AN ECOLOGICAL STUDY ON PHEASANTS OF THE GREAT HIMALAYAN NATIONAL PARK, WESTERN HIMALAYA

Thesis submitted to the
Forest Research Institute – Deemed University
Dehra Dun

FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY IN
WILDLIFE BIOLOGY

By

K. RAMESH

Wildlife Institute of India
P.O. Box # 18, Dehra Dun - 248001
Uttaranchal, INDIA

MAY 2003

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

Dr. G. S. Rawat
Professor & Head
Department of Habitat Ecology

I am delighted to forward the thesis of Mr. K. Ramesh titled "AN ECOLOGICAL STUDY ON PHEASANTS OF THE GREAT HIMALAYAN NATIONAL PARK, WESTERN HIMALAYA" for acceptance for the degree of Doctor of Philosophy in Wildlife Biology from the Forest Research Institute – Deemed University, Dehra Dun. I certify that the thesis embodies original findings and interpretation of facts, and was carried out by K. Ramesh under my supervision. I also state that this research work has not been submitted in part or full to any other University/Institute for the award of any degree.

Dehra Dun
08th May 2003

Rawat
(Dr. G. S. Rawat)
Ph.D. Supervisor

Post Box No.18, Chandrabani, Dehradun - 248001. India
EPABX: +91-135 - 640111 to 640115, 640990; FAX: 640117; GRAM: WILDLIFE
E-Mail: wii@wii.gov.in

ACKNOWLEDGEMENT

I find it appropriate to dedicate the thesis to the Wildlife Institute of India, which further reinforced my belief and conviction that opportunity is the key factor that determines the growth of oneself and the society. But for the facilities, opportunities (both material and intellectual) and conducive atmosphere at WII, I cannot think if I could have ever come close to this level of career development. I appreciate those people who had the vision and the ability to bring about this composite stature of WII, which I wish, would continue to go along forever, for the benefit of wildlife science and conservation. I am obliged to the panel of unknown faces then, who showed faith in me and sending me to the Great Himalayan National Park (a hitherto unheard place for me) to study mountain ungulates and later the pheasants there. I hope I have not let them down. I sincerely apologize to Dr. G. S. Rawat, my Ph.D supervisor, for prolonging the thesis completion much to his dislike, and thank him in many words for his patience, inspiration and able guidance all through the study. Though not officially involved in my Ph. D program, Dr. S. Sathyakumar has always been great help and I could go up to him at anytime for anything. Thank you sir. I thank the FREEP-GHNP research project for logistics, infrastructure and financial supports for this study.

Several individuals and organization helped during various phases of my research career. Dr. R. Nagarajan at A.V.C. College showed me the way to wildlife research. Christy, Justus, Charu, Advait, Ravichandran and Jayapal were quite supportive in my initial days at WII. The members of the research team in GHNP (Dr. H.S. Pabla, Mr. A. S. Negi, Dr. V.B. Mathur, Dr. P. K. Mathur, Mr. Sanjeeva Pandey, Mr. B.M.S. Rathore, Mr. A. K. Bhardwaj, Mr. Pratap Singh, Dr. Amita Baviskar, Dr. Sarnam Singh, Dr. Virendra Sharma, Dr. Sudesh Nagia, Dr. Tony Gaston, Dr. Peter Garson, Ms. Camille Richard, Ms. Maureen Decoursey, Dr. Richard Tucker, Dr. V.P. Uniyal, S. K. Singh, Pradeep Kumar, Badrish Mehra, Vinod T.R., Suneet Naithani, Milind Saxena, Hazart Abraham and Vedhu Jha) helped in various ways during the study and I relished their association. Himat, Pritam, Dole Ram and Sher Singh were humbly dedicated and they pulled me through with difficult phases during fieldwork and were responsible for converting my field base camp at Rolla (Tirthan Valley) to a mini-house with swimming pool and playground. I spent memorable days in their company and life was more enjoyable when Sanjay and Pradeep were around. Families of Mr. Khub Ram, Mr. Bhub Singh, Ms. Bhagawati Uniyal and several other friends at Banjar and Gushaini ensured that I don't fall homesick. I admit that I had a wonderful life during the four years in Himachal Pradesh in association with these people and the beautiful landscape. The officials from the rank of PCCF to Forest Watcher in the Himachal Pradesh Forest Department were extremely helpful and there was no element of misunderstanding and problems whatsoever. I truly thank you all, and particularly, Mr. Sanjeeva Pandey, Mr. N.K. Gulearia, S.K. Gulearia, Mr. Anil Joshi, Mr. Balak Ram and staff of Tirthan Range ensured that I was not left wanting for support in the field. I have great admiration for the people around GHNP for their humbleness, help and hospitality.

