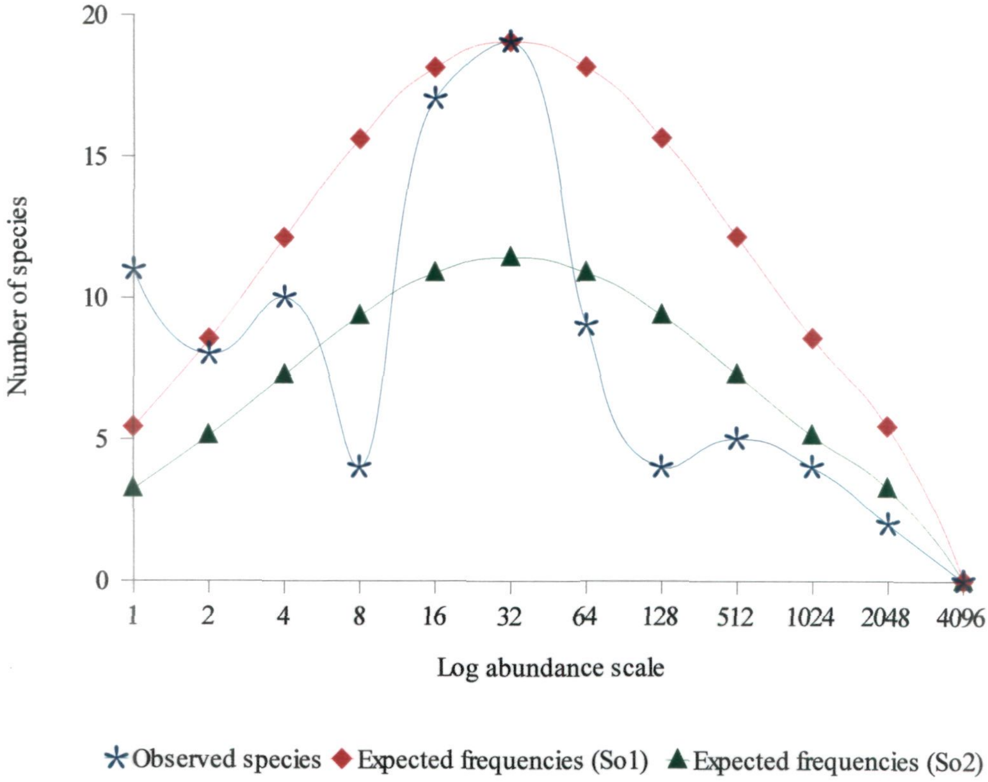


Fig. 5.13 Abundance-distribution pattern in oak habitat in Vinaiyak during premonsoon and fitted log normal curves with a = 0.293.

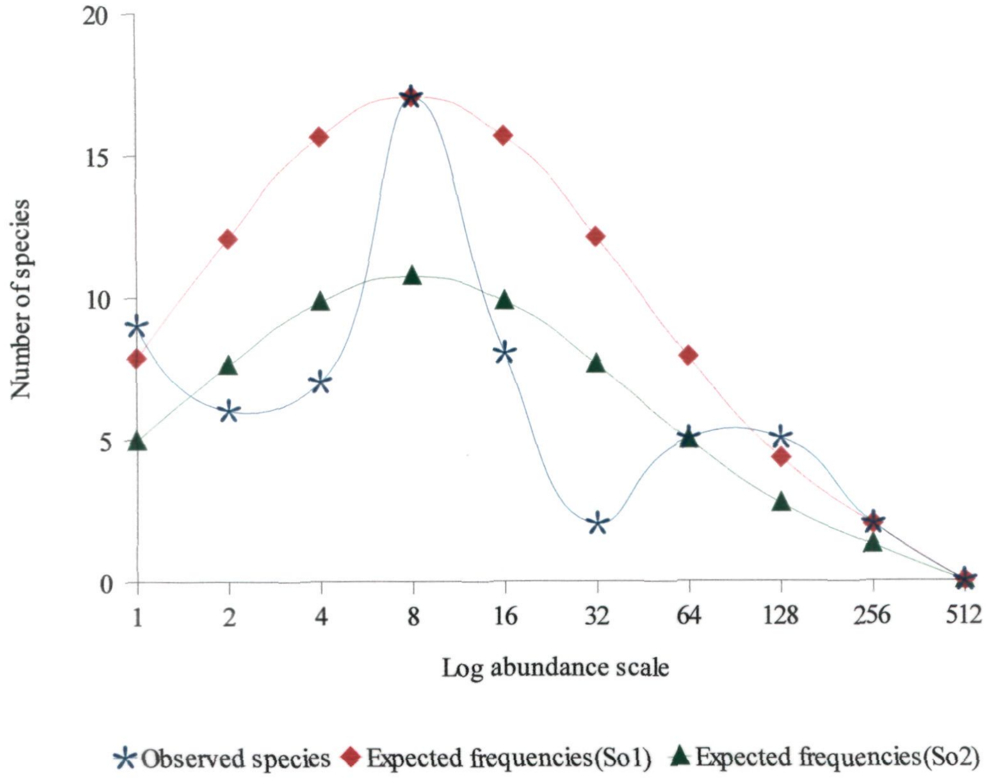
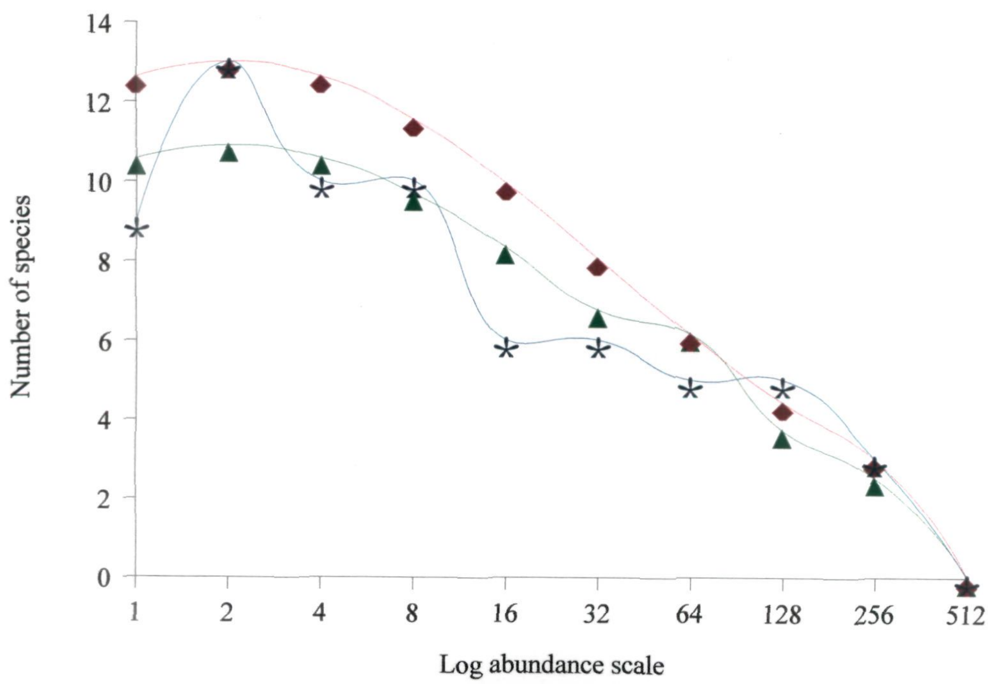


Fig. 5.14 Abundance-distribution pattern in mixed-coniferous habitat in Vinaiyak during pre monsoon and fitted log normal curves with a= 0.173.



5.3.3.2.2 *Distribution- Abundance model for Postmonsoon season*

The Oak habitat in postmonsoon season showed same pattern as Mixed habitat during premonsoon season. 46 observed species formed the total nine octaves. The expected frequencies were 70.9 at So = 12 and 44.90 at So = 7.6. The second set of parameters was found to be good fit for these data by a = 0.191 and So = 7.6. The expected number of species in the community was 70 (Table 5.28). The curve showed more area under the right hand side than the left (Fig. 5.15).

In Mixed habitat, the total number of observed species was 43, which was close to the number of species at So = 6.8 and a = 0.245 i.e. 42 (Table 5.28 & Fig. 5.16). The theoretical number of species available for observation S* gave a total of 49 species for the area which has six more species than the observed.

5.4 DISCUSSION

Data on the abundance of wildlife populations are critically important in the preparation of environmental assessments, which includes impact statements. Although techniques for censusing game species have received most emphasis in the past century, several techniques have also been developed to measure the absolute and relative abundance of avian populations. These methods vary widely in both degree of bias and sample variance. Generally, the mapping of territories of singing males (Williams, 1936; Enemar, 1959; Robbins, 1970) and locating all nests (Schiermann, 1930; 1934; Lack, 1935) are considered the least biased methods. These methods are presumed to be accurate because they require many hours of fieldwork and familiarity with an area and its bird populations, but true population densities, and degree of bias are infact unknown.

Table 5.28 The Estimated frequencies and the observed species by fitting log normal model in different habitat types in postmonsoon season in Vinaiyak reserve forest.

a = parameter, obs. = observed number of species , S(o) = observed number of species in the modal octave, S (R) = observed number of species in the octave, S* = theoretical number of species available for observation, χ^2 = goodness of fit test.

Habitat	Oak	Mixed
a	0.191	0.245
obs.	46	43
So_1	12	9
S (R)	70.9	56.04
S*	111.20	65.02
χ^2	17.11	6.48
So_2	7.6	6.8
S (R)	44.90	42.34
S*	70.42	49.13
χ^2	13.22	4.58

Fig. 5.15 Abundance-distribution pattern in oak habitat in Vinaiyak during post monsoon and fitted log normal curves with a = 0.191.

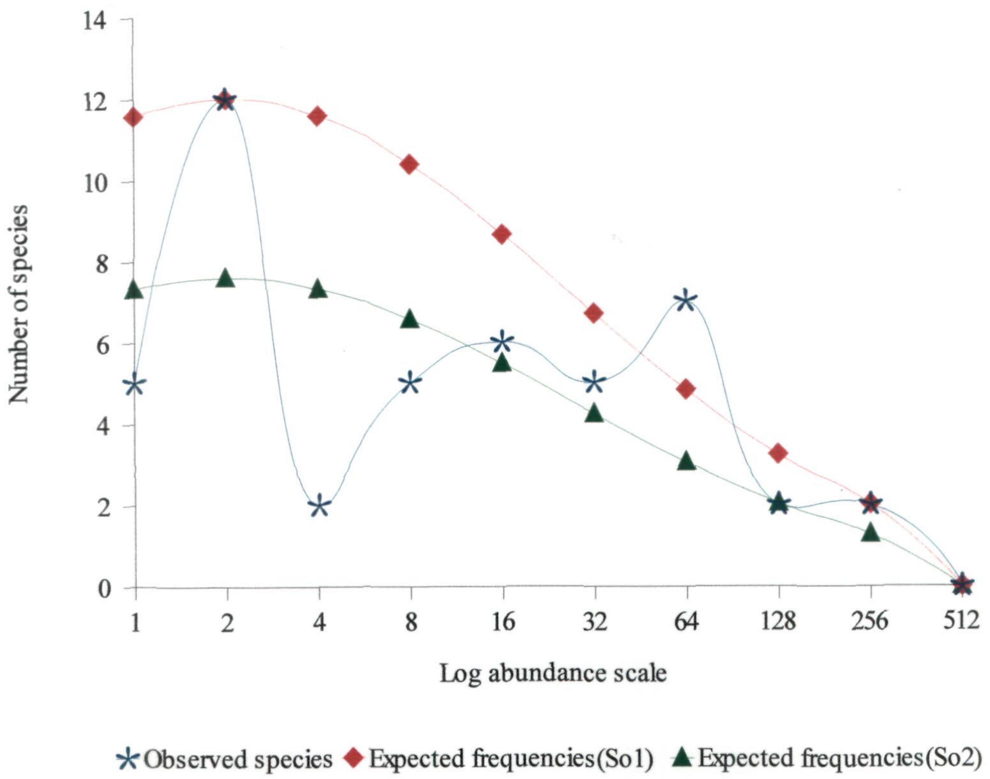
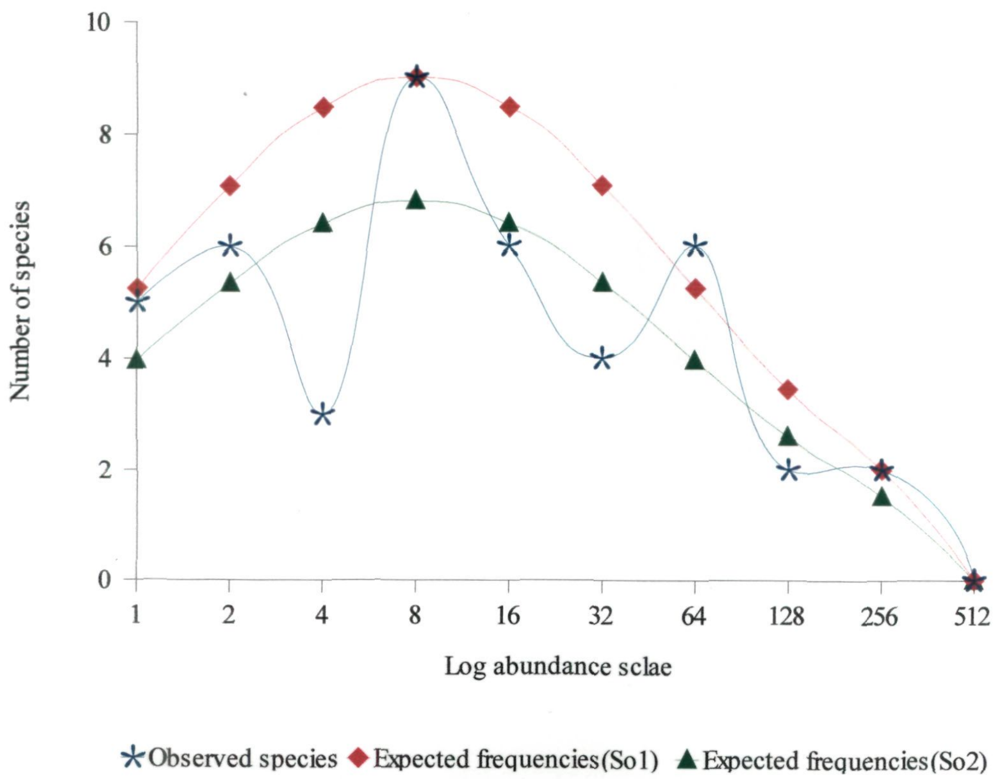


Fig.5.16 Abundance-distribution pattern in mixed- coniferous habitat in Vinaiyak during post monsoon and fitted log normal curves with a = 0.245.



The time required to employ these methods is extensive. Line transect methods are generally considered as less time consuming, but the bias and variance associated with line transect estimates is often deemed unacceptable (Enemar, 1959).

Some authors have examined the relative merits and inadequacies of line transect techniques. In an early study, Amman & Baldwin (1960) compared the accuracy and variation of five line transect methods when used to estimate density of woodpecker. Gates (1969) used computer simulation to evaluate the bias and variance of six line transect methods. Emlen (1971) reviewed the general characteristics and applicability of seven transect methods to estimate songbird numbers, but conducted limited field evaluation on only three methods. Robinette *et al.* (1974) evaluated the bias of 10 different line transect methods, but most of their field studies involved censuses of wooden blocks. Seber (1973), Eberhardt (1978) and Gates (1979) have provided detailed reviews of the development and theory of several line transect methods. Of these only the later included evaluation of the methods by examination of original field data. Burnham *et al.* (1980) discussed the properties and attributes of several line transect methods and have described some of the more robust methods in detail.

Recording birds in distance bands allows population densities to be estimated using distance sampling techniques (Bibby *et al.* 1992; Buckland *et al.* 1993). Since the detection of randomly distributed objects will decline with distance from a transect line, an increasing proportion of objects present will go undetected with distance. Detection declines with distance because birds close to the transect are more obvious, e.g. more easily heard or seen, or more likely to be flushed. Distance sampling methods model the decline in detectibility with distance for each species and incorporates an estimate of undetected individuals in the true density estimate (Bibby *et al.* 1992; Buckland *et al.* 1993). One of the strengths of the method is that it is able to estimate habitat- specific bird detectabilities, which otherwise confound density comparisons between habitats (Bibby & Buckland, 1987; Buckland *et al.* 1993).

I used distance sampling software developed by Buckland *et al.* (1993) (DISTANCE, version 2.2; Laake *et al.* 1994). As the data were collected in four distance bands, it was possible to fit a number of different models for the detection function. However, because the outer distance band was unbounded (e.g. birds were recorded to infinite distance), bird numbers in this outer class were difficult to interpret, yet preliminary analyses showed that they can have a considerable influence on model fits and density estimates. For this reason, I used bird data in all four classes and fit all models in all cases (on the advice of S.T. Buckland). A number of previous studies have used a half- normal detection function with binomial bird data (Bibby *et al.* 1985; Bibby & Buckland, 1987; Buckland *et al.* 1993). Distance sampling methods are based upon assumptions, the most important being i) that all birds on the transect line are detected; ii) that transect lines are randomly or systematically located; iii) that birds do not move in response to the observer prior to detection; iv) that distances are measured without error; v) that the detection curve has a shoulder, i.e. detection rates are high at first but then decline.

Bird densities were estimated within broad habitat types at both the intensive sites treating habitat separately (i.e. as strata) within DISTANCE. Detectability function was defined by stratum, since I expected large differences in detectability between habitats. In this way, density was calculated for species in each of the major habitats using species and habitat specific detection curves. Preliminary analyses using Oriental dove data of premonsoon season of BWS showed that model fits (as measured by the Akaike's Information Criteria; Akaike, 1973) were improved when the bird detectability function differed between habitats compared to a model in which the detection function was same across the habitats. This confirms that some birds are easier to detect in some habitats and supports this modeling approach.

There are major problems of detectibility within any study that attempts to compare density between habitats that are typically dense, with degraded habitats where the vegetation has been cleared. Within a dense habitat more effort is needed to record all of the species present. There will also be fewer encounters so that less density can be calculated compared to a more open habitat. One of the major assumptions of the distance method is that all birds at zero meters are detected (Buckland, 1993). This assumption is clearly violated to a greater degree in dense habitats where the transect line is not visible ahead, compared to open habitats, where birds are more likely to be seen moving away from the observer. The net result of all the biases due to detectability are that the number of calculable densities and the actual densities calculated will all be lower in a dense, pristine habitat relative to an open, degraded habitat. The bird density was found to be higher in premonsoon season in BWS while in Vinaiyak it was higher in postmonsoon season though the difference was not significant during premonsoon and postmonsoon densities at the latter site. Generally high bird densities were found in summer (Bell, 1980; Recher *et al.* 1983; Osborne & Green, 1992). The detection of resident species was highest during premonsoon. In breeding season the chances of encountering birds are higher than in non- breeding season. The difference in density pattern in BWS and VRF was mainly because of their locations. During postmonsoon, the less local migrants and migrant species were recorded in Binsar than in Vinaiyak. The VRF is situated along the ridge and the forest touches with the forest of Corbett National Park at lower altitude, which provides subtropical and tropical conditions whereas BWS is an isolated forest pocket surrounded by degraded oak-pine and pine forest and there is no continuous forest. In extreme weather conditions (snowfall), the birds find no suitable place to go for any activity whereas in VRF, they find more suitable tropical conditions in continuos forest. For e.g. the local migrants such as Black & yellow Grosbeak, Orange-flanked bush robin, White-collared Black bird were recorded in VRF in early March and then disappeared from the area and again arrived in November and December. What needs to be appreciated is not the inconsistency of this observation with those of other workers, but it may point towards the importance of Vinaiyak forest as wintering sites for local migrants and migrant species.

Whittaker (1975) reviewed the uses and interpretation of species importance curves (abundance- distribution curves) in the analysis of dominance and diversity in communities. In the communities with low species richness, these curves approach a straight line or geometric form. Such communities are dominated by a few abundant species, followed by a continuum of rare ones. Species rich communities, tend to have similar number of common and rare species, and more of intermediate importance. In such communities where diversity is higher, species importance curves approach the lognormal form of Preston (1948). Species importance curves have been used to infer competitive interactions and pattern of niche partitioning in avifauna (Rev, 1975). The shapes of these curves are probably affected by competition for food, but no general agreement exists regarding their theoretical implications or the conclusions can be drawn from them (Whittaker, 1975).

CHAPTER 6

HABITAT USE

6.1 INTRODUCTION

Bird population and species have often been associated with different plant communities (eg. Adams, 1908; Beecher, 1942; Kendeigh, 1948; Twomey, 1945). Several studies have identified the factors responsible for variations in avifauna from habitat to habitat outside India (Anderson, 1970; Beedy, 1981; Manuwal, 1983) and within India (Beehler *et al.* 1987; Danials, 1989; Johnsingh *et al.* 1987; Javed, 1996). Studies on bird species diversity became widespread after Robert MacArthur and associates (MacArthur & MacArthur, 1961; MacArthur *et al.* 1962; 1966) showed that within a given region, information theory measures of bird species diversity and of habitat structure are linearly related. Within broad limits, these diversity studies showed that structural aspects of habitats can be used to predict diversity and are at least correlated with features of the habitat that the birds themselves use (Cody, 1985).

MacArthur & MacArthur (1961) indicated that bird species diversity was associated with foliage height diversity. Although their studies have been disputed in different forest types but the work they conducted helped other workers in defining habitat variables. In establishing bird-habitat relationship, the multivariate techniques are of much use. By using this technique, James (1971) was able to show how a perceptual cue of the environmental, called a 'niche gestalt' could be defined for each bird species based on information from multivariate tests. Although multivariate statistical analyses have been frequently applied in different studies (Tomoff, 1974; Wiens & Rotenberry, 1981; Rotenberry, 1985; Moskat, 1988), the analysis of bird-vegetation relationships suffers from methodological problems (Moskat, 1991). The [site x birds x vegetation] type data matrices cannot be analyzed directly by standard ordination techniques. Methodological problems increase when the ecological data relate to long ecological gradients, such as in a successional sere (Gauch, 1982).

The present chapter deals with the multivariate techniques by keeping following objectives in mind-

- To estimate the bird species diversity (BSD) and richness (BSR) in general and in different habitat types of Binsar WLS and Vinaiyak RF in particular.
- To observe the seasonal pattern in BSD and BSR.
- To observe the effect of disturbance on BSD and BSR.
- To establish the bird community relationship with habitat variables and structure (vertical heterogeneity and horizontal heterogeneity).

The following null hypotheses were set for this study-

- There is a significant difference in BSD and BSR in different seasons.
- Disturbance has significant effect on BSD and BSR and diversity values are less in disturbed area.
- Bird species diversity and richness have significant positive relationship with foliage height diversity.

6.2 METHODOLOGY

6.2.1 Data collection

Sampling of birds at different sites and in different habitat types have been explained in earlier chapters.

Habitat structure is known to play a key role in determining bird community structure as well as diversity and richness (MacArthur & MacArthur, 1961; Willson, 1974). Therefore data on following habitat variables were also collected: Tree density, diversity and richness, tree cover, shrub density, shrub diversity, shrub richness, ground cover, vertical heterogeneity, horizontal heterogeneity or patchiness. Vegetation sampling has been discussed in separate chapter in detail. Vertical heterogeneity was estimated at the vegetation plots by noting the foliage on ordinal scale i.e. low = 1, medium = 2 and high = 3 in the height intervals 0-1m, 1.1-2m, 2.1-4m, 4.1-8m, 8.1-16m, 16.1-24m, 24.1-32m and >32m directly above and within a 0.5m radius of these points. These observations were taken at 5m and 10m distance from the center point in four directions i.e. total eight observations were taken at each plot. An aluminium pole of 4m height was used for this exercise, beyond this height it was not possible because of rough terrain.

During surveys, to assess the impact of degradation on avian community, data were collected on lopping, cutting and cattle dung at each point. Human and livestock population was also recorded for every dependent village on oak patch.

6.2.2 Analyses

6.2.2.1 *Diversity and Richness estimation*

Data collected by line transect and point count methods were analyzed for intensive sites and surveyed sites respectively to calculate bird species richness and diversity.

Species richness was calculated by Margelef's richness index,

RI = S-1 / ln N

where, S = Total number of species, N = Total number of individuals

Species diversity was calculated by using Shannon-Weiner index (Magurran, 1988),

$H' = - \Sigma \text{ pi ln pi}$

where pi = proportion of individuals found in the i^{th} species

This index assumes that individuals are randomly sampled from an 'indefinitely large' population (Pielou, 1975). This index also assumes that all species are represented in the sample.

The diversity was also calculated at each point for vertical heterogeneity and the coefficient of variation of the mean number of vertical strata per point was used as the index of horizontal heterogeneity (Daniels *et al.* 1992).

6.2.2.2 *Habitat use analysis*

One of the aims of vegetation analysis was to be able to later correlate bird community attributes to vegetation variables. When dealing with an n-dimensional data matrix, interpretations may be more meaningful if the number of axes can be reduced to a number, which can be easily visualized. Principal component analysis (PCA) can be used to accomplish such a task. PCA produces linear combinations of the original variables in such a manner as to explain progressively smaller portions of the total variance in the data. This total variance is the sum of the variances for each of the variables. The first axis is constructed so that linear combination of variables represents the greatest amount of response variance. The second axis, which is orthogonal to the first, represents the second greatest amount of variance and so on. The sum of the variance of components is the total variance. Data were subjected to PCA in order to produce an ordination of vegetation attributes. Before performing PCA, data were converted to standardised form by subtracting from each observation the mean of the data set and dividing it by the standard deviation (Zar, 1984). The new variable had mean of zero and variance of one. The procedure is very useful if one wishes to compare the distribution of one variable to that of another when the two variables are expressed in different units of measurement (Davis, 1973). In order to minimize problems associated with multicollinearity (Neter & Wasserman, 1974), some environmental variables, which were highly correlated with others, were omitted (Table 6.1). PCA was run seasonwise, as data were collected accordingly. Then multiple regression analysis was performed by taking bird species diversity and richness as dependent factors and extracted factors as independent factors, to see the relationship between bird and vegetation attributes.

Multivariate statistical methods are frequently used to analyze ecological data. There are many types of distributions of ecological data, and of species responses along ecological gradients (Austin, 1979; 1985). In Vinaiyak reserve forest, Whittaker's (1987) vegetation-environment plexus concept for general ecological application was extended. Moskot (1991) proposed to call it the multivariate plexus concept to indicate that it is based on multivariate analyses, like the eigen vector ordination techniques and non-metric multidimensional scaling. The multivariate plexus procedure maps the physiognomic and floristic components into a low-dimensional space together with the bird species diversity and richness, and it demonstrates graphically the degree of their interrelationships. Vegetation variables were separated into two categories: physiognomic characteristics of the habitat and floristic composition. The basic physiognomy variables are listed in Table 6.1.

The floristic variables included measures of the percentage contribution of tree species to the tree foliage cover and the same for shrub species contributions to shrub foliage cover. Table 6.2 shows the tree species and shrub species taken into account for both premonsoon and postmonsoon season. The rare species were omitted from the analysis. Tree species were same for both the seasons as it hardly changes in the span of two-three months but shrub cover varied in terms of species and cover.

Variables showing non normal distributions were standardised. The measurements were arranged in four-way data matrix (quadrates x vegetation physiognomy x vegetation floristic x bird attributes). The main steps are as follows:

1. Principal Component Analysis (PCA) to reduce the physiognomy data set.
2. Detrendend Correspondence analysis (DCA) to simplify the floristic data set.
3. Evaluation of the relation between vegetation (physiognomy and floristic) components and bird attributes by Kendall's rank correlation coefficients.

4. An ordination of the vegetation components and bird attributes by non-metric multidimensional (NM-MDS) scaling into a common space of reduced dimensionality.

The PCA started from the correlation matrix. Here components having eignvalue greater than 1.0 were considered to be important (Harman, 1976). Following PCA, the VARIMAX orthogonal rotation technique was applied to construct easier interpretable pattern of component loadings.

The floristic data collected at each of the 90 quadrates contained many zero values, which could cause distortions in PCA (Swan, 1970). To avoid these, the classical DCA was chosen to reveal the structure of floristic data. Program DECORANA (Hill, 1979) was applied and only the first two axes were used for representation of the floristic data.

Kendall's rank correlation coefficient was used for a direct measurement of bird-habitat relations. Coefficients were computed between all possible pair wise combinations of vegetation components and bird species attributes using the SPSS/PC+ program package. As the NM-MDS program applied needs a distance matrix for input, complements of the rank correlations were computed.

$C_{ij} = 1 - \text{abs}\ (\tau)$, where c = complement coefficient, τ = Kendall's rank correlation coefficient, i j = variable indices.

The ordination of vegetation physiognomic and floristic components together with bird attributes was carried out by NM-MDS. This technique rearranges points in a reduced dimensionality space with the provision that the rank order of the new between-point distances must agree with the rank order of the original distances as closely as

Table 6.1 Variables, which were taken into account and discarded in PCA during survey and in premonsoon (Pre) and postmonsoon season (Post) at Binsar Wildlife Sanctuary (BWS) and Vinaiyak Reserve forest (VRF).

Variables	Survey	BWS		VRF	
		Pre	Post	Pre	Post
Altitude	+	-	-	+	+
Slope	+	-	-	+	+
Patch size	+	-	-	-	-
Tree cut	+	+	+	+	+
Tree lop	+	dropped	+	+	+
Cattle dung	+	+	+	+	+
Tree cover	+	+	+	+	+
Tree density	+	+	+	dropped	dropped
Tree diversity	+	dropped	dropped	dropped	dropped
Tree richness	+	+	+	+	+
Shrub density	+	+	+	+	+
Shrub diversity	+	dropped	+	dropped	dropped
Shrub richness	+	dropped	dropped	dropped	dropped
Seedling density	+	+	+	-	-
Seedling diversity	dropped	dropped	+	-	-
Seedling richness	dropped	+	dropped	-	-
Sapling density	+	+	+	-	-
Sapling diversity	dropped	dropped	dropped	-	-
Sapling richness	dropped	dropped	+	-	-
Herb density	+	+	+	dropped	dropped
Herb diversity	dropped	+	dropped	+	+
Herb richness	dropped	dropped	dropped	dropped	dropped

Grass density	+	dropped	+	+	+
Grass diversity	dropped	dropped	dropped	dropped	dropped
Grass richness	dropped	dropped	+	dropped	dropped
Vertical diversity	-	-	+	+	+
Horizontal heterogeneity	-	-	+	+	+
Insect biomass	-	-	-	+	+

Table 6.2 List of dominant tree and shrub species of Vinaiyak taken into account for DECORANA.

Season	Tree species	Shrub species
Premonsoon	*Quercus leucotricophora*	*Nerium* sp.
	Quercus floribunda	*Myrcine africana*
	Rhododendron arboreum	*Daphne papyracea*
	Lyonia ovalifolia	*Athyrium* sp.
	Abies pindrow	*Rubus biflorus*
	Cedrus deodara	*Berberis aristata*
	Pinus wallichiana	*Boeninghausienia albiflora*
	Viburnum mullaha	*Polysticum squarossum*
	Litsea umbrosa	*Thalictrium.foliolosum*
		Indigofera heterantha
		Arundinella nepalensis
Postmonsoon	*Quercus leucotricophora*	*Nerium* sp.
	Quercus floribunda	*Myrcine africana*
	Rhododendron arboreum	*Daphne papyracea*
	Lyonia ovalifolia	*Athyrium* sp.
	Abies pindrow	*Rubus biflorus*
	Cedrus deodara	*Berberis aristata*
	Pinus wallichiana	*Boeninghausienia albiflora*
	Viburnum mullaha	*Polysticum squarossum*
	Litsea umbrosa	*Thalictrium foliolosum*
		Indigofera heterantha
		Arundinella nepalensis

possible (Davison, 1983). All analyses were performed on SPSS/PC+ 7.5 version software package (Norusis, 1990).

6.3 RESULTS

6.3.1 Diversity pattern in Binsar Wildlife Sanctuary

The bird species diversity and richness were calculated in different habitat types of Binsar Wildlife Sanctuary (BWS). These indices were calculated season wise and the effect of disturbance was also observed.

6.3.1.1 *Diversity pattern in different habitat types of BWS*

In BWS four habitat types were identified; oak, pine, mixed and riverine. Paired sample t-test showed significant difference in bird species diversity of oak and pine forest ($t = -3.16$, $p < 0.006$) as well as in bird species richness ($t = -2.36$, $p < 0.03$) during premonsoon season. Differences were also observed in mixed and pine forest ($t = 3.90$, $p < 0.006$) for bird diversity and bird richness ($t = 3.64$, $p < 0.008$) in postmonsoon season. Pine and riverine habitats also differed significantly in terms of bird richness ($t = -2.79$, $p < 0.02$) during postmonsoon season. Bird diversity and richness were highest in pine habitat during premonsoon while diversity was highest for riverine and richness was highest in oak habitat during postmonsoon season. None of the other habitats were significantly different from each other in terms of bird species diversity and richness across the seasons (Table 6.3).

6.3.1.2 *Seasonal patterns in diversity measures of birds*

Data were pooled into two seasons, premonsoon and postmonsoon, to find out seasonal differences in the total number of birds (Table 6.3). Paired sample t-test revealed significant difference in bird species diversity ($t = -10.89$, $p < 0.001$) and richness ($t = 9.37$, $p < 0.001$) between the seasons at BWS. Significant differences in bird species diversity and richness were observed in all habitats between seasons (Table 6.4).

The null hypothesis is accepted here by having significant differences in different habitat types in different seasons. The diversity and richness were higher during premonsoon season in all habitat types than the postmonsoon season.

6.3.1.3 *Effect of disturbance on avian community*

To observe the effect of disturbance on birds in different habitats, paired sample t-test was performed. Significant differences were observed in pine habitat during premonsoon season for bird species diversity ($t = -2.73$, $p < 0.02$) in BWS. There was no significant difference in bird species diversity of disturbed and undisturbed habitats of oak during premonsoon season (Table 6.5). Significant differences were observed in bird species diversity and richness in overall disturbed and undisturbed habitats in premonsoon (BSD $t = 2.59$, $p < 0.01$; BSR $t = 2.89$, $p < 0.01$) as well as in postmonsoon season (BSD $t = 4.21$, $p < 0.001$; BSR $t = -3.13$, $p < 0.007$). Diversity and richness were maximum in disturbed habitats.

The null hypothesis is rejected because the diversity and richness were found to be higher in disturbed habitats in both seasons.

Table 6.3 Seasonwise bird species diversity (BSD) and bird species richness (BSR) in different habitats in Binsar Wildlife Sanctuary during 1996-97.

Season		Oak	Pine	Mixed	Riverine
Premonsoon 96	BSD	2.26	2.66	2.41	2.37
	BSR	3.12	3.66	3.03	3.17
Postmonsoon 97	BSD	1.33	1.02	1.31	1.41
	BSR	1.83	1.26	1.75	1.79

Table 6.4 Paired sample t- test values within habitat types for Birds species diversity (BSD) and richness (BSR) in different seasons of BWS.

Diversity measures	Oak	Mixed	Pine	Riverine
BSD	5.02(16)***	5.29(7)*	7.18(15) ***	5.43(8) ***
BSR	4.41(16) ***	3.72(7)**	7.12(15) ***	6.03(8) ***

d.f. in parentheses

*= significant at 0.001 level, ** = significant at 0.007 level , *** = significant at 0.000 level

6.3.2 Diversity patterns in Vinaiyak reserve forest

The diversity indices were measured in the similar manner as in Binsar Wildlife Sanctuary.

6.3.2.1 *Diversity pattern in different habitat types*

In VRF, two habitat types were found i.e. oak and mixed coniferous forest. Maximum bird diversity and richness were calculated for oak forest (2.49 & 3.30) during premonsoon season as well as during postmonsoon season (2.22 & 2.80) (Table 6.6). No significant difference was observed in oak and mixed forest in terms of bird diversity and richness. Both forest types contained more or less same abundance of species.

6.3.2.2 *Seasonal variation in diversity measures in Vinaiyak*

During premonsoon season, bird species richness was high in comparison to postmonsoon season (Table 6.6) in Vinaiyak reserve forest. Significant difference was observed only in mixed habitat in bird species richness ($t = 2.03$, $p < 0.05$) for both seasons. In oak habitat also, bird species diversity and richness was high during premonsoon than postmonsoon season. But there was significant difference in overall bird species diversity ($t = -10.89$, $p < 0.001$) and richness ($t = 9.37$, $p < 0.001$) during premonsoon and postmonsoon season. Increasing number of species during premonsoon may be due to resident species.

6.3.2.3 *Effect of disturbance on diversity measures in Vinaiyak*

In Vinaiyak reserve forest, significant differences were observed for bird species diversity in oak habitat for pre ($t = 2.36$, $p < 0.02$) and postmonsoon seasons ($t = 16.09$, p

Table 6.5 Seasonwise mean bird species diversity (BSD) and bird species richness (BSR) in disturbed (D) and undisturbed (UN) area in different habitat types in Binsar WLS.

Season		Oak		Pine	
		D	UN	D	UN
Premonsoon 96	BSD	2.35	2.18	2.95	2.38
	BSR	3.54	2.71	4.04	3.28
Postmonsoon 97	BSD	1.81	0.91	1.51	0.53
	BSR	2.21	1.49	1.87	0.66

Table 6.6 Seasonwise bird species diversity (BSD) and bird species richness (BSR) in different habitats in Vinaiyak Reserve forest during 1998.

Season		Oak	Mixed
Premonsoon	BSD	2.49	2.48
	BSR	3.30	3.29
Postmonsoon	BSD	2.22	2.20
	BSR	2.80	2.70

< 0.00) while in mixed habitat, it appeared only during postmonsoon season ($t = 5.68$, $p < 0.00$). Bird species richness also showed significant differences during pre ($t = 3.50$, $p < 0.002$) and postmonsoon season ($t = 3.78$, $p < 0.002$) in oak habitat but only during postmonsoon in mixed coniferous forest ($t = 2.67$, $p < 0.01$) (Table 6.7).

Overall bird species diversity in disturbed and undisturbed habitats were not significantly different during premonsoon while it was significant in postmonsoon season ($t = 5.56$, $p < 0.00$).

6.3.3 Habitat use

6.3.3.1 *Survey*

The principal component analysis is based upon the vegetation structure of all 120 censuses. The question of how all 24 variables are related was simplified by eliminating variables of the vegetation, which were redundant, adding no new information as to how forests vary. Eight variables were deleted with little loss of explanatory information. The choice of these eight variables was determined by examining repeated principal component analyses in which different combinations of the variables had been entered into the program.

The interpretation of principal component axes is based on the relative sizes of correlations between axes and originally measured variables. This is accomplished by examination of sets of correlations within components (Table 6.8). Correlations between the components and the originally measured variables suggest the following interpretation of the axes:

Table 6.7 Seasonwise mean bird species diversity (BSD) and bird species richness (BSR) in disturbed (D) and undisturbed (UN) oak and mixed habitats in Vinaiyak reserve forest.

Season		Oak		Mixed	
		D	UN	D	UN
Premonsoon 98	BSD	2.4	2.57	2.57	2.44
	BSR	3.66	4.13	4.02	3.97
Postmonsoon 98	BSD	2.29	1.76	2.34	1.74
	BSR	3.04	2.11	3.29	2.32

a. PC I expressed the trend for the tree density, tree diversity, tree richness and sapling density to increase together (open to close forest) and it explained 24.97% of total variance.

b. PC II was dominated by increase in canopy cover and shrub density, diversity and richness (thick canopy cover with dense ground cover) and it explained 19.19% of total variance.

c. PC III was related to increase in patch size, low disturbance in terms of cattle dung and relatively high ground cover and it explained 17.68% of total variance.

Oak patches with high tree density and diversity had high value on PC I. Areas like Kunjakharak, Sunderdunga and Sobala had low scores on this axis. Munsiary, Gasi, Duku and Daphiadhura scored high on this axis. Pindari, Mukteshwer and Gager were particularly high on PC II, reflecting their high canopy cover in combination with ground cover. Sunderdunga, Pindari, Gasi and Sobala possessed high scores on PC III (large patch size, high ground cover).

Multiple regression models were constructed using dimension values and bird diversity, richness and density values explained 31.6% of the variation in bird species diversity (Table 6.9) and 28.0% of the variation in bird species richness (Table 6.10). Bird diversity and richness increased with low disturbance, high ground cover and small patch size. Patch size should not be considered here as a dominant variable as it was having low loading on the PC III. But low disturbance and high ground cover had high loading PC III. Bird density was not correlated with any of the factors.

Table 6.8 Principal component analysis based on a correlation matrix of 16 of the variables during survey.

Variables		PC I	PC II	PC III
	% variance	24.97	19.19	17.68
	Total variance	61.84 %		
Altitude		-0.122	-0. 036	0.168
Canopy cover		-0.394	0.512	0.240
Cattle dung		0.166	-0.137	-0.752
Grass density		-0.056	0.047	-0.812
Herb density		0.328	0.018	0.732
Seedling density		0.089	0.307	0.101
Shrub density		- 0.269	0.867	0.172
Shrub diversity		0.331	0.892	0.008
Sapling density		0.746	-0.377	0.427
Shrub richness		0.306	0.908	-0.128
Tree cover		0.376	0.217	-0.440
Tree density		0.528	0.146	0.466
Tree diversity		0.945	0.135	0.011
Tree richness		0.911	0.176	-0.067
Lopping		0.225	-0.440	-0.466
Slope		-0.024	-0.059	-0.079
Patch size		0.033	0.026	0.510
Eigen value		4.24	3.26	3.007

6.3.3.2 *Binsar Wildlife Sanctuary*

Since the two seasons were sampled in Binsar Wildlife Sanctuary so the habitat use evaluation was performed seasonwise.

6.3.3.2.1 *Premonsoon season*

The principal component solution described patterns of the environmental characteristics of bird species diversity and richness on the basis of three independent dimensions rather than 11.

Components may be defined by a concise description of the common features associated with the variables loading upon them. Component scores for each variable were calculated. The pattern of factor loadings on PC I showed that all of the weights were of the same approximate magnitude (Table 6.11).

Overall six components were extracted by PCA whose eigen values were >1.00. First three components were selected for describing environmental attributes as they contributed maximum variance in equation.

Component I: Variables loading on PC I were canopy cover, tree density, tree diversity, seedling density and shrub density. This component deals with close canopy and dense forest. Tree density and diversity had higher component scores.

Multiple regression analysis showed no significant correlation between Bird species diversity and component I. While Bird species richness was significantly negatively correlated with it. It accounted for only 7% variance (Table 6.12). Explaining it in another manner that during premonsoon season birds preferred more open forest than close and dense stands.

Table 6.9 Multiple regression analysis on Bird species diversity during survey. R^2 = coefficient of determination, F = F value.

Model	Variables	Correlation	R^2	F	Significance
PC III	High ground cover, Low disturbance, Large patch size	-	0.316	6.92	0.01

Table 6.10 Multiple regression analysis on Bird species richness during survey. R^2 = coefficient of determination, F = F value.

Model	Variables	Correlation	R^2	F	Significance
PC III	High ground cover, Low disturbance, Large patch size	-	0.280	5.83	0.02

Component II: The variables loading on PC II were cattle dung, herb density, herb diversity, canopy cover and seedling density. This component dealt with more open forest as well as with enough ground cover and had disturbance.

Stepwise Regression model showed no correlation with bird species diversity but it showed positive relation with bird species richness (Table 6.12). This relationship strengthened the early model i.e. birds preferred disturbed and open forest more than the close one. Bird species diversity and richness were also found to be maximum in Pine forest, which was more open and disturbed than the oak forest. Daniels (1992) and Javed (1996) also found the same results in Western Ghats and Terai region respectively.

Component III: Variables loading on Component III were seedling richness, tree density, cattle dung and tree cut. This component described less disturbed and dense forest in terms of trees. No significant correlation was found between III component and bird species diversity and richness. These extracted components convey general patterns as to how vegetation structure and bird communities are organized.

6.3.3.2.2 *Postmonsoon season*

Since data collection was made seasonwise, it was analyzed accordingly. Bird community showed different patterns of diversity and richness in different seasons (Beedy, 1981; Thiollay, 1994). Because PCA is usually based on a correlation matrix, it is of value to examine the correlations among vegetation variables. Many variables were highly correlated with each other. Horizontal heterogeneity was negatively correlated with vertical diversity, tree density and shrub diversity. It depicted the forest with uniform stands in horizontal manner but not in vertical position. Increasing tree numbers

Table 6.11 Factor loadings for the first, second and third principal components during premonsoon season 1996 in Binsar Wildlife Sanctuary.

Variables		PC I	PC II	PC III
	% variance	33.62	13.36	11.57
	Total variance	58.55%		
Canopy cover		0.473	-0.616	0.174
Cattle dung		0.083	0.578	-0.542
Tree cut		-0.209	-0.092	-0.613
Herb density		-0.039	0.779	0.083
Herb diversity		-0.199	0.766	0.056
Seedling density		0.387	-0.479	0.159
Shrub density		0.616	-0.242	0.097
Seedling richness		0.125	-0.008	0.778
Sapling density		0.223	-0.183	0.023
Tree density		0.839	-0.230	0.327
Tree richness		0.897	-0.041	0.035
Eigen values		3.69	1.47	1.27

Table 6.12 Multiple regression analysis on Bird species richness during premonsoon season in Binsar Wildlife Sanctuary. R^2 = coefficient of determination, F = F value.

Model	Variables	Correlation	R^2	F	Significance
PC I	High canopy cover, Tree density, richness, Shrub density	-	0.073	4.56	0.03
PC I					
PC II	Low canopy cover, Seedling density, High herb density, diversity and cattle dung	+	0.145	4.83	0.01

as well as shrub diversity decreased the patchiness. Canopy cover was also positively correlated with tree density, richness and shrub density, diversity, showing the dense and mature forest. Whereas it was negatively correlated with grass and herb density and these two variables were also negatively correlated with tree density and richness. This corresponds to going from dense and mature forest to the open with high ground cover forest.

The results of the PCA are summarised in Table 6.13. The first component accounted for 25.8% of the variance in the original data. Tree density, richness, and shrub density, diversity and canopy cover as well as tree cut showed positive correlations with the first axis. This axis also showed negative correlations with herb richness and seedling density. Therefore, this axis represented a gradient starting with the disturbed forest areas with dense cover to open areas with high ground cover. Stepwise regression displayed that bird species diversity and richness were positively correlated with this axis (Table 6.14 & 6.15). It suggests that birds preferred dense but disturbed forest in postmonsoon season. Species diversity and richness were found maximum in riverine habitat and disturbed oak habitat respectively.

The second axis, which accounted for an additional 12.57% of the variance, was correlated positively with grass density, richness and herb density and negatively correlated with canopy cover, tree density and seedling diversity. This corresponds to a gradient going from areas of low canopy cover with high ground cover. Bird species diversity and richness were not at all correlated with this axis. But these diversity measures were correlated with first axis, which is just opposite to second axis and self-explanatory.

Table 6.13 Factor loadings on first, second and third components extracted during postmonsoon season 1997 in Binsar Wildlife Sanctuary.

Variables		PC I	PC II	PC III
	% variance	25.80	12.57	11.01
	Total variance	49.38%		
Canopy cover		0.266	-0.790	0.035
Cattle dung		-0.065	0.227	-0.108
Lopping		-0.111	-0.014	-0.035
Tree cut		0.574	-0.126	0.005
Vertical diversity		0.045	0.045	-0.047
Horizontal heterogeneity		-0.100	-0.004	-0.023
Grass density		-0.191	0.846	-0.152
Grass richness		0.049	0.292	0.019
Herb density		0.072	0.724	-0.041
Seedling density		-0.290	-0.214	0.734
Seedling diversity		0.147	-0.298	0.794
Shrub density		0.811	0.025	0.118
Shrub diversity		0.833	-0.102	0.188
Sapling density		0.305	0.179	0.780
Sapling richness		0.318	-0.005	0.678
Tree density		0.571	-0.446	0.143
Tree richness		0.743	-0.236	0.095
Eigen values		4.38	2.13	1.87

Third axis accounted for an 11.01% of the variance and it was correlated with seedling density, diversity and sapling density and diversity. It represented areas with more shrub layer rather than tree and ground cover. Bird diversity measures were not correlated with this axis also.

So the best predictor model for bird species diversity and richness was the PC I, which explained 25.80% of the variation.

6.3.3.3 *Bird- Habitat relationship in Vinaiyak Reserve Forest*

Two seasons, i.e. premonsoon season and postmonsoon seasons were sampled in Vinaiyak reserve forest also. The multivariate plexus analysis was performed on this context.

6.3.3.3.1 *Premonsoon season*

For the multivariate plexus-procedure, rare species of birds were omitted from the data set. Vegetation physiognomy components were extracted by PCA. Four eigen values showed values larger than 1.0, accounting for 67.87% of the total variance. The contribution of the fourth eigen vector was only 13.32% and the scree-test suggested the use of only first three components. It is desirable to reduce the number of components to two or three if possible (Pielou, 1984), so first three components were selected to represent vegetation physiognomy. The structure of component loadings can be more easily interpreted after a VARIMAX orthogonal rotation, because this rotation technique attempts to increase high loadings on a component and reduces small loadings to zero, maximizing the variance of component loadings (Bennett & Bowers, 1976). An

Table 6.14 Stepwise multiple regression analysis on three components by taking bird species diversity as a dependent variable. R^2 = coefficient of determination, F = F value.

Model	Variable	R^2	Correlation	F	Significance
PC I	High tree density, richness, canopy cover, shrub diversity, low herb richness and seedling density, high tree cut	0.07	+	4.83	0.03

Table 6.15 Stepwise multiple regression analysis on the three components by taking bird species richness as a dependent variable. R^2 = coefficient of determination, F = F value.

Model	Variable	R^2	Correlation	F	Significance
PC I	High tree density, richness, canopy cover, shrub diversity, low herb richness and seedling density, high tree cut	0.100	+	6.43	0.01

orthogonal rotation does not change the sum of the variance explained by the selected components, but it distributes the variance more equally between them (Rummel, 1970; Bennett & Bowers, 1976). Component I (PC 1) contained high loadings of the following variables: Tree richness, shrub density, vertical diversity, horizontal heterogeneity (-), grass density (-) and weight of insects (-). It portrayed the tree and shrub character of the habitat, also including the grass density and horizontal heterogeneity by negative sign. Component II (PC 2) had high loading for following variables: Grass density, herb diversity, canopy cover (-) and insect biomass (-). It represented the open forest characters. Variables altitude, slope, tree richness and insects biomass (-) showed high loadings on component III (PC 3), which may be interpreted as a high altitude, steep slope closed forest (Table 6.16).

Correspondence analysis computed on the basis of plant species number revealed two floristic components (Fig. 6.1). The first axis showed the altitude character as it indicated the dispersal of plant species from high altitude to low altitude (from *Abies pindrow, Cedrus deodara* to *Boeninghausienia albiflora* and *Myrcine africana*). Oak trees (*Quercus leucotricophora* and *Quercus floribunda*) and *Rhododendron arboreum, Lyonia ovalifolia* were clustered in the middle of both the axes as second axis indicated the gradient of plant richness or abundance along the axis (high to low tree richness). Since each of the first two eigen values showed much higher values than either the third or fourth ones computed by DECORANA (I = 0.315, II = 0 .215, III = 0.146, IV = 0.119), there was no need to keep more than two axes.

Kendall's rank correlation coefficient measures the similarity between vegetation components and bird species diversity and richness. The Non metric-multidimensional result was plotted into a 2- dimensional space and all correlations between vegetation components and bird species diversity and richness were drawn in the plexus diagram (Fig. 6.2). Kendall's correlation is not a simple coefficient, but a test of association (Sokal & Rohlf, 1981).

The floristic component did not show any significant correlation with any physiognomic components. But both axes were significantly correlated with each other ($\tau = -0.619$, $p < 0.05$).

This is understandable as the first, *Abies pindrow*, *Pinus wallichiana* was having low tree abundance and occupied higher position on the second axis and lowest position on the first axis. Bird species diversity and richness showed significant relationship with PC III ($\tau = 0.217$, $p < 0.002$ & $\tau = 0.225$, $p < 0.002$). Axis II also showed significant correlation with bird species diversity ($\tau = -0.714$, $p < 0.02$). The effect of these components on bird species diversity was similar. PC III represented high altitude, high slope and high tree richness and bird species diversity was positively correlated with this. So birds preferred areas high in tree richness. PC I and PC II did not show any significant relationship with bird species diversity and richness. Regression also showed the same results for PC components and bird species diversity and richness (Table 6.17 & 6.18). PC III showed significant positive relationship with bird species diversity and richness.

6.3.3.3.2 *Postmonsoon season*

The above mentioned analysis was also performed for the postmonsoon season to observe the changes in bird community seasonwise. The results of the PCA are summarised in Table 6.19. It gave the eigen values for each of the first three components

Table 6.16 Factor loadings on first, second and third components of premonsoon season 1998 in Vinaiyak Reserve Forest.

Variables		**PC I**	**PC II**	**PC III**
	% variance	24.84	15.84	13.85
	Total variance	54.53%		
Altitude		-0.047	0.122	0.905
Canopy cover		-0.020	-0.576	-0.055
Grass density		-0.330	0.690	0.051
Herb diversity		0.159	0.812	0.105
Horizontal heterogeneity		-0.936	0.029	0.028
Slope		0.118	-0.124	0.350
Shrub density		0.214	-0.079	-0.190
Tree richness		0.517	-0.019	0.313
Vertical diversity		0.921	-0.083	-0.001
Insect biomass		-0.546	-0.269	-0.540
Eigen values		2.48	1.58	1.38

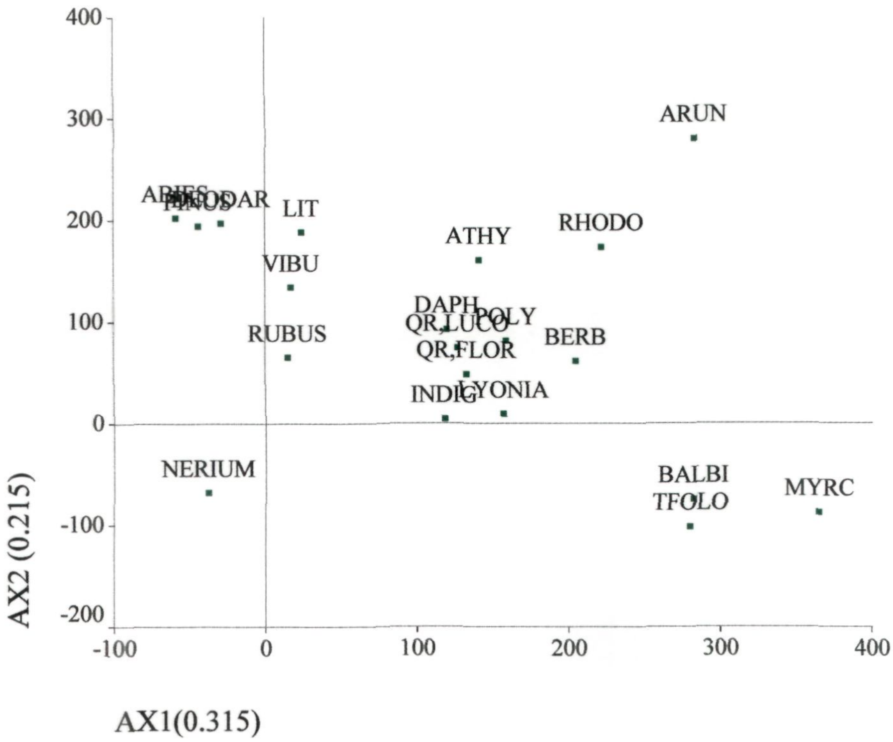


Fig. 6.1 Distribution of different plant species on two axes obtained by DECORANA during pre monsoon season 98 in Vinaiyak.

ABIES = *Abies pindrow*, DEODAR= *Cedrus deodara*, LIT = *Litsea umbrosa*, ATHY= *Athyrium*, RHODO= *Rhododendron arboreum*, VIBU = *Viburnum mullaha*, ARUN=*Arundenaria*, DAPH= *Daphne* sp., POLY= *Polysticum*, RUBUS = *Rubus biflorus*, QR, LUCO= *Quercus leucotricophora*, QR, FLOR= *Quercus floribunda*, INDIGO= *Indigofera* sp., LYONIA= *Lyonia ovalifolia*, BALBI= *B. albiflora*, TFOLO= *T. foliolosum*, MYRC= *Myrcine africana*, NERIUM= *Nerium* sp., PINUS= *Pinus wallichiana*.

Fig. 6.2 Ordination of vegetation components and BSD, BSR obtaine

by multivariate plexus analysis during pre monsoon in Vinaiyak.

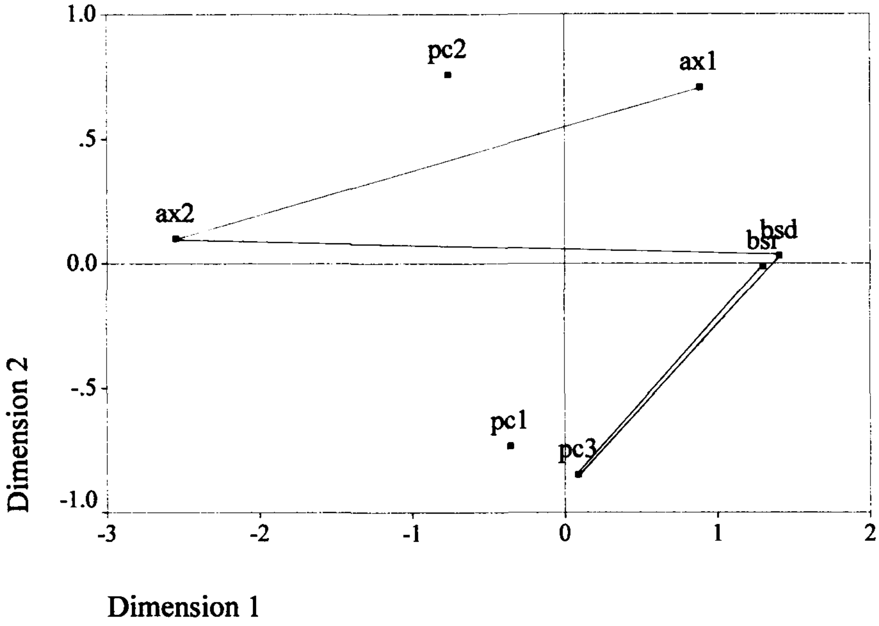
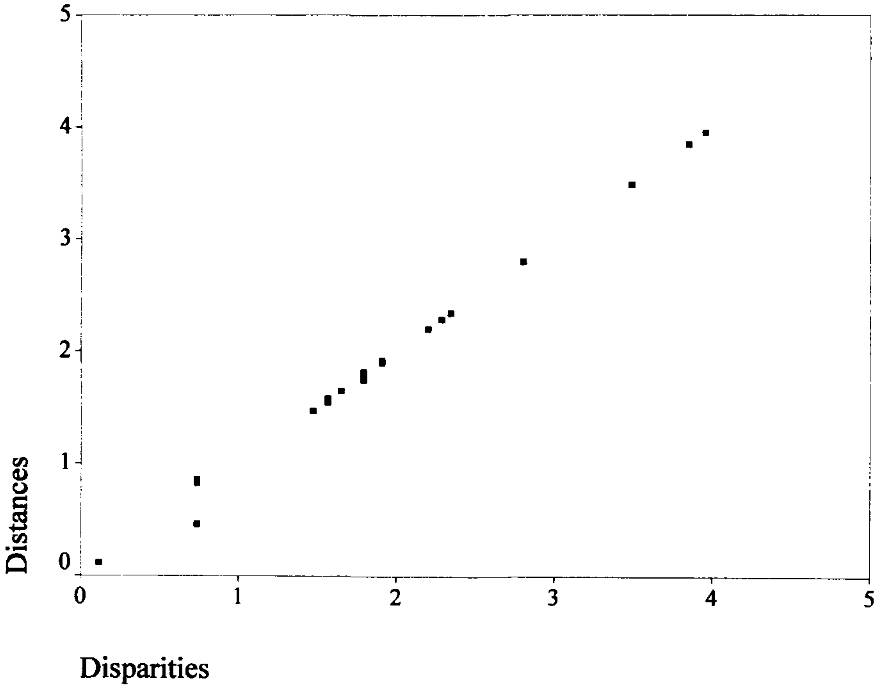


Fig. 6.3 Scatterplot of Linear Fit (Shepard diagram).



and indicated how much of the variation in the physiognomy variables is explained by each of these components. In addition the component loadings are given, which describe the loadings of each variable on each component.

Total five components were extracted which explained 74.63% of total variance. The first principal component explained only 20.77% of the total variance. These values were low and suggested that there was no strong relationship between the variables in this sample. Tree richness and vertical diversity had high positive loadings while horizontal heterogeneity had negative loadings on PC I. It described mature forest with high vertical diversity. PC II described low altitude forest with high canopy cover and shrub cover. Third component (PC III) had high positive loadings of grass density and herb diversity and negative loading of tree richness. It was interpretable as a high ground cover forest with low tree richness.

To spread the variance evenly into components, scores were computed after VARIMAX rotation. DECORANA revealed two floristic components. The first axis (0.304 eigen value) contained the plant abundance gradient from low to high. *Quercus floribunda, Quercus leucotricophora, Rhododendron arboreum, Lyonia ovalifolia, Desmodium gangeticum, Boeninghausienia albiflora* and *Myrcine* sp. were evenly dispersed on this axis. After the monsoon, shrubs like *Myrcine* and *Boeninghausienia albiflora* grow exponentially and which was clearly reflected from the axis. Second axis (0.215 eigen value) contained the gradient of cover from low to high. *Abies pindrow, Cedrus deodara* and *Rubus biflorus* had low cover than *Quercus* species and *Arundinella nepalensis*. Third (0.132) and fourth (0.095) axes had low eigen values so they were not considered.

Table 6.17 Stepwise Multiple Regression analysis on the three components by taking bird species diversity as a dependent variable. R^2 = coefficient of determination, F = F value.

Model	Variable	R^2	Correlation	F	Significance
PC III	High altitude, tree richness, slope and low insect biomass	0.07	+	7.08	0.003

Table 6.18 Stepwise Multiple Regression analysis on the three components by taking bird species richness as a dependent variable. R^2 = coefficient of determination, F = F value.

Model	Variable	R^2	Correlation	F	Significance
PC III	High altitude, tree richness, slope and low insect biomass	0.07	+	7.12	0.003

Table 6.19 Rotated component matrix of vegetation physiognomy variables obtained by PCA during postmonsoon season 1998 at Vinaiyak Reserve Forest.

Variables		PC I	PC II	PC III
	% variance	20.77	14.89	14.12
	Total variance	74.63%		
Altitude		-0.124	-0.224	0.095
Canopy cover		-0.124	0.842	0.106
Grass density		-0.060	-0.070	0.779
Herb diversity		-0.014	0.158	0.828
Horizontal heterogeneity		-0.962	-0.065	-0.009
Slope		0.158	-0.007	-0.115
Shrub density		0.126	0.320	0.091
Tree richness		0.379	0.072	-0.268
Vertical diversity		0.959	-0.037	-0.079
Insect biomass		-0.124	-0.766	0.012
Eigen values		2.07	1.48	1.41

Kendall's rank correlation test showed some correlations. The first floristic component showed highly significant negative correlation with PC III ($\tau = 0.810$, $p < 0.01$). As it is clear from Fig. 6.4 that this gradient is going towards high plant abundance and PC III showed low tree richness and high ground cover. There were no other significant correlations between vegetation components (Fig. 6.5). None of the floristic component showed any correlation with bird species diversity and richness while PC II was significantly negatively correlated with bird diversity measures.

During postmonsoon season birds preferred more open and low shrub cover areas rather than closed forest, as indicated by the results. It may be because insects' availability was less in such areas as PC II showed the decreasing nature of insects. Close canopy forest was mainly preferred by some habitat specialist birds e.g. Striated laughing thrush *Garrulax striatus*, Variegated laughing thrush *Garrulax variegatus* and Chestnut-crowned laughing thrush *Garrulax erythrocephalus*. Regression results also showed similar results. PC II accounted for 23% variance in the model for bird species diversity as well as for bird species richness (Table 6.20 & 6.21).

The above cases showed important negative relationships between vegetation components and bird diversity measures. Non-metric multivariate plexus analysis is helpful in representing interrelationships of both types; it is having monotonic tendency to plot similar variables closer to each other than the less similar ones and significant positive and negative correlations are indicated (Moskot, 1991). The success of an NM-MDS is measured by Kruskal's stress value (Kruskal, 1964). In the present analysis the stress (0.03) for premonsoon season and 0.01 for postmonsoon season was much lower. A very low stress value (about 0.01) could indicate a fully degenerate solution (Kruskal

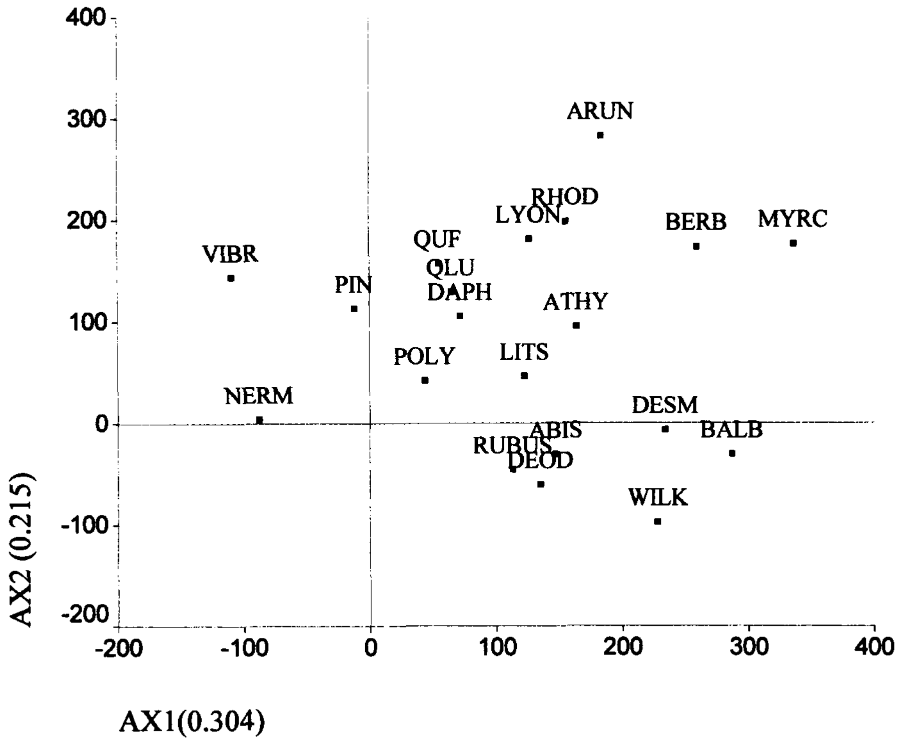


Fig. 6.4 Distribution of different plant species on two axes obtained DECORANA during post monsoon season 98 in Vinaiyak.

ARUN= *Arundenaria*, VIBR= *Viburnum mullaha*, RHOD= *Rhododendron arboreum*, LYON= *Lyonia ovalifolia*, BERB= *Berberis aristata*, MYRC= *Myrcine africana*, QUF = *Quercus floribunda*, QLU= *Quercus leucotricophora*, PIN= *Pinus wallichiana*, DAPH= *Daphne* sp., ATHY= *Athyrium* sp., POLY= *Polysticum*, LITS= *Litsea umbrosa*, DESM= *Desmodium*, BALB= *B. albiflora*, ABIS= *Abies pindrow*, RUBUS = *Rubus biflorus*, DEOD= *Cedrus deodara*, WILK= *Wilkstromia*.

Fig. 6.5 Ordination of vegetation components and BSD, BSR obtained multivariate plexus analysis during post monsoon in Vinaiyak.

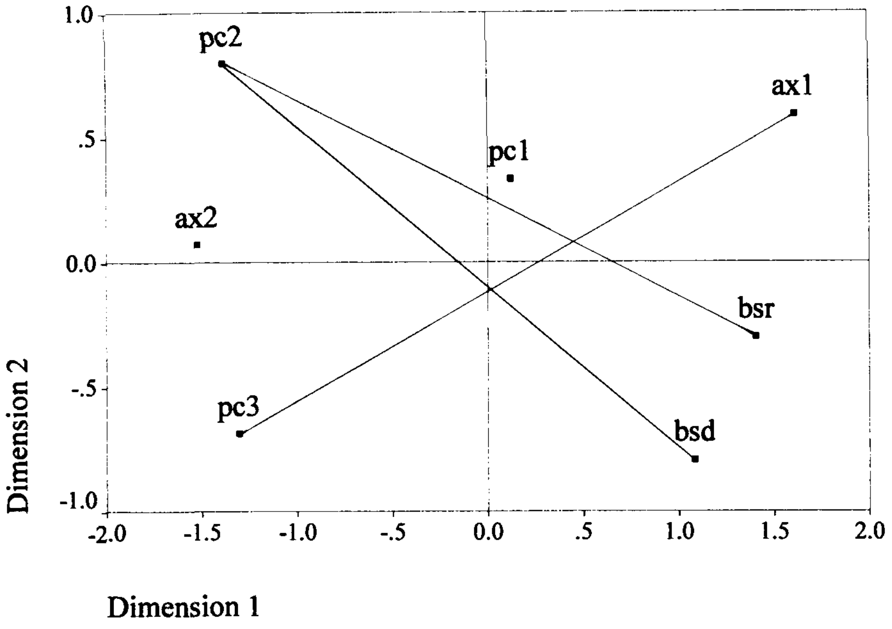
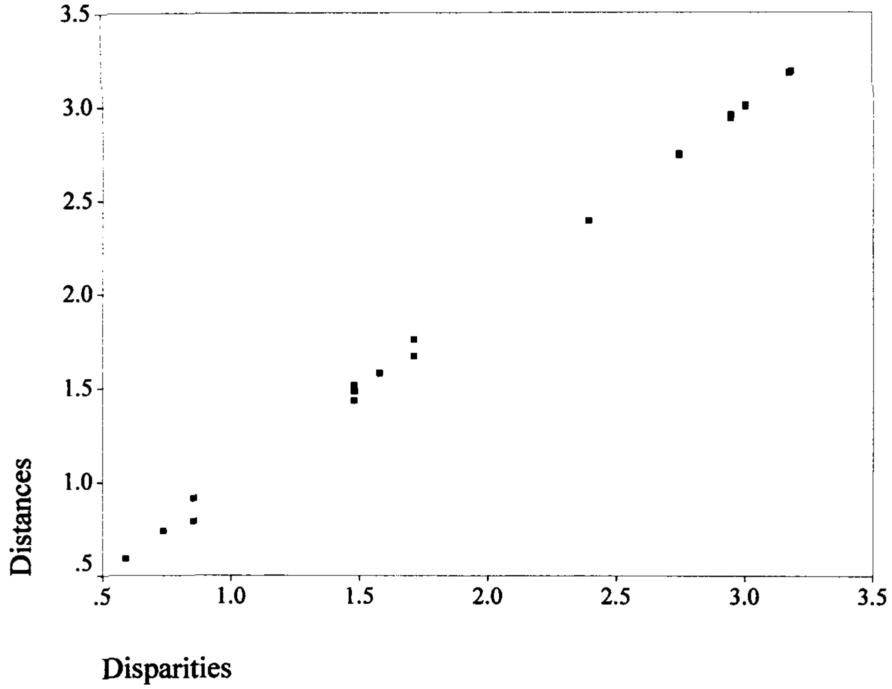


Fig. 6.6 Scatterplot of Linear Fit (Shepard diagram).



& Wish, 1978; Dillon & Goldstein, 1984). The aim of this method is to reduce stress as much as possible. The stress function is normally drawn as a diagram, known as a Shepard diagram, with the dissimilarity values in the variables plotted in rank order against the distances on the ordination plot. If there is a good match and stress is low, the points will lie on a steadily increasing curve (Coker, 1992) and exactly it has been shown in Fig 6.3 & Fig. 6.6 in both the seasons.

6.4 DISCUSSION

The concept of species diversity in community ecology has been intensively debated by ecologists over the years. With the use of a host of diversity indices, much work on bird communities and vegetation has been done during the last three decades. The results have usually been interpreted in terms of biological processes.

Bird species diversity and richness was highest in Pine habitat in Binsar Wildlife Sanctuary during premonsoon season. It may be due to good visibility of birds. Pine forest is more open than oak forest. Some birds might be undetected during counts in oak forest. While species diversity was highest in riverine habitat during postmonsoon season because of availability of more insects in this habitat. After monsoon, many shrubs and herbs grow which attract insects as well as birds. Water level also increases in small streams, which increase the insects, fishes and ultimately attract forktails, redstarts and flycatchers. Where as in Vinaiyak, the species diversity was highest in oak habitat during premonsoon season as well as in postmonsoon season. Only two broad habitats were present i.e. Oak and Mixed coniferous and maximum fruiting tree and shrub species

Table 6.20 Stepwise Multiple Regression analysis on the three components by taking bird species diversity as a dependent variable. R^2 = coefficient of determination, F = F value.

Model	Variable	R^2	Correlation	F	Significance
PC II	Low altitude and insect biomass, high canopy cover and shrub density	0.23	-	26.47	0.00

Table 6.21 Stepwise Multiple Regression analysis on the three components by taking bird species richness as a dependent variable. R^2 = coefficient of determination, F = F value.

Model	Variable	R^2	Correlation	F	Significance
PC II	Low altitude and insect biomass, high canopy cover and shrub density	0.23	-	26.68	0.00

occurred only in oak habitat such as *Myrica esculenta, Rubus biflorus, Berberis aristata* and *Quercus* species.

Bird species diversity, richness and density were highest in disturbed areas as compared to undisturbed areas. Studies in other parts of India, Daniels *et al.* (1992) in Western Ghats, Javed (1996) in Terai region also showed the same results. It rejected the null hypothesis that bird diversity and richness were minimum in disturbed habitats. Birds always prefer relatively open areas for feeding and perching. In Vinaiyak, bird density was maximum in undisturbed habitat during premonsoon season but it was not significantly greater than disturbed habitat. Some studies (Haworth & Thompson, 1990; van der Zande *et al.* 1980; Tuite, 1981; Fraser *et al.* 1985; Laurila, 1989) on water fowl showed that birds avoid different types of human disturbance e.g. pollution, mines, roads, construction etc. While other workers (Foin *et al.* 1977; Watson, 1979; Robertson & Flood, 1980; Burger *et al.* 1982; Storey, 1987; Watson, 1988b; Hill & Rosier, 1989) showed preference in disturbed habitats by passeriformes and showed that increase in bird density in disturbed areas was due to increase in common species.

The majority of pristine habitat species was clearly adaptable to habitat degradation and occurred in reasonable abundance in disturbed habitat. In Binsar Wildlife Sanctuary, Black-throated tit *Aegithalos concinnus*, White-throated laughing thrush *Garrulax albogularis*, Green-backed tit *Parus monticolus* and Grey-hooded warbler *Seicercus xanthoschistos* were in abundant number in oak habitat while Black-headed Jay *Garrulus lanceolatus*, Green-backed tit *Parus monticolus*, Bar-tailed treecreeper *Certhia himalayana*, Oriental dove *Streptopelia orientalis* and Slaty-headed Parakeet *Psittacula himalayana* were found maximum in pine habitat. Whereas Rufous Sibia *Heterophasia* *capistrata*, Chestnut-bellied rock thrush *Monticola rufiventris*, Fire-breasted flowerpecker *Dicaeum ignipectus*, Scaly thrush *Zoothera dauma* and Ashy-throated warbler *Phylloscopus maculipennis* were oak specific birds. These were never found in Pine habitat while Blue-capped rock thrush *Monticola cinclorhynchus*, Grey tree pie *Dendrocitta formosae*, Spangled drongo *Dicrurus hottentottus* and Tree pipit *Anthus trivialis* were Pine habitat specific birds. These are large body sized birds, which need more open space to perch and feed. These species were also found in disturbed areas of the respective habitats in great number. Collared grosbeak *Mycerobas affinis*, Golden bush robin *Tarsiger chrysaeus*, Little pied flycatcher *Ficedula westermanni*, Long-tailed broadbill *Psarisomus dalhousiae*, Yellow-billed blue magpie *Urocissa flavirostris* and Emerald dove *Chalcophaps indica* were oak habitat specific species in Vinaiyak reserve forest while White-cheeked nuthatch *Sitta himalayensis*, Spotted Nutcracker *Nucifraga caryocatactes*, Tree pipit *Anthus trivialis*, Jungle myna *Acridotheres fuscus* and Lesser-racket tailed drongo *Dicrurus remifer* were the mixed coniferous habitat specific bird species. Primary forest is naturally fragmented due to the interaction between slope, aspect and altitude that allows patches of forest to establish beyond the main forest. Fragmentation also occurs due to the effects of landslides, fire and also by human interference such as beaten path, roads and fire line.

Field ornithologists have long recognised that species select habitat for nest site, foraging, perching and other activities within certain specific habitats (Lack, 1933; Lack & Venables, 1939). The assumption was that birds respond to a complex pattern of stimuli rather than to simple variables (Svardson, 1949; James, 1971). Studies have shown birds to be distributed along gradients e.g. moisture (Smith, 1977), altitude

(Anderson, 1970a), succession (Bond, 1957) and competition (Cody &Walter, 1976). Such findings appeared to be related to habitat gradient studies where forest species are characterised as associated with dense under storey, heavy canopy or other variables that are part of the changing structure in forest succession.

The objective of Principal Component Analysis (PCA) and multivariate plexus analysis (MPA) is to examine the pattern of bird community structure in different types of forest structure. During surveys, point transects were established mainly in interior of the forest, where grazing and human disturbance were usually low. So, the cattle dung and lopping were found low in number in the interior of the forest as compared to the fringes of the forest patch. Bird diversity and richness were found to be associated with high ground cover, low disturbance and small patch size. But all these parameters were the components of PC III and having very low contributing variance (17.68%) so the effect of combinations of these parameters was not very high in bird species diversity and richness. The aim behind surveys was mainly for the documentation of status and distribution of bird species in different oak forests of Kumaon so a strong bird–habitat relationship could not be established because it was observed during intensive studies in Binsar Wildlife Sanctuary and Vinaiyak Reserve Forest. Different results were observed during pre and postmonsoon in bird-habitat relations at both places.

In BWS, birds preferred open and disturbed areas as compared to undisturbed areas during premonsoon season. In breeding season, to fulfil the requirements of feeding, birds come out in open areas. Since increased edge is a factor that does attract bird species as shown by Lay (1938) and Johnson (1947), such changes in forest habitat increase the diversity of the community by attracting different species. Most of the species attracted to the edge, however are not migrant species (Anderson, 1979a). Thus edge may be good for restricted species but not good for migrant species. While during postmonsoon season, bird diversity and richness decreased due to decrease in the number of migrant species and also birds preferred more dense area in terms of trees and shrub density and diversity. The factor of major concern was rainfall. During late wet season several days of continuous rain may limit census opportunities and thus the sightings of most of the species were restricted in close canopy itself. While in Vinaiyak reserve forest, where vegetation composition was totally different from the BWS, the results of bird-habitat relationships were also different.

The need to analyze species distribution and environmental data jointly has prompted the development of several combined methods in the last few years. Gauch & Stone (1979) and Sheard & Gale (1983) combined the analysis of plant species and environmental data. Similar analysis was done on bird-vegetation data by Prodon & Lebreton (1981). Each of these studies derived vegetation components by eigen vectors ordination (PCA or CA) and then analyzed components by Canonical correlation analysis (CCA). Gauch & Stone (1979) obtained better results by ordinating the vegetation and environmental data sets by CA separately than by using CCA. Sheard & Gale (1983), moreover, found this combined technique to perform better than when PCA or CCA was applied alone. Another similar approach was used by Carleton (1984), who applied a method called "residual ordination analysis" (ROA) that is based on DCA and CCA. Because of the several linear assumption of this technique, it was considered to be only a preliminary exploration technique.

The dependency of avian communities on vegetation structure seems to be a scale dependent process (Rottenberry, 1985). On a larger, between habitat-type scale, avian community structure is associated with physiognomic components (MacArthur & MacArthur, 1961; Willson, 1974; Rottenberry & Weins, 1980), whereas on a smaller, within habitat scale, bird community composition is often more closely associated with floristic components (Tomoff, 1974; Weins & Rottenberry, 1981). The present study revealed strong association between birds and PC I – PCII – PCIII - AX1 - AX2 complex. These results suggested that the key factors differentiating bird community structure can not be the gross common character of the habitat on a small scale, but on a large scale birds can relate to them by habitat selection. This complex contains both tree and shrub characters in both the seasons, both in physiognomic and floristic sense. Bird densities were also evaluated but not used in bird-habitat relationship. Sometimes density is influenced by several factors, in addition to habitat structure, in which case density may be a misleading indicator of habitat quality (Van Horne, 1983). According to Fretwell- Lucas model (Fretwell & Lucas, 1970), non-linearity in habitat density relationships are most likely when the reproductive success of species is a function of habitat type. So, in establishing the relationship in bird-habitat, only diversity and richness were taken into account.

CHAPTER 7

AVIAN FORAGING PATTERN

7.1 INTRODUCTION

Avian foraging strategies combine complex interactions among morphology, prey preference, foraging behaviour, habitat selection, prey availability and relationships with predators and competitors (Morrison *et al.* 1990). Quantifying these components of a species foraging strategy can explain niche relationship (Robinson & Holmes, 1982), patterns of habitat use (Karr & Brawn, 1990), and community structure (MacArthur, 1958) and can also help to focus conservation efforts (Petit *et al.* 1995). However much of the data necessary to characterize a species foraging strategy, are lacking including dietary information (Rosenberg & Cooper, 1990).

Studies on foraging pattern mainly considered the method of exploiting the resources, as birds often exhibit differences in how they exploit resources. Some species, for instance, are generalists and they will search food at all heights and on a variety of substrates, while others show varying degrees of specialization.

Species, therefore, differ in their response to changes in their habitat that may result from the influence of human activities. Logging, the establishment of plantations and increased incidence of wildfire are examples of events initiated by people, which can change the structure of vegetation and plant species composition of forests and thereby affect the survival of forest birds. Thus, knowledge of key resources and how they are shared among members of the guild would give valuable inputs for the conservation and management of species and their habitats. Although foraging guild has been well documented for European and North American bird species (Crome, 1978; MacNally, 1994; Recher *et al.* 1985; Morton, 1980; Poulin & Lefebrre, 1996), no such studies are available in India. However, in some community studies (Beehler *et al.*1987; Daniels, 1989; JohnSingh & Joshua, 1994; JohnSingh *et al.* 1987; Sundramoorthy, 1991) the foraging of birds was discussed based on the information given by Ali & Ripley (1987). An attempt was made by Javed (1996) and Gokula & Vijayan (2000) to fill this lacuna.

Studies of resource partitioning and community structure have had limiting similarity as a constructive and central assumption (MacArthur, 1972; Pianka, 1973; 1975, Cody, 1974; Schoener, 1974; Brown, 1975; Diamond, 1975a; M'Closkey, 1976). A theoretical basis for an upper limit to the degree of niche overlap has been developed by May & MacArthur (1972) in their analytical model of niche overlap as a function of environmental variability. They have shown that for species rich communities, maximum niche overlap is insensitive to changes in either environmental variability or number of species. However, for low diversity communities the theory indicates that at a given level of environmental variability, niche separation should increase as the number of species increase.

Pianka (1972) has developed a niche overlap hypothesis, which states that maximal tolerable overlap should vary inversely with the intensity of competition. Using the concept of diffuse competition (MacArthur, 1972), Pianka (1974) has shown niche overlap to be a negative function of the number of species present in desert lizard communities. M'Closkey (1978) has provided a similar result for desert rodent communities, showing niche separation to be positively correlated with species diversity.

In this chapter, the study and analysis was designed to understand the underlying community pattern and resource partitioning among the Kumaon avian species, determining the overall community structure.

7.2 METHODOLOGY

7.2.1 Data collection

Foraging records were collected at the study area during three years of fieldwork from 1996 to 1998. Data were collected from transects and point transects in whole Kumaon. Most of the records were collected within the first three hours after sunrise. Observations of foraging behaviour were opportunistic but I attempted to observe species at various times of day and in all habitat types so that observations of rarer species could also be collected. No observations were made for the swallows, swifts and raptors. Mixed flocks were avoided to study the foraging patterns as it affects the independence of foraging behaviour of each species. I included data only from foraging sequences that lasted 10 seconds but not more than five minutes, and only when I felt I had not disturbed the bird's foraging routine (e.g. when birds were not flushed from the ground and when they appeared to behave naturally). Although birds were not marked, observations were temporally and spatially separated such that observations were probably taken from different individuals. At least five observations were made for each species.

For each foraging attempt microhabitat details such as height above the ground level, substrate and species of plant on which the prey was, and foraging method were recorded. The details of each foraging strategy are given below-

7.2.1.1 *Foraging Height*

Foraging attempts were assigned to five height categories-

1. 0 meter (Ground)

2. 0.1-2 meter

3. 2.1-4 meter

4. 4.1-10 meter

5. > 10 meter

Some prominent trees were also selected and marked with heights and were used as reference.

7.2.1.2 *Foraging Substrate*

A substratum was the material from which food was taken by the birds. Substrates were classified as-

1. Ground- including debris, litter and grass
2. Trunk / main branches- the main axis of trees
3. Foliage- leaves including leaf-blades and petioles
4. Twigs- small branches to which leaves were attached
5. Flowers and fruits
6. Air

Among these, the nectar / seed / fruit category represents the food taken by the birds. As other five categories are meant purely for insectivorous birds, to separate the non-insect feeders from the insect feeders, the nectar / seed / fruit category was included as one substrate.

7.2.1.3 *Foraging Methods*

Foraging methods of insectivorous birds were broadly categorized as follows-

1. Glean- a stationary food item is picked from its substrate by a standing or hopping bird.
2. Probe- as glean, only the birds beak penetrates or lifts the substrate to locate concealed food.
3. Pounce- a bird flies from a perch and grabs the food item as it lands on the substrate, which is similar to flycatcher- gleaning.
4. Sally or flycatching- a bird fly into air to catch flying prey.

To classify or cluster the species on micro level, the sally and glean were classified further into finer levels based on the location of the prey (Table 7.1). In order to separate the non-insect feeders from the insect feeders, methods were classified based on the food items (nectar / seed / fruit) rather than method adopted. Moreover, the fruit/ nectar classification was used to record all fruigivores and nectarivores behaviour. In total 16 categories were used to collect information on foraging (Table 7.1) which encompasses the behaviours described by Crome (1978) and expanded by Holmes *et al.* (1979) and MacNally (1994). For the purposes of getting sufficient sample size, the observations were pooled for all the individuals across the seasons irrespective of years with the assumption that there is very little or no change in the foraging behaviour of the bird during different time of the year. As thirty independent observations are recommended to represent the behaviour of a bird accurately (Morrison, 1984), all those species who were abundant in Kumaon were used for analysis.

Table 7.1 Definition of foraging activities used to assess guild structure of avifauna.

No.	Activity (description)
1.	Canopy- sally (Sally to airborne insects in or above the canopy)
2.	Bush- sally (Sally from perched position to airborne insects from the bushes)
3.	Ground- sally (Sally from perched position to airborne insects from the ground)
4.	Leaf- glean (Gleaning of perched prey from leaves of trees)
5.	Twig- glean (Gleaning of perched prey from twigs of trees)
6.	Bush- glean (Gleaning of perched prey from bush)
7.	Bark- tear (Searching for prey by tearing the bark)
8.	Wood- probe (Probing the bark)
9.	Wood- glean (Gleaning of perched prey on trunks)
10.	Litter- search (Scratch and search through litter for insects)
11.	Ground- pounce (Attack on grounded prey from perched position)
12.	Ground- search (Searching ground for insects)
13.	Arboreal- granivory (Consumption of seeds in trees)
14.	Ground- granivory (Consumption of seeds in ground)
15.	Fruit- exploiting (Consumption of fruits)
16.	Flower- exploiting (Consumption of pollen and nectar or blossoms)

7.2.2 Statistical analyses

7.2.2.1 *Specialists- Index J'*

The foraging specialization of each foraging dimension (height, substrate, and method) was analyzed using the Shannon-Weiner Index (1949)-

$H' = -\Sigma\ pi \ln pi$

where H' = diversity and pi = the proportion of observation in subset i

These values were then converted to a standardized range using the formula-

$J' = H' / H_{max}$

where J' = specialization and H_{max} = the H' value obtained when the observations are distributed equally across all subsets of the foraging dimension followed by Crome (1978) and Recher *et al.* (1985).

The maximum diversity (H_{max}) which could possibly occur would be found in a situation where all species were equally abundant, in other words if $H' = H_{max} = \ln S$ (Magurran, 1988).

J' values range between one to zero, with foraging specialization increasing as J' falls.

7.2.2.2 *Niche Overlap*

The degree of species overlap in niche utilization for different categories recorded (i.e. foraging method, substrate and height) has been quantitatively expressed using Horn's (1966) equation-

$$R_o = R_o = \frac{\Sigma\ (x_l + y_l) \log (x_l + y_l) - \Sigma\ x_l \log x_l - \Sigma\ y_l \log y_l}{(X+Y) \log (X+Y) - X \log X - Y \log Y}$$

where X and Y are the total number of observation for species, for the particular category and x_l and y_l are the number of occurrences made in the i^{th} sub division within each category for X and Y species respectively.

A second overlap parameter is total spatial niche overlap: this is obtained by summing the overlap on species X of all other species present-

$R_o = \Sigma R_o$

A value for the mean total overlap can then be obtained as the average of the total niche overlap for each species-

$Rx = (\Sigma R_o) / N$

where N = the number of species

7.2.2.3 *Cluster Analysis*

To compare foraging methods, substrate use and height use between species, cluster analyses were performed on three different data matrix (species X different subsets) i.e. 64 x 16, 64 x 6, 64 x 5, following Holmes *et al.* (1979). The analyses used the Nearest neighbour clustering method with Jaccard's measure coefficient. This measure was used because of binary data.

The SPSS software (Norusis, 1990) was used for the data analyses.

7.3 RESULTS

A total of **5243** observations were made on 64 bird species (Table 7.2). The maximum observations were of Spot-winged tit *Parus melanolophus*, Grey-hooded warbler *Seicercus xanthoschistos* and Yellow-browed warbler *Phylloscopus inornatus*

Table 7.2 Number of foraging records of 64 bird species with codes and sample size made in Kumaon.

No.	Species name	Code	No. of observations
1.	Ashy drongo	A drongo	42
2.	Bar-tailed creeper	BT creeper	240
3.	Black & Yellow grosbeak	BY grosbeak	25
4.	Black-breasted sunbird	BB sunbird	17
5.	Black bulbul	B Bulbul	40
6.	Black-headed jay	BH jay	99
7.	Black-lored tit	BL tit	47
8.	Black-throated tit	BH tit	235
9.	Blue-whistling thrush	BW thrush	61
10.	Brown-fronted woodpecker	BFWP	45
11.	Chestnut-bellied nuthatch	CB nuthatch	26
12.	Chestnut-bellied rock thrush	CBR thrush	48
13.	Chestnut-crowned laughing thrush	CCL thrush	13
14.	Chestnut-eared bunting	CE bunting	12
15.	Chestnut-tailed minla	CT minla	28
16.	Common myna	C myna	13
17.	Dark-sided flycatcher	DS flycatcher	21
18.	Dark-throated thrush	DT thrush	25
19.	Eurasian cuckoo	E cuckoo	30
20.	Eurasian jay	E jay	217
21.	Eurasian tree creeper	ET creeper	43
22.	Great barbet	G barbet	50
23.	Green-backed tit	GB tit	296
24.	Green-tailed sunbird	GT sunbird	12
25.	Grey-headed canary flycatcher	GHC flycatcher	137
26.	Grey-hooded warbler	GH warbler	333
27.	Grey tree pie	GT pie	22
28.	Grey-winged black bird	GWB bird	104
29.	Hill partridge	H partridge	41
30.	Himalayan woodpecker	HWP	93
31.	Indian cuckoo	I cuckoo	18
32.	Jungle crow	J crow	51
33.	Koklass	Koklass	29
34.	Large hawk cuckoo	LH cuckoo	39

35.	Long-tailed minivet	LT minivet	42
36.	Maroon oriole	M oriole	12
37.	Mistle thrush	M thrush	47
38.	Orange-flanked bush robin	OFB robin	72
39.	Oriental dove	O dove	319
40.	Plain leaf warbler	PL warbler	13
41.	Plum-headed parakeet	PH parakeet	40
42.	Red-billed blue magpie	RBB magpie	14
43.	Red-breasted parakeet	RB parakeet	24
44.	Ring dove	R dove	15
45.	Rufous-bellied niltava	RB niltava	71
46.	Rufous-bellied woodpecker	RB woodpecker	57
47.	Rufous sibia	R sibia	256
48.	Slaty-headed parakeet	SH parakeet	21
49.	Spot-winged tit	SW tit	504
50.	Spotted forktail	S forktail	22
51.	Streaked laughing thrush	SL thrush	70
52.	Striated laughing thrush	STR L thrush	46
53.	Ultramarine flycatcher	U flycatcher	80
54.	Verditer flycatcher	V flycatcher	77
55.	Western-crowned warbler	WC warbler	20
56.	Whiskered yuhina	W yuhina	50
57.	White-browed shrike babbler	WBS babbler	61
58.	White-cheeked nuthatch	WC nuthatch	26
59.	White-tailed nuthatch	WT nuthatch	178
60.	White-throated laughing thrush	WTL thrush	65
61.	White-throated tit	WT tit	55
62.	Whitecrested Kalij	Kalij	26
63.	Yellow-breasted green finch	YBG finch	75
64.	Yellow-browed warbler	YB warbler	333
Total			5243

while the minimum observations or the rarer ones were of Chestnut-eared bunting *Emberiza fucata*, Maroon oriole *Oriolus traillii* and Chestnut-crowned laughing thrush *Garrulax erythrocephalus*.

7.3.1 Use of Foraging Height

Of the total five height categories in the forest of Kumaon, all of them were used by 64 bird species (Table 7.3). Although most of the species foraged over a broad range of heights, they were grouped according to the layer of vegetation in which the majority of their foraging was recorded.

Total 22 species foraged on or near the ground but main species were Kalij, Koklass, Hill partridge, White-throated laughing thrush, Streaked laughing thrush, Grey-winged black bird, Oriental dove, Ring dove and Spotted forktail. The shrub / short tree layer was utilized by 50 species but the percentage was highest in case of Orange-flanked bush robin and Yellow-browed warbler. The 2-4 meter layer was minimum used by the species, however 26 species in a very low percentage used this layer.

The tree layers i.e. 4-10m and > 10m were frequently used by maximum number of species. Total 56 and 58 bird species foraged on this layer. The main species were Brown-fronted woodpecker, Black-headed jay, Grey-hooded warbler, Grey-headed flycatcher, Oriental dove, Black-breasted sunbird, Rufous sibia, Indian cuckoo and Maroon oriole. For the avian community as a whole, a higher percentage (38.67% and 38.35%) of foraging activity in height were recorded in the tree layers (4-10m and > 10m).

Table 7.3 Height distribution of birds in the forest of Kumaon (% of prey attacks).