Back at WII, Mr. Qamar Quershi was always helpful and he has contributed immensely in the last chapter of the thesis. My interactions with and critical comments from Dr. Peter Garson, Dr. John Carroll, Dr. Philip McGowan, Dr. Rahul Kaul, Dr. Virendra Sharma, Gopi Sundar, Christy, Jayapal, Yoganand, Charu, Sridhar, Suresh, Areendran, Ishwar, Karthik, Advait, Bhaskar, Rashid and Dr. Jagdish were of great help and have contributed in shaping my thought process and completion of the work.

I feel obliged to thank the entire team of library staff, efficiently headed by Mr. M. S. Rana for providing all required facilities in the library. His vision and teamwork are outstanding, and I found the work culture in the WII library exemplary. Shashi and Padma could be nasty at times with their punching comments!, but were enthusiastically helpful. Shashi and Vermaji in particular know the library so well that they could meet up to everything required from them and helped me in all possible ways. Ms. Sunita Agarwal, Mr. Madan, Mr. Kishan, Mr. Mahesh Ghosh, Mr. Virender and all other staff were readily available for help and thank them for making life much easier and getting the job done efficiently. Computer and GIS facility is an other hallmark of WII, all the staff (Mr. Rajesh Thapa, Mr. Sukumar, Mr. Lekh Nath, Mr. Virender Sharma, Mr. Dinesh Pundir, Mr. Veerappan and the Computer Engineers) were very supportive and helped me whenever I reached out to them. I thank them all and also Dr. V.B. Mathur and Mr. Qamar Qureshi for working towards developing the facilities stronger and user friendly. Panna Lal at DIP/GIS lab introduced me to GIS and I am amazed at his patience and 'never say no' attitude for any help, I approached him for. Drs. Manoj and Navneet Gupta were good company and showed willingness to help me out. I cannot think how the thesis would have taken shape, without these facilities and their support.

Dr. K. Sankar, Dr. Ravi Chellam, Dr. S.P. Goyal, Mr. B.C. Chaudhary and RAC members provided useful inputs and support when required. I thank Dr. A.J.T. Johnsingh for his encouragement and allowing me to take time off from the Terai Arc Tiger Conservation Landscape Project to complete the thesis. Dr. Archana Sharma has always been supportive and encouraging ever since I landed in WII and I thank her for concern and interest in my well being. I am delighted to have been in the company of several friends and colleagues at WII. Antesh, Yashveer, Karunakaran, Appu, Nima, Shomita, Chandu, Wesley, Khalid, Sivakumar, Adhikari, Anu, Kashmira, Tanu, Sanjay, Anjali, Anil and Rina were motivating and provided moral support that helped towards completion of this work. Priya did the editorial job and I thank her for the strenuous effort, sitting up to late night and carefully going through each word of the document, which greatly improved the readability of the thesis. I might have overlooked the comments by her and several other people on different chapters. If there are any gross mistakes (conceptual, data quality, interpretation and language) in this thesis, which I am sure are many, is entirely mine. I thank Yogi for his intellectual inputs and he bought me a laptop at a crucial time, which enabled me to complete the thesis.

I sincerely acknowledge the material, infrastructure and personal support provided by the Director and other administrative, technical and non-technical staff of WII, without which it would have been difficult to carry out this work. I thank Ms. Anita (Finance Section) and Mr. Ismail (Photocopying room) for their valuable help. The World Pheasant Association and IUCN-Pheasant Specialist Group donated radio-tags and related equipments for the study. I thank Dr. John Corder for generously providing me his collection of pheasant pictures used in the thesis. I truly thank those people who were skeptical of my ability to do work in the Himalaya and the kind of research that I intended, as it provided an enhanced thrust to do a better job. At the final stage of the thesis preparation, Priya, Ishwar, Yogi, Rajapandian, Meena and Devendar shared the burden and made sure that I sailed through smoothly. I thank them all and the others who genuinely offered help. I appreciate everyone whom I have thanklessly missed to remember and have contributed intentionally and unintentionally towards completion of the work, and also all those who are my well-wishers.

(K. Ramesh)

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Pheasants (Family *Phasianidae*, Order *Galliformes*) are large, ground dwelling birds with brightly colored plumage. They inhabit diverse habitats in the tropical and temperate forests of Asia and Africa. With the exception of one species (Congo peafowl, *Afropavo congensis*) found in the central African rainforests, the rest 50 species are native to Asia. Out of which 17 are distributed in India and 14 are restricted to the Himalayan ranges. These birds have long been exploited for meat and plumage, causing a decline in their populations. Currently, 29 species (57%) are listed as rare, endangered or vulnerable in the IUCN/Pheasant Specialist Group's Conservation Action Plan. Many pheasant species are likely to go extinct within the next 100 years, if the over exploitation and habitat destruction continues. The current state of knowledge on the Himalayan pheasants is sketchy and it is necessary to obtain scientific data to better understand their behavior and ecological requirements. This would, in turn, lead to effective management and conservation. This Ph. D. study was conceived in this background and is an essential step towards bridging the knowledge gap.