Species name	Foraging height				
	1	2	3	4	5
Ashy drongo	2.38	19	-	31	47.6
Bar-tailed creeper	-	13.8	2.92	65	18.3
Black & Yellow grosbeak	100	-	-	-	-
Black-breasted sunbird	-	-	-	71.4	28.6
Black bulbul	-	22.5	-	37.5	40
Black-headed jay	7.07	14.1	1.01	36.4	41.4
Black-lored tit	-	8.11	-	54.1	37.8
Black-throated tit	-	20.9	0.43	39.6	39.1
Blue-whistling thrush	62.3	1.64	-	31.1	4.92
Brown-fronted pied wp	-	13.3	-	64.4	22.2
Chestnut-bellied nuthatch	-	-	-	66.7	33.3
Chestnut-bellied rock thrush	-	11.1	11.1	22.2	55.6
Chestnut-crowned l thrush	23.1	7.69	-	30.8	38.5
Chestnut-eared bunting	50	50	-	-	-
Chestnut-tailed minla	-	-	11.1	66.7	22.2
Common myna	100	-	-	-	-
Dark-sided flycatcher	-	27.3	-	54.5	18.2
Dark-throated thrush	27.3	18.2	-	27.3	27.3
Eurasian cuckoo	-	20	10	10	60
Eurasian jay	-	18.4	-	28.6	53
Eurasian tree creeper	-	15.4	7.69	53.8	23.1
Great hill barbet	-	15	5	30	50
Green-backed tit	0.34	17.2	0.68	40.9	40.9
Green-tailed sunbird	-	16.7	-	33.3	50
Grey-headed canary flycat.	-	13.1	2.92	66.4	17.5
Grey-hooded warbler	-	19.2	1.2	42	37.5
Grey tree pie	-	16.7	-	41.7	41.7
Grey-winged black bird	100	-	-	-	-
Hill partridge	100	-	-	-	-
Himalayan woodpecker	-	9.68	1.08	67.7	21.5
Indian cuckoo	-	11.1	-	33.3	55.6
Jungle crow	-	5.88	1.96	15.7	76.5
Koklass	100	-	-	-	-
Large hawk cuckoo	-	-	-	11.1	88.9
Long-tailed minivet	-	9.52	4.76	31	54.8
Maroon oriole	-	8.33	-	25	66.7

Mistle thrush	42.6	2.13	2.13	14.9	38.3
Orange-flanked bush robin	1.39	43.1	1.39	23.6	30.6
Plain leaf warbler	-	23.1	-	23.1	53.8
Plum-headed parakeet	-	-	-	50	50
Red-billed blue magpie	7.14	7.14	-	57.1	28.6
Red-breasted parakeet	-	-	-	-	100
Ring dove	100	-	-	-	-
Rufous-bellied niltava	1.41	23.9	4.23	50.7	19.7
Rufous sibia	0.30	16.4	-	28.9	54.3
Rufous turtle dove	100	-	-	-	-
Sapsucker	-	29.8	1.75	56.1	12.3
Slaty-headed parakeet	-	19	4.76	19	57.1
Spot-winged tit	-	17.9	0.79	30.8	50.6
Spotted forktail	100	-	-	-	-
Streaked laughing thrush	100	-	-	-	-
Striated laughing thrush	-	18.8	-	43.8	37.5
Ultramarine flycatcher	-	22.5	1.25	52.5	23.8
Verditer flycatcher	-	9.09	-	55.8	35.1
Western-crowned warbler	-	-	-	40	60
Whiskered yuhina	-	6.9	6.9	55.2	31
White-browed shrike babbler	-	18	-	47.5	34.4
White-cheeked nuthatch	-	7.69	-	34.6	57.7
White-tailed nuthatch	-	18	0.56	41.6	39.9
White-throated l thrush	100	-	-	-	-
White-throated tit	-	6.67	-	26.7	66.7
Whitecrested Kalij	96.2	3.85	-	-	-
Yellow-breasted green finch	-	14.3	-	5.71	80
Yellow-browed warbler	-	23.1	0.9	35.1	40.8

7.3.2 Use of Foraging Substrate

Six substrates i.e. Ground, Trunk or main branches, Foliage, Twig, Nectar/Seed/ Fruit and Air were recognized in Kumaon forest (Table 7.4). Avian species in Kumaon used foliage as their maximum (36.68%) foraging substrate while they used ground as their minimum (7.47%) foraging substrate.

Ground

Total 17 species foraged at the ground level out of which nine species, namely Kalij, Koklass, Hill partridge, White-throated laughing thrush, Grey-winged black bird, Common myna and Black & yellow Grosbeak used solely this substrate. While Mistle thrush, Chestnut-crowned laughing thrush and Red-billed blue magpie used this substrate less frequently than the others. Both insectivores and granivores used this substrate. Koklass foraged on ground but it is a herbivore.

Trunk / main branches

Bar-tailed tree creeper, Eurasian tree creeper, White-cheeked nuthatch, Woodpeckers obtained their prey from the trunk / main branches. 12.89% species used this substrate. In addition to this substrate, White-tailed nuthatch utilized twig and Himalayan woodpecker also foraged in foliage for obtaining insects.

Foliage

This substrate was mostly used by the avian species, mainly warblers i.e. Grey-hooded warbler, Plain leaf warbler, Yellow-browed warbler, Eurasian Jay, Indian cuckoo,

Table 7.4 Percent use of substrate by birds in the forest of Kumaon. (1 = ground, 2 = trunk, 3 = foliage, 4 = twigs, 5 = flower & fruits, 6 = air).

Species name	Substrate					
	1	2	3	4	5	6
Ashy drongo	2.38	-	-	-	-	97.6
Bar-tailed creeper	-	100	-	-	-	-
Black & Yellow grosbeak	100	-	-	-	-	-
Black-breasted sunbird	-	-	-	-	100	-
Black bulbul	-	-	-	-	100	-
Black-headed jay	6.06	-	93.9	-	-	-
Black-lored tit	-	-	-	100	-	-
Black-throated tit	-	-	-	100	-	-
Blue-whistling thrush	39.3	-	60.6	-	-	-
Brown-fronted pied woodpecker	-	84.4	15.56	-	-	-
Chestnut-bellied nuthatch	-	50	50	-	-	-
Chestnut-bellied rock thrush	-	-	100	-	-	-
Chestnut-crowned laughing thrush	69.23	-	30.7	-	-	-
Chestnut-eared bunting	-	-	-	-	100	-
Chestnut-tailed minla	-	-	100	-	-	-
Common myna	100	-	-	-	-	-
Dark-sided flycatcher	-	-	-	-	-	100
Dark-throated thrush	18.18	-	81.8	-	-	-
Eurasian cuckoo	-	-	100	-	-	-
Eurasian jay	-	-	100	-	-	-
Eurasian tree creeper	-	100	-	-	-	-
Great hill barbet	-	-	-	-	100	-
Green-backed tit	0.34	-	7.09	92.57	-	-
Green-tailed sunbird	-	-	-	-	100	-
Grey-headed canary flycatcher	-	-	-	-	-	100
Grey-hooded warbler	-	-	23.42	76.58	-	-
Grey tree pie	-	-	100	-	-	-
Grey-winged black bird	100	-	-	-	-	-
Hill partridge	100	-	-	-	-	-
Himalayan woodpecker	-	68.8	31.18	-	-	-
Indian cuckoo	-	-	100	-	-	-
Jungle crow	-	-	100	-	-	-
Koklass	100	-	-	-	-	-
Large hawk cuckoo	-	-	100	-	-	-

Long-tailed minivet	-	-	-	-	-	100
Maroon oriole	-	-	100	-	-	-
Mistle thrush	82.9	-	17.02	-	-	-
Orange-flanked bush robin	-	-	100	-	-	-
Plain leaf warbler	-	-	100	-	-	-
Plum-headed parakeet	-	-	-	-	100	-
Red-billed blue magpie	64.29	-	35.7	-	-	-
Red-breasted parakeet	-	-	-	-	100	-
Ring dove	-	-	-	-	100	-
Rufous-bellied niltava	-	-	100	-	-	-
Rufous sibia	-	-	100	-	-	-
Rufous turtle dove	-	-	-	-	100	-
Sapsucker	-	87.7	12.28	-	-	-
Slaty-headed parakeet	-	-	-	-	100	-
Spot-winged tit	-	-	36.51	63.49	-	-
Spotted forktail	100	-	-	-	-	-
Streaked laughing thrush	100	-	-	-	-	-
Striated laughing thrush	-	-	100	-	-	-
Ultramarine flycatcher	-	-	30	-	-	70
Verditer flycatcher	-	-	-	-	-	100
Western-crowned warbler	-	-	100	-	-	-
Whiskered yuhina	-	-	-	100	-	-
White-browed shrike babbler	-	-	100	-	-	-
White-cheeked nuthatch	-	100	-	-	-	-
White-tailed nuthatch	-	92.13	-	7.86	-	-
White-throated laughing thrush	100	-	-	-	-	-
White-throated tit	-	-	-	100	-	-
Whitecrested Kalij	100	-	-	-	-	-
Yellow-breasted green finch	-	-	-	-	100	-
Yellow-browed warbler	-	-	100	-	-	-

Eurasian cuckoo. The other species predominantly used the foliage for feeding purpose. Large or heavy body weight bird species used the tree foliage while warblers used the shrub as well as tree foliage for foraging.

Twigs

Only four species namely Black-throated tit, White-tailed nuthatch, Black-lored tit and Whiskered yuhina absolutely exploited their prey from twigs. While other species such as Spot-winged tit, Green-backed tit and Grey-hooded warbler also used this substrate. These species also preferred foliage substrate but after twigs.

Air

Total six species used this substrate for foraging purpose i.e. Grey headed canary flycatcher, Long tailed minivet, Dark-sided flycatcher, Verditer flycatcher, Ultramarine flycatcher and Ashy drongo. Only Ultramarine flycatcher used foliage substrate and Ashy drongo used ground for foraging purpose.

Nectar / seed / fruits

Eleven species formed this guild and all used this substrate absolutely. These species were Black bulbul, Black-throated sunbird, Plum-headed parakeet, Chestnut-eared bunting, Ring dove, Oriental dove, Great barbet etc. (Table 7.4).

7.3.3 Use of Foraging Methods

Based on the 16 foraging techniques employed by birds, 11 major methods were possibly distinguished for the birds in Kumaon forest. At least one bird species was found predominantly using any one of the 16 foraging techniques. The major prey attack maneuvers used by birds in Kumaon forest were Canopy sallying, Leaf gleaning, Twig gleaning, Bush gleaning, Bark tearing, Wood probing, Wood gleaning, Litter search, Ground search, Ground grain gleaning and Fruit exploiting (Table 7.5).

Canopy sallying

Six bird species were recognized as salliers. No absolute use of this method was found in any of the birds. Ashy drongo, Grey-headed canary flycatcher, Long-tailed minivet and Verditer flycatcher were the dominantly canopy salliers while Dark-sided flycatcher and Ultramarine flycatcher were bush salliers as well as canopy salliers. One record of Ashy drongo was made as ground sallier also but not frequent sightings occurred.

Leaf gleaning

Total 14 species used this guild. Only Western-crowned warbler used this method absolutely while Grey-hooded warbler, Plain leaf warbler, Yellow-browed warbler, Black-lored tit used it predominantly. Spot-winged tit, Black-throated tit and Black-lored tit used mainly this method along with twig gleaning.

Twig gleaning

The number of bird species forming the twig gleaning guild was more than the other groups. Eurasian cuckoo, Large hawk cuckoo, Indian cuckoo and Maroon oriole exploited absolutely this foraging maneuver. Rufous sibia, Black-headed Jay, Dark-throated thrush, Spot-winged tit, Chestnut-bellied rock thrush, Striated laughing thrush and Whiskered yuhina also used this method along with other methods.

Bush gleaning

Chestnut-tailed minla, Chestnut-bellied rock thrush, Rufous-bellied Niltava, White-browed shrike babbler, Striated laughing thrush and White-throated tit used predominantly this method. No bird was found using absolutely this guild.

Bark tearing

Only two species i.e. Bar-tailed tree creeper and Eurasian tree creeper used this method but not absolutely. These species used wood-gleaning method also.

Wood gleaning and probing

Six species were found in this guild. Woodpeckers and Nuthatches used this guild predominantly along with wood gleaning method. Eight species exploited the wood gleaning method. All woodpeckers and tree creepers used this method also.

Table 7.5 Percent prey attack maneuvers by birds in the forest of Kumaon. (codes for foraging maneuvers and species, see details in table 7.1 & 7.2 respectively)

Species name	Foraging maneuvers															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A drongo	66.6	-	33:3	-	-	-	-	-	-	-	-	-	-	-	-	-
B Bulbul	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-
BB sunbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
BFWP	-	-	-	-	-	-	-	84.4	15.5	-	-	-	-	-	-	-
BH jay	-	-	-	-	84.85	-	-	-	9.1	-	-	6.1	-	-	-	-
BL tit	-	-	-	51.3	48.7	-	-	-	-	-	-	-	-	-	-	-
BT creeper	-	-	-	-	-	-	77.1	-	22.9	-	-	-	-	-	-	-
BT tit	-	-	-	14.4	60.8	24.6	-	-	-	-	-	-	-	-	-	-
BW thrush	-	-	-	-	31.1	-	-	-	-	29.5	-	39.3	-	-	-	-
BY grosbeak	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-
C myna	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-
CB nuthatch	-	-	-	-	33.3	-	-	66.6	-	-	-	-	-	-	-	-
CBR thrush	-	-	-	-	72.2	27.8	-	-	-	-	-	-	-	-	-	-
CCL thrush	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-
CE bunting	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-
CT minla	-	-	-	-	66.6	33.3	-	-	-	-	-	-	-	-	-	-
DS flycatcher	18.2	81.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DT thrush	-	-	-	-	81.8	-	-	-	-	-	-	18.2	-	-	-	-
E cuckoo	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-
E jay	-	-	-	19.3	80.6	-	-	-	-	-	-	-	-	-	-	-
ET creeper	-	-	-	-	-	-	61.5	-	38.5	-	-	-	-	-	-	-
G barbet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-

Table continued-

Species name	Foraging maneuvers															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
GB tit	-	-	-	-	85.5	-	-	-	-	-	-	14.5	-	-	-	-
GH warbler	-	-	-	86.2	9.6	4.2	-	-	-	-	-	-	-	-	-	-
GHC flycatcher	56.2	30.7	-	8	-	5.1	-	-	-	-	-	-	-	-	-	-
GT pie	-	-	-	-	50	-	-	-	-	-	50	-	-	-	-	-
GWB bird	-	-	-	-	4.8	-	-	-	-	82.7	-	12.5	-	-	-	-
H partridge	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-
HPWP	-	-	-	-	-	-	-	48.4	51.6	-	-	-	-	-	-	-
I cuckoo	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-
J crow	-	-	-	-	-	-	-	-	-	-	86.3	13.7	-	-	-	-
Kalij	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-	-
Koklass	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-
LH cuckoo	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-
LT minivet	71.4	-	-	-	28.5	-	-	-	-	-	-	-	-	-	-	-
M oriole	-	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-
M thrush	-	-	-	-	10.6	-	-	-	-	10.6	-	78.7	-	-	-	-
NYB sunbird	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
O dove	-	-	-	-	-	-	-	-	-	-	-	-	1.6	98.4	-	-
OFB robin	-	-	-	19.4	23.6	16.6	-	-	-	-	40.3	-	-	-	-	-
PH parakeet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-
PL warbler	-	-	-	76.9	23.1	-	-	-	-	-	-	-	-	-	-	-
R dove	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-
R sibia	-	-	-	-	91	8.98	-	-	-	-	-	-	-	-	-	-
RB niltava	-	-	-	5.6	51	43.6	-	-	-	-	-	-	-	-	-	-
RB parakeet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-

Table continued-

Species name	Foraging maneuvers															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RB woodpecker	-	-	-	-	5.3	-	-	68.4	26.3	-	-	-	-	-	-	-
RBB magpie	-	-	-	-	-	-	-	-	-	50	-	50	-	-	-	-
S forktail	-	-	-	-	13.6	-	-	-	-	-	22.7	63.6	-	-	-	-
SH parakeet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-
SL thrush	-	-	-	-	-	-	-	-	-	50	-	50	-	-	-	-
STR L thrush	-	-	-	-	62.5	37.5	-	-	-	-	-	-	-	-	-	-
SW tit	-	-	-	17.3	75.4	7.34	-	-	-	-	-	-	-	-	-	-
U flycatcher	33.7	35	-	6.2	17.5	7.5	-	-	-	-	-	-	-	-	-	-
V flycatcher	72.7	15.6	-	-	11.7	-	-	-	-	-	-	-	-	-	-	-
W yuhina	-	-	-	34.5	65.5	-	-	-	-	-	-	-	-	-	-	-
WBS babbler	-	-	-	18	49.2	32.8	-	-	-	-	-	-	-	-	-	-
WC nuthatch	-	-	-	-	-	-	-	69.3	30.7	-	-	-	-	-	-	-
WC warbler	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-
WT nuthatch	-	-	-	-	9.5	-	-	64	26.4	-	-	-	-	-	-	-
WT tit	-	-	-	-	60	40	-	-	-	-	-	-	-	-	-	-
WTL thrush	-	-	-	-	-	-	-	-	-	78.5	-	21.5	-	-	-	-
YB warbler	-	-	-	83.8	12	4.2	-	-	-	-	-	-	-	-	-	-
YBG finch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-

Litter search

Grey-winged black bird, White-throated laughing thrush, Streaked laughing thrush, Mistle thrush, Blue whistling thrush and Red-billed blue magpie used this guild. Red-billed blue magpie used 50% of this method and 50% ground search method.

Ground pounce and search

Kalij, Hill partridge, Black & Yellow Grosbeak, Common myna and Chestnut-crowned laughing thrush exploited ground search maneuver absolutely (100%). While Mistle thrush, Red-billed blue magpie and Spotted forktail used this method partially. Jungle crow, Orange-flanked bush robin and Grey tree pie frequently used the ground pouncing method.

All the above mentioned methods are applied to get the invertebrate prey. In the case of nectar / seed / fruits as food the method applied was glean but it will overlap with insect gleaners. Hence, they are treated separately as nectar gleaning, fruit gleaning and seed gleaning.

Ground granivory

Only three species i.e. Koklass, Oriental dove and Ring dove frequently used this method. Oriental dove was seen once using arboreal feeding also.

Fruit exploiting

All members of this group i.e. Black bulbul, Plum-headed parakeet, Red-breasted parakeet, Great barbet, Chestnut-eared bunting, Yellow-breasted green finch used only this foraging maneuver.

Nectar gleaning

The Black-throated sunbird and Green-tailed sunbird were the species coming under this group and both of them used only this method.

7.3.4 Niche overlap

One way of measuring the extent, to which foraging activities of the various species overlap, is by calculating the overlap values. This was done with respect to foraging height (5 categories), foraging substrate (6 categories) and foraging methods (16 categories). Overlap between species was calculated and then mean overlap of each species with others is presented. The results suggested that all the bird categories in this study overlapped with others in at least one foraging dimension (Table 7.6).

Among three dimensions (foraging height, foraging substrate and foraging methods), highest mean overlap for the whole avian community was found in the foraging height (0.20 ± 0.07) while lowest was in foraging method (0.04 ± 0.02). In foraging height categories the minimum niche overlap was shown by Hill partridge (0.04), Ring dove (0.05), Koklass (0.05) and Kalij (0.06). These species did not share any other height category with any bird species. The maximum niche overlap was shown by

White-throated tit (0.31), Yellow-browed warbler (0.29) and Striated laughing thrush (0.28) (Table 7.6).

Oriental dove (0.007), Verditer flycatcher (0.008) and White-tailed nuthatch (0.01) did not share any other category of foraging substrate with any other bird species. Verditer flycatcher used only foliage substrate while White-tailed nuthatch foraged only on trunk and twig substrate. The maximum niche overlap was showed by Rufous sibia (0.12), Black-headed jay (0.116) and Blue whistling thrush (0.108).

In using foraging methods, the minimum niche overlap was shown by Black-throated sunbird (0.002), Ashy drongo (0.005) and Oriental dove (0.006). These birds used only one foraging method or two (very partially). Verditer flycatcher (0.123), Spot-winged tit (0.102) and Black-headed jay (0.09) shared maximum foraging methods with other bird species. Spot-winged tit used twig gleaning as well as bush gleaning and leaf gleaning where as Verditer flycatcher foraged by canopy sallying, bush sallying and twig gleaning.

7.3.5 Diversity Index and Specialists Index

In foraging height dimension (5 categories), the minimum diversity was found in Large hawk cuckoo (0.34), Black-throated sunbird (0.59) and Yellow-breasted green finch (0.62) while maximum diversity was found in Dark-throated thrush (1.37), Chestnut-crowned laughing thrush (1.26) and Black-headed jay (1.24). The specialist bird species in this category were all ground feeding birds such as Black & Yellow grosbeak, Common myna, Hill partridge, Koklass, Ring dove, Oriental dove etc. (Table 7.7).

Table 7.6 Mean Niche Overlap for each bird species in the forest of Kumaon.

Species name	Niche Overlap			
	Foraging Height	Foraging Substrate	Foraging Method	Overall
Ashy drongo	0.18	0.02	0.01	0.07
Bar-tailed creeper	0.26	0.02	0.02	0.09
Black & Yellow grosbeak	0.13	0.04	0.05	0.07
Black-breasted sunbird	0.09	0.04	0.00	0.04
Black bulbul	0.17	0.02	0.01	0.08
Black-headed jay	0.23	0.12	0.10	0.15
Black-lored tit	0.29	0.02	0.06	0.12
Black-throated tit	0.28	0.02	0.04	0.11
Blue whistling thrush	0.15	0.11	0.09	0.11
Brown-fronted pied woodpecker	0.17	0.05	0.01	0.07
Chestnut-bellied nuthatch	0.13	0.05	0.04	0.07
Chestnut-bellied rock thrush	0.16	0.07	0.06	0.09
Chestnut-crowned laughing thrush	0.27	0.08	0.05	0.13
Chestnut-eared bunting	0.10	0.04	0.05	0.90
Chestnut-tailed minla	0.13	0.07	0.05	0.08
Common myna	0.13	0.04	0.05	0.07
Dark-sided flycatcher	0.28	0.02	0.02	0.10
Dark-throated thrush	0.13	0.07	0.06	0.08
Eurasian cuckoo	0.14	0.08	0.07	0.09
Eurasian jay	0.23	0.08	0.08	0.13
Eurasian tree creeper	0.29	0.02	0.02	0.11
Great hill barbet	0.19	0.04	0.04	0.08
Green-backed tit	0.27	0.06	0.08	0.13
Green-tailed sunbird	0.25	0.03	0.01	0.09
Grey-headed canary flycatcher	0.23	0.02	0.06	0.10
Grey-hooded warbler	0.22	0.08	0.06	0.11
Grey tree pie	0.22	0.09	0.05	0.12
Grey-winged black bird	0.22	0.04	0.04	0.10
Hill partridge	0.04	0.03	0.05	0.04
Himalayan woodpecker	0.22	0.06	0.02	0.10
Indian cuckoo	0.22	0.08	0.07	0.12
Jungle crow	0.22	0.07	0.03	0.10
Koklass	0.06	0.04	0.06	0.05
Large hawk cuckoo	0.21	0.11	0.09	0.13

Long-tailed minivet	0.23	0.01	0.09	0.11
Maroon oriole	0.24	0.10	0.08	0.13
Mistle thrush	0.22	0.05	0.04	0.10
Orange-flanked bush robin	0.23	0.05	0.04	0.10
Plain leaf warbler	0.25	0.10	0.06	0.13
Plum-headed parakeet	0.10	0.03	0.03	0.05
Red-billed blue magpie	0.26	0.09	0.04	0.12
Red-breasted parakeet	0.27	0.05	0.04	0.12
Ring dove	0.04	0.03	0.01	0.02
Rufous-bellied niltava	0.24	0.05	0.05	0.11
Rufous sibia	0.19	0.12	0.09	0.13
Rufous turtle dove	0.07	0.01	0.01	0.02
Sapsucker	0.23	0.02	0.02	0.09
Slaty-headed parakeet	0.27	0.02	0.02	0.10
Spot-winged tit	0.29	0.10	0.10	0.16
Spotted forktail	0.09	0.03	0.05	0.05
Streaked laughing thrush	0.08	0.05	0.05	0.05
Striated laughing thrush	0.29	0.10	0.08	0.15
Ultramarine flycatcher	0.26	0.03	0.07	0.11
Verditer flycatcher	0.26	0.01	0.12	0.13
Western-crowned warbler	0.22	0.10	0.04	0.12
Whiskered yuhina	0.15	0.03	0.07	0.08
White-browed shrike babbler	0.25	0.05	0.05	0.11
White-cheeked nuthatch	0.28	0.02	0.02	0.10
White-tailed nuthatch	0.28	0.01	0.01	0.10
White-throated laughing thrush	0.21	0.01	0.01	0.07
White-throated tit	0.31	0.03	0.09	0.14
Whitecrested Kalij	0.06	0.04	0.05	0.04
Yellow-breasted green finch	0.18	0.03	0.03	0.08
Yellow-browed warbler	0.29	0.01	0.02	0.10
Mean ± S.E.	0.20± 0.07	0.04± 0.02	0.05±0.03	0.10±0.04

The minimum diversity was found in Ashy drongo (0.11), Black-headed jay (0.22) and White-tailed nuthatch (0.27) in foraging substrate dimension where as maximum diversity was found in Chestnut-bellied nuthatch (0.69), Blue whistling thrush (0.67) and Spot-winged tit (0.65). 48 species were the specialists' birds in this dimension such as Black bulbul, Black-throated sunbird, Oriental dove, Jungle crow (Table 7.7).

In foraging method dimension, the minimum diversity was found in Oriental dove (0.08), Rufous sibia (0.30) and Jungle crow (0.39) while maximum diversity was found in Ultramarine flycatcher (1.40), Orange-flanked bush robin (1.32) and Blue whistling thrush (1.09). Bird species such as Black bulbul, Black-throated sunbird, Plum-headed parakeet, Black & Yellow grosbeak were called as specialist of this dimension.

Of the three dimensions specialization was more in the foraging substrate (48 species) followed by foraging method (22 species) and foraging height (11 species) (Table 7.7). Avian species such as Black & Yellow grosbeak, Common myna, Common hill partridge, Koklass, Ring dove, Red-breasted parakeet and Streaked laughing thrush can be considered as specialists as their J' values were '0' in all three dimensions.

7.3.6 Determination of foraging guilds

The relationships among 64 bird species based on height, substrates and foraging methods, are summarized in the cluster diagrams (Fig 7.1, 7.2, 7.3).

Fig 7.1 shows cluster diagram based on foraging height. Species were separated into a number of guilds based on usage of similar heights. Guild 1 consisted Ground feeding species such as Kalij, Koklass, Chestnut-eared bunting, Hill partridge. Guild 2 consisted species, which foraged at tree layer and shrub layer such as White-throated tit,

Table 7.7 Extent of specialization by birds in different foraging dimensions as shown by J' values the forest of Kumaon. J' values range from 0-1, and specialization increases as J' falls.
(Specialists are in bold type).

Species name	Foraging Height		Foraging Substrate		Foraging Method	
	H'	J'	H'	J'	H'	J'
Ashy drongo	1.12	0.3	0.11	0.03	0.64	0.17
Bar-tailed creeper	0.96	0.18	-	**0.00**	0.54	0.10
Black & Yellow grosbeak	-	**0.00**	-	**0.00**	-	**0.00**
Black-breasted sunbird	0.59	0.31	-	**0.00**	-	**0.00**
Black bulbul	1.07	0.29	-	**0.00**	-	**0.00**
Black-headed jay	1.24	0.27	0.23	0.05	0.53	0.11
Black-lored tit	0.90	0.25	-	**0.00**	0.69	0.19
Black- throated tit	1.08	0.20	0.65	0.25	0.69	0.26
Blue whistling thrush	0.87	0.21	0.67	0.16	1.09	0.27
Brown- fronted pied woodpecker	0.88	0.23	0.43	0.11	0.43	0.11
Chestnut-bellied nuthatch	0.63	0.36	0.69	0.39	0.64	0.36
Chestnut-bellied rock thrush	1.15	0.40	-	**0.00**	0.59	0.20
Chestnut-crowned laughing thrush	1.26	0.49	-	**0.00**	0.93	0.17
Chestnut-eared bunting	0.69	1	-	**0.00**	-	**0.00**
Chestnut-tailed minla	0.84	0.29	-	**0.00**	0.64	0.22
Common myna	-	**0.00**	-	**0.00**	-	**0.00**
Dark sided flycatcher	0.99	0.41	-	**0.00**	1.02	0.25
Dark- throated thrush	1.37	0.57	0.47	0.2	0.47	0.20
Eurasian cuckoo	1.08	0.47	-	**0.00**	-	**0.00**
Eurasian jay	1.00	0.19	-	**0.00**	0.49	0.09
Eurasian tree creeper	1.15	0.45	-	**0.00**	0.66	0.24
Great hill barbet	1.14	0.38	-	**0.00**	-	**0.00**
Green-backed tit	1.08	0.19	0.28	0.05	0.41	0.07
Green-tailed sunbird	1.01	0.41	-	**0.00**	-	**0.00**
Grey-headed canary flycatcher	0.95	0.19	-	**0.00**	1.04	0.21
Grey-hooded warbler	1.10	0.19	0.54	0.09	0.49	0.08
Grey tree pie	1.02	0.41	-	**0.00**	0.69	0.28
Grey-winged black bird	-	**0.00**	-	**0.00**	0.56	0.12
Hill partridge	-	**0.00**	-	**0.00**	-	**0.00**
Himalayan woodpecker	0.87	0.19	0.62	0.14	0.69	0.15

Indian cuckoo	0.93	0.32	-	**0.00**	-	**0.00**
Jungle crow	0.73	0.19	-	**0.00**	0.40	0.10
Koklass	-	**0.00**	-	**0.00**	-	**0.00**
Large hawk cuckoo	0.35	0.16	-	**0.00**	-	**0.00**
Long-tailed minivet	1.06	0.28	-	**0.00**	0.60	0.16
Maroon oriole	0.82	0.33	-	**0.00**	-	**0.00**
Mistle thrush	1.17	0.31	0.46	0.12	0.67	0.17
Orange-flanked bush robin	1.18	0.28	-	**0.00**	1.32	0.31
Plain leaf warbler	1.01	0.39	-	**0.00**	0.54	0.21
Plum-headed parakeet	0.69	0.50	-	**0.00**	-	**0.00**
Red-billed blue magpie	1.05	0.40	-	**0.00**	-	**0.00**
Red-breasted parakeet	-	**0.00**	-	**0.00**	-	**0.00**
Ring dove	-	**0.00**	-	**0.00**	-	**0.00**
Rufous-bellied niltava	1.20	0.28	-	**0.00**	0.87	0.20
Rufous sibia	1.0	0.18	-	**0.00**	0.30	0.05
Rufous turtle dove	-	**0.00**	0.62	0.24	-	**0.00**
Sapsucker	1.01	0.25	-	**0.00**	0.90	0.29
Slaty-headed parakeet	1.09	0.36	0.37	0.09	0.77	0.19
Spot-winged tit	1.05	0.17	0.66	0.11	0.71	0.11
Spotted forktail	-	**0.00**	-	**0.00**	0.47	0.20
Streaked laughing thrush	-	**0.00**	-	**0.00**	-	**0.00**
Striated laughing thrush	1.04	0.38	-	**0.00**	0.69	0.30
Ultramarine flycatcher	1.07	0.24	-	**0.00**	0.77	0.18
Verditer flycatcher	0.91	0.21	-	**0.00**	0.67	0.26
Western-crowned warbler	0.67	0.29	-	**0.00**	-	**0.00**
Whiskered yuhina	1.06	0.31	-	**0.00**	0.64	0.19
White-browed shrike babbler	1.03	0.25	-	**0.00**	0.08	0.01
White-cheeked nuthatch	0.88	0.27	0.61	0.14	1.41	0.32
White-tailed nuthatch	1.06	0.21	-	**0.00**	0.62	0.19
White-throated laughing thrush	-	**0.00**	-	**0.00**	0.67	0.25
White-throated tit	0.80	0.30	0.28	0.05	0.86	0.17
Whitecrested Kalij	0.16	0.05	-	**0.00**	-	**0.00**
Yellow-breasted green finch	0.62	0.17	-	**0.00**	-	**0.00**
Yellow-browed warbler	1.11	0.19	-	**0.00**	0.52	0.12
Number of Specialists		11		48		22

Black-lored tit, Black bulbul, Eurasian jay. Ashy drongo, Rufous sibia, Dark-throated thrush, Blue whistling thrush formed third guild which foraged on ground as well as at the tree layer. Some species were also there which used all height categories such as Whiskered yuhina, White-tailed nuthatch, Great barbet, Long-tailed minivet.

Species were distinguished in different guilds on the basis of using similar substrate. Black bulbul, Plum-headed parakeet, Great barbet and other fruigivore, nectarivore and grainivore species formed first guild while Dark-sided flycatcher, Verditer flycatcher, Long-tailed minivet and Grey-headed canary flycatcher formed similar guild on the basis of air substrate (Fig 7.2). Where as Brown-fronted woodpecker, White-cheeked nuthatch, Bar-tailed tree creeper and Eurasian tree creeper were found feeding on tree trunk. Ground substrate was also separated by Streaked laughing thrush, White-throated laughing thrush, Koklass, Kalij, Grey-winged black bird. Some species foraged on ground as well as in foliage, so they formed distinct guild like Red-billed blue magpie, Mistle thrush, Blue whistling thrush, Dark-throated thrush. An independent guild formed by twig substrate using species for instance Black-lored tit, Whiskered yuhina, Black-throated tit and White-throated tit. Foliage was used by Chestnut-tailed minla, Rufous sibia, Eurasian cuckoo, Eurasian jay and hence formed a separate guild (Fig 7.2).

Cluster diagram based on foraging methods (Fig 7.3) contained so many similar guilds. Two major guilds formed separated insectivorous and non-insectivorous species. Guild 1 contained fruit exploiting species such as Black bulbul, Plum-headed parakeet, Great barbet, Black-headed green finch, Slaty-headed parakeet. Another guild contained only three species i.e. Koklass, Oriental dove and Ring dove, whereas another guild included those species which foraged by ground searching like Grey-winged black bird,

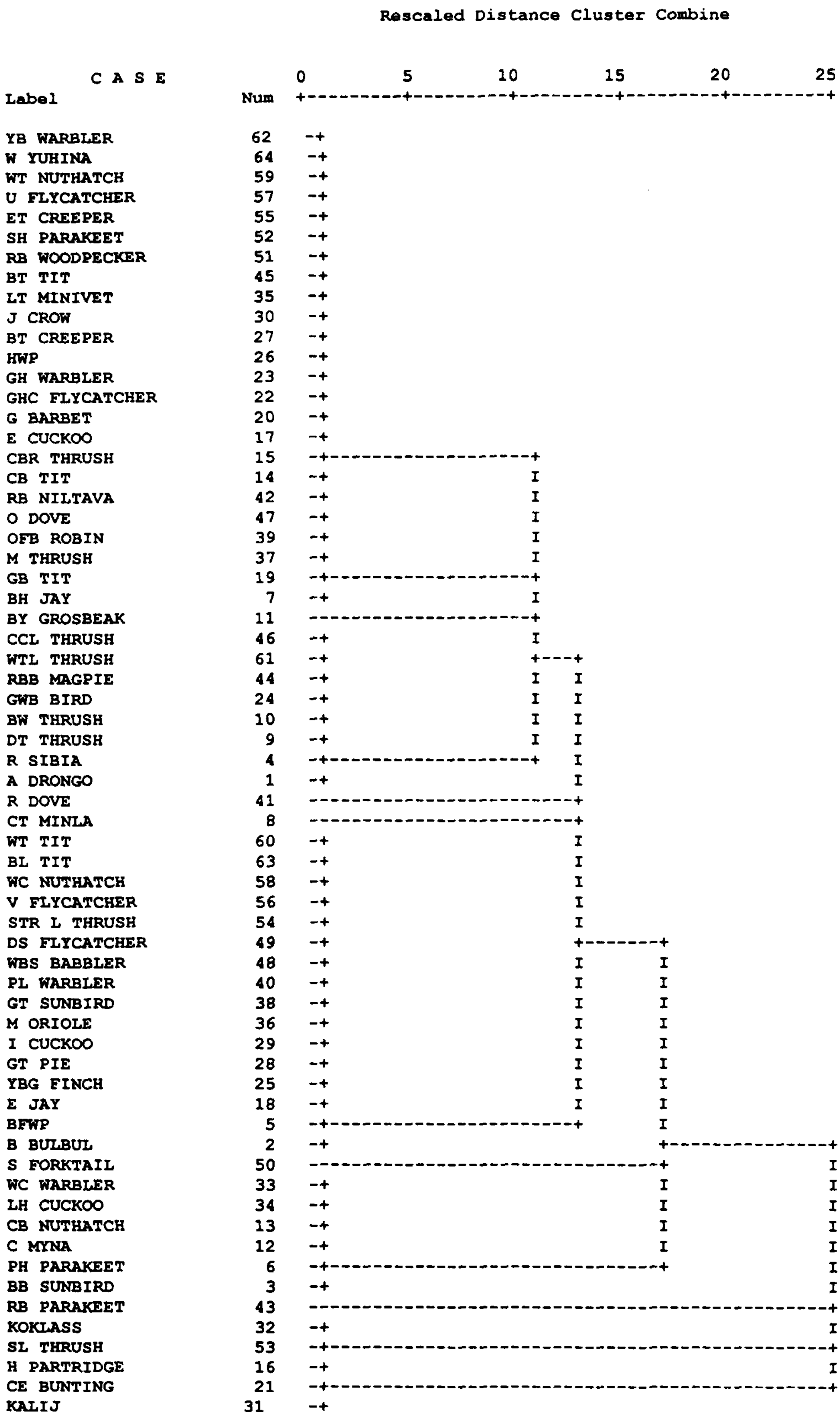


Fig. 7.1 Interspecific relationships of 64 bird species, based on multivariate analysis of foraging height.

Red-billed blue magpie, White throated laughing thrush, Kalij, Black & Yellow grosbeak. Canopy sallying species formed separate guild like Long-tailed minivet, Verditer flycatcher, Ultramarine flycatcher, Grey-headed canary flycatcher. Twig gleaners and bush gleaners formed distinct guild, which included birds such as Striated laughing thrush, White-throated tit, Chestnut-bellied rock thrush, Chestnut-tailed minla and Rufous sibia.

7.4 DISCUSSION

Among birds, there are four major groupings based on the food eaten, insectivorous, nectarivorous, granivorous and fruigivorous. The height and height related characteristics separate the ground foragers from the other species. There were therefore three distinct foraging environments (ground, plants and air) in Kumaon. Plant (shrubs and trees) surface provided microhabitats such as foliage and wood. Each of these regions (environment and microhabitats) was exploited by the bird species that have specialized morphology and behaviour necessary for foraging there. Distinction of ground and above ground (air, shrubs and trees) emphasized the importance of foraging opportunities on these environments. The availability of various plant forms (shrubs, short trees, trees) in this habitat not only increases dimensions of the vertical habitat and, as a consequence, the foliage layering and complexity, but also provides supporting substrates (twigs, trunk/main branches, foliage). The proportion of foliage at different heights is also a function of the branching structure of the plant forms.

In general five substrates such as air, ground, wood (twigs and trunk / main branches), foliage and nectar / seed / fruit were recognized in the Kumaon. It can be

```
                          Rescaled Distance Cluster Combine

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

  BL TIT         63  -+
  W YUHINA       64  -+
  WT TIT         60  -+------------------------+
  BT TIT         45  -+                        I
  RBB MAGPIE     44  -+                        I
  CCL THRUSH     46  -+                        I
  M THRUSH       37  -+                        I
  BW THRUSH      10  -+                        I
  DT THRUSH       9  -+----------------+       I
  BH JAY          7  -+                +-------+
  SW TIT         14  -+----------------+       I
  GH WARBLER     23  -+                I       I
  GB TIT         19  ------------------+       I
  SL THRUSH      53  -+                        I
  WTL THRUSH     61  -+                        I
  S FORKTAIL     50  -+                        I
  KOKLASS        32  -+                        I
  KALIJ          31  -+                        I
  GWB BIRD       24  -+                        I
  H PARTRIDGE    16  -+                        I
  C MYNA         12  -+------------------------+
  BY GROSBEAK    11  -+                        I
  STR L THRUSH   54  -+                        I
  YB WARBLER     62  -+                        I
  WBS BABBLER    48  -+                        I
  RB NILTAVA     42  -+                        I
  PL WARBLER     40  -+                        I
  OFB ROBIN      39  -+                        I
  M ORIOLE       36  -+                        I
  LH CUCKOO      34  -+                        I
  WC WARBLER     33  -+                        I
  J CROW         30  -+                        I
  I CUCKOO       29  -+                        I
  GT PIE         28  -+                        I
  E JAY          18  -+                        I
  E CUCKOO       17  -+                        I
  CBR THRUSH     15  -+                        I
  CT MINLA        8  -+                        I
  R SIBIA         4  -+------------------------+
  BB SUNBIRD      3  -+                        I
  HWP            26  -+                        I
  RB WOODPECKER  51  -+                        I
  CB NUTHATCH    13  -+------------------------+
  BFWP            5  -+                        +-----------------------+
  ET CREEPER     55  -+                        I                       I
  WC NUTHATCH    58  -+------------------------+                       I
  BT CREEPER     27  -+                        I                       I
  WT NUTHATCH    59  --------------------------+                       I
  DS FLYCATCHER  49  -+                        I                       I
  V FLYCATCHER   56  -+                        I                       I
  LT MINIVET     35  -+------------------------+                       I
  GHC FLYCATCHER 22  -+                        I                       I
  U FLYCATCHER   57  --------------------------+                       I
  A DRONGO        1  --------------------------+                       I
  O DOVE         47  -+                                                I
  SH PARAKEET    52  -+                                                I
  RB PARAKEET    43  -+                                                I
  R DOVE         41  -+                                                I
  GT SUNBIRD     38  -+                                                I
  YBG FINCH      25  -+                                                I
  CE BUNTING     21  -+                                                I
  G BARBET       20  -+                                                I
  PH PARAKEET     6  -+------------------------------------------------+
  B BULBUL        2  -+
```

Fig. 7.2 Interspecific relationships of 64 bird species, based on multivariate analysis of foraging substrate.

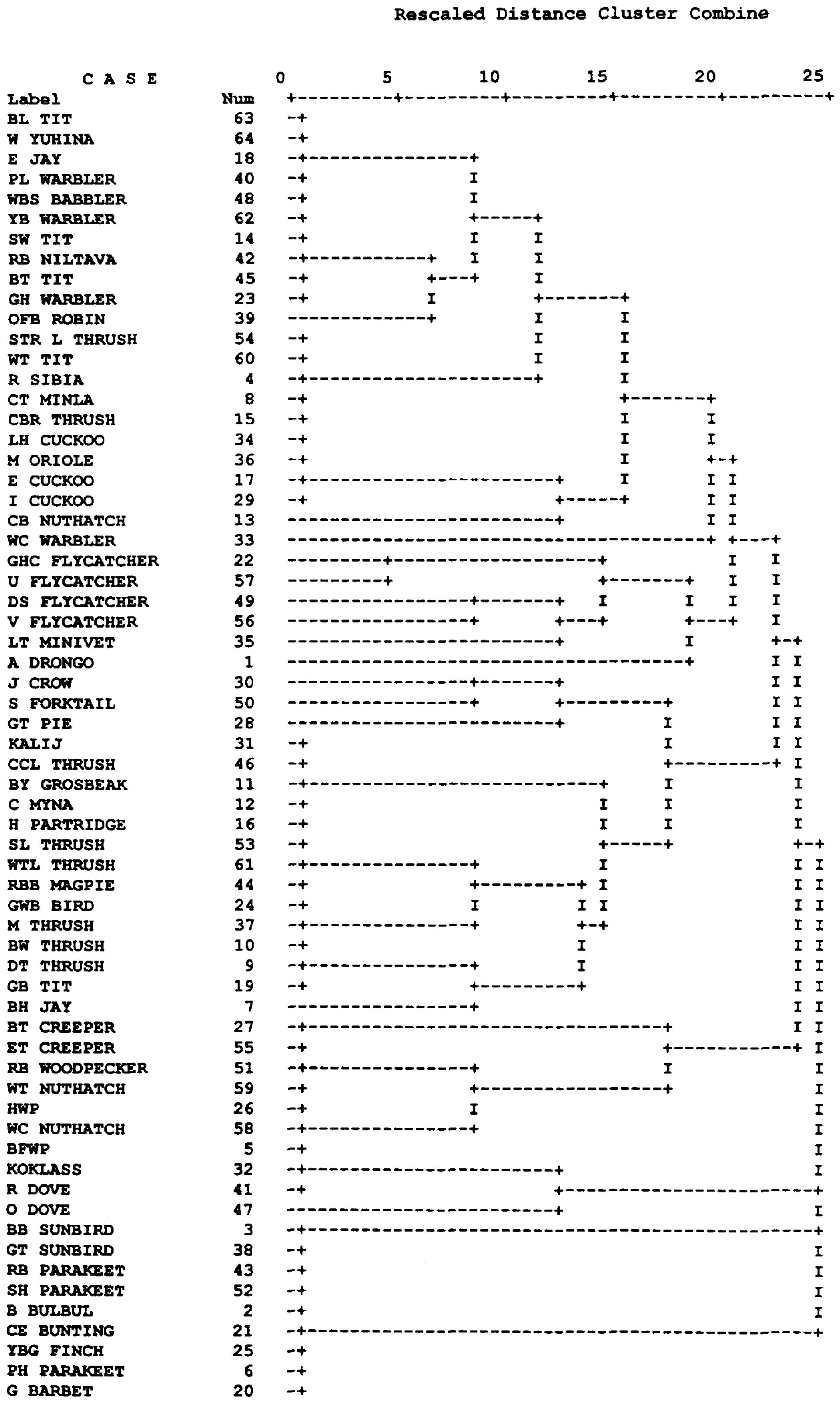


Fig. 7.3 Interspecific relationships of 64 bird species, based on multivariate analyses of foraging methods.

further reduced into air, ground and plants for which larger number of bird species fall under the plant-guild because plants offer a greater variety of micro habitats (trunk, branches, twigs, foliage) to find suitable food in this habitat.

In total, birds in the study area chiefly used 11 methods to obtain food. In the present study, closely related species used the same basic searching methods indicating the importance of phylogenic and evolutionary process in determining patterns (Robinson & Holmes, 1982). However adaptive radiation in certain groups provides facilities for them to diverse resource utilization using different methods. In most of the cases, guild was formed by a group of species, which are similar in their morphological adaptation. For example, all the woodpeckers were chiefly wood gleaning and mostly on the trunk / main branches. But, species with different morphologies also utilize the same general searching mode and take the similar types of prey, suggesting that morphology does not necessarily predetermine the foraging behaviour or diet, as has been inferred by insectivorous birds (Ricklefs & Travis, 1980). Therefore, it may be concurred with Hutto (1981) that morphological analyses will never provide a complete characterization of the food exploitation patterns and ecological relations of co- occurring bird species.

Resource partitioning reduces the effect of competition by decreasing the amount of overlap between the competing species (Weins, 1989). So, the incidence of overlap amongst potential competitors may be used to assess the extent of resource partitioning on the niche dimensions measured. All the birds in these habitats overlapped with others but only to a smaller extent. Although some species had higher overlap in one dimension, they had marginal overlap in other dimensions. However, it can be said that partitioning of foraging dimensions among birds occurred in Kumaon as reported earlier of bird communities of various places (Recher *et al.* 1985).

Niche overlaps are shaped by several factors (Cody, 1974; MacArthur, 1968). In this study in all three dimensions (foraging height, foraging substrate and foraging methods), for the avian community as a whole, highest mean niche overlap was found in the use of foraging height followed by foraging substrate and the least in the foraging method. The birds are evolved with special morphological adaptations to use specific method and exploit particular substrates for their prey and hence morphology of birds may constrain the usage of foraging methods and substrates (Alatalo, 1981; 1982; Rolando & Robotti, 1985). It may be the reason for birds showing small niche overlap values in these two categories. High value in the height dimension can be attributed to the distribution of different food items (insects, fruits, seeds and flowers) particularly at certain height category. For example, both seeds and insects were available at the ground layer and similarly, insects were available close to a height where flowers, fruits and seeds were available. In general, the shape of the niche overlap (low or high) shown by birds can be attributed to the availability of food resources, morphology of species and competition as suggested by Alatalo (1981, 1982), Rolando & Robotti (1985) and Szekely (1985).

Among the three dimensions, there were more number of specialists in the substrate category. Organisms may specialize only when resources are available in restricted or particular environment, or otherwise morphology of organisms influence diets (Rolando & Robotti, 1985). Among the dimensions (foraging height, foraging substrate and foraging methods), prey largely depends on the substrate and thus, substrate determines what sort of prey it can support. Birds are evolved with special morphological adaptations to exploit particular substrates for particular prey and hence specialists were more in the substrates.

It is frequently reported in the literature (Weins, 1969; James, 1971; Anderson & Shugart, 1974) that bird species select certain parts of the habitat based on specific search images. But care should be taken in emphasizing habitat keys.

CHAPTER 8

THREATS AND CONSERVATION STRATEGIES

8.1 INTRODUCTION

Birds together with vascular plants are the most commonly used groups in the studies of assessment and evaluation of nature. A lot of effort seems to have been directed at the identification and protection of birds and their habitats. It has been argued that if bird communities are protected, then many other communities will be protected, and that evaluation of bird communities can be used as an indicator of the quality and conservation interest of the habitats. In general, birds are easily observed and many of them are familiar to people. The conspicuousness and popularity of birds would seem to be two reasons why there has been a considerable interest in studying and protecting birds.

Analyses of threats to bird community are complicated by the possibility that bird species might respond to changes in their environment in different ways (Gaston, 1994). So the effective nature conservation initially requires accurate methods of identifying habitats and localities most worthy for preservation and management as nature reserves. Conservation assessment can be done at the level of individual taxon viz., a species or a genus and also at the level of a community (Nature Conservancy, 1983 & 1986). Usher (1986) has suggested the requisites for an assessment exercise. He has pointed out the importance of distinguishing three separate, but closely related features- attributes, criteria and values. Attributes are properties of a locality or habitat, which can be used to reflect the conservation interest in it. An attribute may be a list of taxa of birds found in a locality or habitat. A criterion is used to express an attribute in a form that can be used in an assessment such as richness of taxa or diversity can be a criterion. Values can be placed upon the stages of the criterion. Thus, if a series of localities / habitats are looked at, more value might be placed on the locality / habitat with a higher richness of taxa.

No research work has been carried out in the Kumaon Himalaya to find out the kind and intensity of threats on birds. Most of the work has focused on documenting species list (Lesson, 1826; Vigors, 1830; Whymper, 1902; Irby, 1861; Hudson, 1930; Koelz, 1950; Ganguli, 1966; Newsome, 1979; Tak & Sati, 1994; Sultana & Khan, 2000). Conservation of birds was also one of the purpose of my study, so I undertook following objectives for this chapter-

- To identify major threats on avian community
- To observe the relationship of Bird species diversity and richness with patch size.
- To assign conservation values to different sites in terms of avian community and to identify the centers of high bird diversity.
- To prepare a conservation strategy for the protection of birds and their habitat in Kumaon Himalaya.

8.2 METHODOLOGY

8.2.1 Data collection

While surveying the Kumaon hills, several threats on biodiversity (plants and birds) have been found and assessed. These threats were classified in two groups i.e. abiotic and biotic pressures. Abiotic pressure was: Fire and biotic pressures were:

Lopping, Cutting, Grazing, Grass harvesting, Fuel wood collection, Leaf and grass collection, Medicinal plant extraction, Bark and torch wood collection, Tourism impact, Lichen and moss collection, Poaching and animal product trade, Timber collection, Construction work inside the sanctuaries and protected areas, Nomadic pressure, Human population, Livestock population, Literacy rate, Land area available for cultivation & other activities, Number of villages in and around the forest patch, Source of income and forest patch size.

8.2.1.1 ***Abiotic pressure - Fire***

During the surveys of Kumaon, out of 23 surveyed oak patches fire was found at Binsar Wildlife Sanctuary, Jageshwer and Daphiadhura (an oak-forest patch in AWS). A total of 100 plots were sampled at Binsar Wildlife Sanctuary, and 20 & 10 plots were sampled at Daphiadhura and Jageshwer respectively. Circular plot method following Dombois & Ellenberg (1974) was adopted for the vegetation sampling in the burnt patches. At each sampling plot a 10m radius circular plot was randomly established to quantify burnt trees. GBH (Girth at Breast Height) in cm, total tree height and height of fire (in meters), and status of tree (dead or alive) were recorded for each tree at each plot.

Regeneration was quantified in terms of seedling and saplings in 3m radius circular plot within the existing 10m radius circular plot. Tree species up to 0.50m was considered as seedling while 0.51m to 4.0m was taken as sapling. The number of seedlings and sapling of each tree species and their status was recorded within the 3m radius circular plot. The same circular plot (3m radius plot) was also used for the assessment of shrub layer. Data on ground cover (herbs and grasses) were recorded in four 0.25m^2 quadrates randomly placed at four places within the10m radius circular plot.

Data on disturbance factors such as number of cut trees, lopped trees and dung piles were also recorded within the 10m radius circular plot. Besides, occurrence of fire at the rest of the patches was recorded on ordinal scale by interviewing village people and from the forest department.

8.2.1.2 ***Biotic pressures***

Biotic pressures (listed above) were also quantified for each site. Data were collected by means of surveys of oak patches and dependent villages in and around these oak patches. Block Division Office and National Information Center were also consulted for anthropogenic status, literacy rate, land area available and source of income of locals of the surveyed sites. Apart from this, lopping, cutting and grazing were quantified in 10meter radius circular plot during the vegetation sampling of each oak patch. Grass harvesting, fuel wood collection, leaf and grass collection, medicinal plant collection, bark and torch wood collection, tourism impact, lichen and moss collection, poaching and animal product trade, timber collection, construction work inside the sanctuaries and protected areas and nomadic pressure were quantified on ordinal scale.

8.2.2 Analyses

8.2.2.1 ***Fire***

Analytical features of fire sampling were computed by following a series of tests. The density and confidence intervals were computed per hectare for trees, seedlings, saplings and shrubs while herbs and grasses were calculated per square meter by the following formula,

Density = Number of individuals / Total area covered

Mean density of each tree species of burnt patch was also calculated. Over all mean tree diversity was calculated by Shannon-Weiner Index (Magurran, 1988) of plant species by following formula,

$H' = -\sum pi \ln pi$ (pi = proportion of individuals found in i^{th} species)

While mean species richness was calculated by Margelef's Index (Magurran, 1988)

$R = S-1/ \ln N$

where S = Number of species, N = Number of individuals.

Trees were categorized arbitrarily into six GBH classes (0- 25, 26- 50, 51-100, 101-200, 201-400 and >400 cm) and height of fire was also categorized into eight classes i.e. 0-50, 51-100, 101-200, 201-400, 401-800, 801-1600, 1601-3200 and >3200 cm. Tree species diversity and richness was also calculated for different fire height categories and GBH classes by above-mentioned formulae. The Importance Value Index (IVI) for each tree species was calculated from the sum of its relative density, relative frequency and relative basal area.

Percentage of overall dead trees and percent dead of each tree species was calculated for each fire affected patches. The Bonferroni confidence intervals were constructed following Neu *et al.* (1974) to detect significant differences in species specific mortality pattern. To observe the maximum regeneration for tree species, percent regeneration of seedlings of different tree species was also calculated to assess the regeneration pattern.

A chi-square contingency test (Fowler & Cohen, 1986) was performed to find out differential mortality pattern in different GBH class in terms of dead trees and the same test was performed for height categories also.

Top five IVI ranking dead tree species and different GBH classes were taken into account for chi-square contingency test to pin point the association between the dead tree species and GBH classes while the same test was performed for top four IVI ranking dead tree species and different height categories to pin point the association between dead tree species and different height categories.

Data for rest of the oak-forest patches where fire did not occur in the recent past, were collected on ordinal scale i.e. low, medium and high ratings. In these forest patches occasional occurrence of fire was considered as low (1), medium (2) was taken into account where fire occurred after two years while it was considered high (3) where fire occurred every year.

8.2.2.2 ***Biotic pressures***

All parameters of biotic pressures were converted into ratings of low (1), medium (2) and high (3) in the threat context. But the conversion was different for all parameters, which is given below (Table 8.1).

1. **Patch size-** Patch size was considered as a threat to biodiversity conservation. The surveyed oak-forest patches in Kumaon Himalaya ranged from 2.5 km^2 (Jilling in Naini Tal district) to 54 km^2 (Gandhura in Pithoragarh district). Keeping in view, the patches falling under the range category between 1-10 km^2 were considered as small

patch size, medium sized patches were considered between 11-20 km² while patches of >20 km² area were considered as large oak forest patches.

2. **Human population-** The human population in and around surveyed oak patches ranged between nil to 20,000 persons. The constant value (density index- persons / km²) was used for each category (low, medium and high). Density index of 0-100 persons / km² was considered as sparsely distributed and 101-200 persons / km² as a medium density while >200 persons / km² were taken into account as densely populated.
3. **Livestock population-** It ranged from nil to 50,000 livestock approximately. Livestock population in a patch from 0-2500 was considered as a low, 2501-7500 livestock as medium and >7500 livestock as high. The forest patches having the mentioned dependent livestock population were given ordinal scale ratings of low (1), medium (2) and high (3) respectively.
4. **Number of villages-** The number of dependent villages in and around the surveyed sites ranged from nil to 32. Considering them as threats to biodiversity, the sites having 0-10 dependent villages were given low threat rank, 11-20 dependent villages as medium threat and >20 dependent villages were considered as high threat upon biodiversity.
5. **Source of income-** The source of income decides amount and kind of dependency of the people on the forest patch. The source of income was also considered as indirect threat to biodiversity in terms of number of income sources available at each surveyed forest patch. The patches having more than two sources of income exerted low threats, the patches having two income sources were considered as medium while

the patches having nil source of income taken as high threat i.e., more dependency on the forests.

6. **Land occupied by people-** The land available to the locals was calculated by recording the actual land occupied by people living in and around each surveyed oak patch. Later, the land occupied by the locals was calculated in terms of percentage out of the total patch size. The more the land occupied by the locals in and around each oak patch the more threats to biodiversity. It was considered as low threat on forest patch when locals occupied upto 5% of the actual forest patch size, medium threat when they occupied 6-30% land inside the forest patch and high threat when they occupied more than 30% land of the actual oak forest patch.
7. **Percent cultivation-** Percent cultivation was calculated from the land area occupied by people settled in and around each oak patch. Cultivation on 0-25 % occupied land was considered as low threat, 26-50% occupied land as a medium and when cultivation was on more than 50% occupied land, it was considered as high threat.
8. **Percent literacy-** Literacy helps in making people aware about the importance of forest and its biodiversity. So, the status of literacy (% literacy) of the local people was taken as the level of threat experienced at each surveyed oak-forest patch. Literacy upto 25% was considered as high threat, 26-50% as medium threat and more than 50% as low threat on the forest and on the biodiversity values of each forest patch.
9. **Lopping-** Within the 10m radius vegetation-sampling plot, total number of trees and the trees lopped was counted. The proportion (%) of trees lopped out of total trees sampled was calculated and converted into ordinal scale ratings of low, medium and

high for each patch. The forest patches experiencing lopping upto 30% were taken as low, 31-60% as medium and more than 60% as high threat.

10. **Tree cutting**- Sampling plots were established for assessing vegetation attributes at each oak-forest patch. Within the vegetation sampling plots number of stumps were also counted. The number of trees and stumps added to quantify the proportion of stumps. Proportion (%) of stumps out of total number of trees counted was calculated for each forest patch. 20% tree cutting was considered as low, 21-40% as medium and more than 40% as high.
11. **Grazing**- Grazing was quantified in terms of dung piles found at each sampling plot at each oak patch. Dung piles found at all the surveyed oak-forest patches were added together and the proportion of dung piles out the total was estimated for each oak-forest patch. The patches falling under 0-25% of dung category were taken as low, 26-50% as medium and more than 50% as high in terms of grazing.
12. **Tapping**- Tapping mainly affects the resin producing tree species. Its frequent and excessive extraction makes the tree species disease and fire prone. Keeping in view, it was also considered as one of the threats to biodiversity. The duration between the two extractions was considered as tapping intensity. The occasional extraction was taken as low tapping, extraction after two years as medium and extraction every-year as high tapping.
13. **Grass harvesting**- Grass harvesting was recorded, as number of bundles (1 bundle = 20 kg approximately) required by each family as fodder for livestock at each oak-forest patch. It was enquired from locals regarding quantity of grass consumed by one domestic animal/day. Each domestic animal required 10kg / day approx. Range of 0-5

bundles required by single family for their cattle was considered as low grass harvesting, 6-20 bundles as medium and > 20 bundles / family required at the patches were taken as high grass harvesting.

14. **Medicinal plants extraction**- The kind of use and purpose of the collection was considered as intensity of threats on biodiversity. The collection of medicinal plants for local use was taken as lower extraction, extraction for local use and some portion of it used for commercial purpose was rated as medium extraction and collection exclusively for commercial purpose was considered as higher extraction.
15. **Fuel wood collection-** Fuel wood harvesting plays a significant and direct role in forest loss all over the world (Myers, 1984). It has also been established that highest rates of forest decline since 1960s have occurred in areas with heavy dependence on fuel wood in developing and non oil producing countries (Ekkholm, 1976; IUCN, 1980; Allen & Barnes 1985; Postel & Heise, 1988). In the light of above reasons we placed fuel wood collection a great threat to biodiversity. Dependent families and fuel wood collectors were asked for their per day need (kg / day) of fuel wood and it was found that 20kg / day / family of fuel wood was required. A family consisted of on an average eight-members so, total wood required by total families of the dependent villages was estimated for each surveyed patch. The estimated required fuel wood was converted in quintals / day from kg / day. The range (minimum-maximum) of fuel wood required all over the surveyed forest patches was divided in to the ratings of low, medium and high and the patches falling under the categories were provided values accordingly. 0-15 quintal / day was considered as low collection, 15-30

quintals / day as medium and more than 30 quintals / day as high fuel wood collection.

16. **Bark extraction-** The barks of plant species like *Viburnum* sp., *Taxus baccata* and *Abies pindrow* etc. are extracted for medicinal use. The extraction was so heavy that it exposed the plant species to the outer environment. The affected plant species get infected with diseases and become dry after excessive extraction. A sac filled with 50 kg of extracted bark was taken as unit extraction / year. A definite range (sacks / year) was made for bark extraction for different categories (low, medium and high). Low extraction ranged between 0-25 sacks / year, the medium ranged between 26-75 sacks / year and more than 75 sacks / year extraction as high.
17. **Tourism-** I considered tourism as threat to biodiversity conservation. Clean and less polluted environmental surrounding of the Kumaon hills attract large number of tourists throughout the year. Towns and surrounding natural habitats (including protected areas) are receiving maximum pressures from the tourist inflow. The town acts as transit camp for providing basic necessities to them but ultimately they go to surrounding natural areas. I collected data for the surveyed oak-forest patches receiving approximate number of tourists every year. The actual numbers were divided in three categories. The patches receiving up to 500 individuals of the tourists experienced low pressure, from 501-1000 as medium pressure and the patches receiving more than 1000 every year were considered as high pressure experiencing from tourism.
18. **Lichen and Moss collection-** Collection / extraction of any forest produce from the forests is threat to them. Except few, lichen and moss collection was observed almost

at all the surveyed forest patches. The extraction was mainly for commercial purpose. The unit of quantification was a sac of 50 kg. I recorded number of sacks extracted / year at each patch. Extraction up to 25 sacks / year was low, 26-75 sacks / year was medium and more than 75 sacks of lichen and moss extraction was considered as high.

19. **Poaching and animal trade**- Animals are facing severe threat due to poaching activity. Hunting / killing of animals for any purpose was recorded as threats to biodiversity at each site. The killing of the animals was rated with weights (low, medium and high) given to the purpose and the use of the killed animal. The purpose of killing of wild animals differed in different surveyed localities. The aim of killing was enquired from locals. When it was for the personal / local consumption, it was rated as low threat, the killing for the commercial purpose was considered as medium threat to the animals and when the animals were killed for personal / local and commercial purposes then it was thought to be high threat for the animals.

20. **Timber-wood collection**- Not all the tree species were used for timber. Selected timber wood producing tree species were cut for different purposes (house construction, furniture making, bridge construction etc.). The reasons for timber wood collection were responsible to the kind or/type (low, medium and high) of threat experienced at each patch. Timber wood extraction for local use was accounted for low threat to the biodiversity, medium was the threat when it was exclusively extracted for commercial purpose and the high threat was when timber wood was extracted for local as well as commercial use.

21. **Construction work**- I considered construction work in and around the surveyed oak patch as direct and indirect threat to biodiversity. Construction work inside the forest is impossible without forest clearing. The type of construction work at each site was rated on the ordinal scale of low, medium and high. The construction of houses for locals was considered as low threat because limited space was required for the purpose, while construction work for commercial purposes (Tourist infrastructure, shopping complex, commercial cum residential complex) accounted for medium threat. The areas having all kinds of construction works (for local use, commercial purpose and other big construction work like dams, military operation units etc. rated as high threat.
22. **Nomadic pressure**- Excessive grazing by sheep & goats cause great damage to forest. They particularly feed on the regenerating plant species, which decide future status of any forest. The number of grazers was directly related to the intensity of grazing threat to the site. The intensity of threat was recorded on the ordinal scale of low, medium and high. The sites experiencing grazing up to 1000 sheep & goats were taken low nomadic pressure areas while from 1001-5000 sheep & goats as medium and more than 5000 sheep & goats holding areas received high nomadic pressure.

8.2.2.3 *Threat index*

Each threat parameter was converted into the ordinal scale ratings of low (1), medium (2), and high (3) in terms of threats. To generate threat index (mean threat score) for all the surveyed sites, all the converted ratings of threats were added together and then divided by number of threat parameters.

Table 8.1 Details of categories taken into account for different biotic threats in Kumaon Himalaya.

Threat	Categories		
	Low	**Medium**	**High**
NVL	1= low (1-10)	2 = med (11-20)	3 = high >20)
HUP/km^2	1= low (0-100)	2 = med (101-200)	3 = high (>200)
PSZ (km)	1= small (1-10)	2 = med (11-20)	3 = large (>20)
SOI	1= >2 sources	2 = 2 sources	3 = nill
LA	1= 0-5 % PSZ	2 = 6-30 % PSZ	3 = >30 % PSZ
PRC	1= low (0-25 %)	2 = med (26-50 %)	3 = high (>50 %)
PRL	1= low (0-25 %)	2 = med (26-50 %)	3 = high (>50 %)
LIP	1= low (0-2500)	2 = med (2501-7500)	3 = high (>7500)
LOP	1= low (0-30%)	2 = med (31-60%)	3 = high (>60%)
CUT	1= low (0-20%)	2 = med (21-40%)	3 = high (>40%)
GRAZ	1= low (0-25%)	2 = med (26-50%)	3 = high (>50%)
TAP	1= occasional	2 = after 2 years	3 = every year
GRH	1= low (0-5 bn)	2 = med (6-20 bn)	3 = high (>20 bn)
MP	1= local use	2 = local & comm	3 = commercial
FR	1= occasional	2 = after 2 years	3 = every year
FWC	1= low (0-15 q)	2 = med (16-30 q)	3 = high (>30 q)
BRE	1= 0-25 sacks	2 = 26-75 sacks	3 = >75 sacks
TU	1= 0-500 indv	2 = 501-1000 indv	3 = >1000 indv
LMC	1= 0-25 sacks	2 = 26-75 sacks	3 = >75 sacks
PAT	1= local consmp	2 = commercial	3 = local & comm
TM	1= local consmp	2 = commercial	3 = local & comm
CW	1= own purpose	2 = govt &local	3 = local, govt.& com
NP	1= 0-1000 cattle	2 = 1001-5000 cattle	3 = >5000 cattle

NVL = no.of villages, **HUP** = human population, **PSZ** = patch size, **SOI** = source of income, **LA** = land area owned by locals, **PRC** = percent cultivation, **PRL** = percent literacy, **LIP** = livestock population, **LOP** = lopping, **CUT** = cutting, **GZ** = grazing, **TAP** = tapping, **GRH** = grass harvesting, **MP** = medicinal plant extraction, **FR** = fire, **FWC** = fuel wood collection, **BRE** = bark extraction, **TU** = tourism, **LMC** = lichen & moss collection, **PAT** = poaching and trade, **TM** = timber collection, **CW** = construction work, **NP** = nomadic pressure, **comm** = commercial, **consmp** = consumption, **bn** = bundles (1bn=20kg), **1sack** =50 kg, **q** = quintal

$$\text{Mean threat score} = \frac{\text{Sum of ratings of all threat parameters}}{\text{Total number of threat parameters}}$$

The surveyed sites were categorized, on the basis of generated mean threat score, as the areas having low, medium and high threats. A definite range of mean threat score was given to each threat category. The low threat category was taken between 0-1 mean threat score, the medium threat category between 1.1-2 and >2 mean threat score values were accounted for high threat category.

A Simple Linkage Cluster analysis was performed to classify sites on the basis of threat ratings (low, medium and high). Similar analysis was performed for the sites on presence / absence of threats. Multiple regression analysis was done to see the relationship in four dependency factors viz. human population, source of income, land holding and cattle population with total fuel wood consumption of the families at each site.

To observe the relationship between bird species diversity and richness with the other mentioned 23 threat parameters, multiple regression analysis was performed. The stepwise procedure was chosen for this analysis. A non- parametric test Kendall's tau_ b was also performed to see the relationship in various threat parameters.

8.2.2.4 ***Assigning conservation values***

For assessing the conservation value of each surveyed site in terms of birds, a conservation index was calculated following Jarvinen and Vaisanen (1978), V_k index or 'the conservation value of the k^{th} habitat'

$V_k = \Sigma V_{ik}$

where V_{ik} is the conservation value of the i^{th} species in habitat k.

$$V_{ik} = \frac{n_i A}{N^2_i} \delta_{ik}$$

here, ni = population size of the i^{th} species in a smaller region, such as country or part of a country, A = area of this region, Ni = population size of the i^{th} species in a larger region, such as several countries, and δ_{ik} = density of the i^{th} species in habitat k. Jarvinen and Vaisanen (1978) used this index to compare the conservation value of single populations (V_{ik}) or different habitat types (V_k); I will use it to compare different sites having oak habitat within the Kumaon Himalaya. In this calculation the defined parameters were as follows,

$$V_{is} = \frac{n_i A}{N^2_i} \delta_{is}$$

n_i = number of individuals of i^{th} species in the oak habitat, A = area of the oak habitat in a site, N_i = number of total individuals of i^{th} species in whole Kumaon, δ_{ik} = density of the i^{th} species in site. So the conservation value of each site was calculated by the following formula,

$Vs = \Sigma V_{is}$

8.2.2.5 *Spatial analysis*

Different themes (aspects) were used as layers to prepare thematic maps in terms of various threats (methodology discussed in Chapter 3). Spatial analysis was performed by using threat index and sets of threat parameters as different layers for the preparation of thematic maps for birds for the surveyed sites.

The threat index and the mean of two sets of threat parameters; i) cutting, lopping, grazing, grass harvesting, ii) human & livestock population, were converted into ordinal scale ratings (low, medium and high) and used as separate layers. Bird species diversity values were also categorized as low (0-1), medium (1.1-2.5) and high (> 2.5) and used as a layer. This layer was overlaid upon threat index and mean threat scores of sets of parameters separately.

8.3 RESULTS

Fire caused great damage in Binsar Wildlife Sanctuary, Jageshwer and Daphiadhura.

8.3.1 Overall density and species density of all burnt patches

The density parameter of the community analysis gives an idea of the quantity of the species. Table 8.2 summarizes the mean density (individuals / ha), standard error and confidence interval (95% confidence level) while table 8.3 gives the details of diversity and richness for trees, shrubs, herbs, grasses and regenerating tree (seedlings and saplings) species for each site. The maximum mean density (815.29 / ha ± 89.72) of tree species was quantified for Jageshwer and minimum (538.25 / ha ± 39.44) for Daphiadhura in Askot Wildlife Sanctuary. Maximum regeneration in terms of seedlings and saplings of different tree species was observed at Daphiadhura while minimum in Binsar. Tree species diversity (1.28 ± 0.26) and richness (1.14 ± 0.31) was maximum at

Table 8.2 Overall density values of vegetation at burnt patches.

Site	Density	± S.E.	C.I. (95% confidence level)
Binsar			
Trees/ha	625.16	23.42	± 45.92
Shrubs/ha	17600.8	976.11	± 1913.13
Herbs/m^2	18.44	2.36	± 1.21
Grass/m^2	27.06	1.41	± 2.75
Seedling/ha	1617.13	129.52	± 253.87
Sapling/ha	693.56	95.81	± 187.79
Daphiadhura			
Trees/ha	538.25	39.44	± 77.31
Shrubs/ha	7271.76	927.9	± 1818.65
Herbs/m^2	35.85	2.73	± 5.36
Grass/m^2	15.86	3.12	± 6.12
Seedling/ha	4883.22	500.82	± 981.59
Sapling/ha	4653.22	591.15	± 1158.64
Jageshwer			
Trees/ha	815.29	89.72	± 175.86
Shrubs/ha	16914.4	3826.75	± 7500.28
Herbs/m^2	16.9	2.66	± 5.23
Grass/m^2	37.0	1.93	± 3.78
Seedling/ha	3290.9	471.96	± 925.02
Sapling/ha	1486.2	591.64	± 1159.6

Table 8.3 Diversity values of the vegetation at burnt patches in Kumaon.

Site	Diversity ± S.D.	Richness ± S.D.
Binsar		
Trees	1.06 ± 0.3	0.99 ± 0.37
Shrubs	1.26 ± 0.45	1.22 ± 0.5
Herbs	0.87 ± 0.48	0.88 ± 0.54
Grass	1.08 ± 0.36	1.02 ± 0.39
Seedling	0.65 ± 0.51	0.81 ± 0.65
Sapling	0.18 ± 0.34	0.24 ± 0.46
Daphiadhura		
Trees	1.21 ± 0.21	1.06 ± 0.32
Shrubs	0.96 ± 0.48	0.98 ± 0.52
Herbs	1.21 ± 0.35	1.05 ± 0.35
Grass	0.56 ± 0.43	0.43 ± 0.36
Seedling	1.08 ± 0.35	1.07 ± 0.34
Sapling	1.12 ± 0.57	1.28 ± 0.69
Jageshwer		
Trees	1.28 ± 0.26	1.14 ± 0.31
Shrubs	0.78 ± 0.42	0.78 ± 0.43
Herbs	1.21 ± 0.55	1.12 ± 0.64
Grass	1.33 ± 0.32	1.17 ± 0.23
Seedling	0.93 ± 0.35	1.02 ± 0.50
Sapling	0.35 ± 0.49	0.37 ± 0.51

Jageshwer while minimum diversity (1.06 ± 0.3) and richness (0.99 ± 0.37) was at Binsar.

Mean density (ha^{-1} ± S.E.) of each tree species was also calculated for each site. It was found maximum (277.5 ± 183.14) for *Quercus leucotricophora* in Binsar followed by *Rhododendron arboreum* (190.72 ± 126.14) and *Lyonia ovalifolia* (128.14 ± 76.1) and minimum (31.84 ± 0) for *Euonymus* sp., *Symplocos theifolia, Pyrus pashia, Toona serrata* and *Swida* sp. (Table 8.4). While maximum density (194.26 ± 85.76/ha) was accounted for *Quercus lanuginosa* followed by *Lyonia ovalifolia* (187.89 ± 64.4) and *Rhododendron arboreum* (120.31 ± 80.68) at Daphiadhura in Askot Wildlife Sanctuary and minimum (31.84 ± 0) was observed for *Toona serrata, Cedrus deodara, Alnus nepalensis* and *Myrica esculenta* (Table 8.5). *Rhododendron arboreum* had maximum (277.07 ± 175.8) mean tree density followed by *Quercus leucotricophora* (264.33 ± 156.1) and *Lyonia ovalifolia* (133.75 ± 14.35), and minimum (31.84 ± 0) for *Pyrus pashia, Viburnum mullaha* and *Litsea umbrosa* (Table 8.6) in Jageshwer.

8.3.2 Survival and mortality rate of species

Fire directly affects plant growth, survival and reproduction and can impact the dynamics of seed and regeneration (Bond & van Wilgen, 1996). Each tree species showed different response towards fire. Consequently, differential survival and mortality pattern was observed for each tree species. Over all mortality of tree species was observed at each fire site. Maximum tree species mortality (48.37%) was observed for *Quercus leucotricophora* and minimum mortality (0.001%) in case of *Pyrus pashia* and *Swida* sp. in Binsar Wildlife Sanctuary (Table 8.7).

Table 8.4 Density of different tree species in Binsar Wildlife Sanctuary.

Species	Density/ha	± S.E.	C.I. (95% confidence level)
Quercus leucotricophora	277.52	3.66	± 36.26
Rhododendron arboreum	190.72	2.81	± 26.35
Lyonia ovalifolia	128.14	1.77	± 16.27
Pinus roxburghii	89.85	4.86	± 25.69
Viburnum mullaha	62.69	2.01	± 11.38
Alnus nepalensis	63.69	5.53	± 20.69
Quercus floribunda	58.79	6.45	± 23.27
Cedrus deodara	74.31	12.01	± 20.8
Swida oblonga	45.11	3.48	± 12.05
Myrica esculenta	39.80	3.61	± 10.21
Pyrus pashia	31.84	0	± 0
Swida sp.	31.84	0	± 0
Symplocos theifolia	31.84	0	± 0
Toona serrata	31.84	0	± 0
Euonymus sp.	31.84	0	± 0

Table 8.5 Density of different tree species in Daphiadhura.

Species	Density/ha	± S.E.	C.I. (95% confidence level)
Quercus lanuginosa	194.26	8.41	± 37.59
Lyonia ovalifolia	187.89	6.31	± 28.22
Rhododendron arboreum	120.31	8.79	± 37.27
Swida oblonga	110.01	11.45	± 37.98
Alnus nepalensis	31.84	0	± 0
Quercus leucotricophora	63.69	0	± 0
Praxinus micrantha	47.77	22.07	± 31.21
Quercus floribunda	31.84	0	± 0
Toona serrata	31.84	0	± 0
Cedrus deodara	31.84	0	± 0
Myrica esculenta	31.84	0	± 0

Table 8.6 Density of different tree species in Jageshwer.

Species	Density/ha	± S.E.	C.I. (95% confidence level)
Quercus leucotricophora	264.33	30.59	± 96.75
Rhododendron arboreum	277.07	34.45	± 108.95
Lyonia ovalifolia	133.75	14.35	± 45.39
Myrica esculenta	127.38	26.75	± 70.77
Pinus roxburghii	76.43	14.23	± 31.83
Viburnum mullaha	31.84	0	± 0
Pyrus pashia	31.84	0	± 0
Litsea umbrosa	31.84	0	± 0

Table 8.7 Percent mortality between and within tree species in BWS.

Species	No. of dead trees	% Dead (between sp.)	No. of alive trees	%Mortality (within sp.)
Quercus leucotricophora	328	48.37	526	38.41
Quercus floribunda	8	1.17	16	33.34
Rhododendron arboreum	99	14.6	428	18.79
Lyonia ovalifolia	119	17.55	219	35.21
Euonymus sp.	0	0.00	1	0.00
Symplocos theifolia	0	0.00	1	0.00
Pyrus pashia	1	0.10	2	33.34
Toona serrata	0	0.00	1	0.00
Cedrus deodara	6	0.8	1	85.72
Pinus roxburghii	30	4.42	49	39.78
Alnus nepalensis	17	2.50	11	60.72
Viburnum mullaha	53	7.80	10	84.17
Myrica esculenta	3	0.44	7	30.00
Swida oblonga	13	1.99	4	76.48
Swida sp.	1	0.10	1	50.00

In Daphiadhura, maximum mortality (38.95%) was observed for *Lyonia ovalifolia* and minimum (0.58%) for *Quercus floribunda* and *Cedrus deodara* (Table 8.8) while in Jageshwer mortality was maximum (32.07%) for *Rhododendron arboreum* and minimum (0.94%) for *Viburnum mullaha* (Table 8.9).

8.3.3 The Importance Value Index (IVI)

The total basal area occupied by a plant species in an area is considered as dominance. The maximum IVI (95.51) was accounted for by *Quercus leucotricophora* and considered as the most dominant tree species followed by *Rhododendron arboreum* (76.56) and *Lyonia ovalifolia* (41.17). The minimum IVI was calculated for *Euonymus* species (2.93) (Table 8.10). The IVI value was ranked in the ascending order of 1, 2, 3 and so on and the species possessing highest IVI value were ranked 1 followed by 2, 3 and so on according to the decreasing order of their IVI values. While at Daphiadhura (AWS) *Quercus lanuginosa* had the maximum IVI (120.3) followed by *Lyonia ovalifolia* (56.43) and *Rhododendron arboreum* (47.71), the minimum IVI (4.85) for *Myrica esculenta*, *Quercus floribunda*, *Toona serrata and Cedrus deodara* (Table 8.11). In Jageshwer, the maximum IVI was calculated for *Quercus leucotricophora* (90.6) followed by *Rhododendron arboreum* (89.02) and *Lyonia ovalifolia* (47.96). *Litsea umbrosa* had the minimum IVI (5.51) (Table 8.12).

8.3.4 Effect of fire on different GBH classes of different tree species

In BWS maximum tree diversity (1.66) and richness (1.87) were found in GBH class 0-25 and 26-50 cm respectively while in Daphiadhura and Jageshwer tree species

Table 8.8 Percent mortality between and within tree species in Daphiadhura.

Species	No. of Dead trees	% Dead (between sp.)	No. of alive trees	%Mortality (within sp.)
Quercus leucotricophora	2	1.16	0	100
Quercus floribunda	1	0.58	0	100
Quercus lanuginosa	23	13.37	99	18.85
Rhododendron arboreum	47	27.32	21	69.11
Lyonia ovalifolia	67	38.95	51	56.77
Toona serrata	1	0.58	0	100
Cedrus deodara	1	0.58	0	100
Alnus nepalensis	2	1.16	2	50
Myrica esculenta	0	0	1	0
Swida oblonga	25	14.53	13	65.78
Praxinus micrantha	3	1.74	0	100

Table 8.9 Percent mortality between and within tree species in Jageshwer.

Species	No. of dead trees	% Dead (between sp.)	No. of alive trees	%Mortality (within sp.)
Quercus leucotricophora	12	11.32	71	14.45
Rhododendron arboreum	34	32.07	53	39.08
Lyonia ovalifolia	30	28.3	12	72.42
Pyrus pashia	0	0	1	0
Pinus roxburghii	5	4.71	7	41.66
Viburnum mullaha	1	0.94	1	50
Myrica esculenta	24	22.64	4	85.7
Litsea umbrosa	0	0	1	0

Table 8.10 Importance value index and ranking of each tree species of Binsar Wildlife Sanctuary.

Species	IVI value	IVI rank
Quercus leucotricophora	95.51	1
Rhododendron arboreum	76.56	2
Lyonia ovalifolia	41.17	3
Pinus roxburghii	18.08	4
Viburnum mullaha	14.26	5
Alnus nepalensis	10.03	6
Quercus floribunda	8.58	7
Cedrus deodara	7.09	8
Swida oblonga	7.03	9
Myrica esculenta	6.07	10
Pyrus pashia	3.47	11
Swida sp.	3.23	12
Symplocos theifolia	2.98	13
Toona serrata	2.95	14
Euonymus sp.	2.93	15

Table 8.11 Importance value index and ranking of each tree species of Daphiadhura.

Species	IVI Value	IVI Rank
Quercus lanuginosa	120.3	1
Lyonia ovalifolia	56.43	2
Rhododendron arboreum	47.71	3
Swida oblonga	28.48	4
Alnus nepalensis	9.11	5
Quercus leucotricophora	8.52	6
Praxinus micrantha	8.08	7
Quercus floribunda	4.85	8
Toona serrata	4.85	8
Cedrus deodara	4.85	8
Myrica esculenta	4.85	8

Table 8.12 Importance value index and ranking of each tree species at Jageshwer.

Species	IVI Value	IVI Rank
Quercus leucotricophora	90.6	1
Rhododendron arboreum	89.02	2
Lyonia ovalifolia	47.96	3
Myrica esculenta	32.32	4
Pinus roxburghii	21.11	5
Viburnum mullaha	7.64	6
Pyrus pashia	5.83	7
Litsea umbrosa	5.51	8

diversity and richness were maximum in the GBH class 0-25 cm (Table 8.13). Two-way ANOVA showed significant difference between GBH classes of dead trees ($F = 33.85$, d.f. = 5,20; $p < 0.01$) in BWS (Fig. 8.1). Significant difference was also observed in the dead trees of different tree species ($F = 5.28$, d.f. = 4,20; $p < 0.01$).

To avoid limitations of the χ^2 contingency test, GBH class 101-200, 201-400 and >400 cm were merged in one class and the result showed significant difference in the different GBH class of dead tree ($\Sigma\ \chi^2 = 292.89$, d.f. = 3; $p < 0.001$) and the highest mortality was found in the GBH class 0-25 cm and least mortality was observed in the merged GBH class (>101 cm). In Daphiadhura GBH class 201-400 & >400 were merged to pin point the exact affected GBH class. The result showed that GBH class >201 cm was least affected while 26-50 cm GBH class most affected ($\Sigma\ \chi^2 = 65.15$, d.f. = 4; $p < 0.001$) (Fig. 8.3). In Jageshwer GBH class 101-200 & 201-400 cm were merged and the result showed that survival was highest in class > 101 cm ($\Sigma\chi^2 = 78.71$, d.f. = 3; $p< 0.001$) (Fig. 8.5). GBH class 51-100, 101-200, 201-400 and >400 cm of top five IVI ranking tree species were merged to follow the assumption of the statistical test. χ^2 contingency test and the result showed maximum mortality in 0-26 cm GBH class for *Viburnum mullaha* and least mortality was found in >51 cm for *Lyonia ovalifolia* in BWS. In Daphiadhura the result was not significant for top five IVI ranking tree species ($\Sigma\chi^2= 6.74$, d.f.= 6; $p > 0.06$) while test could not be performed for Jageshwer.

8.3.5 Effect of fire on height categories of different tree species

Maximum tree diversity in the burnt patches was observed in the fire height category between 401-800 cm in BWS, Jageshwer and Daphiadhura, while maximum

Table 8.13 Tree species diversity and richness in different GBH classes at Binsar, Jageshwer and Daphiadhura after the fire in postmonsoon 96.

GBH classes	1	2	3	4	5	6
Binsar						
Diversity	1.66	1.41	1.36	1.23	1.13	0
Richness	1.45	1.87	1.55	1.66	1.31	0
Jageshwer						
Diversity	1.59	1.51	1.4	1.05	0.64	0
Richness	1.3	1.15	1.13	0.78	0.91	0
Daphiadhura						
Diversity	1.49	1.48	1.39	1.11	0.55	0
Richness	1.59	1.1	1.3	1.26	0.59	0

GBH class (in cm) 1= 0-25, 2 = 26-50, 3 = 51-100, 4 = 101-200, 5 = 201-400, 6 = >400

Fig. 8.1 Number of dead trees in different GBH class in Binsar Wildlife Sanctuary.

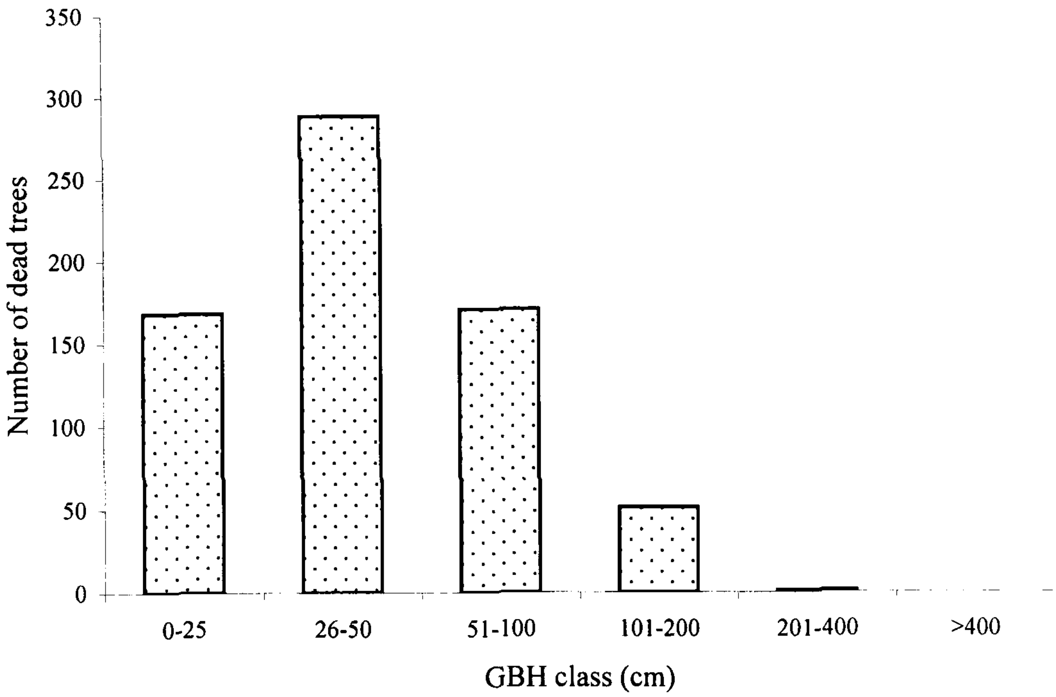
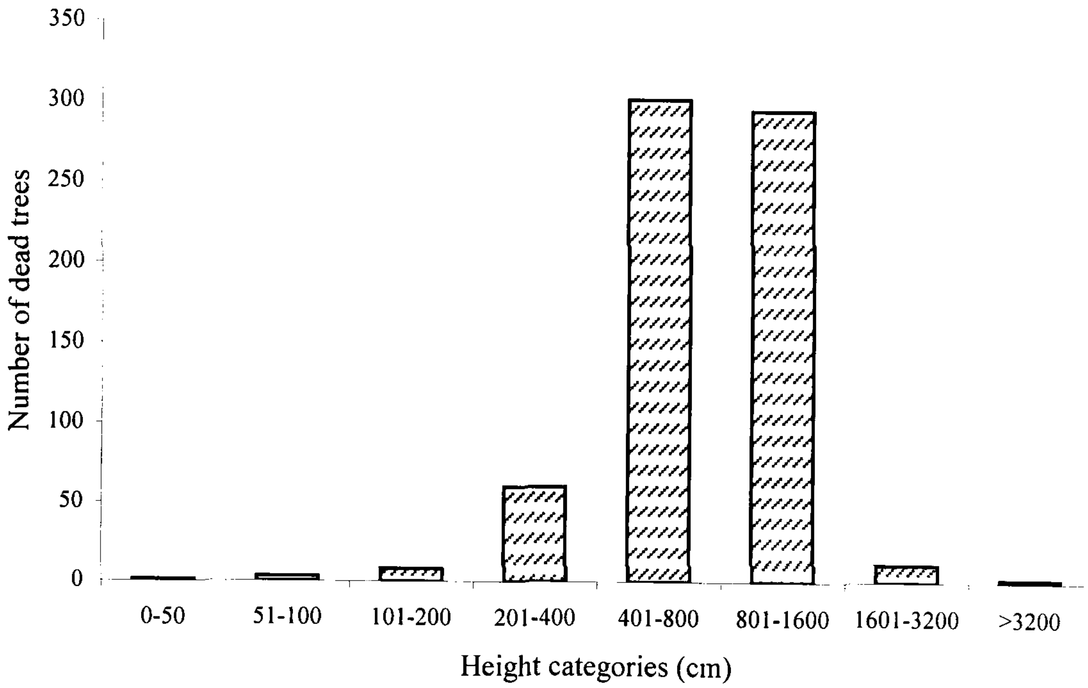


Fig. 8.2 Number of dead trees in different height categories in Binsar Wildlife Sanctuary.



tree species richness at these places was observed in 801-1600 cm, 201-400 and 401-800 cm categories respectively (Table 8.14). Two-way ANOVA showed significant difference between different fire height categories in dead trees ($F = 4.3$, d.f. = 7, 28; $p < 0.01$) in BWS (Fig. 8.2).

The mortality rate also differed significantly among tree species ($F = 4.82$, d.f. = 4, 28; $p < 0.01$). Height categories 0-50, 51-100 and 101-200 cm were merged into single category and 801-1600, 1601-3200 and > 3200 cm were merged in another category to overcome the limitations of the statistical test. Maximum mortality was found in > 801 cm fire height category and least was found in < 200 cm category. In Daphiadhura the category 801-1600 cm was most affected (Fig. 8.4) while in Jageshwer categories 0-50 cm and 51-100 cm were merged in single class and categories 801-1600 & 1601- 3200 cm were merged and the test between these showed that the category > 801 cm was most affected (Fig. 8.6).

In BWS height categories 0-50, 51-100, 101-200 & 201-400 and 801-1600, 1601-3200 & > 3200 cm of top four IVI ranking tree species were merged to get two separate categories to avoid the statistical limitations. Significant difference ($\Sigma\chi^2 = 83.03$, d.f. = 6; $p < 0.001$) was observed in the mortality of different height categories of different tree species and *Viburnum mullaha* falling under the fire height category 401-800 cm was most affected and category > 800 cm was least affected in the same species. Test for Jageshwer and Daphiadhura could not be performed due to limitation in data set.

In BWS mortality of *Rhododendron arboreum* (18.79%), *Euonymus* sp. (0%), *Symplocos theifolia* (0%) and *Toona serrata* (0%) was significantly less than expected according to availability (Table 8.15) while other species had significantly higher

Table 8.14 Tree species diversity and richness in different height categories at Binsar, Jageshwer and Daphiadhura after the fire in postmonsoon 96.

Fire height categories	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Binsar								
Diversity	1.32	1.32	1.28	1.41	1.57	1.27	0.98	0
Richness	1.26	1.1	1.35	1.62	1.78	1.84	0.72	1.44
Jageshwer								
Diversity	0.59	0.64	1.52	1.26	1.43	1.39	0.64	0
Richness	0.73	0.91	1.44	1.55	1.41	0.97	0.91	0
Daphiadhura								
Diversity	0	0	0	0	1.45	1.36	0	0
Richness	0	0	0	0	1.63	1.5	0	0

Fire height categories (in cm) 1= 0-50, 2 = 51-100, 3 = 101-200, 4 = 201-400, 5 = 401-800, 6 = 801-1600, 7 = 1601-3200 and 8 = >3200

Table 8.15 Proportion available (Pi), Proportion dead ($\bar{P}$i), Bonferroni confidence interval and significant mortality of each tree species at BWS (0 = in proportion to availability, - = less mortality in proportion to availability).

Tree species	Pi	$\bar{P}$i	Bonferroni C.I.	Significant mortality
Quercus leucotricophora	0.436	0.483	$0.428 \leq p_1 \leq 0.539$	0
Quercus floribunda	0.012	0.012	$-0.0002 \leq p_2 \leq 0.024$	0
Rhododendron arboreum	0.269	0.146	$0.107 \leq p_3 \leq 0.185$	-
Lyonia ovalifolia	0.173	0.175	$0.03 \leq p_4 \leq 0.19$	0
Euonymus sp.	0.0005	0	$0 \leq p_5 \leq 0$	-
Symplocos theifolia	0.0005	0	$0 \leq p_6 \leq 0$	-
Pyrus pashia	0.001	0.001	$-0.205 \leq p_7 \leq 0.207$	0
Toona serrata	0.0005	0	$0 \leq p_8 \leq 0$	-
Cedrus deodara	0.003	0.008	$-0.001 \leq p_9 \leq 0.017$	0
Pinus roxburghii	0.040	0.044	$0.022 \leq p_{10} \leq 0.66$	0
Alnus nepalensis	0.014	0.025	$0.02 \leq p_{11} \leq 0.029$	0
Viburnum mullaha	0.032	0.078	$0.048 \leq p_{12} \leq 0.108$	0
Myrica esculenta	0.005	0.004	$-0.003 \leq p_{13} \leq 0.012$	0
Swida oblonga	0.008	0.019	$0.004 \leq p_{14} \leq 0.035$	0
Swida sp.	0.001	0.001	$-0.003 \leq p_{15} \leq 0.005$	0

Fig. 8.3 Number of dead trees in different GBH class in Daphiadhura.

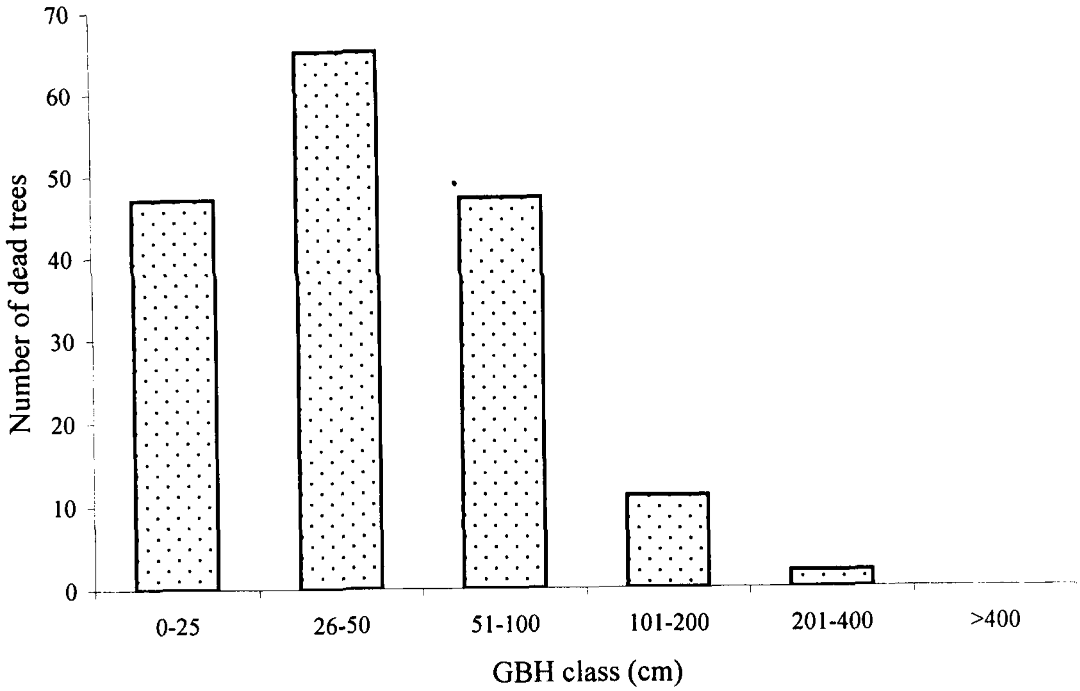


Fig. 8.4 Number of dead trees in different height categories in Daphiadhura.