The primary focus of the study was to describe the ecological and spatial distribution of three sympatric pheasant species, namely, Himalayan monal (*Lophophorus impejanus*), koklass (*Pucrasia macrolopha*) and western tragopan (*Tragopan melanocephalus*) in the Great Himalayan National Park (GHNP; 31° 33' - 31° 57' N and 77° 17' - 77° 52' E) in Himachal Pradesh, India. The specific were to: (i) review and test the currently available count techniques and provide estimates of relative abundance; (ii) document group size characteristics; (iii) describe habitat preference and investigate species coexistence; and (iv) develop a spatial model to predict availability of the potential habitats and the probability of occurrence of the study species.

The study design included three broad approaches, namely, 1) field sampling, to estimate relative abundance and other behavioral and ecological parameters, 2) associative approach, to establish a relationship between the ecological distribution of the study species and habitat characteristics, and 3) Geographical Information System (GIS) based predictive spatial modelling. An area of 16 km^2 was selected within GHNP, based on reconnaissance survey and literature, to serve as an intensive study area. This area supported a considerable abundance of the study species, is representative of the habitat diversity and favoured efficient sampling. The field study was done during October to December 1995, winter (January-March) of 1996, April 1997 to November 1999 and winter (January) of 2000. Intensive sampling was done from April 1997 - November 1999.

The potential count techniques relevant for the study species were gathered from literature for field validation and for estimation of relative abundance. Six trails or bridle paths (each 0.7 to 1.2 km long) representing various vegetation types and elevation gradients were identified in the intensive study area. These trails were monitored for counting birds twice a month in all the seasons (Spring, Autumn and Winter) except during the monsoon. During the breeding season, calling males were counted for three hours in the mornings from 10 fixed stations on the trails. Each station, with a minimum radius of 300m, was sampled twice a month during the breeding season for two years. In addition, surveys and opportunistic searches were made to record occurrence and group size characteristics of the species in other parts of GHNP. Evidence of species occurrence (both sighting and indirect signs such as calls, faeces, tracks, and feathers) were recorded and marked on 1:50,000 topographic maps. Habitat use was measured at two hierarchical levels, represented by macrohabitat (vegetation type, elevation, aspect and slope) and microhabitat (immediate environment such as tree cover, shrub density and litter cover). Abundance estimates were related to the macrohabitat parameters to assess the relative habitat preference of the species. Microhabitat variables were measured at each bird location and these data were used to describe microhabitat use. One western tragopan was fitted with a radio-transmitter and studied for seven months (May-November 1999). This radio tracking assisted in getting additional information on this rare species. Using the field data and the spatial database on habitat characteristics derived from satellite imagery and topographic maps of the study area, a model was developed to predict the potential habitat availability and the probability of occurrence of each species. Parametric, non-parametric and classification tree procedures were used for aspatial data analysis. For spatial analysis, Boolean logic, logistic and autologistic models were used.

There is no common method that could be applied to estimate abundance of all the study species. This is primarily because of the different behavioural traits of the species. The Himalayan monal was conspicuous but does not give breeding calls, whereas the koklass and the western tragopan were secretive, but made loud calls during the breeding season. The trail count was found to be efficient for obtaining an index of abundance and a density estimate for the Himalayan monal, whereas, call count gave a relatively unbiased abundance estimate for koklass and western tragopan. Spot mapping was found to be a useful method for estimating abundance of western tragopan. The count techniques adopted in the study have assumed equal probability of detection across habitat types. The detection probability is likely to be constant for the Himalayan monal because of its characteristic behaviour of giving alarm calls or flushing at greater distances, even in dense habitats. However, for the koklass and western tragopan that tend to skulk under bush/rock cover, the detection probabilities may vary. These methods are applicable for long term monitoring of population trends, as the probability of detecting the species is likely to be constant over the years, unless the habitat undergoes major changes. To apply these count techniques to the rest of the distribution range of the study species, modification is needed to include a correction factor that accounts for the variation in detection probabilities across sampling areas.