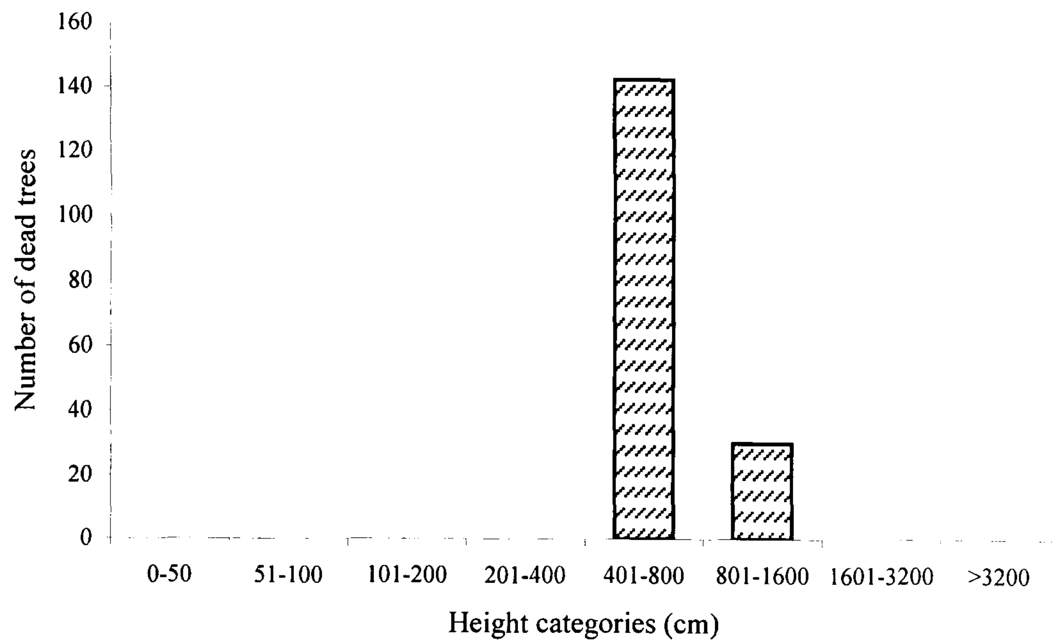


Fig. 8.5 Number of dead trees in different GBH class in Jageshwer.

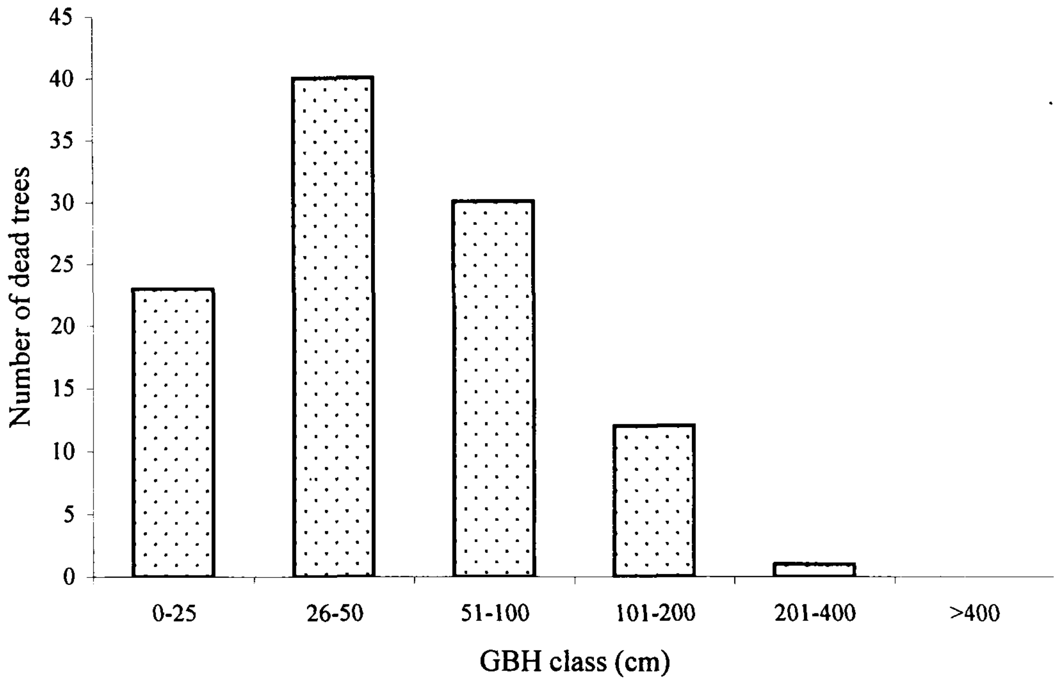
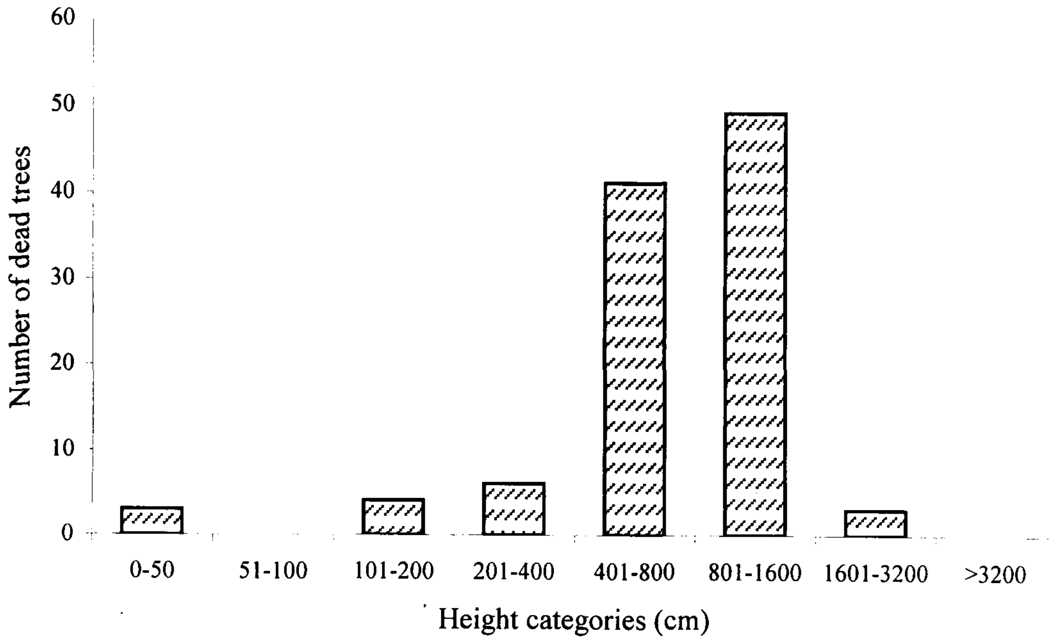


Fig. 8.6 Number of dead trees in different height categories in Jageshwer.



mortalities than expected. *Quercus lanuginosa* (18.85%) in Daphiadhura while *Pyrus pashia* (0%) and *Litsea umbrosa* (0%) in Jageshwer had significantly less mortality than expected according to availability (Table 8.16 & 8.17). But *Lyonia ovalifolia* (72.42%) had significantly more mortality than expected in Jageshwer.

8.3.6 Regeneration

A total of 18 regenerating (seedlings) tree species were encountered after the fire of premonsoon 1995 in BWS. Maximum regeneration was accounted for by *Swida oblonga* (31.14%) followed by *Quercus leucotricophora* (25.75%) and *Lyonia ovalifolia* (9.98%), and minimum regeneration (0.2%) was recorded for *Persea duthiei*, *Praxinus micrantha* and *Phoenix humilis* (Table 8.18). Maximum density (1022.3 / ha ± 988.19) was calculated for *Quercus leucotricophora* and minimum density (353.86 / ha ± 0) for *Persea duthiei, Praxinus micrantha, Phoenix humilis* (Table 8.18). A total of nine and 12 regenerating (seedlings) tree species were found in Jageshwer and Daphiadhura respectively. Maximum regeneration was observed for *Quercus leucotricophora* (43.75%) at Jageshwer while *Quercus lanuginosa* (42.02%) at Daphiadhura. Minimum regeneration was observed for *Litsea umbrosa* (0.89%) at Jageshwer while *Pyrus pashia* (0.36%) and *Lindera pulcherrima* (0.36%) at Daphiadhura in Askot Wildlife Sanctuary. Maximum density of seedlings was found for *Pyrus pashia* (5307.85 / ha ± 0) at Jageshwer while *Toona serrata* (5307.85 / ha ± 0) at Daphiadhura.

11 tree species at sapling stage were recorded from Binsar. The maximum density was accounted for by *Swida oblonga* (325.54 / ha ± 533.88). Maximum mortality was found in *Lyonia ovalifolia* (64.29%) and mortality was observed in *Quercus floribunda*,

Table 8.16 Proportion available (Pi), proportion dead ($\bar{P}i$), Bonferroni confidence interval and significant mortality of each tree species at Daphiadhura (0 = in proportion to availability, - = less mortality in proportion to availability).

Tree species	Pi	$\bar{P}i$	Bonferroni C.I.	Significant mortality
Quercus leucotricophora	0.005	0.012	$-0.113 \leq p_1 \leq 0.035$	0
Quercus floribunda	0.003	0.006	$-0.01 \leq p_2 \leq 0.022$	0
Quercus lanuginosa	0.339	0.133	$-0.06 \leq p_3 \leq 0.206$	-
Rhododendron arboreum	0.189	0.273	$0.178 \leq p_4 \leq 0.368$	0
Lyonia ovalifolia	0.328	0.389	$0.285 \leq p_5 \leq 0.493$	0
Toona serrata	0.003	0.006	$0.01 \leq p_6 \leq 0.022$	0
Cedrus deodara	0.003	0.006	$0.01 \leq p_7 \leq 0.022$	0
Alnus nepalensis	0.011	0.012	$-0.113 \leq p_8 \leq 0.035$	0
Myrica esculenta	0.003	0	$0 \leq p_9 \leq 0$	-
Swida oblonga	0.106	0.145	$0.07 \leq p_{10} \leq 0.221$	0
Praxinus micrantha	0.008	0.017	$-0.01 \leq p_{11} \leq 0.045$	0

Table 8.17 Proportion available (Pi), Proportion dead ($\bar{P}i$), Bonferroni confidence interval and significant mortality of each tree species at Jageshwer (0 = in proportion to availability, - = less mortality in proportion to availability, + = more mortality in proportion to availability).

Tree species	Pi	$\bar{P}i$	Bonferroni C.I.	Significant mortality
Quercus leucotricophora	0.324	0.113	$0.03 \leq p_1 \leq 0.196$	0
Rhododendron arboreum	0.339	0.321	$0.198 \leq p_2 \leq 0.443$	0
Lyonia ovalifolia	0.164	0.283	$0.169 \leq p_3 \leq 0.405$	+
Pyrus pashia	0.003	0	$0 \leq p_4 \leq 0$	-
Pinus roxburghii	0.046	0.047	$-0.008 \leq p_5 \leq 0.103$	0
Viburnum mullaha	0.008	0.009	$-0.015 \leq p_6 \leq 0.034$	0
Myrica esculenta	0.109	0.226	$0.12 \leq p_7 \leq 0.336$	0
Litsea umbrosa	0.003	0	$0 \leq p_8 \leq 0$	-

Table 8.18 %Seedling (SD) and density of different tree species at the burnt sites during 1996-97 in Kumaon.

Species	Binsar		Jageshwer		Daphiadhura	
	SD	% regeneration	SD	% regeneration	SD	% regeneration
Quercus leucotricophora	773 ± 555	25.75	1926 ± 710	43.75	-	-
Quercus floribunda	471± 204	0.79	-	-	-	-
Quercus lanuginosa	-	-	-	-	2280 ± 1127	42.01
Rhododendron arboreum	655 ± 424	9.98	1011 ± 476	17.85	825 ± 608	12.68
Lyonia ovalifolia	676 ± 463	8.78	619 ± 338	6.2	898 ± 470	11.95
Persia duthiei	353 ± 0	0.2	-	-	-	-
Euonymus tingens	707 ± 288	1.59	-	-	-	-
Euonymus sp.	884 ± 204	1.99	1061 ± 0	2.67	-	-
Pyrus pashia	579 ± 455	3.59	5307 ± 0	13.39	353 ± 0	0.36
Toona serrata	530 ± 250	0.59	-	-	5307 ± 0	5.43
Pinus roxburghii	884 ± 895	7.98	-	-	353 ± 0	0.72

Alnus nepalensis	566 ± 193	1.59	-	-	530 ± 250	1.08
Viburnum mullaha	412 ± 144	1.39	442 ± 176	4.46	-	-
Myrica esculenta	393 ± 117	1.99	471 ± 204	3.57	884 ± 250	1.81
Swida oblonga	1022 ± 988	31.14	707 ± 408	7.14	1194 ± 546	19.56
Meliosoma dillenaeafolia	-	-	-	-	1415 ± 0	1.44
Litsea umbrosa	-	-	353 ± 0	0.89	-	-
Lindera pulcherrima	636 ± 296	1.79	-	-	353 ± 0	0.36
Praxinus micrantha	353 ± 0	0.2	-	-	825 ± 204	2.53
Benthamidia capitata	353 ± 0	0.2	-	-	-	-
Albezzia lebback	707 ± 0	0.39	-	-	-	-

Euonymus sp., *Pyrus pashia*, *Alnus nepalensis*, *Myrica esculenta* and *Lindera pulcherrima*. A total of eight and nine tree species (saplings) were recorded from Jageshwer and Daphiadhura respectively. Maximum density was calculated for *Rhododendron arboreum* (424.63 / ha ± 813.78) and *Lyonia ovalifolia* (424.63 / ha ± 760.76) at Jageshwer. Maximum mortality at Jageshwer was recorded for *Rhododendron arboreum* (60%). Maximum sapling density at Daphiadhura was recorded for *Lyonia ovalifolia* (1220.81 / ha ± 1629.58) and also the maximum mortality observed for the same species (26.31%). Minimum mortality was recorded for *Pyrus pashia* (0.58%) (Table 8.19).

8.3.7 Mean threat score for sites

The generated mean threat score for various surveyed sites varied from 0.78 to 2.3. On this basis, the sites Jilling and Sunderdunga have fallen under low threats (0-1 mean threat score) while Binsar Wildlife Sanctuary, Sitlakhet, Jageshwer, Pindari, Gandhura (AWS) and Munsiary under high threats (>2 mean threat score) and rest of the sites have fallen in medium threat category (1.1-2 mean threat score) (Table 8.20). Highest mean threat score (2.3) was recorded for Jageshwer and minimum mean threat score (0.78) was recorded for Sunderdunga reserve forest. Similar results were also obtained on the basis of threat index by single linkage cluster analysis and the Jilling and Sunderdunga formed one cluster while Binsar, Sitlakhet, Jageshwer, Maheshkhan, Vinaiyak and Daphiadhura (AWS) formed separate cluster (Fig. 8.7).

Results for similarity in the presence/absence of different threats at various sites (Fig. 8.8) showed slightly different pattern from single linkage cluster analysis obtained

Table 8.19 Sapling density (SAD) and % dead of different tree species at the burnt sites during 1996-97 in Kumaon.

	Binsar		Jageshwer		Daphiadhura	
Species	**SAD**	**% dead**	**SAD**	**% dead**	**SAD**	**% dead**
Quercus leucotricophora	49 ± 261	49.29	176 ± 382	0	-	-
Quercus floribunda	14 ± 111	0	-	-	-	-
Quercus lanuginosa	-	-	-	-	601 ± 629	19.29
Rhododendron arboreum	17.69 ± 116.6	4.76	424 ± 813	60	920 ± 1156	21.63
Lyonia ovalifolia	233 ± 562	64.29	424 ± 760	0	1220 ± 1629	26.31
Euonymus sp.	3 ± 35	0	128 ± 426	20	-	-
Pyrus pashia	3 ± 35	0	64 ± 213	0	17 ± 79	0.58
Cedrus deodara	-	-	-	-	53 ± 173	1.75
Alnus nepalensis	7 ± 70	0	-	-	488 ± 943	1.16
Viburnum mullaha	24 ± 135	4.76	128 ± 426	20	-	-

Myrica esculenta	7 ± 49	0	-	-	438 ± 886	2.92
Swida oblonga	325 ± 533	11.9	326 ± 106	0	573 ± 1051	25.14
Litsea umbrosa	-	-	74 ± 141	0	-	-
Lindera pulcherrima	7 ± 70	0	-	-	-	-
Praxinus micrantha	-	-	-	-	530 ± 1006	1.75

Table 8.20 Ranking of sites on the basis of the mean threat score.

Sites	Mean Threat score	Rank
Kilbery	1.61	2
Vinaiyak	1.87	2
Kunjakharak	1.91	2
Maheshkhan	1.65	2
Gager	1.87	2
Mukteshwer	1.83	2
Jilling	1.00	1
Binsar WLS	2.17	3
Pandavkholi	1.48	2
Sitlakhet	2.04	3
Jageshwer	2.3	3
Gasi	1.83	2
Dhakuri	2.00	2
Wachham	1.91	2
Sunderdunga	0.78	1
Pindari	2.04	3
Daphiadhura	1.61	2
Majtham	1.52	2
Gandhura	2.04	3
Sobala	1.78	2
Duku	1.39	2
Munsiary	2.13	3
Mechh	1.83	2

```
                         Rescaled Distance Cluster Combine

                    0         5        10        15        20        25
SITES        Num    +---------+---------+---------+---------+---------+

GASI         12     -+
MECHH        23     -+
MUKTESHWER    6     -+
SOBALA       20     -+-+
KUNJAKHARAK   3     -+ I
WACHHAM      14     -+ I
VINAIYAK      2     -+ +-+
GAGER         5     -+ I I
PINDARI      16     -+ I I
MUNSIYARY    22     -+ I I
BINSAR        8     -+-+ I
SITLAKHET    10     -+   I
GANDHURA     19     -+   I
DHAKURI      13     -+   I
KILBERY       1     -+   I
DAPHIADHURA  17     -+-+ +-------------------------------------------+
MAHESHKHAN    4     -+ +-+                                           I
PANDAVKHOLI   9     -+-+ I                                           I
MAJTHAM      18     -+ I I                                           I
DUKU         21     ---+ I                                           I
JAGESHWER    11     -----+                                           I
JILLING       7     ---------------+---------------------------------+
SUNDERDUNGA  15     ---------------+
```

Fig. 8.7 Dendrogram of different sites on the basis of threat index using Single Linkage.

```
                            Rescaled Distance Cluster Combine

                          0         5        10        15        20        25
Sites            Num      +---------+---------+---------+---------+---------

DAPHIADHURA      17       -+---+
MAJTHAM          18       -+   I
GANDHURA         19       -----+-----+
KUNJAKHARAK       3       -----+     I
SOBALA           20       -----------+
VINAIYAK          2       -----------+
DHAKURI          13       -+---------+
PINDARI          16       -+         I
JAGESHWER        11       -----+-----+
MUNSIYARY        22       -----+     I
GASI             12       -----+-----+
WACHHAM          14       -----+     +---------------+
DUKU             21       -----+     I               I
MECHH            23       -----+     I               I
MUKTESHWER        6       -----+     I               I
SHITLAKHET       10       -----+-----+               I
GAGER             5       -----+     I               +---------------------+
BINSAR            8       -----+     I               I                     I
PANDAVKHOLI       9       -----------+               I                     I
MAHESHKHAN        4       -----------+               I                     I
KILBERY           1       -----------+               I                     I
JILLING           7       ---------------------------+                     I
SUNDERDUNGA      15       -------------------------------------------------+
```

Fig. 8.8 Dendrogram of presence/absence of threats using Single Linkage.

on the basis of mean threat score. Jilling and Sunderdunga experienced similar kind of threats such as no tree cutting, lopping, grazing, forest fire and bark extraction was observed at both the sites. Binsar Wildlife Sanctuary, Gager, Sitlakhet, Mukteshwer, Mechh, Duku (AWS) and Wachham experienced tree cutting, lopping, grazing, grass harvesting, fuel wood collection and poaching and wild animal product trade but no bark extraction was found at these places. No tapping, medicinal plant extraction, tourism and construction work was observed at Daphiadhura and Majtham in Askot Wildlife Sanctuary.

Statistical results showed that the relationship between fuel consumption with each dependent factor except livestock population was significant. The regression coefficients of fuel wood collection was highly related with human population, land area available for different purposes and source of income through different means. The factors, human population and source of income together accounted for 68.6% of variation in fuel wood collection ($F = 21.86$; $p < 0.001$). The regression of fuel wood collection with land area available was significant ($F = 12.42$; $p < 0.002$) with regression coefficients and also accounted for 37.2% variation (Table 8.21).

8.3.8 Relationship of diversity values with various threat parameters and threat index

Multiple regression analysis showed significant positive relationship with bird species diversity and richness with the patch size and negative significant relationship with nomadic pressure and source of income (Table 8.22 & 8.23). Bird species diversity and richness increased with increase in patch size in Kumaon Himalaya and also the

Table 8.21 Stepwise multiple regression on fuel wood collection with different disturbance factors as dependent variables.

Model	V	MR	R^2	C	F value	Significance level
1	Human population	0.74	0.55	+	26.11	0.00
2	Source of income	0.83	0.69	+	21.85	0.00
1	Land area available	0.61	0.37	+	12.42	0.002

(V = Variables, MR = Multiple regression, R^2 = Coefficient of determination, C = Correlation, F = F values,)

Table 8.22 Stepwise multiple regression on threat parameters with bird species richness as dependent variable.

Model	V	MR	R^2	C	F value	Significance level
1	SOI	0.48	0.23	-	6.46	0.01
2	SOI, PSZ	0.67	0.45	+	8.43	0.00
3	SOI, PSZ, NP	0.83	0.69	-	10.06	0.00

(V = Variables, MR = Multiple regression, R^2 = Coefficient of determination, C = Correlation, F = F values, SOI = Source of income, PSZ = Patch size, NP = Nomadic pressure)

Table 8.23 Stepwise multiple regression on threat parameters with bird species diversity as dependent variable.

Model	V	MR	R^2	C	F value	Significance level
1	SOI	0.49	0.24	-	6.74	0.01
2	SOI, PSZ	0.63	0.39	+	6.62	0.00

(V = Variables, MR = Multiple regression, R^2 = Coefficient of determination, C = Correlation, F = F values, SOI = Source of income, PSZ = Patch size, NP = Nomadic pressure) increase in nomadic pressure decreased the diversity values at sites. Kendall's tau_b test also showed significant positive relationships among bird species diversity and richness with patch size ($\tau = 0.401$; $p < 0.02$ and $\tau = 0.371$; $p < 0.03$ respectively). This test also showed relationship between the threat parameters such as human population was positively correlated with construction work ($\tau = 0.389$; $p < 0.04$) and fuel wood collection ($\tau = 0.562$, $p < 0.005$), whereas cutting was also positively correlated with number of villages ($\tau = 0.509$, $p < 0.01$).

8.3.9 Assigning conservation values to sites in relation to birds

The assessment of conservation values of the sites is useful for developing a regional conservation strategy. This analysis helped in pinpointing the localities that required protection under a nature reserve system on a priority basis. Vinaiyak had highest conservation value (1.0) followed by Sunderdunga (0.33), Binsar (0.21), Gandhura (0.15), Duku (0.12), Pindari (0.12) and Dhakuri (0.11) (Table 8.24). In these localities Binsar, Gandhura and Duku were having the legal protection being a sanctuary while Sunderdunga falls in the buffer zone of Nandadevi Biosphere Reserve. Only Vinaiyak and Pindari were left as a reserve forest and also having high conservation potential. The importance of these localities will be discussed below.

8.3.10 Spatial relationship between Birds and threat parameters

Significant relationship was observed between bird species diversity and threat index ($r = 0.489$, $p < 0.03$) (Fig. 8.9). Result showed that Pindari, Binsar, Sitlakhet and Jageshwer experienced high threat as well as high bird diversity except Gandhura, which

Table 8.24 Conservation values of different surveyed sites on the basis of bird species present therein.

Sites	District	Conservation value (CV)
Vinaiyak	Naini Tal	1.000
Sunderdunga	Bageshwer	0.330
Binsar	Bageshwer	0.206
Gandhura	Pithoragarh	0.154
Duku	Pithoragarh	0.125
Pindari	Bageshwer	0.125
Dhakuri	Bageshwer	0.107
Gasi	Bageshwer	0.087
Munsiary	Pithoragarh	0.083
Jageshwer	Almora	0.070
Daphiadhura	Pithoragarh	0.070
Sobala	Pithoragarh	0.063
Mechh	Champawat	0.046
Wachham	Bageshwer	0.035
Kilbery	Naini Tal	0.034
Maheshkhan	Naini Tal	0.034
Majtham	Pithoragarh	0.032
Sitlakhet	Almora	0.028
Kunjakharak	Naini Tal	0.026
Pandavkholi	Almora	0.016
Mukteshwar	Naini Tal	0.010
Gager	Naini Tal	0.001
Jilling	Naini Tal	0.000

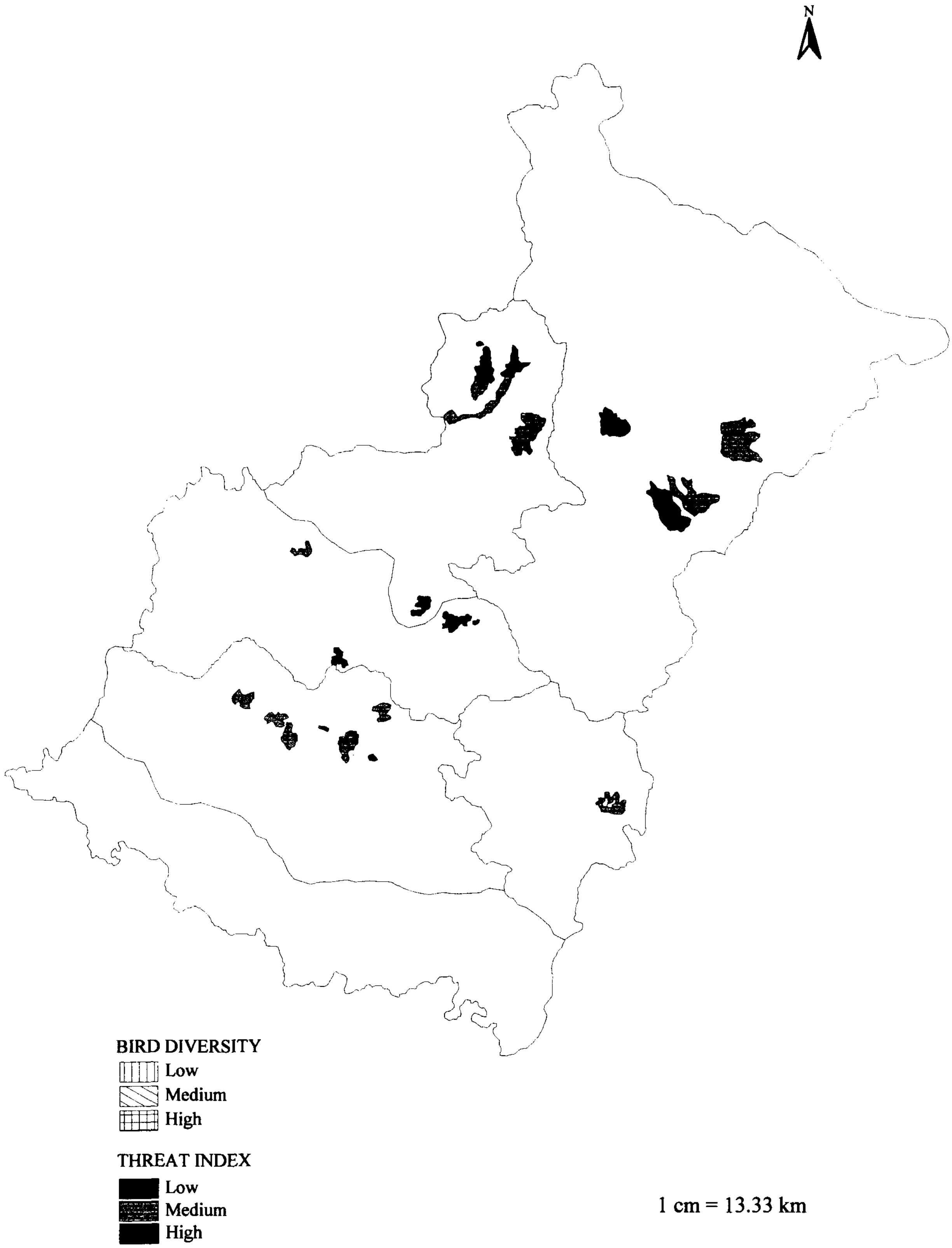


Fig. 8.9 Bird species diversity in relation to threat index in Kumaon Himalaya.

had low bird diversity. While Sobala, Daphiadhura, Majtham, Gasi, Kunjakharak and Maheshkhan had medium threats but showed high bird diversity. The effect of cutting, lopping, grazing and grass harvesting changed the status of sites in terms of threat intensity. But the result was not showing significant relationship in bird diversity and threat parameters. The medium threat areas except Maheshkhan, had fallen into high threat category and also possessed high bird diversity (Fig. 8.10). The overlaying of bird diversity on the mean value of human and livestock population (anthropogenic pressure) showed that Binsar, Jageshwer and Sitlakhet had high pressure as well as high bird diversity (Fig. 8.11). The result again was not significant for anthropogenic pressure.

8.4 DISCUSSION

The greatest damage to natural habitat and wildlife today is due to ever-increasing exploitation of land and natural resources. The ever-increasing exploitation is resulting in damage, loss and fragmentation of natural areas in all continuously inhabited parts of the world; whether it be desert region, temperate region or tropical (Pyne, 1981). Himalayas too suffered with similar trend in resource use. Himalayas hold a significant unit in the Indian subcontinent and is being utilized as supplier of natural resources by human since the start of the civilization in this region. Later the origin and settlements in and around the valleys depleted the biodiversity values of the entire region. The over crowding led to resource crunch and compelled them to move and expand up to the higher elevation in the difficult and remote areas. In due course of time the newly inhabited areas experienced similar threats as the previous ones at lower elevations.

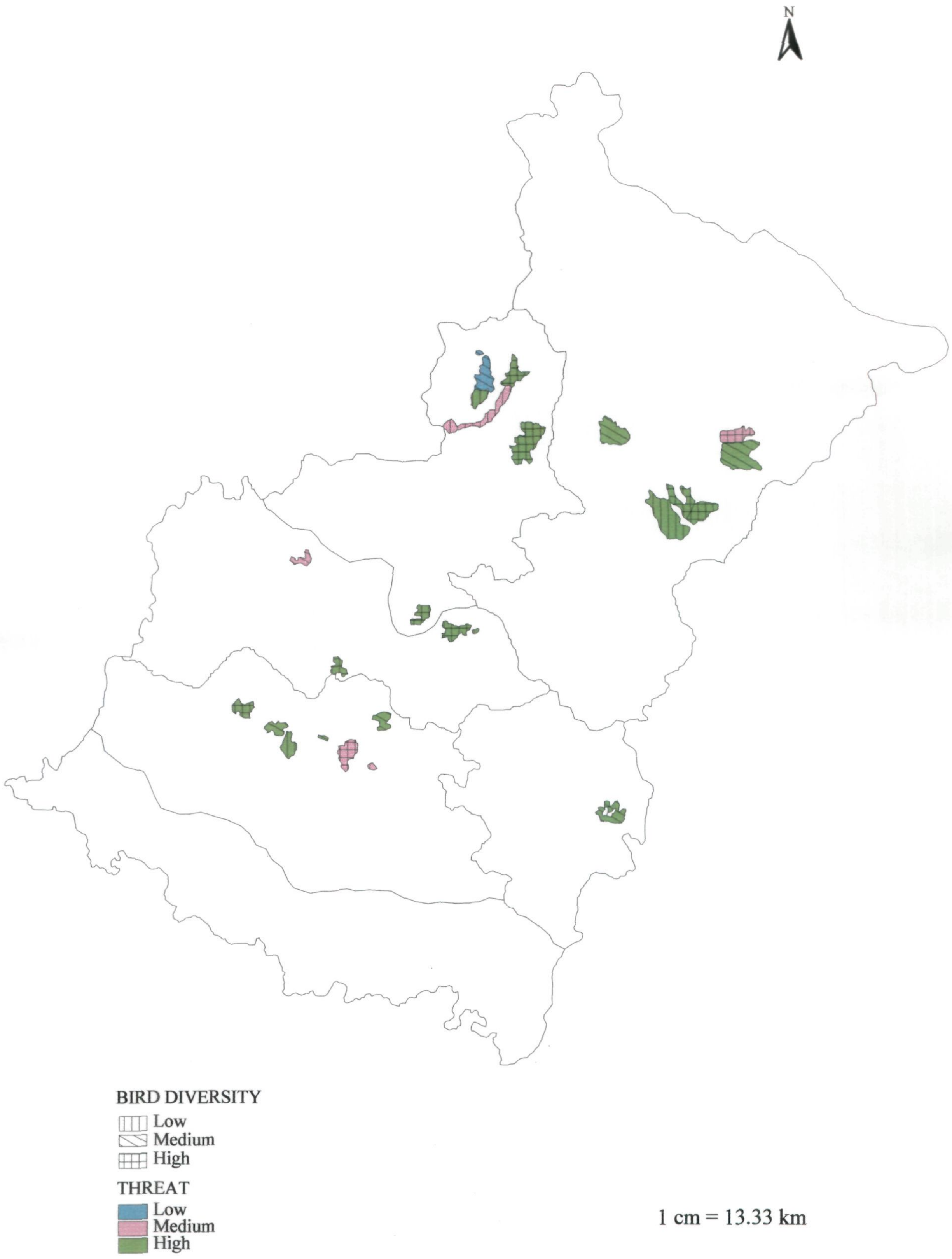


Fig. 8.10 Bird species diversity in relation to threats in Kumaon Himalaya.

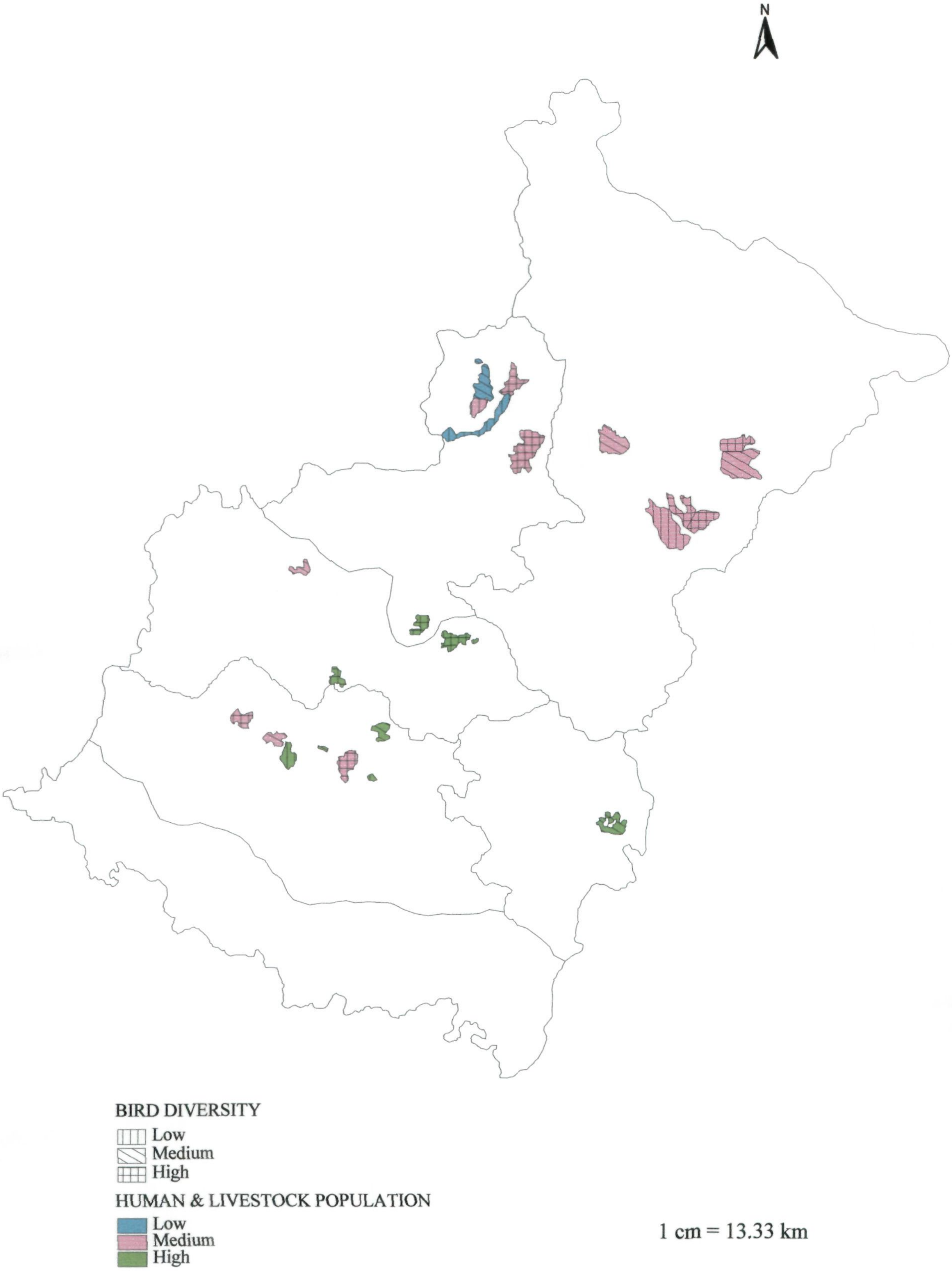


Fig.8.11 Bird species diversity in relation to human & livestock population in Kumaon Himalaya.

Human population of the Himalaya is now 43 million (Dewan, 1988). It has been almost doubled in the last 30 years. The Himalayas as a whole has a density of about 110 person/km² as compared to 221 persons/km² for whole India. The highest density is in Shivaliks (234 persons/km²) followed by the middle Himalayas with 75 persons / km² and least density is in higher Himalayas (18 persons/km²) (Dewan, 1988). The many fold increase in development activities such as establishment of urban centers, road construction, mining, industrial setup, raw material supply, led to destruction of habitats and forests in general and affected biodiversity values of the entire region in particular.

Kumaon Himalaya which hold 4.70 % of land of the Himalayas within the Indian limits, extend from lower to higher Himalayas, and it can be considered as representative unit possessing all climatic conditions experienced by entire Himalayan region. The region is densely populated by human beings and well connected with road transport throughout its range. The easy approach to most parts of the region lead to the development of the area, as is being happening in other parts of the country. Consequently, random forest clearing was observed for the purpose and most parts of the region are facing severe threats in terms of loss of biodiversity values.

The present study was conducted for the assessment of various threats on avian community. It was observed that this region too possesses similar threats on avian community as rests of the human inhabited regions of the Himalayas. The scattered human settlements from foothills to sub-alpine zone experienced different kind and intensity of threats, which showed the specificity and magnitude at different representative locations. I identified 23 parameters as threats to avian community. Out of 23 surveyed sites, fire was found at Daphiadhura, Jageshwer and Binsar Wildlife

Sanctuary. According to the reports of the forest department the maximum wide spread fire event with an affected area of 460 km^2 was observed during 1984 in whole of Kumaon and again after a span of 10 years i.e. 1995, the affected area under fire was 309 km^2. The occurrence of fire at the rest of surveyed oak patches was low. Kilbery, Jilling, Mukteshwer, Gasi, Dhakuri, Wachham, Sunderdunga, Pindari, Sobala, Duku, Munsiary and Mechh did not experience fire in the recent past. But great damage was observed due to fire during the years 1916, 1931, 1948, 1972, 1974, 1980-81 in Naini Tal forest division (Working Plan Naini Tal Forest Division, 1988-1998). In Kilbery and Mukteshwer, regular checks and vigil by forest department must have prevented intentional fires experienced by other remote areas. The status of Jilling is different from the rest of oak patches. It is a privately owned estate of small area of <3 km^2 in size. This could be the reason for Jilling, though it is surrounded by many dependent villages, it did not have any fire in the recent past. Mechh (now in Champawat district) was found to be highly degraded with maximum dependent human and a sizeable livestock population. The houses were situated very closely and in the vicinity of the forest and locals extend great help to cease forest fire that's why this site too did not experience any fire in recent years.

Gasi, Dhakuri, Wachham, Sunderdunga, Pindari, Sobala, Duku and Munsiary never had forest fire in the past. These sites were located at higher Himalayas with the altitude starting from >2600m leading to sub alpine and alpine meadows. Specific to their location these sites are not frequently visited either by locals or by tourists through out the year. Besides, being very close to snow clad peaks and immediate barrier of the Himalayas, these sites receive frequent showers and long duration snow fall. This makes the ground wet and humid which might be the reason to make these areas free from intentional or accidental or natural fires.

It has been observed that wild forest fire events on a large scale occur usually within a gap of 3 or 4 years (Sharma & Rikhari, 1997). During the present study, fire was only recorded from Daphiadhura, Jageshwer and Binsar Wildlife Sanctuary. No previous record of forest fires could be made except from Binsar Wildlife Sanctuary where workers (Sharma & Rikhari, 1997; Rikhari & Palni, 1999) reported findings of forest fire events occurred during the years 1992 and 1995. The fires at this place occurred during the summer season (April-May). This was owing to availability of low water content, highly inflammable ignition material (Sharma & Rikhari, 1997), high surrounding temperature and accumulation of oak leaf and conifer litter, low humidity in the same period (Rawat & Singh, 1989). The intensity and expansion of forest fires at Daphiadhura and Jageshwer was low and in small areas (0.01% and 0.005% respectively) as compared to Binsar Wildlife Sanctuary where up to 30% of the Sanctuary area was under intensive fire. The fire at these sites was classified as class 2 according to classification of Van Wagner (1983).

The *Quercus* species occupied maximum basal area and maximum tree species density at the burnt sites and also ranked first according to IVI values. Softness and thinness have been considered as the main factors, which a species susceptible to fire induced mortality (Sharma & Rikhari, 1997). However, a greater mortality in *Quercus* species as compared to *Lyonia ovalifolia* and *Rhododendron arboreum* in Binsar WLS suggested that other factors, apart also contribute. These are intensity of fire and tree trunk thickness (GBH), which contributed to the degree of susceptibility and kind of damage to the affected tree species.

Mortality in proportion to availability was observed in most of the fire affected tree species at Binsar, Jageshwer and Daphiadhura. The tree species like *Rhododendron arboreum*, *Euonymus* sp., *Symplocos theifolia* and *Toona serrata* had shown significantly lower mortality as compared to expected by chance in Binsar. Low mortality in *Rhododendron arboreum, Toona serrata* and *Symplocos theifolia* was due to the fact that most of the individuals of these species had thick GBH than the other species like *Quercus* sp. and *Lyonia ovalifolia* in Binsar wildlife Sanctuary. *Quercus lanuginosa* and *Myrica esculenta* also had low mortality at Daphiadhura because mostly the trees of these species suffered significantly higher in Jageshwer. Intensity of fire (>15 m) coupled with more species had fallen into low GBH category resulted in greater mortality in individuals. As for a given species thickness increases with stem diameter, which primarily increase with age. Thus fire causes death of younger or smaller individuals in a population and thinner bark within a community (Peterson & Ryan, 1986; Uhl & Kaufmann, 1990).

It was observed that all the vegetation layers were found to be badly affected. Secondary layers mostly the shrubs and tree species at the sapling stages were found dead. Though many workers (Heinselman, 1981; Kilgore, 1981; Christensen, 1981; Mueller-Dombois, 1981; Fox *et al.* 1985; Hulbert, 1988; Migley & Clayton, 1990; van Hensbergen *et al.* 1992; Bond & van Wilgen, 1996) have documented that post fire conditions have many advantages for seedlings. Space is freed by burning of established plant, resources (light, water and nutrients) increased and seed and seedling predation declines.

Fire stimulates vegetative reproduction of many woody and herbaceous species when the over storey is reduced. Sprouting from *Quercus*, *Alnus*, *Rhododendron* was mostly observed in Binsar, Jageshwer and Daphiadhura. But other face of fire was equally bad for these forest patches. The fire opened the canopy and created gaps which is the detrimental for ground nesting birds and close forest birds such as thrushes, pheasants, bush birds etc (Srivastava *et al.* 1999). The fire has a negative impact on fruiting trees also so it directly influences the feeding requirement of fruigivorous birds such as bulbuls and parakeets. The worst part of fire in terms of adverse effect on vegetation was that people were seen cutting the dead trees and the affected forest patch would ultimately become a permanent gap in coming years until the regeneration reaches at the level of native forest.

There is general consensus that fire is responsible for insignificant levels of direct faunal mortality, fire size and seasonality influence animal survival (Spellberg *et al.* 1996). During the assessment of fire, no dead mammal or bird species were encountered. The literature on the effects of fire on fauna is not enough. Part of the reason is that it is difficult to pinpoint cause and effect relationship between the action of fire and the response of animals. This might be due to the cause that sudden and drastic modification of habitat due to fire at these sites created inhospitable habitats. The fire was assessed after one year and large scale cutting of the dead trees in these areas has created large gaps, which detracted large mammal and secretive birds, especially pheasants which utilize it as cover or for food.

Besides fire (abiotic factor) which had detrimental effect on birds and plant species, other factors (biotic) imposed significant threat on the existing biodiversity values of the surveyed oak patches of Kumaon. The nature, kind and intensity of these threats varied from patch to patch or groups of patches experienced similar kind of threats. Out all of the threat factors, it was observed that the human factor residents or tourists, and their relative activities like regulated possession of livestock, land area holding capacity for different purposes, development of the area for employment generation directly or indirectly exerted threats upon the existing biodiversity values.

Human population in the hill regions up to 3000m has, in many cases, multiplied as fast or faster than the population in Gangetic plain or the coastal plains of India. A comparative study of 18 sampled districts has shown that the population of districts below 3000m elevation in the Himalayas has risen by 170% since 1971, while those of selected districts in the Gangetic plains have risen by 127% and those in the coastal plain only 99% (Moodie, 1981). The population pressure in the Kumaon has led to deforestation for alternative means of livelihood and is becoming critical every year. General increase in the livestock population was observed with the increase of human population in different localities of the Kumaon. The livestock depend on the forest in two ways firstly, the forest is used for grazing round the year, and the cattle feed on young plants, and the leaves and twigs of small plants. Secondly, the leaves and twigs of oak trees are lopped and grass harvesting for cattle feed by the owner. Lopping also leads to stunted growth but the species like *Myrica esculenta* and *Aesculus indica* survived after such brutal treatment.

The increased human population throughout the Kumaon required more fuel wood, the only alternative for construction. According to a study conducted by Mauch (1974), 90% wood extraction from the forests in the Kalinchowk, Nepal was for fuel purpose. *Quercus* sp., *Cedrus deodara*, *Pinus* sp., *Abies pindrow* and *Taxus baccata* are generally used as timber wood in Kumaon. The threatened species like *Cedrus deodara* and *Taxus baccata* are used as timber wood for house construction in Pindari region in Bageshwer and Vinaiyak in Naini Tal districts.

8.4.1 Intensity of threats experienced by sites

On the basis of generated threat index, Jilling and Sunderdunga areas were considered as low threatened oak-forest patches. Though both the areas were in same category of threat but the characteristic of these areas were totally different from each other. Sunderdunga in spite of being a large forest patch was devoid of any human habitation. It had very low number of human presence in the form of tourist during summer and autumn season. High degree of medicinal plant extraction, lichen & moss collection and poaching & trade of endangered mammal and bird species e.g. Musk deer *Moschus moschiferus*, Himalayan black bear *Selenarctos thibetanus*, Leopard *Panthera pardus*, Monal pheasant *Lophophorus impejanus* and Satyr pheasant *Tragopan satyra* were the major threats experienced by this patch. Jilling was a small forest patch, which had least conservation potential in terms of area and animal species composition. But being a privately owned estate, it enjoyed as a protected area status and here all the activities (cutting, lopping, grazing etc.) were practiced for personal use only.

Out of 15 sites falling in medium threat category six groups were recognized on the basis of similarity in threat parameters evaluated at different sites. Kilbery, Maheshkhan and Pandavkholi had good forest cover but to some extent they were facing high degree of threats in terms of lopping, cutting, grazing, grass harvesting, fuel wood and receiving sizeable number of tourists every year. The second group included Gasi, Wachham, Duku, Mechh and Mukteshwer. Gasi and Wachham were the sites regularly visited by nomads with >50,000 sheep and goats at least twice a year and they keep them there permanently during the seasons. Bark extraction of *Viburnum* sp. for medicinal purpose was observed as a common practice at Vinaiyak but this area was totally free from poaching and trade of wild animals & their products while in Gager it was a common practice.

Binsar Wildlife Sanctuary (BWS), Sitlakhet, Jageshwer, Pindari, Gandhura (Askot Wildlife Sanctuary) and Munsiary were highly threatened areas in terms of loss of biodiversity values. Pindari, Gandhura and Munsiary were very large oak patches, Binsar, Sitlakhet and Jageshwer were relatively smaller than these. But the intensity of threat was very high in all these patches. In spite of being a protected area, BWS was facing many threats. The number of dependent villages (32) and human & livestock population was very large so lopping, cutting, grazing, grass harvesting and fuel wood collection were at large scale (Fig. 8.12). Privately owned estates inside the sanctuary also created many threats (Fig. 8.13). The situation in Sitlakhet was worse than BWS though both had been grouped in a single cluster. Most of the area of Sitlakhet was highly degraded and surrounded by pine forest. Being close to Almora, it was densely populated with human and livestock population and was well connected with road network all around. It was

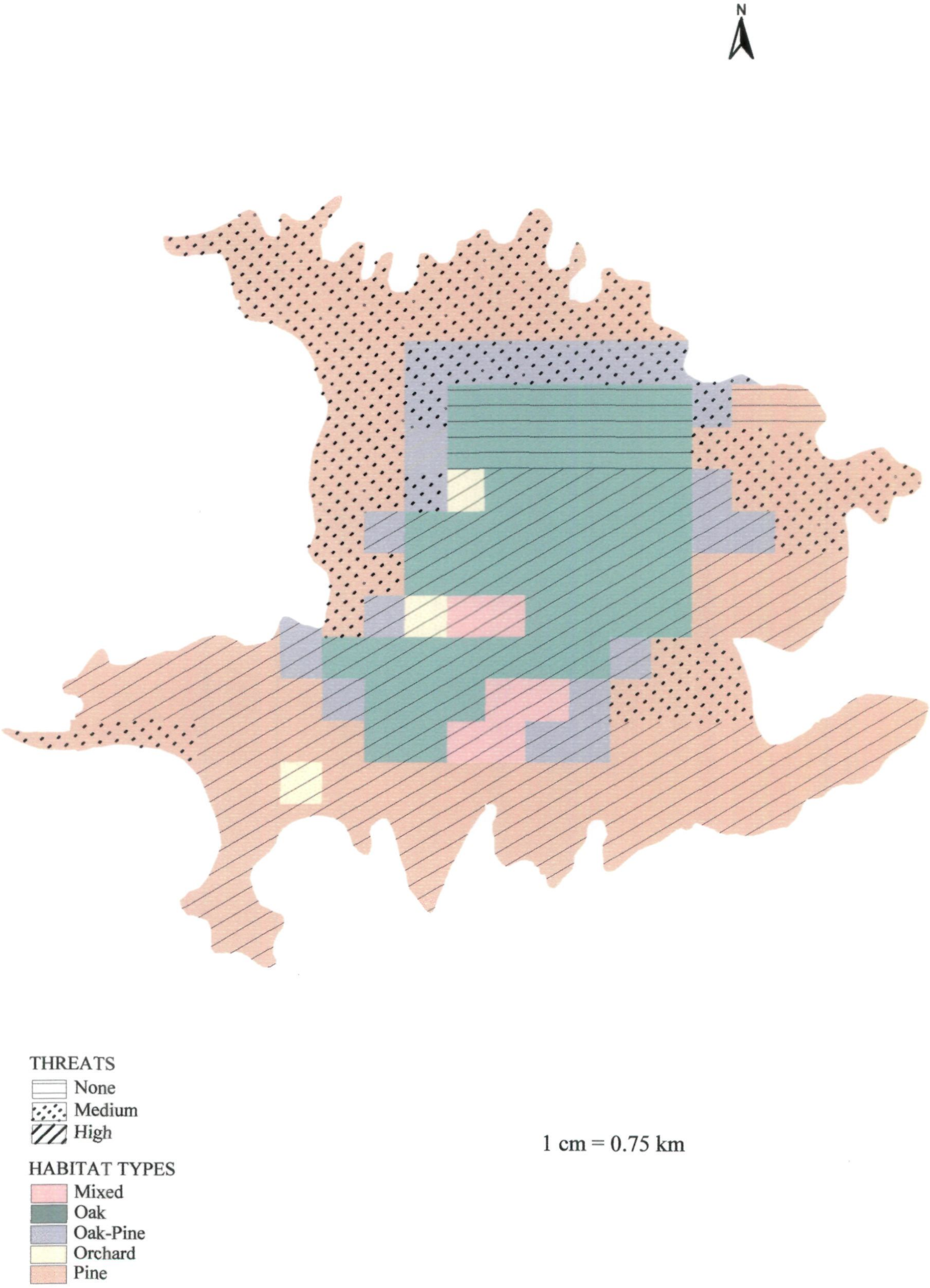


Fig. 8.12 Intensity of threats in different habitat types in Binsar Wildlife Sanctuary.

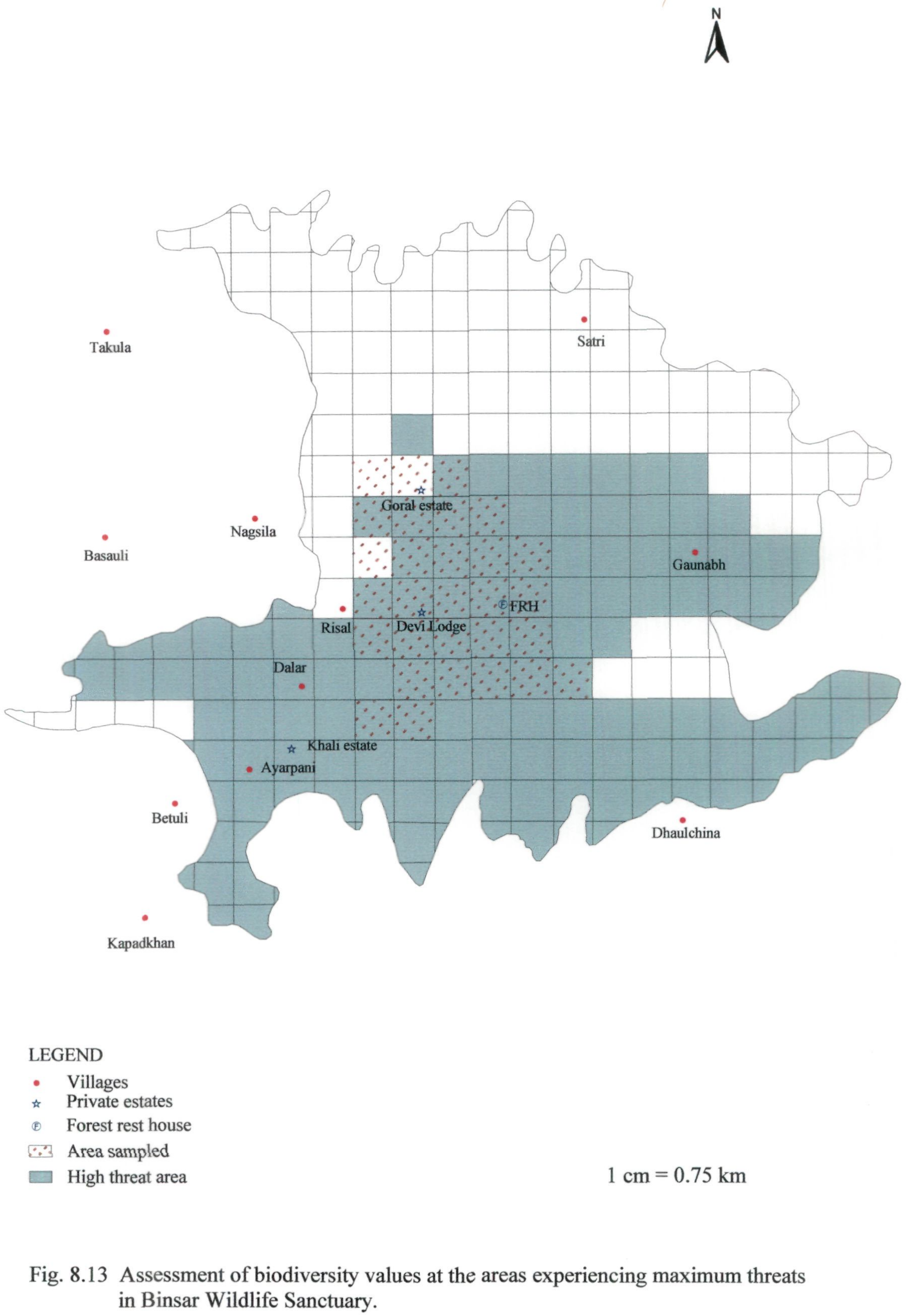


Fig. 8.13 Assessment of biodiversity values at the areas experiencing maximum threats in Binsar Wildlife Sanctuary.

devoid of dense oak patch so people mostly depend on the degraded oak-forest to meet their needs of fuel wood and fodder.

Jageshwer and Munsiary were exploited in terms of forest resource utilization. Both act as trade centers for illegal collection of wild animal products. Munsiary being very close to Indo-Tibetan border was the last main town for the people going to Tibet via Ralam Dhura and Yankchak Dhura passes for trade and religious purposes and it was the first Indian market for the Tibetans for selling wool, wool products and medicinal plants. While in Jageshwer poaching of wild animals and extraction of medicinal plants was recorded.

Gandhura was an oak patch of Askot Wildlife Sanctuary with few dependent villages and low densities of human and more live stock population. It was a large isolated oak patch and devoid of any direct approach through mettaled road. The state of this patch was found to be very good in terms of forest cover.

Pindari like Gandhura too formed separate group in terms of existing threats therein. But the area was unique in keeping rich biodiversity values as compared to other surveyed location of Kumaon. Being representative of maximum bird species, and endangered plants like *Taxus baccata* and many rare and endangered medicinal plant species. Except poaching of wild animals for their products, medicinal plant extraction and lichen-moss collection, the extraction of other forest products were for local consumption only. The first three activities were mainly for commercial purposes. The alpine and sub-alpine zones of Pindari were rich in medicinal plant species, which were extracted for local use as well as for commercial purposes. New IUCN Red List Criteria have listed many of them as critical, endangered and vulnerable. The medicinal plants like Atees *Acotinum heterophyllum* (Critical), Mansi *Nardostachys grandiflora* (Endemic), Kutki *Picrorhiza kurroa* (Endangered), Salam panja *Orchis latifolia* (Threatened), Vankakri *Podophyllum hexandrum* (Critical), Salam misri *Polygonatum verticillatum* (Endangered), Hathajari *Dactylorhiza hatazirea* (Critical), Chipi *Angelica glauca* (Endangered) and Guchhi *Morchella* sp. are heavily extracted for commercial purposes every year.

Exploitation of flora was exclusively restricted to some shrubs and tree species. A highly endangered tree species *Taxus baccata* was used for timber and its bark and leaves are sold. Bark and leaves were used to make anti cancer drug. The rest of the tree species are exploited for timber wood, fuel wood and lopped for leaves & branches mainly for local use only. The shrub like *Arundinella nepalensis* was heavily extracted for its products for local use as well as for commercial purposes. Sheep and goat grazing was found very high. Owing to heavy sheep & goats grazing the ground cover of the area was found to be heavily grazed and consequently low abundance of seedlings of plants was observed. Pindari region is known for three world famous glaciers namely Pindari, Kafni and Sunderdunga, and these places attract thousands of tourists during summer and winter every year, which exerts a great threat to forest and wildlife therein. The last point of Pindari glacier trekking route leads to the base of the Nanda Devi peak which falls in the vicinity of Nanda Devi Biosphere Reserve and which has been declared as World Heritage Site by UNESCO's Man and Biosphere (MAB) program in 1992. This is the home of so many endangered mammal species like Musk deer *Moschus moschiferus*, Snow leopard *Panthera uncia*, Himalayan Tahr *Hemitragus hylocrius* and Blue sheep *Pseudois nayaur*.

8.4.2 Where to conserve bird community in Kumaon Himalaya

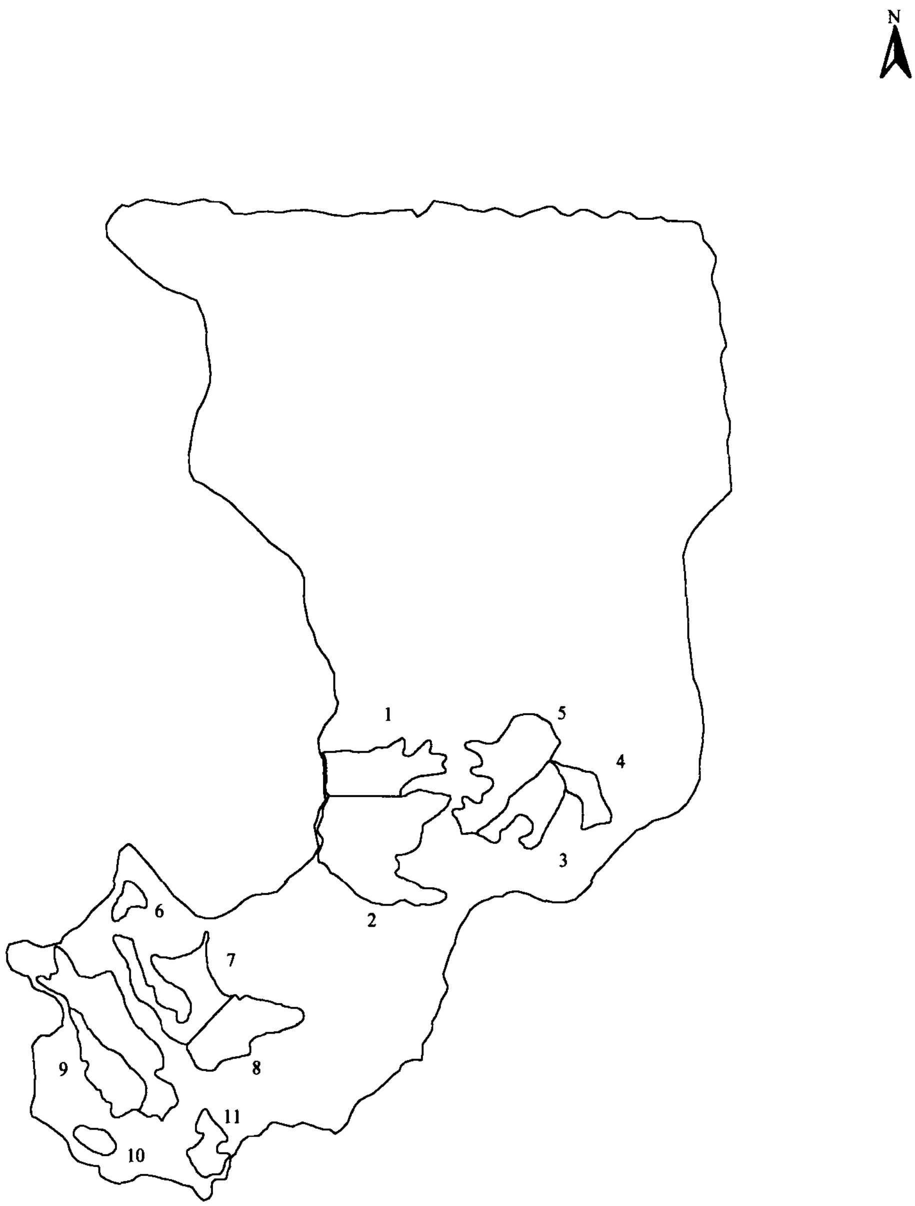
The present study was aimed to study the ecology of avian community of Kumaon Himalaya and to prepare conservation strategies for them. The main two queries of conservation i.e. Where to conserve? and How to conserve or Recommendations; will be discussed in the light of the outcome of intensive study on birds and threats upon them.

In the Kumaon Himalaya, temperate forests include habitats of mixed broad leaves, moist oak and rhododendron and dry coniferous of pines and firs; higher up, sub alpine forest of birch, rhododendron and juniper occurs. The forest areas of this region were vitally important for many of its bird species. Several wide spread endemic species are chiefly confined to tropical deciduous forest such as Plum- headed parakeet (*Psittacula cynocephala*), which has a preference for this type of forest but in Kumaon it was sighted in temperate forest up to 2300 m asl. Temperate forests types support a relatively high proportion of species with restricted distributions, notably the White-throated tit (*Aegithalos niveogularis*), which frequents bushes in mixed forest and dwarf shrub berries near the tree line in the breeding season (Grimmett *et al.* 1998). This bird was frequently sighted in Pindari region, Vinaiyak reserve forest, Sobala (Askot wildlife sanctuary) and sometimes in Binsar Wildlife Sanctuary. Another endemic bird is the Pied thrush (*Zoothera wardii*), which breeds in open broad-leaved forest in the Himalayas and hills of North East India. This bird was seen twice in Pindari region and once in Vinaiyak reserve forest. Birdlife International has analyzed the distribution patterns of birds with restricted ranges. It's analyses showed that restricted range species tend to occur at places, which are often islands or isolated patches of a particular habitat. These are known as endemism, and are often called Endemic Bird Areas or 'conservation hotspots'. Birdlife has identified eight centers of endemism in the Indian subcontinent and Western Himalayas is one of them (Grimmett *et al.* 1998). The 11 species endemic to the Western Himalaya include the probably extinct Himalayan Quail, which was once distributed in Naini Tal region, and the other Cheer pheasant (*Catreus wallichii*) is thought to be at the risk of extinction, sighted in Pindari and Vinaiyak area only. Another pheasant, Satyr tragopan (*Tragopan satyra*) is also restricted to the Kumaon Himalaya towards its Western Himalayan limit. It is not found in Garhwal Himalaya. All these species are threatened by habitat loss, deterioration and hunting. In whole bird community, the family pheasanidae suffered a lot by human beings. It has been shot and snared for food and sports. Its cultural and aesthetic association with man has become the major threat for its survival.

Without studying the vegetation of any area, no one can even think of conserving that area. So endangered and critical plant species were also considered. Out of 26 endemic centers of plants in India, Kumaon Himalaya is one of them. According to new IUCN Red list criteria, medicinal plants of Kumaon were also categorized and species such as *Aconitum falconeri, Aconitum heterophyllum, Dioscorea deltoidea, Nardostachys jatamansi, Orchis latifolia* are critical, *Berberis aristata, Berberis chirita, Saussurea gossypiphora, Swertia augustifolia* are endangered where as *Hedychium spicatum, Thalictrum foliolosum* are vulnerable species. All critical species were found in upper ridges of Pindari region. All these biodiversity values are suffering from habitat loss only. Since in nature no organism lives in isolation, each species is dependent on other species as also on ecological system. As there is complete interdependence in nature, change in a habitat affects the diversity of the species contained in it. Conversely, any change in the number and assemblage of species also affects the nature of the habitat. So there is a need to conserve biodiversity because of interdependence of species in nature for survival demands conservation of all elements of biodiversity. In the report submitted to Ministry of Environment & Forests, Govt. of India (Hussain *et al.* 2000), the conservation strategies were prepared by keeping in mind major elements of biodiversity such as birds, mammals, a separate group of birds, phasianidae and plants. But here only avian community had been taken into consideration.

The first stage of most conservation planning is to identify areas that want protection. The main criteria used to identify such areas are biodiversity, rarity, population abundance, environmental representativeness, and site area. Where distribution data are both comprehensive and accurate, it is possible to identify areas of high species richness for certain taxa, focusing on threat level (e.g. endangered species) or biogeographical status (e.g. endemic species) (Diamond, 1986; Myers, 1990; International Council for Bird Preservation, 1992; Prendergast *et al.* 1993; Dobson *et al.* 1997). In past the protection of individual, usually rare species was used to select the site for protection but this approach to reserve selection has its strength and weakness (Prendergast *et al.* 1999).

I have already discussed the importance of avian community in Kumaon Himalaya. There are only two wildlife sanctuaries existing in Kumaon i.e. Askot Wildlife Sanctuary (Pithoragarh district, area = 600 km^2) (Fig. 8.14) and Binsar Wildlife Sanctuary (Bageshwer district, area = 45.59 km^2) (Fig. 8.15). The percent (3.1%)



LEGEND

1	Sobala	(Surveyed)
2	Duk	(Surveyed)
3	Jiunfigard	
4	Rungling	
5	Ahirigomri	
6	Thakla	
7	Dhaphiadhura	(Surveyed)
8	Majtham	(Surveyed)
9	Gandhura	(Surveyed)
10	Sirtham	
11	Payan	

1 cm = 6 km

Fig. 8.14 Map showing forest patches of Askot Wildlife Sanctuary in Pithoragarh district.

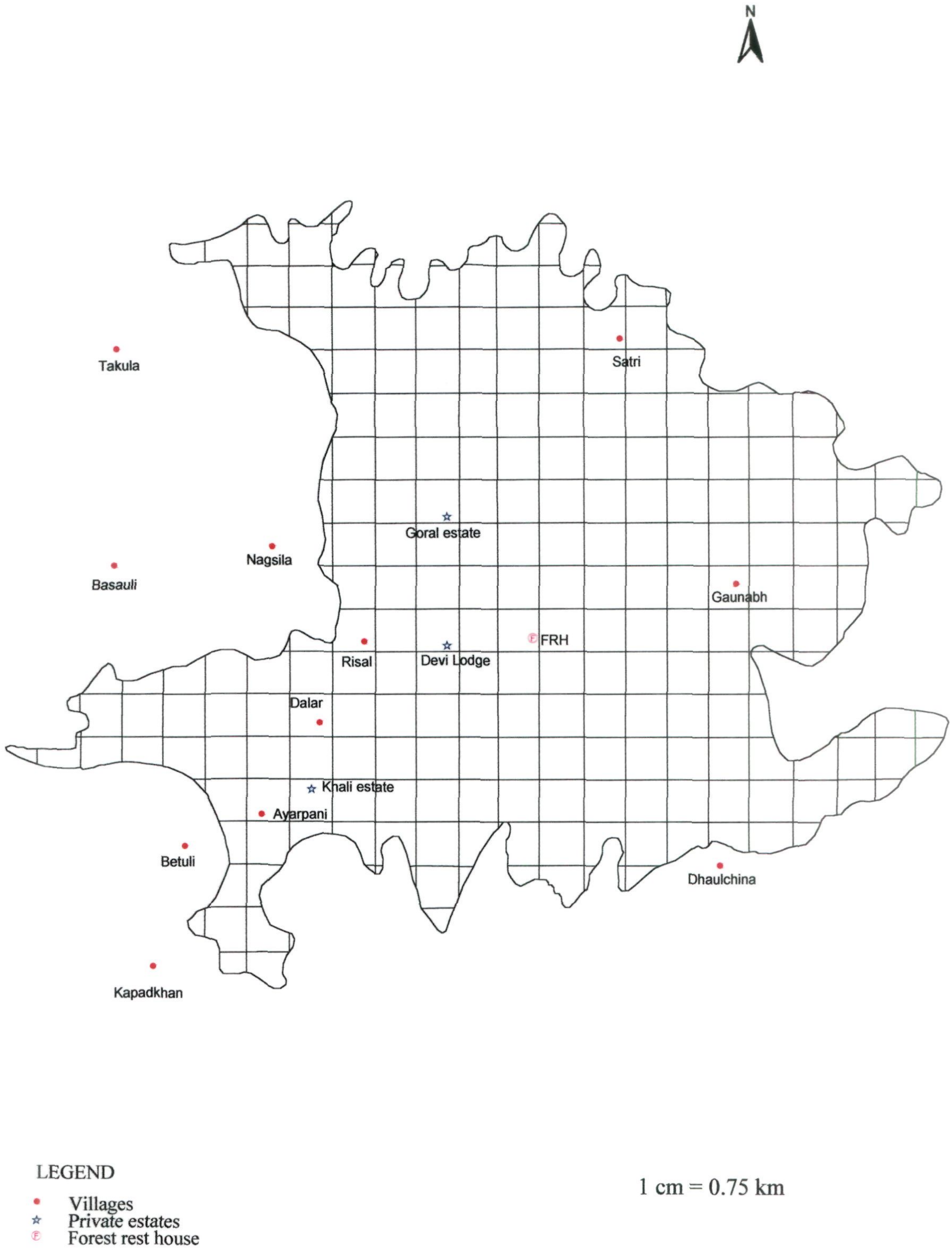


Fig. 8.15 Location of villages in and around Binsar Wildlife Sanctuary.

protected area is too small as compared to the whole geographical area of Kumaon (2,1032 km^2). Both the sanctuaries were facing severe threats. Binsar sanctuary has limited conservation potential by having only approximately 4 km^2 of oak patch (Fig. 8.16). This patch is just like an island without any connection with another oak patch. Therefore, in order to conserve endemic bird species more areas have to be brought under the network of protected areas.

By assigning conservation values to sites in terms of birds, the maximum value was obtained for Vinaiyak. The other four sites followed by it, are protected. Other sites such as Pindari and Dhakuri are unprotected and having high conservation value also. So, I recommend creation of two more sanctuaries in the Kumaon Himalaya in Bageshwer district (Pindari area) (Fig. 8.17) and Naini Tal district (Kilbery-Vinaiyak-Kunjakharak area) (Fig. 8.18). Blue prints of these sanctuaries were prepared from the toposheets of Survey of India. These areas hold maximum biodiversity and are relatively less disturbed. The boundary of both the proposed sanctuaries was carved out in such a manner that maximum villages were excluded. The main reason for this was to avoid conflict between villagers and Govt. officials as well as between livestock and wild animals. However the conservation value of Kilbery (0.03) and Kunjakharak (0.026) was not high but these sites were in continuation with Vinaiyak (here after Naina Sanctuary) forest, which enhanced the importance of these sites in conserving birds for several another reasons. Chir pheasant was sighted in the forest between the Vinaiyak and Kunjakharak only in this area. So it is necessary to protect the forest between Kilbery and Kunjakharak. The patches of Dhakuri, Khati, Pindari and Sunderdunga (hereafter Pindari Sanctuary) are in continuation and thus have more conservation value rather than protecting isolated

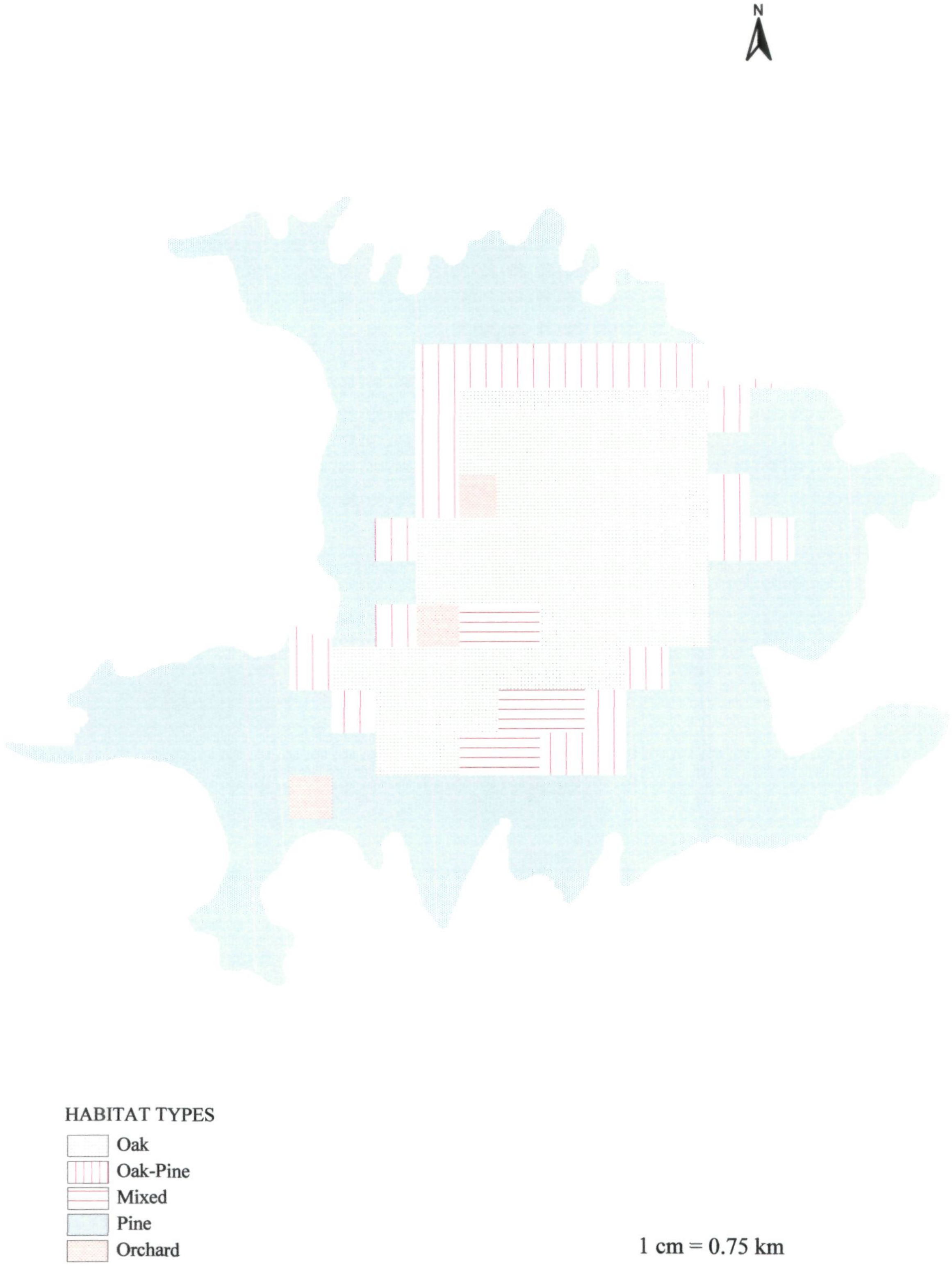
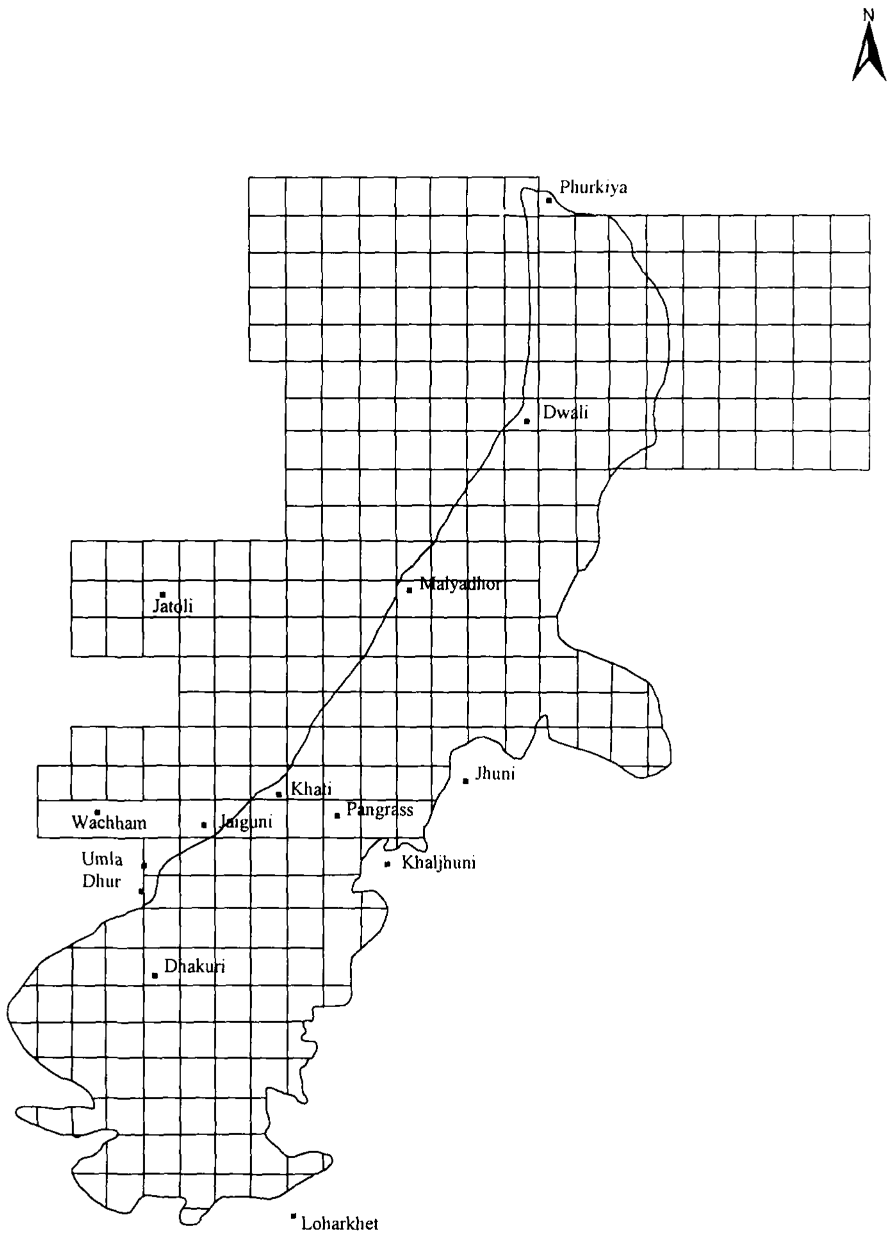
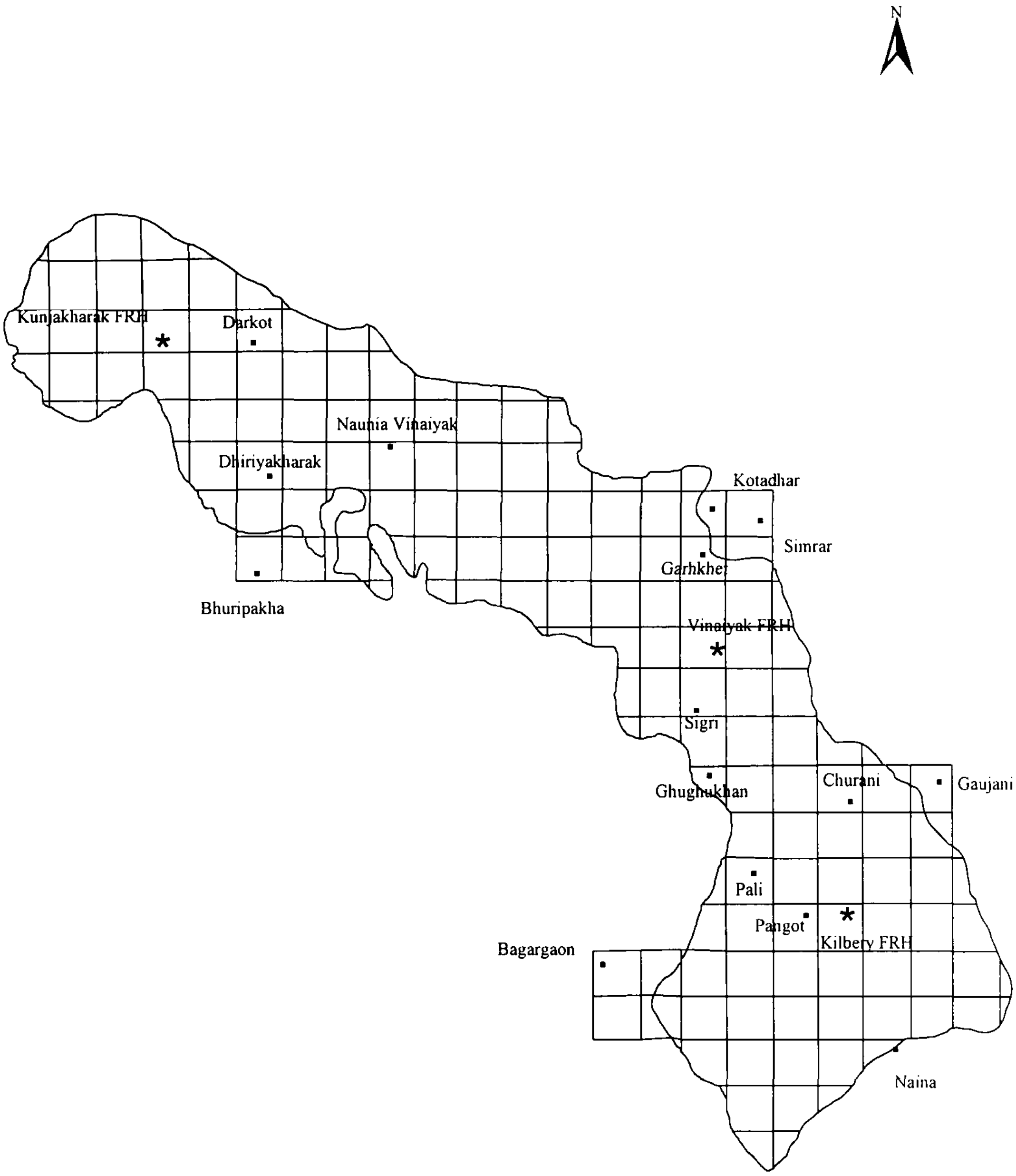


Fig. 8.16 Forest cover of Binsar Wildlife Sanctuary in Almora district.



1 cm = 1.56 km

Fig. 8.17 Location of villages in and around proposed Pindari Wildlife Sanctuary in Bageshwer district.



LEGEND

■ Villages

✱ Forest rest house

1 cm = 1.12 km

Fig. 8.18 Location of villages in and around proposed Naina Wildlife Sanctuary in Naini Tal district.

individual patches such as Maheshkhan, Mukteshwer and Jageshwer. The carved maps of proposed sanctuaries were divided into grids of 1x 1 km. Different themes (map layers) of spatial data were collected. The themes were habitat types, cutting, lopping, grazing, grass harvesting, human & livestock population, lichen & moss collection and Arundenaria collection. Data on all these themes were collected for each grid by visiting in field and for inaccessible grids, data were collected with the help of binoculars and informations were also gathered from locals. The combination of two polygonal data themes was combined into a single digital map. The area of Pindari sanctuary was figured out around 144.7 km^2 while for Naina Sanctuary approximately 87.23 km^2.

An early debate within conservation biology occurred over whether species richness is maximized in one large nature reserve or several smaller ones 'SLOSS' (Single large or several small) of an equal total area (Diamond, 1975b; Simberloff & Abele, 1976; 1982; Terborgh, 1976; Terborgh & Winter, 1980). The supporters of large reserves argue that only large reserves have sufficient populations of big, wide-ranging species and low-density species to maintain long term populations. Also, a large reserve minimizes edge effects, encompasses more species and has greater habitat diversity than a small reserve. These advantages of large reserves follow from island biogeography theory. Opposing this viewpoint, other conservation biologists argue that well placed small reserves are able to include a greater variety of habitat types and more populations of rare species than one large block of the same area (Jarvinen, 1979; Simberloff & Gotelli, 1984). In the present study bird species diversity and richness was positively correlated with patch size so it can be argued here that big patch size can hold more bird richness than a smaller one. But the topography of hills should also be kept in mind. On hills the smaller area in terms of square kilometer is larger than the plains. Moreover the large area is difficult to manage on hills. Often there is no choice other than to accept the challenge of managing species in small reserves when land around the small reserve is unavailable for conservation purposes. The land around the proposed Naina Wildlife Sanctuary (Fig. 8.19) and Pindari Wildlife Sanctuary (Fig. 8.20) is highly degraded habitat and would create problems to Govt. officials for its management, if it is protected. It is clear from maps that area near the villages is degraded and there is much pressure on oak patches as compared to pine forest and mixed forest in Naina Wildlife Sanctuary (Fig. 8.21) while in alpine or sub alpine forest in case of Pindari Wildlife Sanctuary (Fig. 8.22 & 8.23). As suggested by Game & Peterkin (1984) and Soule & Simberloff (1986) that strategy on reserve size depends on the group of species under consideration as well as the scientific circumstances. A conservation area should be rounded in shape i.e. low edge to area ratio. But land acquisition is typically a matter of opportunity rather than a matter of completing a geometric pattern. Shape is not an important determinant of species richness and decisions should be made on other practical grounds (Burgman *et al.* 1988).

The boundary of Nanda Devi Biosphere Reserve (NDBR) touches the boundary of Pindari Wildlife Sanctuary and by declaring it as a protected area, the buffer zone of NDBR will act as a corridor between them or this sanctuary will be an extension of NDBR and will serve as a buffer zone or transitional zone of Biosphere reserve. Naina Wildlife Sanctuary and the buffer zone of Corbett Tiger Reserve & National Park will act as a corridor between them. These corridors would allow plants and birds especially ground feeders to disperse from one reserve to another, facilitating gene flow and

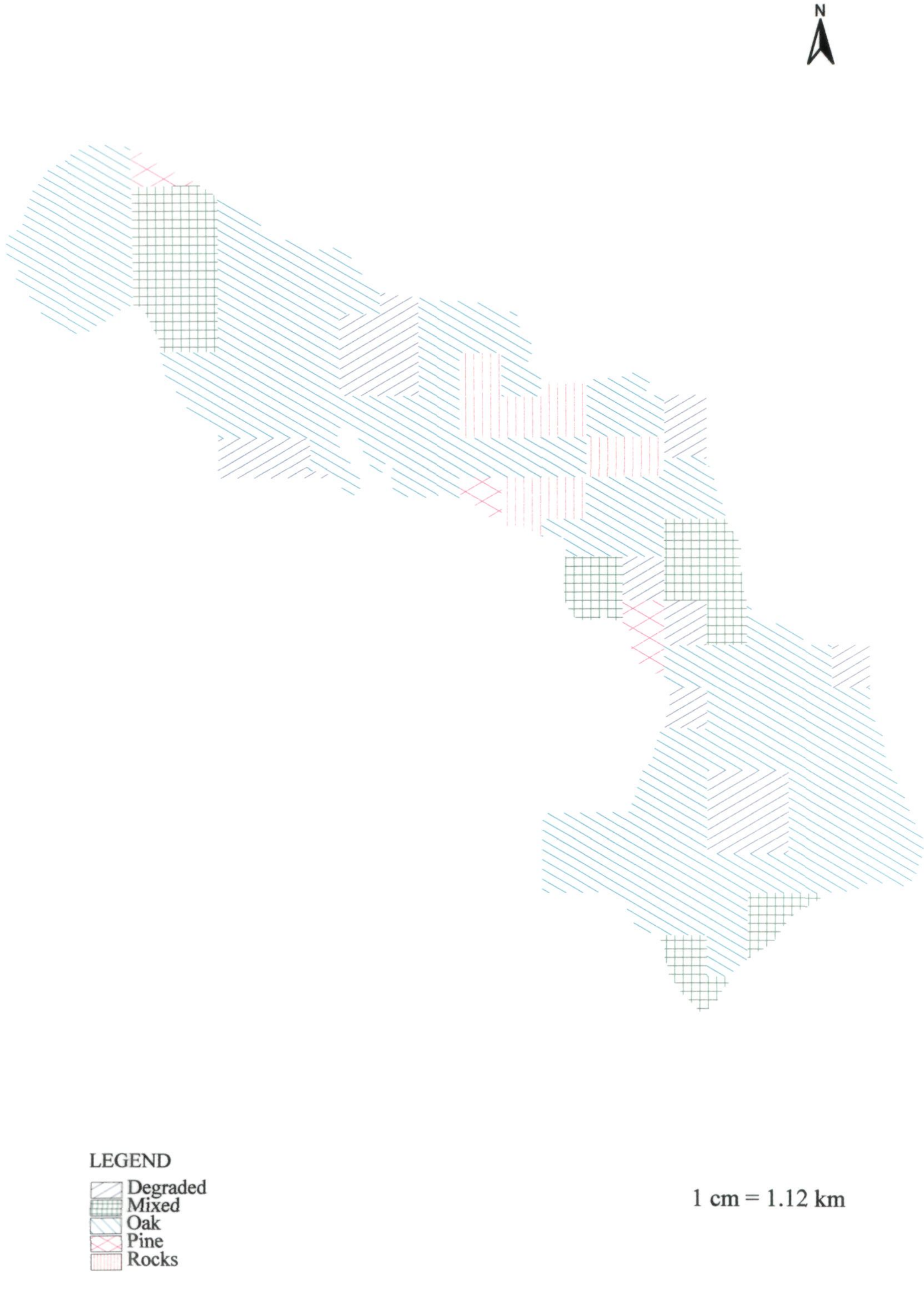


Fig. 8.19 Forest cover of proposed Naina Wildlife Sanctuary in Naini Tal district.

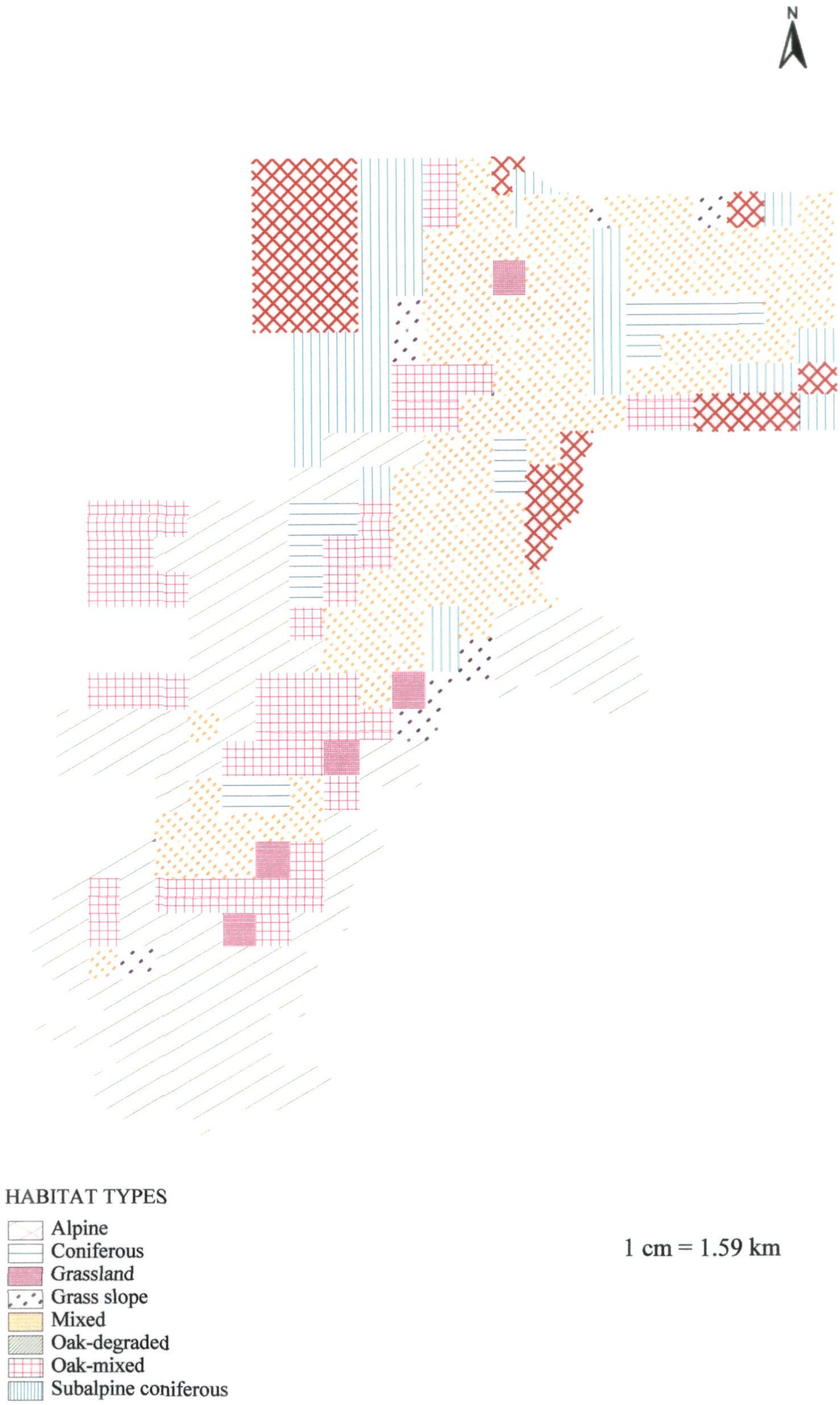


Fig. 8.20 Forest cover in and around proposed Pindari Wildlife Sanctuary in Bageshwer district.

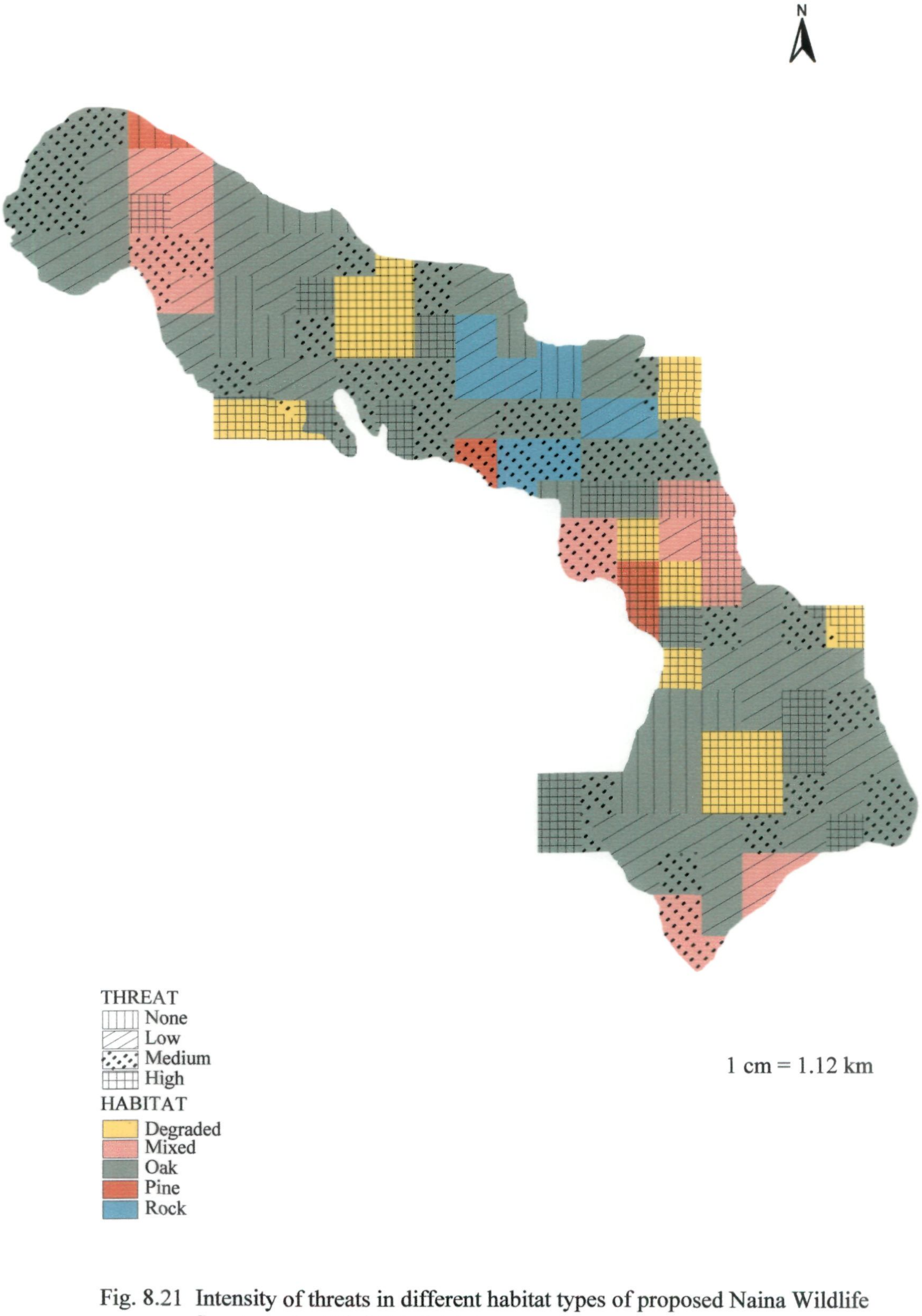


Fig. 8.21 Intensity of threats in different habitat types of proposed Naina Wildlife Sanctuary in Naini Tal district.

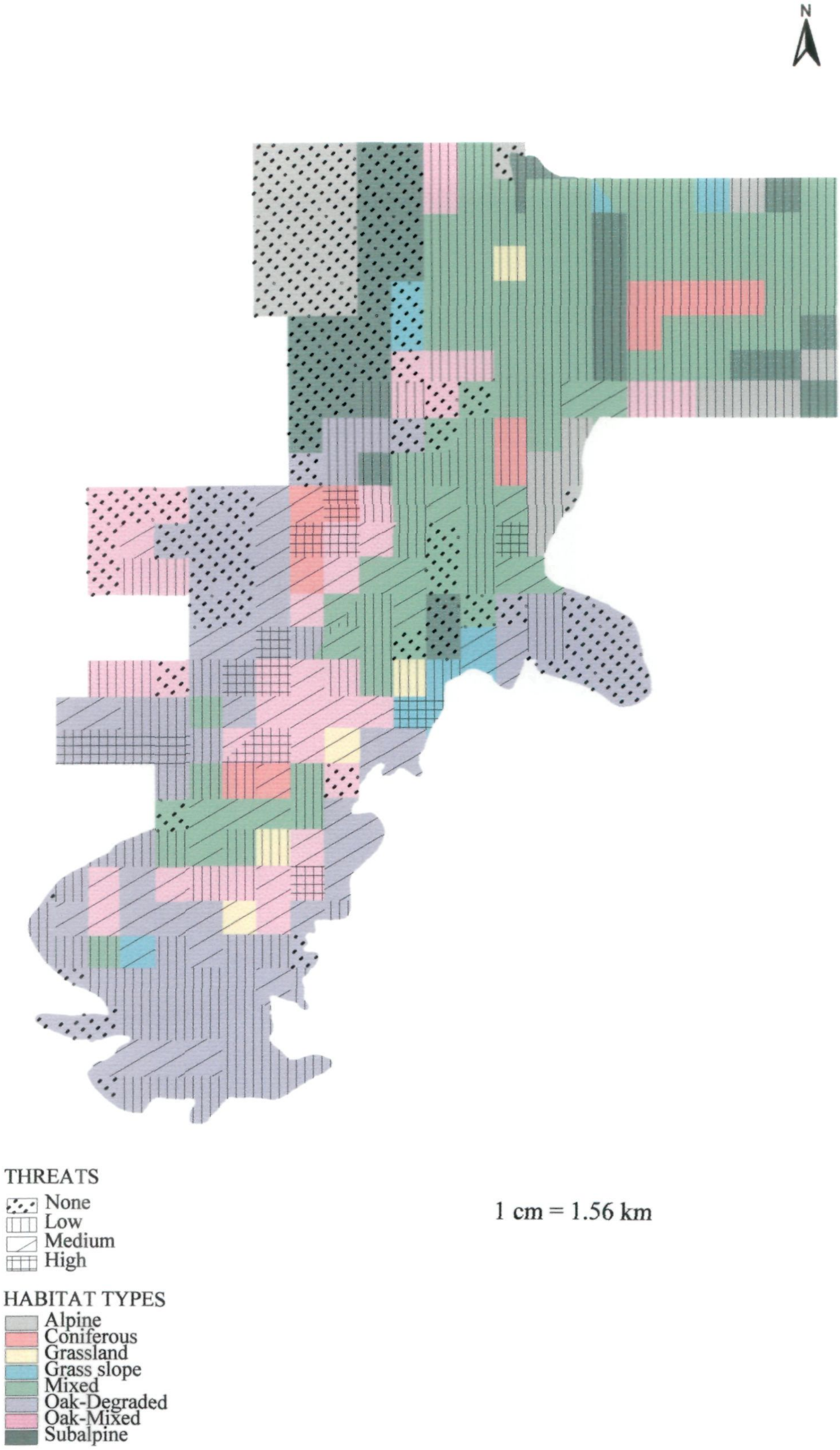


Fig. 8.22 Intensity of threats in different habitat types in and around proposed Pindari Wildlife Sanctuary.

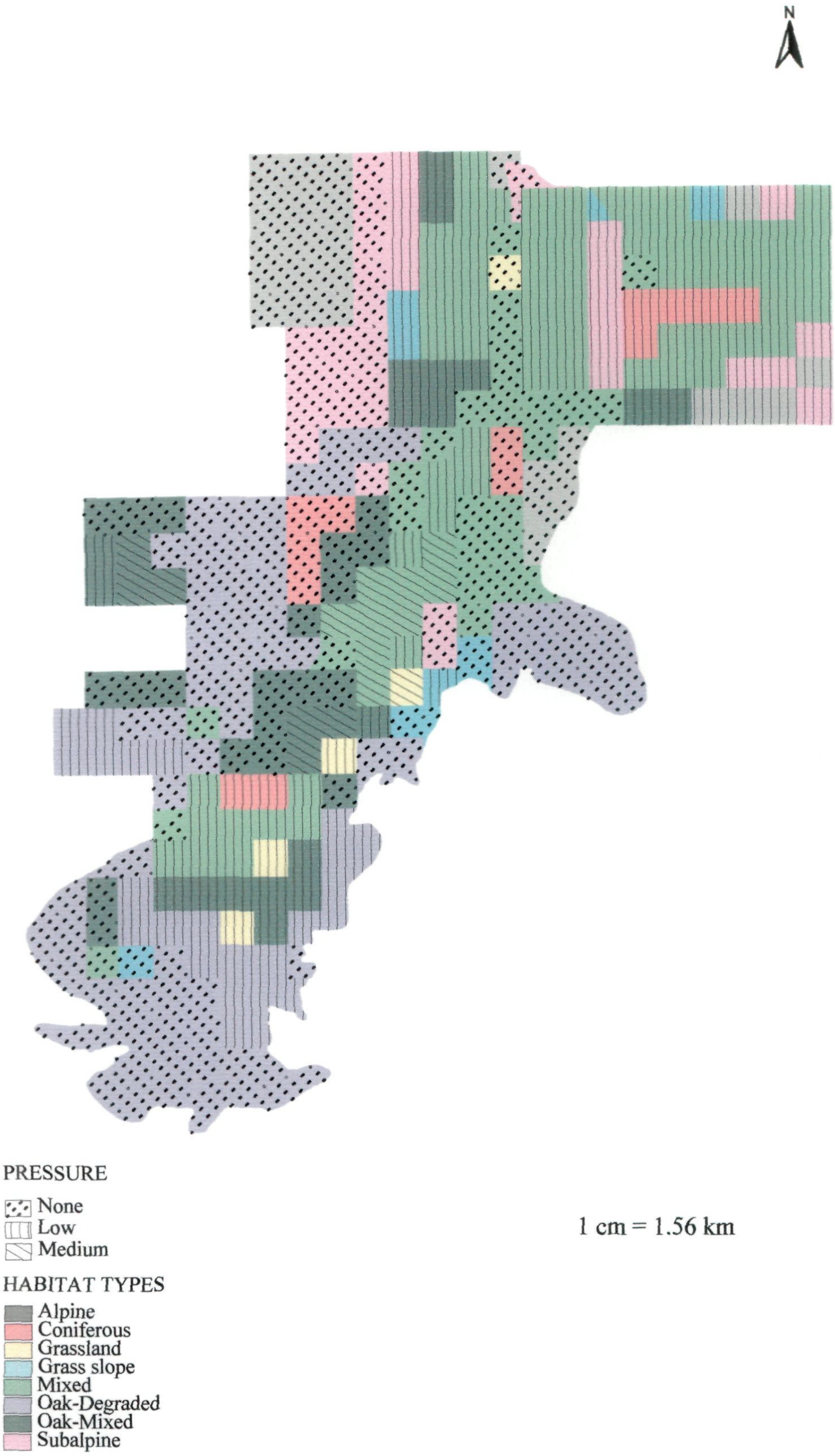


Fig. 8.23 Intensity of Arundinaria & Lichen - Moss collection and medicinal plants extraction in and around proposed Pindari Wildlife Sancturary.

colonization of suitable sites. They would also help to preserve birds that must migrate seasonally among a series of different habitats to obtain food (Primack, 1993). Samant *et al.* (1993) also suggested some river catchment areas as botanical hotspots for conservation and Pindari catchment is one of them. The area supports high plant diversity. Several species recorded from Pindari area in past could not be recorded in recent years, showing their possible extinction from this area, e.g. *Cochlearia scapiflora, Triosetum hirsutum, Astragalus pindarensis, Calanthe alpina, C. puberula, Aorchis roborovskii, Pleione hookeriana* (Pangtey, 1991).

8.4.3 How to conserve landscape in terms of avian community

Though it is not possible to prevent habitat loss in nearby towns but the extent of dependency can be reduced and at least forest in remote areas can be saved. Apart from creation of two new sanctuaries in Kumaon to conserve the avian community of forest, I also recommend the following efforts, which if implemented would certainly conserve the avian communities and Kumaon in future-

1. The afforestation program can be started in the villages and forests where the effects of deforestation and soil erosion are in most damaging state. As an immediate step all ridges and barren land should be afforested with native tree species.
2. Some of the land under cultivation, particularly at higher altitudes, is of poor quality and on such steep gradients forestry practices would be a proper use of those lands. Opportunity should be offered to landholders to surrender their land to the government for afforestation against adequate compensation. The purpose of increasing the forest area through afforestation of arable land would be achieved

cheaper than full compensation given for land. Conservation of biodiversity will not be possible without assessing the local needs.

3. The existing protected areas or the areas which are going to be conserved by Govt., should be conserved through Eco-tourism. Through this scheme locals also can get employment and the awareness for environment or wildlife conservation can be developed among the dependents of forest.
4. There is an urgent need to examine conservation status of all types of vegetation, communities and habitats, important and selected plant and animal taxa by using remote sensing imagery, geographical information system and gap analysis. GIS analyses would make it possible to high light critical areas that should be avoided for development projects. This approach will high light correlations among the abiotic and biotic elements of the landscape, help to plan protected areas that include ecosystem diversity and even suggest potential sites to search having rare species. The recent advances in GIS (with powerful methods for spatial data analysis) will no doubt contribute to further development of computer based method of wilderness evaluation and make it a very important tool for management and monitoring changes as well as for evaluating vast expanses of wilderness areas. The approach of GIS in this study was only a mere start, a lot of work is required in future on the relationship between birds and landscape ecology of Kumaon.

The preservation of the Himalayas, for their own sake, and as a system of support for the varied forms of life dependent on them, must involve the people as much as national and state government. It can be achieved only by willing involvement of local people but it is for the government to take the initiative. However, it requires a positive, constructive and sustained policy for the development of natural resources.

REFERENCES

Abdulali, H. (1952). Finn's Baya (*Ploceus megarhynchus* Hume). *J. Bombay Nat. Hist. Soc.* **51**: 200-204.

Adams, C.C. (1908). The ecological succession of birds. *Auk* **25:** 109- 153.

Adhikari, B.S.; M. Joshi; H.C. Rikhari & Y.S. Rawat (1992). Cluster Analysis (Dendrogram) of high altitude (2150-2500m) forest vegetation around glacier in Kumaun Himalaya. *J. Environ. Biol.* **13(2)**: 101-105.

Ahmed, A. & A. H. Musavi (1993). Preliminary ecological studies in 1991 on the white crested kaleej pheasant at Ranikhet, Kumaon Himalayas, India. In (ed. D. Jenkins) *Pheasants in Asia* 1992. World Pheasant Association, Reading, UK. Pp. 73-75.

Ahmed, A. (1997). Birding on treks around Nainital. *Newsletter for Birdwatchers* **37:** 41-42.

Akaike, M. (1973). Information theory and an extension of the maximum likelihood principle. International Symposium on Information Theory (eds. B.N. Petrov & F. Csaki). 267-281.

Alatalo, R.V. (1981). Interspecific competition in tits *Parus* spp. and the Goldcrest *Regulus regulus*: foraging shifts in multi specific flocks. *Oikos* **37:** 335-344.

Alatalo, R.V. (1982). Multidimensional foraging niche organization of foliage gleaning birds in northern Finland. *Ornis Scandinavica* **13**: 56-71.

Ali, S. & J. H. Crook (1959). Observations on Finn's Baya (*Ploceus megarhynchus* Hume) rediscovered in the Kumaon terai, 1959. *J. Bombay Nat. Hist. Soc.* 56: 457-483.

Ali, S. & S. D. Ripley (1987). *Compact handbook of birds of India and Pakistan.* New Delhi: Oxford University Press.

Ali, S. (1935). Mainly in quest of Finn's Baya. *Indian Forester* ?: 365-374.

Allen, J.C. & D.F. Barnes (1985). The causes of deforestation in developing countries. *Annals of Association of American Geographers* **75:** 163-184.

Ambedkar, V. C. (1969). Observations on the breeding biology of Finn's Baya (*Ploceus megarhynchus* Hume) in the Kumaon terai. *J. Bombay Nat. Hist. Soc.* **65**: 596-607.

Ambedkar, V. C. (1970). Nests of the Baya, *Ploceus philippinus* (Linnaeus) on telegraph wires. *J. Bombay Nat. Hist. Soc.* **66**: 624.

Ambedkar, V. C. (1972). On the breeding biology of the Black-throated [*Ploceus benghalensis* (Linnaeus)] and the Streaked Weaver Birds [*Ploceus manyar flaviceps* (Lesson)] in the Kumaon terai. *J. Bombay Nat. Hist. Soc.* **69:** 268-282.

Ambuel, B. & S.A. Temple (1983). Area dependent changes in the bird communities and vegetation of southern Wisconsin forests. *Ecology* **64:** 1057-1068.

Amman, G.D. & P.H. Baldwin (1960). A comparision of methods for censusing woodpeckers in spruce-fir forests of Colorado. *Ecology* **41**: 699-706.

Anderson, A. (1878). On a new species of Indian *Prinia. Proc. Zool. Soc. London* 1878: 370-371.

Anderson, B.W.; R.D. Ohmart & J. Rice (1981). Seasonal changes in avian densities and diversities. *Studies in Avian biology* **6:** 262-264.

Anderson, D.W. & J.O. Keith (1980). The human influence on seabird nesting success 'Conservation implications'. *Biological Conservation* **18:** 65-80.

Anderson, D.W. (1988). Does response relationship between human disturbance and brown pelican breeding success. *Wildlife Society Bulletin* **16:** 339-345.

Anderson, S.H. & H.H. Shugart Jr. (1974). Habitat selection of breeding birds in an east Tennessee deciduous forest. *Ecology* **55**: 828-837.

Anderson, S.H. (1970). The avifaunal composition of Oregon white oak stands. *The Condor.* **72:** 417-423.

Anderson, S.H. (1970a). *Forest birds of western Oregon.* Ph.D. thesis. Oregon State University, Corvallis.

Anderson, S.H. (1979). Changes in forest bird species composition caused by transmission line corridor cuts. *Am. Birds* **33**: 3-6.

Anonymous. (1991). *The State of Forest Report,* Forest Survey of India, Ministry of Environment & Forest, Govt. of India.

Asad, A.; V. Prakash & S. Javed (1994). The western tragopan. *Sanctuary Asia.* Vol **15(2).**

Atkinson, E.T. (1882, 1884, 1886). *Gazetteer of the Himalayan districts of North-West provinces of India.* Vol. X (1882), XI (1884) and XIII (1886), Govt. India Press, Allahabad.

Austin, M.P. (1979). Current approaches to the nonlinearity problem in vegetation analysis. *Contemporary Quantitative Ecology and Related Ecometrics.* Statistical Ecology Series **12**: 197-210.

Austin, M.P. (1985). Continuum concept, ordination methods, and niche theory. *Ann. Rev. Ecol. Syst.* **16**: 39-61.

Beecher, W.J. (1942). *Nesting birds and the vegetation substrate.* Chicago Ornithol. Soc., Chicago.

Beedy, E.C. (1981). Bird communities and forest structure in the Sierra Nevada of California. *The Condor* **83(2)**: 97-105.

Beehler, B. (1981). Ecological structuring of forest bird communities in New Guinea. *Monographiae Biologicae* **42**:837-861.

Beehler, B.; K.S.R. Krishnaraju & Shahid Ali (1987). Avian use of man disturbed forest habitats in the Eastern Ghats, India. *Ibis* **129:**197-211.

Bell, H.L. (1980). Effects of power line clearing on birds. *Corella.* **4**: 8-19.

Bell, H.L. (1984). The importance of foothill forest in the diversity of rainforest birds in New Guinea. *Emu* **84:** 225-235.

Bennett, S. & D. Bowers (1976). *An Introduction to Multivariate Techniques for Social and Behavioral Sciences.* John Wiley and Sons, New York.

Best, L.B. (1975). Interpretational errors in the 'mapping method' as a census technique. *Auk* **92:** 452-460.

Best, L.B. (1981). Seasonal changes in detection of individual bird species. *Studies in Avian biology* **6:** 252-261.

Bibby, C.J. & S.T. Buckland (1987). Bias of bird census results due to detectability varying with habitat. *Acta Ecologia,* **8:** 103-112.

Bibby, C.J.; B.N. Phillips & A.J.E. Seddon (1985). Birds of restocked conifer plantations in Wales. *Journal of Applied Ecology,* **22:** 619-633.

Bibby, C.J.; N.D. Burgess & D.A. Hill (1992). *Bird Census Techniques.* Academic Press, London,UK.

Birks, H.T.B. (1987). Recent methodological developments in quantitative descriptive biogeography. *Ann. Zool. Fennici.* **24:** 165-178.

Blake, J. G. & B. A. Loiselle (2000). Diversity of birds along an elevational gradient in the Cordillera Central, Costa Rica. *The Auk* **117 (3):** 663-686.

Blake, J.G. & J.R. Karr (1984). Species composition of bird communities and the conservation benefit of large vs small forests. *Biological Conservation* **30:** 173-188.

Blake, J.G. (1983). Trophic structure of bird communities in firest patches in east central Illinois. *Wilson Bulletin* **95:** 416-430.

Blakesley, J.A. & K.P. Reese (1988). Avian use of campground and non campground sites in riparian zones. *Journal of Wildlife Mangement* **52**: 399-402.

Blondel, J.; C. Ferry & B. Frochot (1981). Point counts with unlimited distance. *Stud. Avian Biol.* **6:** 414-420.

Bock, C.E. & J.F. Lynch (1970). Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada. *Condor* **72:** 182-189.

Bond, R.R. (1957). Ecological distributions of breeding birds in upland forest of southern Wisconsin. *Ecological Monograph* **27:** 351-384.

Bond, W.J. & B.W. van Wilgen (1996). *Fire and plants.* Population and community biology series 14, M.B. Usher *et al.* (eds.), Chapman & Hall Publication.

Brash, A.R. (1987). The history of avian extinction and forest conversion on Puerto Rico. *Biological Conservation* **39:** 97-111.

Briggs, F.S. (1931). Birds observed in the neighbourhood of Ranikhet. *Journal of Bombay Natural History Society* **34:** 1072-1079.

Brithers, T. & A Spingarn (1992). Forest fragmentation and alien plant invasion of central Indiana old growth forest. *Conservation Biology* **6:** 91-100.

Brooks, W. E. (1869). Notes on birds observed near Nynee Tal and Almorah, from April to June 1868. *Ibis* **5 (2):** 43-60.

Brown, J.H. (1975). Geographical ecology of desert rodents. In *Ecology and evolution of communities (eds. M.L.Cody & J.M. Diamond)* pp. 315-341.

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

Burger, J.; J. Shisler & F.H. Lesser (1982). Avian utilization of six marshes in New Jersey. *Biological Conservation* **23**: 187-212.

Burgman, M.A.; H.R. Akcakaya & S.S. Loew (1988). The use of extinction models for species conservation. *Biological Conservation* **43:** 9-25.

Burnham, K.P., Anderson,D.R. & Laake, J.L. (1981). Line transect estimation of bird population density using a Fourier Series. *Studies in Avian Biology* **6:** 466-482.

Burnham, K.P.; D.R. Anderson & J.L. Laake (1980). Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* **72.**

Burrard, S.G. & H.H. Hayden (1933). *A sketch of the geography and geology of the Himalaya Mountain and Tibet.* Manager of Publications, Govt. of India, Delhi. 369.

Cairns, D. (1980). Nesting density, habitat structure and human disturbance as factors in black guillemot reproduction. *Wilson Bulletin* **92:** 352-361.

Carleton, T.J. (1984). Residual ordination analysis: a method for exploring vegetation-environment relationships. *Ecology* **65:** 469-477.

Champion, H.G. & S.K. Seth (1968). *The Forest Types of India.* Govt. of India publication, FRI, Dehra Dun.

Christensen, N.L. (1981). Fire regimes in south central ecosystem. *Proc. of the conference, fire and regimes and ecosystem dynamics,* General technical report, WO-**26** (U.S. Forest Services).

Clark, K.L.; D. Euler & E. Armstrong (1984). Predicting avian community response to lakeshore cottage development. *Journal of Wildlife Mangement* **48:** 1239-1247.

Clout, M.N. & P.D. Gaze (1984). Effect of plantation forestry on birds in New Zealand. *J. Appl. Ecol.* **21:** 795-815.

Cody, M.L. & H. Walter (1976). Habitat selection and inter specific interactions among Mediterranean sylviid warblers. *Oikos* **27:** 210-238.

Cody, M.L. (1974). *Competition and the structure of bird communities.* Princeton university press, Princeton, New Jersey, USA.

Cody, M.L. (1985). *Habitat selection in Birds*. Academic Press, New York.

Coker, P. (1992). *Vegetation description and analysis.* Belhaven Press. London.

Collins, S.L. & S.C. Barber (1985). Effects of disturbance on diversity in mixed grass prairie. *Vegetatio* **64:** 87-94.

Connell, J.H. & E. Orias (1964). The ecological regulation of species diversity. *Am. Nat.* **98:** 399-414.

Cox, G.W. & R.E. Ricklefs (1977). Species diversity and ecological release in Caribbean land bird faunas. *Oikos* **28:** 113-122.

Crome, F.H.J. (1978). Foraging ecology of an assemblage of birds in lowland rainforest in northern Queensland. *Australian Journal of Ecology* **3:** 195-212.

Crooks, K.R.; A.V. Suarez; D.T. Bolger & M.E. Soule (2001). Extinction and colonization of birds on habitat islands. *Conservation Biology* **15(1):** 159-172.

Daniels, R.J.R. (1989). *A conservation strategy for the birds of the Uttara kannada District.* Ph.D. thesis, Indian Institute of Sciences, Bangolore.

Daniels, R.J.R.; N.V. Joshi & M. Gadgil (1992). On the relationship between bird and woody plant species diversity in the Uttara Kannada district of South India. *Proceedings of the National Academy of Sciences USA*, **89**: 5311-5315.

Datta, A. (1998). Hornbill abundance in unlogged forest, selectively logged forest and a forest plantation in Arunachal Pradesh, India. *Oryx* **32(4)**: 285-294.

Davis, D. (1946). Occurrence of the White-bellied or Snow Pigeon (*Columba leuconota leuconota*) at a low level in the Kumaon Himalaya. *J. Bombay Nat. Hist. Soc.* **46:** 184-185.

Davis, J.C. (1973). *Statistical and Data Analysis in Geology.* John Wiley & Sons, Inc. Canada, 472-533.

Davison, M.L. (1983). *Multidimensional Scaling.* John Wiley and Sons, New York.

Dawson, , D.K. (1981). Sampling in a rugged terrain. *Studies in Avian Biology* **6:** 311-315.

DeSante, D.F. (1981). A field test of the variable circular plot censusing technique in a California coastal scrub breeding bird community. *Studies in Avian Biology* **6:** 177-185.

Dewan, M.L. (1988). State of Himalayas- Ecology, Environment, Geography, Ressources and Population: A call for Action. In S. K. Chadha (ed.) *Himalayas – Ecology and Environment* 1-33.

Dhar, U.; R.S. Rawal & S.S. Samant (1997). Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: Implication for conservation. *Biodiversity and Conservation* **6:** 1045-1062.

Diamond, J.M. (1970). Ecological consequences of island colonization by southwest Pacific birds.II. The effect of species diversity on total population density. *Proc. Natn. Acad. Sci.* **67:** 1715-1721.

Diamond, J.M. (1975a). Assembly of species communities. In *Ecology and evolution of communities (eds. M.L.Cody & J.M. Diamond)* pp. 342-444.

Diamond, J.M. (1975b). The island dilemma: lessons of modern biogeographic studies for the design of natural resources. *Biological Conservation* **7:** 129-146.

Diamond, J.M. (1986). The design of a nature reserve system for Indonesian New Guinea. In M.E. Soule (ed.), *Conservation Biology: The Science of Scarcity and Diversity.* Sinauer Associates, Sunderland, MA, 485-503.

Dillon, W.R. & M. Goldstein (1984). *Multivariate analysis. Methods and Applications.* John Wiley and Sons, New York.

Dobson, A.P.; J.P. Rodriguez; W.M. Roberts & D.S. Wilcove (1997). Geographic distribution of endangered species in the United States. *Science* **275:** 550-553.

Dombois, M.D. & H. Ellenberg (1974). *Aims and Methods of Vegetation Ecology.* John-Wiley & Sons, New York.

Drijvers, R. (1995). Horned Grebe *Podiceps auritus*: a new species for India. *Forktail* **10:** 175- 176.

Eberhardt, L.L. (1978). Transect methods for population studies. *J. Wildl. Manage.* **42:**1-31.

Edwards, D.K.; G.L. Dorsey & J.A. Crawford (1981). A comparision of three avian census methods. *Studies in Avian Biology* **6:** 170-176.

Ekkolm, E.P. (1976). *Losing Ground.* New York: World Watch Institute, W.W. Norton.

Emlen, J. T. (1971). Population densities of birds derived from transect counts. *Auk* **88:** 323-342.

Enemar, A. (1959). On the determination of the size and composition of a passerine bird population during the breeding season. *Var Fagelv?arld, Suppl.* **2:**1-114.

Erdelen, M. (1984). Bird communities and vegetation structure: I. Correlations and comparisions of simple and diversity indices. *Oecologia* **61:** 277-284.

FAO (1993). *Forest Resources Assessment 1990- Tropical Countries.* FAO Forestry Paper **112**, Rome.

FAO (1995). *Forest Resources Assessment 1990- Global Synthesis.* FAO Forestry Paper **124**, Rome.

Field, F. (1922). Notes on the nesting of the Himalayan Tree Creeper (*Certhia himalayana*). *J. Bombay Nat. Hist. Soc.* **28:** 1138-1139.

Finn, F. (1899). (Exhibition of two living specimens of a new species of Indian weaver-bird.) *Proc. Asiatic Soc. Bengal* 1899: 77-78.

Fjeldsa, J. (1999). The impact of human forest disturbance on the endemic avifauna of the Udzungwa Mountains, Tanzania. *Bird Conservation International* **9:** 47-62.

Foin, T.C.; E.O. Garton; C.W. Bowen; J.M. Everingham; R.O. Schultz & B. Holton (1977). Quantitative studies of visitor impacts on environments of Yosemite national Park, California and their implications for park management policy. *Journal of Environmental Management* **5**: 1-22.

Ford, H.A. (1989). *Ecology of birds: an Australian perspective,* Sydney, Surrey Beatty.

Fowler, D.K. & B. S. McGinnes (1973). A circular plot method of censusing post breeding bird populations. *Proc. Annu. Conf. Southeast Assoc. Game Fish Comm.* **27**: 237-243.

Fowler, J. & L. Cohen (1986). *Statistics for Ornithologists.* BTO Guide No. 22.

Fox, B.J.; R.D. Quin & J. Bretenbach (1985). A comparison of small mammal succession following fire in shrub-land of Australia, California and South Africa. *Proc. of the Ecological Society of Australia* **14:** 179-197.

Frankel, R.E. (1977). *Ruderal vegetation Along Some Californian Road Sides.* University of California publication in Geography **20:** 1-163.

Franzreb, K.E. (1976). Comparision of variable strip transect and spot map methods for censusing avian populations in a mixed coniferous forest. *Condor* **78**: 260-262.

Franzreb, K.E. (1981). A comparative analysis of territorial mapping and variable strip transect censusing methods. *Studies in Avian Biology* **6:** 164-169.

Fraser, J.D.; L.D. Franzel & J.E. Mathisen (1985). The impact of human activities on breeding bald eagles in north-central Minnesota. *Journal of Wildlife Management.* **49:** 585-592.

Fretwell, S.D. & H.L. Lucas (1970). On territorial behaviour and other factors influencing habitat distribution in birds. 1. Thereotical development. *Acta Biotheor.* **19:** 16-36.

Galli, A.E.; C.F. Leck & R.T.T. Forman (1976). Avian distribution patterns in forest islands of different sizes in central New Jersey. *Auk* **93:** 356-364.

Game, M. & G.F. Peterken (1984). Nature reserve selection strategies in the woodlands of central Lincolnshire, England. *Biological Conservation* **29:** 157-181.

Ganguli, U. (1966). Three weeks of bird watching in Ranikhet in autumn. *Newsletter for Birdwatchers* **6(2)**: 3-6.

Garson, P.J.; L. Young & R. Kaul (1992). Ecology and conservation of cheer pheasant *Catreus wallichii:* studies in the wild and the progress of a reintroduction project. *Biological Conservation* 59: 23-35.

Gaston, K.J. (1994). *Rarity*. Population and community biology series 13. Chapman & hall, London.

Gates, C.E. (1969). Simulation study of estimators for the line transect sampling method. *Biometrics.* **25:**317-328.

Gates, C.E. (1979). Line transect and related issues. In *Sampling biological populations* (eds. R.M. Cormack; G.P. Patil & D.S. Robson). 71-154.

Gauch, H.G. & E.L. Stone (1979). Vegetation and soil pattern in mesophytic forest at Ithaca, New York. *Am. Midl. Nat.* **102:** 332-345.

Gauch, H.G. (1982). *Multivariate Analysis in Community Ecology.* Cambridge University Press, Cambridge.

Ghorpade, K. D. (1976). Bird notes on an entomological expedition to the Pindari glacier, Kumaon Himalaya. *Newsletter for Birdwatchers* **16(1)**: 2-9.

Gokula, V. & L. Vijayan (2000). Foraging pattern of birds during the breeding season in the thorn forest of Mudumalai wildlife sanctuary, Tamil Nadu, Southern India. *Tropical Ecology* **41(2):** 195-208.

Goldsmith, F.B. (1975). The evaluation of ecological resources in the countryside for conservation purposes. *Biological Conservation* **8:** 89-96.

Gotmark, F.; M. Ahlund & M.O.G. Eriksson (1986). Are indices reliable for assessing conservation value of natural areas? An avian case study. *Biological Conservation* **38:** 55-73.

Gray, J. E. (1829). *The animal kingdom.* In (ed. C. Cuvier and E. Griffith) Aves 3. Pp. 29-48.

Gray, J. E. and T. Hardwicke (1830-1835). *Illustrations of Indian Zoology: chiefly selected from the collection of Major-General Hardwicke.* 2 vols. London: Treutel, Wurtz, Treuttel, Jun. & Richter.

Greig- Smith, P. (1983). *Quantitative Plant Ecology.* Blackwell, Scientific Publications, Oxford UK 359S.

Griffith, E. (1829). The class Aves arranged by the Baron Cuvier, with specific descriptions by Edward Griffith..and Edward Pidgeon.. The additional species inserted in the text of Cuvier by John Edward Gray. In G. L. C. F. D. Cuvier *The animal kingdom arranged in conformity with its organization.* London: G. B. Whittaker.

Grimmett, R; C. Inskipp & T. Inskipp (1998). *Birds of the Indian Subcontinent.* Oxford University Press, Delhi.

Gromadzki, M. (1970). Breeding communities of birds in mid field afforested areas. *Ekol. Polska* **18:** 307-350.

Gupta, P. D. (1998). A report on a visit to Kumaon Hills. *Samsad News* **16(12):** 2.

Hamel, P.B. (1984). Comparision of variable circular plot and spot- map censusing methods in temperate decidous forest. *Ornis Scandinavica* **15:** 266-274.

Hanowski, J.M.; G.J. Niemi & J.G. Blake (1990). Statistical perspectives and experimental design when counting birds on the transects. *Condor* **92** : 326-335.

Hardwicke, T. (1827). Description of two new birds from Nepaul. *Trans. Linn. Soc. London* **15**: 166-169.

Harman, H.H. (1976). *Modern Factor Analysis.* 3rd edition. The University of Chicago Press, Chicago.

Hartert, E. (1917). On some Rallidae. *Nov. Zool.* **24:** 265-274.

Hartley, P.H.T. (1953). An ecological study of the feeding habits of the English titmice. *Journal of Animal Ecology* **33**: 261-288.

Hawarth, P.F. & D.B.A. Thompson (1990). Factors associated with the breeding distribution of upland birds in the South Pennines, England. *Journal of Applied Ecology* **27**: 562-577.

Haylock, J. & A. Lill (1988). Winter ecological energetics of two passerine bird species in temperate wet forest. *Australian Wildlife Research* **15**: 319-329.

Heinselman, M.L. (1981). Fire intensity and frequency as factors in the distribution and structure of northern ecosystem. *Proc. of the conference, fire and regimes and ecosystem dynamics*, General technical report, WO-**26** (U.S. Forest Services).

Helliwell, D.R. (1976). The effects of size and isolation on the conservation value of wooded sites in Britain. *J. Biogeogr.* **3**: 407-416.

Helliwell, D.R. (1985). *Planning for nature conservation.* Packard Publishing, Chichester.

Herrera, C.M. & P. Jordano (1981). *Prunus mahaleb* and birds: the high efficiency seed dispersal system of a temperate fruiting tree. *Ecological Monographs* **51**: 203-218.

Herrera, C.M. (1984a). A study of avian fruigivores, bird dispersed plants, and their interaction in mediterranean scrublands. *Ecological Monograph* **54**: 1-23.

Herrera, C.M. (1984b). Adaptation to fruigivory of mediterranean avian seed dispersers. *Ecology* **65**: 609-617.

Hespenheide, H.A. (1971). Flycatcher habitat selection in the eastern deciduous forest. *Auk* **88**: 61-74.

Hilden, O. (1965). Habitat selection in birds: a review. *Ann. Zool. Fenn.* **2**: 53-75.

Hill, G. & J. Rosier (1989). Wedgetailed shearwaters, white capped noddies and tourist development on Heron Island, Great Barrier Reef Marine Park. *Journal of Environmental Management* **29**: 107-114.

Hill, M.O. & H.G. Gauch (1980). Detrended Correspondence Analysis: an improved ordination technique. *Vegetatio* **42**: 47-58.

Hill, M.O. (1979a). DECORANA-a FORTRAN program for detrended correspondence analysis and reciprocal averaging. *Ecology and Systematics*, Cornell University, Ithaca, New York, USA.

Hill, M.O. (1979b). TWINSPAN-a FORTRAN program for arranging multivariate data in an ordered two- way table by classification of the individuals and attributes. *Ecology and Systematics*. Cornell University, Ithaca, New York, USA.

Hobson, P.A.R. & J. Hallinan (1981). Effect of human disturbance on the breeding behaviour of jackass penguins *Spheniscue demersus*. *South African Journal of Wildlife Research* **11**: 59-62.

Holmes, R.T. & H.F. Recher (1986). Determinants of guild structure in forest bird communities: an intercontinental comparison. *Condor* **88:** 427-439.

Holmes, R.T. & S.K. Robinson (1981). Tree species preferences of foraging insectivorous birds in a northern hardwoods forest. *Oecologia* **48:** 31-35.

Holmes, R.T.; R.E. Jr. Bonney & S.W. Pacala (1979). Guild structure of the Hubbard Brook bird community: a multivariate approach. *Ecology* **60**: 512-520.

Holmes, R.T.; T.W. Sherry & F.W. Sturges (1986). Bird community dynamics in a temperate deciduous forest: long term trends at Hubbard Brook. *Ecol. Monogr.* **56**:201-220.

Horn, H.S. (1966). The measurement of overlap in comparative ecological studies. *American Naturalists* **100:** 419-424.

Howe, R.W. (1979). Distribution and behaviour of birds on small islands in northern Minnesota. *J. Biogeogr*. **6:** 379-390.

Hudson, C. (1930). A list of some birds of the seven hills of Naini Tal, U.P. *Journal of Bombay Natural History Society* **34:** 821-827.

Hulbert, L.C. (1988). Causes of fire effects in tall grass prairie. *Ecology* **69:** 46-58.

Hume, A. O. (1869). (Letter about various Indian birds.) *Ibis* **5 (2):** 355-357.

Hume, A. O. (1870). (Letter about various Indian birds.) *Ibis* **6 (2)**: 283-288.

Hussain, M.S., Aisha Sultana & Jamal A. Khan (2000). *A study of threats to biodiversity conservation of middle altitude oak forest in Kumaon Himalaya.* Final Technical Report, Department of Wildlife Sciences, A.M.U., Aligarh. 227 pp.

Hussain, M.S.; J.A. Khan & R. Kaul (2001). Aspects of ecology and conservation of Kalij *Lophura leucomelana* and Koklas *Pucrasia macrolopha* in the Kumaon Himalaya, India. *Tropical Ecology* **42(1):** 59-68.

Hussain, M.S.; J.A. Khan ; A. Ahmed & R. Kaul (1997). Status and conservation of galliformes in the Kumaon Himalaya, Uttar Pradesh, India. *International Journal of Ecology and Environmental Sciences* **23:** 409-417.

Hutto, R.L. (1981). Seasonal changes in the foraging behaviour of some migratory western wood warblers. *Auk* 98: 765-777.

Hutto, R.L.; S.M. Pletschet & P. Hendricks (1986). A fixed radius point count method for nonbreeding and breeding season use. *The Auk* **103:** 593-602.

International Council for Bird Preservation (1992). *Putting biodiversity on the map: priority areas for global conservation.* Cambridge,UK.

Iqbal, S.M. (1993). Patterns of habitat use by white crested Kaleej pheasant at two sites in the Indian Himalayas in 1988-89. In (ed. D. Jenkins) *Pheasants in Asia* 1992. World Pheasant Association, Reading, UK. Pp. 154.

Irby, L. H. (1861). Notes on birds observed in Oudh and Kumaon. *Ibis* **3:** 217-251.

IUCN (1980). *World Conservation Strategy.* Morges: IUCN.

IUCN (1994). IUCN Red list of Threatened Animals. World Conservation Monitoring Centre, Cambridge, UK, B. Groombridge (ed.).

Jacobs, M.D. & J.S. Walker (1999). Density estimates of birds inhabiting fragements of cloud forest in southern Ecuador. *Bird Conservation International* **9:** 73-79.

Jalal, D.S. (1976). *Land utilization in Pithoragarh district*, Allahabad.

Jalal, D.S. (1988). '*Geographical Perspective of Kumaon*", In (K.S. Validiya ed.) Kumaon: Land and People, Naini Tal : 13-35.

James, F.C. (1971). Ordinations of habitat relationships among breeding birds. *Wilson Bulletin* **83:** 215-236.

Janes, S.W. (1994). Variation in the species composition and mean body size of an avian foliage-gleaning guild along an elevational gradient: Correlation with arthropod body size. *Oecologia* **98**: 369-378.

Jarvinen, O & R. Vaisanen (1978). Habitat distribution and conservation of land bird populations in northern Norway. *Holarct. Ecol.* **1:** 351-361.

Jarvinen, O. (1979). Geographical gradients of stability in European land bird community. *Oecologia* **38:** 51-69.

Jarvinen, O.; K. Kuusela & R.A. Vaisanen (1977a). Effects of modern forestry on the numbers of breeding birds in Finland in 1945-1975. *Silva Fennica* **11**: 284-294.

Javed, S (1996). *A study of bird community structure in terai region.* Ph.D. thesis, A.M.U., Aligarh.

Jepson, P. (1987b). Recent reports. *Oriental Bird Club Bull.* **6:** 36-40.

Jerdon, T. (1860). *Birds of India.*

Johnsingh, A.J.T. & G.S. Rawat (1994). On the man-eating trails of Jim Corbett. *WII Newsletter*, April-June 1994, Wildlife Institute of India, Dehradun.

Johnsingh, A.J.T. & J. Joshua (1994). Avifuana in three vegetation types on Mundanthurai Plateau, South India. *Journal of Tropical Ecology* **10:** 323-335.

Johnsingh, A.J.T.; N.H. Martin, J. Balasingh & V. Chelladurai (1987). Vegetation and avifauna in a thorn scrub habitat in south India. *Tropical Ecology* **28:** 22-34.

Johnson, V.P. (1947). Breeding birds of the forest edge in Illinois. *Condor* **49:** 45-53.

Jones, M.J., M.D. Linsley & S.J. Marsden (1995). Population sizes, status and habitat associations of the restricted-range bird species of Sumba, Indonesia. *Bird Conserv. Internatn.* **5**: 21-52.

Jordano, P. (1982). Migrant birds are the main seed dispersers of blackberries in southern Spain. *Oikos* **38**: 183-193.

Karale, R.L. (1992). *Natural Resources Management- A New Perspective.* NNRMS-ISRO HQ Publications.

Karr, J.R. & J.D. Brawn. (1990). Food resources of understorey birds in central Panama: Quantification and effects on avian populations. In *Avian foraging: Theory, methodology and applications (eds. M.L. Morrison, C.J.Ralph, J.Verner and J.R. Jehl, Jr.). Studies in Avian Biology* **13:** 58-64.

Katti, M.V. (1989). *Bird communities of lower Dhachigum valley, Kashmir.* M. Sc. Dissertation, Surashtra University, Rajkot.

Katti, M.V.; P. Singh; N. Manjerakar; D. Sharma & S. Mukherjee (1992). An ornithological survey in eastern Arunachal Pradesh, India. *Forktail* **7:** 75-89.

Kaul, R. (1993). Habitat utilization by cheer pheasant. In (ed. D. Jenkins) *Pheasants in Asia* 1992. World Pheasant Association, Reading, UK. Pp. 157.

Kazmierczak, K. & R. Singh (1998). *A birdwatcher's guide to India.* Sandy: Prion.

Keast, A. (1988). Annual cycle and taxonomic composition of an Ontario decidous forest bird community. In H. Ouellet (ed.), Acta XIX Congressus Internationalis Ornithologici. Univ. Ottawa Press, Ottawa. Pp. 1346-1355.

Kendeigh, S.C. (1944). Measurement of bird populations. *Ecol. Monogr.* **14**: 67-106.

Kendeigh, S.C. (1948). Bird populations and biotic communities in northern lower Michigan. *Ecology* **29**: 101-114.

Kennedy, J. (1884). *Life and Work in Benaras and Kumaon*, T. Fisher University, London.

Khaling, S. (1998). *Certain aspects of ecology and behaviour of the Satyr Tragopan, Tragopan satyra in the Singhalila National Park, Darjeeling India.* Ph. D. thesis submitted to North Bengal University, Darjeeling,West Bengal.

Kharakwal, A.D. (1951). A study of gneissose granites and associated metamorphic rocks of Lohaghat, Almora District. *Quart. Jour. Geol. Min. Metal Soc. Ind.* **23:** 135-146.

Kilgore, B.M. (1981). The role of fire frequency and intensity in ecosystem distribution and structure: western forests and scrublands. *Proc. of the conference, fire and regimes and ecosystem dynamics*, General technical report, WO-**26** (U.S. Forest Services).

King, W.B. (1978). Endangered birds of the world and current efforts toward managing them. In (ed. S.A. Temple) *Endangered birds* Wisconsin: Croom Helm Limited. Pp 9-17.

Kinnear, N. B. & H. Whistler (1930). (Description of *Sitta castaneoventris almorae.*) *Bull. Brit. Orn. Club* **51**: 27.

Kloss, C. B. (1918). On birds recently collected in Siam. Part I. Phasianidae-Eurylaemidae. *Ibis* **6 (10):** 76-114.

Knops, J.M.H.; J.R. Grifin & A.C. Royalty (1995). Introduced and native plants of the Hestings reservation central coastal California a comparison. *Biological Conservation* **71:** 115-123.

Koelz, W. (1950). New subspecies of birds from southwestern Asia. *Amer. Mus. Novit.* 1452, 10 pp.

Koelz, W. (1954). Ornithological studies. I. New birds from Iran, Afghanistan, and India. *Contrib. Inst. Regional Exploration* **1:** 1-32.

Kruskal, J.B. & M. Wish (1978). *Multidimensional scaling.* Sage University Press Series on Quantitative Applications in the Social Sciences, Sage Publications, Beverly Hills and London 07-011

Kruskal, J.B. (1964). Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika* **29**: 1-27.

Laake, J.L.; S.T. Buckland; D.R. Anderson & K.P. Burnham (1993*).* *Distance user's guide V2.0.* Colorado State University, Fort Collins: Colorado Cooperative Fish & Wildlife Research Unit.

Laake, J.L.; S.T. Buckland; D.R. Anderson & K.P.Burnham (1994*).* *Distance User's GuideV2.1.* Colorado Cooperative Fish & Wildlife Research unit, Colorado State University, Fort Collins,CO.

Lack, D. & L.S. Venables (1939). The habitat selection of British woodland birds. *J. Anim. Ecol.* **8:** 39-71.

Lack, D. (1933). Habitat selection in birds, with special reference to the effects of afforestation on the Breckland avifauna. *J. Anim. Ecol.* **2:** 239-262.

Lack, D. (1935). The breeding bird population of British heaths and moorland. *J.Anim. Ecol.* **4:** 43-51.

Lack, D. (1943). *The life of the Robin.* Witherby, London.

Lauila, T. (1989). Nest site selection in the common elder *Soateria mollisima*: Differences between the archipelago zones. *Ornis Fennica* **66:** 100-111.

Lay, D.W. (1938). How valuable are woodland clearings and birdlife? *Wilson Bulletin* **45**:254-256.

Leck, C.F. (1979). Avian extinctions in an isolated tropical wet forest preserve, Ecuador. *The Auk* **96**: 343-352.

Leck, C.F.; B.G. Murray Jr. & J. Swinebroad (1988). Long term changes in the breeding bird populations of a New Jersey forest. *Biol. Conserv.* **46**: 145-157.

Lesson, R. P. (1826-1829). In *Dictionnaire des sciences naturelles*, ed. Levrault.

Loiselle, B.A. & J.G. Blake (1991). Temporal variation in birds and fruits along an elevational gradient in Costa Rica. *Ecology* **72:** 180-193.

Ludwig, J.A. & J.F. Reynolds (1988). *Statistical Ecology.* John Wiley & Sons, New York.

M'Closkey, R.T. (1976). Community structure in sympatric rodents. *Ecology* **57:** 728-739.

M'Closkey, R.T. (1978). Niche separation and assembly in four species of Sonoran desert rodents. *American Naturalists* **12:** 683-694.

MacArthur , R.H.; M.L. Cody & H.F. Recher (1966). On the relation between habitat selection and species diversity. *Am. Nat.* **100:** 319-322.

MacArthur, R.H. & J.W. MacArthur (1961). On bird species diversity. *Ecology* **42:** 594-598.

MacArthur, R.H. (1958). Population ecology of some warblers of northeastern coniferous forests. *Ecology* **39:** 599-619.

MacArthur, R.H. (1960). On the relative abundance of species. *Am. Nat.* **94:** 25-36.

MacArthur, R.H. (1965). Patterns of species diversity. *Cambridge Philos. Soc. Biol. Rev.* **40:** 510-533.

MacArthur, R.H. (1968). The theory of niche. In *Population Biology and Evolution (ed. R.C. Lewontin)* pp. 159-176.

MacArthur, R.H. (1972). *Geographical ecology.* Harper and Row, New York, USA.

MacArthur, R.H. ; J.W. MacArthur & J. Preer (1962). On bird species diversity. II. Prediction of bird census from habitat measurements. *Am. Nat.* **96:** 167-174.

MacNally, R. (1994). Habitat specific guild structure of forest birds in southeastern Australia: a regional scale perspective. *Journal of Animal Ecology* **63:** 988-1001.

Madsen, J. (1985). Impact of disturbance on field utilization of pink footed geese in west Jutland, Denmark. *Biological Conservation* **33:** 53-63.

Magurran, A.E. (1988). *Ecological Diversity and Its Measurement.* University Press,Cambridge.

Maheshwari, J.K. (1962). Studies on naturalized flora of India. In P. Maheshwari, P.S. John and I.K. Vasil (eds.) *Proceedings of a summer school of botany, Darjeeling* Calcutta, Sree Saraswati Press 156-170.

Maheswaran, G. (1996). World Birdwatch - Nainital and Corbett Tiger Reserve. *Newsletter for Birdwatchers* **36:** 26-28.

Makhan, D.S. (1967). The brown Forest Soils of the Grey Brown Podzolic Soils of the Himalaya. *Nat. Geog. Journ. India* 214-224.

Mani, M.S. (1974). Biogeography of the Himalayas. In M.S. Mani (ed.) *Ecology and Biogeography in India* The Hague 664-681.

Manuwal, D.A. (1983). Avian abundance and guild structure in two Montana coniferous forests. *The Murrelet.* **64:** 1-11.

Margules, C.R. (1986). Conservation evaluation in practice. In M.B. Usher (ed.) *Wildlife conservation evaluation*, Chapman & Hall, London, 289-314.

Martin, T.E. (1980). Diversity and abundance of spring migratory birds using habitat islands on the Great Plains. *Condor* **82:** 430-439.

Martin, T.E. (1981). Limitation in small habitat islands: Chance or competition? *Auk* **98:** 715-734.

May, R.M. & R.H. MacArthur (1972). Niche overlap as a function of environmental variability. *Proceedings of the National Academy of Sciences* **69:** 1109-1113.

May, R.M. (1975). *Patterns of species abundance and diversity.* In Ecology and Evolution of Communities (eds M. L. Cody and J. M. Diamond). Harvard University Press, MA, pp. 81-120.

Meusel, H. (1971). Mediterranean elements in the flora and vegetation of the West Himalayas. In Davis, P.H.; P.C. Harper & I.C. Hedge (eds.) *Plant life of S.W. Asia*, Bot. Soc. Edinburgh 53-73.

Migley, J.J. & P. Clayton (1990). Short term effects of an autumn fire on small mammal populations in southern cape coastal mountain fynbos. *South African forestry journal* **153:** 27-30.

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

Moddie, A.D. (1981). *Himalayan Environment in The Himalaya: Aspects of change.* Eds. J.S. Lal in Association with A.D. Moddie, Oxford University.

MOE&F (1994). *Conservation of Biological Diversity in India: An Approach*, New Delhi.

MOE&F (1997). Report of the Committee on Forest Working Plans, GOI, MOEN & F, New Delhi.

Monk, C.D. (1967). Tree species diversity in the eastern deciduous forest with particular reference to North-Central Florida. *Amer. Natural* **101:** 173-187.

Moore, F. (1856). Notice of some new species of birds. *Proc. Zool. Soc. London* 1855: 215-217.

Morrison, M.L. (1984). Influence of sample size and sampling design on analysis of avian foraging behaviour. *Condor* **86:** 146-150.

Morrison, M.L. C.J. Ralph, J. Verner & J.R. Jehl, Jr. (1990). Avian foraging: Theory, methodology and applications (eds. M.L. Morrison, C.J.Ralph, J.Verner and J.R. Jehl, Jr.). *Studies in Avian Biology* **13.**

Morrison, M.L.; R.W. Mannan & G.L. Dorsey (1981). Effects of number of circular plots on estimates of avian density and species richness. *Stud. Avian Biol.* **6:** 405-408.

Morse, D.H. (1977). The occupation of small islands by passerine birds. *Condor* **79:** 399-412.

Morton, E.S. (1980). Adaptations to seasonal changes by migrant land birds in the Panama Canal zone. In *Migrant birds in the Neotropical Ecology, behaviour, distribution and conservation (eds. A. Keast & E.S. Morton).* Pp. 437-453.

Moskat, C. (1988). Breeding bird community and vegetation structure in a beech forest in the Pilis Mountains, N. Hungary. *Aquila* **95:**105-112.

Moskot, C. (1991). Multivariate Plexus Concept in the Study of Complex Ecological Data: An Application to the Analysis of Bird- Habitat Relationships. *Coenoses* **6(2):** 79-89.

Mukund Rao & V.S. Jayaraman (1995). Guidelines for GIS Standardization. ISRO-NNRMS-TR. **105.**

Mukund Rao; V.S. Jayaraman & M.G. Chandra Sekhar (1994). Organizing Spatial Information Systems around a GIS Core, ISRO- NNRMS-SP. 70-94.

Muller-Dombois, D. (1981). Fire in tropical ecosystem. *Proc. of the conference, fire and regimes and ecosystem dynamics,* General technical report, WO-26 (U.S. Forest Services).

Murray, J.J. (1946). The altitudinal distribution of birds in the Virginea mountains. *Raven* **17:** 70-75.

Myers, N. (1984). *Gaia*, pp. 24-32. New York: Doubleday.

Myers, N. (1990). The biodiversity challenge: expanded hot spots analysis. *The Environmentalist* **10:** 243-256.

Naess, A. (1986). Intrinsic value: will the defenders of nature please rise? In (ed. M.E. Soule) *Conservation Biology* . Pp. 505-515.

Naoroji, R. & C. D'Silva (1998). Sighting of Red Kite *Milvus milvus* at Ranikhet. *J. Bombay Nat. Hist. Soc.* **95:** 339-340.

Narang, M. L. & B. S. Lamba (1979). Occurrence of Nepal Dark Rosefinch, *Carpodacus n. nipalensis* (Hodgson) at Jogeshwar near Almora (U.P.). *Cheetal* **20(2-3):** 60.

Neter, J. & W. Wasserman (1974). *Applied Linear Statistical Models*. Richard D. Irwin, Homewood, III. Pp. 842.

Neu, C.W.; C.R. Byers & J.M. Peen (1974). A technique for analysis of utilization – availability data. *J. Wildl. Manage.* **38**: 541-545.

Newsome, J. (1979). Birding in Almora. *Newsletter for Birdwatchers* **19(7):**10.

Nilsson, S.G. (1977). Density compensation and competition among birds on small islands in a South Swedish lake. *Oikos* **28**: 170-176.

Nilsson, S.G. (1986). Are bird communities in small biotope patches random samples from communities in large patches? *Biological Conservation* **38:** 179-204.

Noon, B.R. (1981). The distribution of an avian guild along a temperate elevational gradient: the importance and expression of competition. *Ecological Monographs* **51**: 105-124.

Norton, B.G. (1987). *Why preserve natural variety*? New Jersey: Princeton University Press.

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

Noy-Meir, I. (1995). Interactive effects of fire and grazing on structure and diversity of Mediterranean grasslands. *Journal of Vegetation Science* **6:** 701-710.

O'Meara, T.E. (1981). A field test of two density estimators for transect data. *Studies in Avian Biology* **6:** 193-196.

Oberholser, H.C. (1905). *Notes on the mammals and summer birds of western North Carolina.* Biltmore Forest School, Biltmore, N.C.

Oelke, H. (1966). 35 years of breeding bird census work in Europe. *Audubon Field Notes* **20:** 635-642.

Ohsawa, M. (1991). Montane evergreen broad leaved forests of the Bhutan. In M. Ohsawa (ed.) *Life zone ecology of Bhutan Himalaya II* Japan: Chiba University Press 89-156.

Ohsawa, M.; P.R. Shakya & M. Numata (1975). Forest vegetation of the Arun Valley, east Nepal. In M. Numata (ed.). *Mountaineering of Mt. Makalu and Scientific Studies in eastern Nepal* 11, 1971 Japan: Chiba University Press.

Ohsawa, M.; P.R. Shakya & M. Numata (1986). Distribution and succession of west Himalayan forest types in the eastern part of the Nepal Himalaya. *Mountain Research and Development* **6:** 143-157.

Orians, G.H. (1969). The number of bird species in some tropical forests. *Ecology* **50:** 783-801.

Osborne, W.S. & K. Green (1992). Seasonal changes in composition, abundance and foraging behaviour of birds in the Snowy Mountains. *Emu.* **92:** 93-105.

Osmaston, A. E. (1916). Curious habits of wood-peckers in the Kumaon hills. *J. Bombay Nat. Hist. Soc.* **24:** 363-366.

Pandey, S. (1993). Pheasant survey and the conservation of protected areas in the upper Beas valley, Himachal Pradesh, India. In (ed. D. Jenkins) *Pheasants in Asia* 1992. World Pheasant Association, Reading, UK. Pp. 58-61.

Pangtey, Y.P.S (1991). *Biogeographic and environment hazard mapping in high altitude zone of Kumaun Himalaya* (III Annual Report, Department of Environment, New Delhi).

Pant, G.B. (1921). *Forest Problem in Kumaun*, Allahabad.

Pant, S.D. (1935). *The social economy of the Himalayas*, George Allen & Unwin, London.

Pate, R. (1916). *Garhwal: Ancient and Modern*, Army Press, Simla.

Pearson, D.L. (1982). Historical factors and bird species richness. In (ed. G.T. Prance) *Biological Diversification in the tropics*. Pp. 441-450.

Peat, J. R. (1984). *A partially objective method for the ecological evaluation of biological communities.* Ph.D. thesis, University of Southampton.

Peterson, D.L. & K.C. Ryan (1986). Modeling post fire conifer mortality for long range planning. *Environmental Management* **10:** 797-808.

Petit, D.R.; J.F. Lynch; R.L. Hutto; J.G. Blake & R.B. Waide. (1995). Habitat use and conservation in the Neotropics. In *Ecology and management of Neotropical migratory birds: A synthesis and review of critical issues* (eds. T.E. Martin & D.M. Finch). Oxford university press, New York pp. 145-197.

Pianka, E.R. & J.J. Schall (1981). Species densities of Australian vertebrates. In (ed. A. Keast) *Ecological Biogeography of Australia*, The Hague. Pp. 1677-1694.

Pianka, E.R. (1972). r and K selection or b and d selection? *American Naturalists* **106:** 581-588.

Pianka, E.R. (1973). The structure of lizard communities. *Annual Review of ecology and Systemeics* **4:** 53-74.

Pianka, E.R. (1974). Niche overlap and diffuse competition. *Proceedings of the National Academy of Sciences* **71:** 2141-2145.

Pianka, E.R. (1975). Niche relations of desert lizards. In *Ecology and evolution of communities (eds. M.L.Cody & J.M. Diamond)* pp. 292-314.

Pielou, E.C. (1975). *Ecological Diversity*. Wiley, NewYork.

Postel, S. & L. Heisi (1988). *Reforesting the Earth.* Washington, D.C.: World Watch Institute. Paper **33**: 5-54.

Poulin, B. & G. Lefebvre (1996). Dietary relationships of migrant and resident birds from a humid forest in central Panama. *Auk* **113**: 277-287.

Poulin, B.; G. Lefebvre & R. McNeil (1994). Effect and efficiency of tartar emetic in determining the diet of tropical land birds. *Condor* **96:** 98-104.

Poulsen, B.O. & N. Krabbe (1998). Avifaunal diversity of five high-altitude cloud forests on the Andean western slope of Ecuador: testing a rapid assessment method. *J.Biogeogr*. **25:** 83-93.

Poulsen, B.O.; N. Krabbe; A. Frolander; M.B. Hinojosa & C.O. Quiroga (1997). A rapid assessment of Bolivian and Ecuadorian montane avifaunas using 20- species lists: efficiency, biases and data gathered. *Bird Conservation International.* **7:** 53-68.

Poulsen, B.O. (1993). Change in mobility among crepuscular ground living birds in an Ecuadorian cloud forest during overcast and rainy weather. *Ornitologia. Neotrop.* **4:** 103-105.

Prater, S. H. (1940). The occurrence of the Yellow-bellied Flowerpecker (*Pachyglossa melanoxantha* Hodgs.) at Almora, U. P. *J. Bombay Nat. Hist. Soc.* **42:** 187.

Prendergast, J.; R.M. Quinn & J.H. Lawton (1999). The gaps between theory and practice in selecting nature reserves. *Conservation Biology* **13 (3):** 484-492.

Prendergast, J.; S.N. Wood; J.H. Lawton & B.C. Eversham (1993). Correcting for variation in recording effort in analyses of diversity hot spots. *Biodiversity Letters* **1:** 39-53.

Preston, F.W. (1948). The commonness and rarity of species. *Ecology.* **29:** 254-283.

Primack, R.B. (1993). *Essentials of conservation biology.* Sinauer Associates Inc., Sunderland, Massachusetts,USA.

Prodon, R & J. D. Lebreton (1981). Breeding fauna of a Mediterranean succession: the halm oak and cork oak series in the eastern Pyrenees.1. Analysis and modelling of the structure of the gradients. *Oikos* **37:** 21-38.

Puri, G.S.; V.M. Meher-Homji; R.K.Gupta & S. Puri (1983). Phytogeographical Ecology. In *Forest Ecology.* IInd edition. Oxford & IBH Publishing Company. **1:** 115-210.

Pyne, I.F. (1981). *Ecological evaluation for conservation.* Edward Arnold, London.

Pyrovetsi, M. & A. Crivelli (1988). Habitat use by water birds in Prespa National Park, Greece. *Biological Conservation* **45:** 135-153.

Rafe, R.W.; M.B. Usher & R.G. Jefferson (1985). Birds on reserves: the influence of area and habitat on species richness. *J. Appl. Ecol.* **22:** 327-335.

Rajan, M.S. (1991). Asian Development Bank Environment Paper No. 9.

Ramakrishnan, P.S. & P.M. Vitousek (1989). Ecosystem level processes and the consequences of biological invasion. In J.A. Drake, M.A. Mooney, F. di Castri, R.H. Groves, F.J. Kruger, M. Rejmanek and M.Williamson (eds.) *Biological invasions: a global perspective* SCOPE 37: John Wiley and Sons 281-300.

Rao, D.P. (1995). *Remote Sensing for Earth Resources.* Association of Exploration Geophysicists.

Rao, V. U. S. (1965). Notes on some birds observed at Naini Tal. *Newsletter for Birdwatchers* **5(8)**: 7.

Rapasky, R.R. & D. Schluter (1994). Habitat distribution of wintering sparrows along an elevational gradient: tests of the food, predation and microhabitat structure hypotheses. *J. Anim. Ecol.* **63:** 569-582.

Rasool, T. J. (1984). Some observations on natural Cheer Pheasant, *Catreus wallichii*, population at Mukteswar Reserve Forest, Kumaon, Naini Tal, U. P. *J. Bombay Nat. Hist. Soc.* **81**: 469-472.

Ratcliffe, D.A. (1971). Criteria for the selection of nature reserves. *Advancement of Science, London* **27**: 294-296.

Raven, P. (1962). The genus Epilobium in the Himalayan region. *Bull. Brit. Mus. (N.H.)* **2:** 282-327.

Rawal, R.S. & Y.P.S. Pangtey (1994). High altitude forest in a part of Kumaun, Central Himalaya. *Proc. Ind. Natn. Sci. Acad.* B60: 557-564.

Rawat, Y.S. & S.P. Singh (1989). Forest floor biomass, litter fall and nutrient return in central Himalayan oak forest. *Vegetatio* **82:**113-125.

Recher, H.F.; G. Gowing; R. Kavanagh; J. Shields & W. Rohan-Jones (1983). Birds resources and time in a tablelands forests. *Proc. Ecol. Soc. Aust.* **12:** 101-123.

Recher, H.F.; R.T. Holmes; M. Schulz; J. Sheilds & R. Kavanagh (1985). Foraging patterns of breeding birds in eucalyptus forest and woodland of southern Australia. *Australian Journal of Ecology* **10:** 399-419.

Rev, N. (1975). Breeding bird community structure and species diversity along an ecological gradient in deciduous forest in western Norway. *Ornis. Scand.* **6**:1-14.

Reynolds, R.T.; J. M. Scott & R.A. Nussbaum (1980). A variable circular plot method for estimating bird numbers. *Condor* **82**: 309-313.

Rickelfs, R.E. & J.Travis (1980). A morphological approach to the study of avian community organization. *Auk* **97:** 321-338.

Rikhari, H.C. & L.M.S. Palni (1999). Fire affects ground flora dynamics of forest ecosystems: A case study from central Himalaya. *Tropical Ecology ISTE* **40(1):** 145-151.

Rikhari, H.C.; P.K. Ralhan & S.P. Singh (1989). Phytosociology and population structure of chir-pine forests in Kumaun Himalaya. *Annals of Biology*, **5 (2):** 129-140.

Robbins, C.S. & W.T. Van Velzen (1967). The breeding bird survey. U.S. Bur. Sport Fish and Wildl.*Spec. Sci. Rep. Wildl.* 102.

Robbins, C.S. (1970). Recommendations for an international standard for a mapping method in bird census work. *Aud. Field Notes* **24:** 723-726.

Robbins, C.S. (1979). Effects of forest fragmentation on bird populations. In (ed. R.M. DeGraaf & K.E. Evans*) Management of north central and northeastern forests for nongame birds*. Pp. 198-212.

Robbins, C.S. (1981). Bird activity levels related to weather. *Studies in Avian biology* **6:** 301-310.

Robertson, R.J. & N.J. Flood (1980). Effects of recreational use of shorelines on breeding bird populations. *Canadian Field Naturalist* **94**: 131- 138.

Robinette, W.L.; C.M. Loveless & D.A. Jones (1974). Field tests of strip census methods. *J. Wildl. Manage.* **38:** 81-96.

Robinson, S.K. & R.T. Holmes. (1982). Foraging behaviour of forest birds: The relationships among search tactics, diets and habitat structure. *Ecology* **63:**1918-1931.

Robson, C. (1985). Recent reports: India. *Oriental Bird Club Bull.* **2:** 36-37.

Robson, C. (1996). From the field: India. *Oriental Bird Club Bull.* **24:** 60.

Rolando, A. & C.A. Robotti (1985). Foraging niches of tits and associated species in orth-western Italy. *Boll. Zool.* **52:** 281-297.

Root, R.B. (1967). The niche exploitation pattern of the blue-grey gnatcatcher, *Ecol. Monogr.* **37:** 317-350.

Rosenberg, K.V. & R.J. Cooper (1990). Approaches to avian diet analyses. In *Avian foraging: Theory, methodology and applications (eds. M.L. Morrison, C.J.Ralph, J.Verner and J.R. Jehl, Jr.). Studies in Avian Biology* **13:** 80-90.

Rosenzweig, M.L. (1995). *Species diversity in space and time.* Cambridge University Press, Cambridge, United Kingdom.

Rotenberry, J.T. (1985). The role of habitat in avian community composition: physiognomy or floristics? *Oecologia* **67:** 213-217.

Sabo, S.R. (1980). Niche and habitat relations in subalpine bird communities of the White Mountains of New Hampshire. *Ecol. Monogr.* **50:** 241-259.

Saklani – Chandola, A.; U. Singh; P. Lakhera; D. Bhatt & K. Pant (1989). Field observations on behavioral ecology of white crested Kaleej pheasant in Garhwal Himalaya. In: (eds. D. Hill; P. Garson & D. Jenkins). *Pheasants in Asia* 1989. World Pheasant Association, Reading, UK. Pp. 154.

Saklani – Chandola, A.; U.S. Rauthan; P. Lakhera & K. Pant (1988). Habitat utilization by the Himalayan white crested Kaleej pheasant. Proc. *3rd Int. Rangeland Congress*, New Delhi.

Samant, S.S.; R.S. Rawat & U. Dhar (1993). Botanical hot spots of Kumaon: conservation perspectives for the Himalaya. In U.Dhar (ed.) *Himalayan Biodiversity- Conservation Strategies.*

Sample, S.D. (1921). *Influences of Geographical Environment*, London.

Sathyakumar, S.; S.N. Prasad; G.S. Rawat & A.J.T. Johnsingh (1993). Ecology of kaleej and monal pheasant in Kedarnath wildlife Sanctuary, Western Himalaya. In (ed. D. Jenkins) *Pheasants in Asia* 1992. World Pheasant Association, Reading, UK. Pp. 83-90.

Saxena, A.K. & J.S. Singh (1980). Analysis of forest grazing land vegetation in part of Kumaun Himalaya. *Indian Journal of Range Management* **1:** 13-32.

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

Saxena, A.K. & J.S. Singh (1984). Tree population structure of certain Himalayan forests and implications concerning the future composition. *Vegetatio* **58:** 61-69.

Saxena, A.K.; S.P. Singh & J.S. Singh (1985). Population structure of forests of Kumaun Himalaya. Implication for management. *J. Environ. Manag.* **19:** 307-324.

Schiermann, G. (1930). Studien u?ber Siedlungsdichte im Brutgebiet. *J. Ornithol.* **78:** 137-180.

Schiermann, G. (1934). Studien u?ber Siedlungsdichte im Brutgebiet II. Der brandenburgische Kiefernwald. *J. Ornithol.* **82:** 455-486.

Schoener, T.W. (1974). Resource partitioning in ecological communities. *Science* **185**:27-39.

Scott, J.M. & F. L. Ramsey (1981). Length of count period as a possible source of bias in estimating bird densities. *Stud. Avian Biol.* **6:** 409-413.

Seber, G.A.F. (1973). *The estimation of animal abundance*. Hafner, New York and Griffin, London.

Shankar-Raman, T.R. (1995). *Shifting cultivation and conservation of tropical forest bird communities in Mizoram, North East India.* M. Sc. Dissertation, Surashtra University, Rajkot.

Shannon, C.E. & W. Weaver (1949). *The Mathematical Theory of Communication.* University of Illinois press, Urbana.

Sharma, S. & H.C. Rikhari (1997). Forest fire in the central Himalaya: climate and recovery of trees. *Int. J. Biometerol.* **40:** 63-70.

Sharpe, R. B. (1890). Notes on specimens in the Hume collection of birds. No. 6. On the Coraciidae of the Indian region, with description of some new species. *Proc. Zool. Soc. London* 1890: 546-552.

Sheard, J.W. & D.W. Gale (1983). Vegetation at Polar Bear Pass, Batharst Island, N.W.T.H. Vegetation–environment relationships. *Can. J. Bot.* **61:** 1637-1646.

Sheilds, W.M. (1977). The effect of time of day on avian census results. *Auk* **94:** 380-383.

Sherry, T.W. & R.T. Holmes (1985). Dispersion patterns and habitat responses of birds in northern hardwood forests. In M.L. Cody (ed.), *Habitat selection in birds.* Academic Press, New York. Pp. 283-309.

Simberloff, D. & N. Gotelli (1984). Effects of insularization on plant species richness in the prairie- forest ecotone. *Biological Conservation* **29:** 27-46.

Simberloff, D.S. & L.G. Abele (1976). Island Biogeography- theory and conservation practice. *Science* **191:** 285-286.

Simberloff, D.S. & L.G. Abele (1982). Refuge design and island biogeographic theory: affects of fragmentation. *American Naturalist* **120:** 41-50.

Singh, J.S & S.P. Singh (1987). Forest vegetation of the Himalayas. *Bot. Rev.* **53:** 82-192.

Singh, J.S. & S.P. Singh (1984). *An integrated ecological study of eastern Kumaun Himalaya with emphasis on natural resources.* Vol. 1-3, Final Report (HCS/DST/187/76). Kumaun University, Naini Tal.

Singh, J.S. & S.P. Singh (1987). Structure and functioning of central Himalayan chirpine forest ecosystem. *Current Science.* **56:** 383-391.

Singh, J.S.; Y.S. Rawat & S.P. Chaturvedi (1984). Replacement of Oak forest with pine in the Himalaya affects the nitrogen. *Nature* **311:** 54-56.

Singh, P. (1994). Recent bird records from Arunachal Pradesh. *Forktail* **10**: 65-104.

Singh, R.L. (1987). U.P. Himalayas. In R.L. Singh (ed.), *India a, regional Geography*, National Geographical Society of India, BHU, Varanasi.

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

Singh, S. R. & A. Singh (1980). A brief report of birding in Nainital during Feb.-March. *Newsletter for Birdwatchers* **20(8):** 4-6.

Singh, S.P.; B.S. Adhikary & D.B. Zobel (1994). Biomass productivity, leaf longevity and forest structure in the central Himalaya. *Ecol. Monogr.* **64:** 401-421.

Smetacek, V. (1975). On the increasing occurrence of typically plains-birds in the Kumaon Hills. *J. Bombay Nat. Hist. Soc.* **71:** 299-302.

Smith, K. G. (1977). Distribution of summer birds along a forest moisture gradient in an Ozark watershed. *Ecology* **5:** 810-819.

Smythies, B. E. (1943). On the occurrence of the Yellow-headed Fantail Warbler (*Cisticola exilis tytleri* Jerdon) in the Kumaon tarai, U. P. *J. Bombay Nat. Hist. Soc.* **44:** 292-296.

Snow, D.W. (1971). Evolutionary aspects of fruit eating by birds. *Ibis* **113:** 194-202.

Sokal, R.R. & F.J. Rohlf (1981). *Biometry.* 2nd edition. Freeman and Co., San Francisco.

Sorenson, A.E. (1981). Interactions between birds and fruit in a temperate woodland. *Oecologia* **50**: 242-249.

Soule, M.E. & D. Simberloff (1986). What do genetics and ecology tell us about the design of nature reserves? *Biological Conservation* **35:** 19-40.

Spate, O.H.K. (1957). *India and Pakistan: A General and Regional Geography.* London: Mathuen & Co.

Spellerberg, I.F. (1981). *Ecological evaluation for conservation.* Edward Arnold, London.

Sridharan, E. (1974). Birdwatching around Naini Tal. *Newsletter for Birdwatchers* **14(10)**: 5-7.

Srivastava, R.K.; K. Chidambaram & G. Kumaravelu (1999). Impact of forest fire and biotic interference on the biodiversity of Eastern Ghats. *The Indian Forester* **125 (5):** 439-444.

Stapanian, M.A. (1982). Evolution of fruit strategies among fleshy fruited plant species of eastern Kansas. *Ecology* **63:** 1422-1431.

Stearn, W.T. (1960). Allium and Milule in the Central and Eastern Himalayas. *Bull. Brit. Mus. (N.H.)* **2:** 161-191.

Steuter, A.A.; C.E. Grygiel & M.E. Biondini (1990). A synthesis approach to research and management planning: the conceptual development and implementation. *Natural Areas Journal* **10:** 61-68.

Stiles, E.W. (1980). Patterns of fruit presentation and seed dispersal in bird disseminated woody plants in the eastern deciduous forest. *American Naturalist* **116:** 670-688.

Stiles, F.G. (1983). Birds: Introduction. In D.H. Janzen (ed.), Costa Rican natural history, University of Chicago Press, Chicago, Illinois. Pp. 141-168.

Stiles, F.G. (1988). Altitudinal movements of birds on the Caribbean slope of Costa Rica: Implications for conservation. In F. Almeda & C.M. Pringle (eds.*), Tropical rain forests: Diversity and conservation,* California Academy of Sciences, San Francisco. Pp. 243-258.

Storey, A.E. (1987). Adaptations for marsh nesting in common and Forster's terns. *Canadian Journal of Zoology* **65:** 1417-1420.

Sultana, A. & J.A. Khan (1999). Avian community in the Kumaon Himalaya, India- a preliminary Study. *International Journal of Ecology and Environmental Sciences* **25:** 167-176.

Sultana, A. & J.A.Khan (2000). Birds of oak forests in the Kumaon Himalaya, Uttar Pradesh, India. *Forktail* **16:** 131-146.

Sundramoorthy, T. (1991). *Ecology of terrestrial birds in Keoladeo National Park, Bharatpur.* Ph.D. Thesis, University of Bombay, Bombay.

Svardson, G. (1949). Competition and habitat selection in birds. *Oikos* **1:** 157-174.

Swan, J.M.A. (1970). An examination of some ordination problems by use of simulated data. *Ecology* **51:** 89-102.

Szekely, T. (1985). Foraging structure of the foliage gleaning and bark foraging guild in winter and spring. *Proceedings of fifth Nordic Ornithological Congress* pp. 140-146.

Tak, P. C. (1995). Aves. In (ed. Director) *Himalayan ecosystem series: fauna of western Himalaya, Part I, Uttar Pradesh.* Calcutta: Zoological Survey of India. Pp 169-200

Tak, P.C. & J.P. Sati (1994). Birds of Goriganga valley, Kumaon Himalaya. *Cheetal* **33(1):** 17-26.

Tanner, J.T. (1955). The altitudinal distribution of birds in a part of the Great Smokey Mountains. *Migrant* **26:** 37-40.

Terborgh, J. & B. Winter (1983). A method for siting parks and reserves with special reference to Columbia and Ecuador. *Biological Conservation* **27:** 45-58.

Terborgh, J. (1971). Distribution on environmental gradients: Theory and a preliminary interpretation of distributional patterns in the avifauna of the Cordillera Vilcabamba, Peru. *Ecology* **52:** 23-40.

Terborgh, J. (1976). Island Biogeography and Conservation: Strategy and Limitations. *Science* **193:** 1029-1030.

Terborgh, J. (1977). Bird species diversity on an Andean elevational gradient. *Ecology* **58:** 1007-1019.

Terborgh, J.; J. Faaborg & H.J. Brockmann (1978). Island colonization by lesser Antillean birds. *Auk* **95:** 59-72.

Terborgh, J.; S.K. Robinson; T.A. Parker III; C.A. Munn & N. Pierpont. (1990). Structure and organization of an Amazonian forest bird community. *Ecological Monographs* **60:** 213-238.

Terborgh, J.W. (1973). On the notion of favorableness in plant ecology. *Am. Nat.* **107:** 481-501.

The Nature Conservancy (1983). *Natural Heritage Program, Operations Manual*, USA.

The Nature Conservancy (1986). *Natural Heritage Program, Operations Manual*, USA.

Thiollay, J.M. (1994). Structure, density and rarity in an Amazonian rainforest bird community. *Journal of Tropical Ecology* **10**: 449-481.

Thompson, J.N. & M.F. Willson (1979). Evolution of temperate fruit/bird interactions: phenological strategies. *Evolution* **33:** 973-982.

Tiwari, A.K. & J.S. Singh (1984). Mapping forest biomass in India through aerial photograph and nondestructive field sampling. *Applied Geography* **4:** 151-165.

Tiwari, A.K. & J.S. Singh (1987). Analysis of forest land-use and vegetation in a part of central Himalaya, using Aerial photograph. *Environmental Conservation*, Vol. 14, No.3.

Tiwari, J.C. (1982). *Vegetational analysis along altitudinal gradients around Naini Tal.* Ph.D. thesis, Kumaun University, Naini Tal.

Tiwari, J.S. & S.P. Singh (1985). Analysis of woody vegetation in mixed oak forest of Kumaun Himalaya. *Proc. Indian Natn. Sci. Acad.* **51:** 332-347.

Tomoff, C.S. (1974). Avian species diversity in desert scrub. *Ecology* **55:** 396-403.

Tuite, C.H. (1981). *The impact of water-based Recreation on the waterfowl of Enclosed Inland Water in Britain.* A report to the sports council and the nature conservancy council, slim-bridge, UK: The Wildfowl Trust, Nature conservancy council and sports council.

Twomey, A.C. (1945). The bird population of an elm-maple forest, with special reference to aspection, territorialism and coaction. *Ecol. Monogr.* **15:** 175-205.

Tyser, R.W. & C.A.Worley (1992). Alien flora in grasslands adjacent to road and trial corridors in glacier National Parks, Montana (USA). *Conservation Biology* **6:** 253-262.

Udaya Lakshmi, V.; M.S.R. Murthy & C.B.S. Dutt (1998). Efficient forest resources management through GIS and remote sensing. *Current Science* **75 (3):** 272-282.

Uhl, C. & J.B. Kauffman (1990). Deforestation, fire susceptibility and potential tree responses to fire in the eastern Amazon. *Ecology* **71:** 437-449.

Upreti, N.; J.C. Tewari & S.P. Singh (1985). The oak forests of Kumaun Himalaya (India). Composition, diversity and regeneration: *Mountain Research and Development* **5:** 163-174.

Usher, M.B. (1986). *Wildlife conservation evaluation: attributes, criteria and values.* In: Wildlife Conservation Evaluation (ed. M.B. Usher), London: Chapman & Hall, 3-44.

Valdiya, K.S. (1980). *Geology of the Kumaun Lesser Himalaya, Wadia Inst. Of Himalayan Geol.*, Dehra Dun 291.

Valdiya, K.S. (1988). *Geology and Natural Environment of Naini Tal Hills, Kumaun Himalaya*, Gyanodaya Prashan, Naini Tal, U.P. 155.

van der Zande, A.N.; W.J. Terkeurs & W.J. vander Weijden. (1980). The impact of roads on the densities of four bird species in an open field habitat-evidence of a long-distance effect. *Biological Conservation* **18:** 299-321.

van Hensbergen, H.J.; S.A. Botha; G.G. Forsyth & D.C. Le Maitre (1992). Do small mammal govern vegetation recovery after fire in Fynbos? In B.W. van Wilgen et al. (eds) *Fire in South African Mountain Fynbos.* Ecological studies 93, Springer-Verlog, Berlin 182-202.

Van Horne, B. (1983). Density as a misleading indicator of habitat quality. *J. Wild. Manag.* **47:** 898-901

Van Wagner, C.E. (1983). Fire behaviour in northern conifer forests and shrublands. In: (eds. W. Wein & D.A. Maclean) *The role of fire in northern circumpolar ecosystems.* John Wiley & Sons, New York, pp 68-80.

Verbeek, N.A.M. (1982). Egg predation by north western crows: its association with human and bald eagle activity. *Auk* **99:** 347-352.

Vigors, N.A. (1830). Exhibition of specimens of several species of birds, apparently undescribed, from the Himalayan Mountains. *Proc. Comm. Zool. Soc. London 1830,* 7-9.

Walton, H. J. (1900). Notes on birds collected in Kumaon. *J. Asiatic Soc. Bengal* **69:** 155-168.

Watson, A. (1979). Bird and mammal numbers in relation to human impact at the ski lifts on Scottish belts. *Journal of Applied Ecology* **16:** 753-764.

Watson, A. (1988b). Dotteral *Charadrius morinellus* numbers in relation to human impact in Scotland. *Biological Conservation* **34:** 245-256.

Weaver, J.E. & R.E. Clements (1966). *Plant Ecology.* TMH Edition, New Delhi **2:** 601

Weber, W.C. & J.B. Theberge (1977). Breeding bird survey counts as related to habitat and date. *Wilson Bulletin.* **89:** 543-561.

Wege, D.C. & A. J. Long (1995). *Key areas for threatened birds in the Neotropics.* BirdLife International, Cambridge, United Kingdom.

Weins, J.A. & J.T. Rotenberry (1981). Habitat associations and community structure of

Weins, J.A. & R.A. Nussbaum (1975). Model estimation of energy flow in northwestern coniferous forest bird communities. *Ecology* **56:** 547-561.

Weins, J.A. (1969). An approach to the study of ecological relationships among grassland birds. *Ornithol. Monogr.* **8.**

Weins, J.A. (1983). Avian community ecology: an iconoclastic view. In (ed. A.H. Brush & G.A. Clark) *Perspectives in Ornithology.* Pp. 355-403.

Wetmore, A. (1939). Notes on the birds of Tennessee. *Proc. U.S. Nat. Mus.* **86:** 175-243.

Whistler, H. (1931b). (Description of new races.) *Bull. Brit. Orn. Club* **52:** 40-41.

Whittaker, H.H. (1975). *Communities and ecosystems.* MacMillan Co., New York.

Whittaker, R.J. (1987). An application of detrended correspondence analysis and non-metric multidimensional scaling to the identification and analyses of environmental factor complexes and vegetation structure. *J. Ecol.* **75:** 363-376.

Whitten, A.J.; K.D. Bishop; S.V. Nash & L. Clayton (1987). One or more extinctions from Sulawesi, Indonesia? *Conservation Biology* **1:** 42-48.

Whymper, S.L. (1902a). Occurrence of the Chesnut-headed Shortwing (*Oligura castaneicoronata*) and nesting of the Black-chinned Yuhina (*Yuhina nigrimenta*) in Kumaon. *J. Bombay Nat. Hist. Soc.* **14:** 607.

Whymper, S.L. (1902b). Bird nesting in Kumaon. *Journal of Bombay Natural History Society* **14:** 624-626.

Wiens, J.A. (1989). *The ecology of bird communities.* **Vol.1 &2.** Cambridge University press, Cambridge.

Williams, A.B. (1936). The composition and dynamics of a beech-maple climax community. *Ecol. Monogr.* **6:** 317-408.

Willis, E.O. (1980). Species reduction in remanescent woodlots in southern Brazil. In *Acta Congr. Int. Ornith.* **2**: 783-786.

Wilson, M.F. (1974). Avian community organisation and habitat structure. *Ecology* **55:** 1017-1029

Winker, K.; P. Escalante; J.H. Rappole; M.A. Ramos; R.J. Oehlenschlager & D.W. Warner (1997). Periodic migration and lowland forest refugia in a 'sedentary' Neotropical bird, Wetmore's Bush- Tanager. *Conservation Biology* **11**: 692-697.

Woolhouse, M.E.J. (1983). The theory and practice of the species area effect, applied to the breeding birds of British woods. *Biological Conservation* **27:** 315-332.

Wright, S.J. (1979). Competition between insectivorous lizards and birds in central Panama. *Am. Zool.* **19**: 1145-1156.

Wright, S.J. (1981). Extinction –mediated competition: the Anolis lizards and insectivorous birds of the West Indies. *Am. Nat.* **117**: 181-192.

Yahya, H. S. A. (1990). Waking time of some birds in Kumaon hills. *Newsletter for Birdwatchers* **30(5 & 6):** 16.

Young, L. & R. Kaul (1987). Conservation of Himalayan pheasants in Kumaun. In (eds. Y. P. S. Pangtey and S. C. Joshi), *Western Himalaya: environment, problems and development*, 2. Nainital: Gyanodaya Prakashan. Pp. 684-691.

Young, L., ; P. J. Garson & R. Kaul (1987). Calling behaviour and social organization in the Cheer Pheasant: implications for survey technique. *World Pheasant Association J.* **12:** 30-43.

Zar, J.H. (1984). *Biostatistical Analysis*. Prentice-Hall, Englewood Cliffs, NJ.

Appendix- List of plants sampled during the surveys of Kumaon in 1996-98.

Trees

1. *Abies pindrow*
2. *Acer cappadocicum*
3. *Aesculus indica*
4. *Alnus nepalensis*
5. *Betula alnoides*
6. *Betula utilis*
7. *Boehmeria sp.*
8. *Cedrus deodara*
9. *Castanopsis tribuloides*
10. *Coriaria nepalensis*
11. *Cupressus torulosa*
12. *Daphnephyllum himalense*
13. *Debregeasia hypoleuca*
14. *Dendroephthoe falcata*
15. *Disporum cantoniense*
16. *Dodecadenia grandiflora*
17. *Elaeagnus umbellata*
18. *Engelhardia spicata*
19. *Euonymus pendulus*
20. *Euonymus tingens*
21. *Eurya acuminata*
22. *Ficus palmata*
23. *Fraxinus sp*
24. *Ilex dipyrena*
25. *Litsea umbrosa*
26. *Lindera pulcherrima*
27. *Lyonia ovalifolia*
28. *Macranga pustulata*
29. *Maytenus rufa*
30. *Meliosma dillenaeafolia*
31. *Myrica esculenta*
32. *Panassia nubicola*
33. *Persea duthiei*
34. *Phoenix humillis*
35. *Picea smithiana*
36. *Pinus roxburghii*
37. *Pinus wallichiana*
38. *Prunus cornuta*
39. *Prunus sp*
40. *Pyrus pashia*
41. *Pyrus vestita*

42. *Quercus floribunda*
43. *Quercus glauca*
44. *Quercus lanuginosa*
45. *Quercus leucotricophora*
46. *Quercus semecarpifolia*
47. *Rhamnus triqueter*
48. *Rhododendron arboreum*
49. *Rhus spp.*
50. *Stranvissia naussea*
51. *Swida oblonga*
52. *Swida spp.*
53. *Symplocos chinensis*
54. *Symplocos theifolia*
55. *Taxus baccata wallichiana*
56. *Toona serrata*
57. *Tsuga demosa*
58. *Ulmus wallichiana*
59. *Viburnum coriacieum*
60. *Viburnum erubescens*
61. *Viburnum mullaha*
62. *Viburnum nersum*

Shrubs

1. *Aechmanthera gossypina*
2. *Berberis aristata*
3. *Boehmenia rugulosa*
4. *Budleja sp*
5. *Cersium verutum*
6. *Clematis roylei*
7. *Cornus oblonga*
8. *Cotoneaster bacillaris*
9. *Cyathula tomentosa*
10. *Daphne cannabina*
11. *Daphne papyracea*
12. *Desmodium gangeticum*
13. *Deutzia staminea*
14. *Euphorbia prolifera*
15. *Ficus scandens*
16. *Flemingia sambuense*
17. *Gaultheria nummularioides*
18. *Girardeia heterophylla*
19. *Hypericum oblongifolium*
20. *Indigofera heterantha*
21. *Jasminum humile*
22. *Leptodermis kumaonensis*

23. *Lespedeza sp.*
24. *Lonicera quinculocularis*
25. *Myrcine africana*
26. *Nerium sp*
27. *Osbeckia stellata*
28. *Philadelphus sp.*
29. *Pouzolzia sp.*
30. *Pyracantha crenulata*
31. *Randia tetrasperma*
32. *Rhamnus virgatus*
33. *Rubus biflorus*
34. *Rubus ellipticus*
35. *Rubus foliolosus*
36. *Rubus paniculatus*
37. *Sarcococa saligna*
38. *Trachelospermum lucidum*
39. *Urtica dioca*
40. *Urtica hyperborea*
41. *Urtica parviflora*
42. *Zanthoxylum acanthopodium*
43. *Zanthoxylum armatum*

Herbs

1. *Adiantum venustum*
2. *Ainsliaea sp.*
3. *Ajuga parviflora*
4. *Anaphalis sp.*
5. *Anemone tetrasepala*
6. *Anemone vitifolia*
7. *Arabis amplexicaulis*
8. *Arisaema flavum*
9. *Artemisia nilagarica*
10. *Artemissia nilgarica*
11. *Asparagus racemosus*
12. *Aster molliusculus*
13. *Aster sp.*
14. *Bergenia sp.*
15. *Bistorta amplexicaulis*
16. *Boeninghausienia albiflora*
17. *Calanthe sp.*
18. *Cannabis sativa*
19. *Cardamine impatiens*
20. *Cirsium wallichii*
21. *Cissampelos pariera*
22. *Condrus crispus*

23. *Conyza stricta*
24. *Crassocephalum sp.*
25. *Curculigo sp.*
26. *Cyanoglossum zeylanicum*
27. *Datura stramonium*
28. *Desmodium triquetrum*
29. *Dioscoria deltoidea*
30. *Elsholtzia eriestachya*
31. *Epilobium sp.*
32. *Erigeron himalayansis*
33. *Eulophia compestris*
34. *Eupatorium adenophorum*
35. *Eupatorium odoratum*
36. *Flemingia strobilifera*
37. *Fragaria sp.*
38. *Fragaria vesca*
39. *Geranium wallichianum*
40. *Gnaphalium sp*
41. *Goodyera biflora*
42. *Hedychium spicatum*
43. *Impatiens urticifolia*
44. *Inula cappa*
45. *Lonicera sp.*
46. *Lysimachia sp*
47. *Onychium contiguum*
48. *Origanum vulgare*
49. *Osyris quadripartila*
50. *Oxalis corniculata*
51. *Parietaria debile*
52. *Pilea sp.*
53. *Plectranthus coesta*
54. *Plectranthus striatus*
55. *Polygonum amplexicaule*
56. *Polygonum chinense*
57. *Polygonum recumbens*
58. *Potamogeton sp.*
59. *Potentilla fulgens*
60. *Potentilla sp.*
61. *Rosularia rosulata*
62. *Rubia sp.*
63. *Rubus nutans*
64. *Rumex hastatus*
65. *Satyrium nepalense*
66. *Scrophularia calycina*
67. *Seigesbeckia chinensis*

68. *Selinum sp.*
69. *Senecio rufinenervis*
70. *Senecio sp.*
71. *Solanum indicum*
72. *Solidago virgaurea*
73. *Stellaria sp.*
74. *Swertia augustifolia*
75. *Tectrastigma affine*
76. *Thymus serpyllum*
77. *Valeriana wallichii*
78. *Viola odortus*
79. *Wikstroemia canescens*

Grass

1. *Apluda mutica*
2. *Arundinella nepalensis*
3. *Arundo spp,*
4. *Bothriochloa pertusa*
5. *Carex cruciata*
6. *Chimonobambusa falcata*
7. *Crysopogon gryllus*
8. *Cymbopogon martinii*
9. *Cynodon dactylon*
10. *Eragrostis spp.*
11. *Eragrostis unioloides*
12. *Erianthus munja*
13. *Heteropogon contortus*
14. *Imperata cylindrica*
15. *Mondo intermedius*
16. *Neyraudia arundinacea*
17. *Pennisetum orientale*
18. *Poa annua*
19. *Saccharum spontaneum*
20. *Sporobolus diander*
21. *Themeda anathera*

Creeper

1. *Cissampelos sp*
2. *Clematis buchananiana*
3. *Gloriosa superba*
4. *Hedera nepalensis*
5. *Hoelbolia latifolia*
6. *Marsdenia lucida*
7. *Marsdenia roylei*
8. *Parthenocissus himalayana*

9. *Rhamnus prostratus*
10. *Smilax aspera*
11. *Smilax vaginata*

Pteridophytes
1. *Asplenium dalhousiae*
2. *Athyrium sp.*
3. *Coniograme sp.*
4. *Cyrtomium caryotedium*
5. *Dicranopteris linearis*
6. *Dryopteris juxtaposita*
7. *Dryopteris wallichii*
8. *Hypolepis punctata*
9. *Polystichum sp.*
10. *Polysticum squarossum*
11. *Pteris biaurita*
12. *Pteris cretica*
13. *Pteris sp.*
14. *Woodwardia unigemmata*