320 sightings of Himalayan monal, 90 sightings of koklass and 30 sightings of western tragopan were obtained in trail counts. Surveys and opportunistic searches provided 204 more sightings of Himalayan monal, 36 sightings of koklass and 15 sightings of western tragopan, thus taking the total to 524, 126 and 45 respectively. Himalayan monal was the most frequently sighted species with an encounter rate ranging between

0.6 and 6.5 birds/km, giving a pooled mean of 2.5 (± 0.26 SE, n=35) birds/km. Pooled mean of the encounter rate obtained for koklass, based on trail count was 0.7 bird/km, but the call count gave 2.9 (± 0.19 SE, n = 20) calling males/call station. Western tragopan was only occasionally sighted and the pooled mean of encounter rate was 0.3 bird/km and only 3 calling males were recorded in the entire intensive study area. Within the study area, the abundance of these species varied significantly between localities. There were seasonal variations in abundance of Himalayan monal and western tragopan, with consistently higher encounter rates in winter for both the species. Koklass did not show any such seasonal variation in the encounter rates. The estimated densities for Himalayan monal (14-27/km^2) and koklass (14-21/km^2) revealed that these two species are not significantly different in terms of population abundance. The low encounter rates and density estimates (1.5-2/ km^2) confirmed that western tragopan is a rare species. Noticeable differences were detected in the abundance of the study species over successive years, perhaps indicating a declining trend in the population. Circumstantial evidences suggested that the decline could be due to disturbances caused by local people collecting mushrooms during the breeding season of the pheasants. Group size of the Himalayan monal ranged from 1 to 11 individuals with an average of 1.6 (± 1.2 SD). There were several observations of unisexual group formation in this bird. Also, larger groups were seen during winter, suggesting that Himalayan monal tend to congregate in winter months. Koklass and western tragopan were mostly seen singly or in pairs and the mean group sizes of these birds were 1.3 (± 0.5 SD) and 1.1 (± 0.3 SD) respectively. There was no seasonal difference in the group sizes of these two species.

The three study species are basically forest dwellers, largely occupying middle elevation areas (2600-3000m) and showed a preference for well-developed understorey environment. All the species appeared to have a strong preference for broad leaf associated vegetation. Himalayan monal was a generalist in using various habitat types, but showed a marked preference to areas dominated by mixed and subalpine forests interspersed with cliffs, regardless of seasons. Koklass and western tragopan seemed to prefer broadleaf forests, with sufficient understorey vegetation represented by species of *Cotoneaster, Indigofera, Viburnum* and ringal bamboo (*Thamnoclamus spathiflorus*). Himalayan monal showed high variation in elevation use and they used areas between 2340m and 3660m in summer. In winter, these birds descended to areas below 3100m in response to heavy snow cover in the higher altitudes. Koklass maintained a relatively constant elevation use, found between 2220m and 3060m throughout the year. Western tragopan too responded strongly to snow conditions in the higher altitude by descending from the summer distribution areas of 2575 - 3200m, to lower elevations between 2220 and 2970m during winter. All these species appeared to prefer south and east facing aspects and gentle to moderate slopes (24-45°) in summer season. The winter distributions were skewed towards south and southeast facing aspects and slightly steeper slopes. Twelve microhabitat variables (three physical – elevation, aspect and slope; and nine biological – vegetation type, tree density, canopy cover, shrub species composition, shrub density, bare ground availability, litter cover, soil depth and distance to water) were found to have strong association with microhabitat use of the species in the summer season. Fallen log density and rock cover were two additional variables that also had a strong association with the

microhabitat use by the species in winter. Himalayan monal appeared to be a habitat generalist, while western tragopan, a habitat specialist. Koklass appeared to show a consistent preference for understorey microhabitat in both the seasons. Broadly, these three species seem to live in the same habitat types, but at a smaller scale of analysis, there was mutual exclusion either spatially or temporally.

Availability of potential habitat for all the study species was proportionately very low (22% for Himalayan monal, 12% for koklass and 10% for western tragopan) as compared to the total area of GHNP (1171 km^2) and is also fragmented in space. About 50% of the available habitats have been predicted to be in the ecozone (outside PA network), where the pheasant populations have either been extirpated or occur in very low abundance. It was possible to predict spatial distribution of these species at a coarse scale based on four spatial correlates, namely, vegetation type, normalized difference vegetation index (surrogate of vegetation cover), elevation and aspect. Logistic regression model accounted for over 60% of the variance for all the species, and provided overall classification accuracy of 83.6%, 86.5% and 82% for Himalayan monal, koklass and western tragopan respectively. Improved versions of the model (autologistic model) that incorporated spatial autocorrelation function in the model equation explained 80% of the variance and increased the accuracy of the model prediction to over 90% for all the species. Validation (based on independent data set) substantiated that the probability of occurrence predicted by the model were largely true for the intensive study area and for parts of GHNP. The results of this study have been presented both numerically and as maps. These findings have high potential to provide a basis for management of the area for pheasants.

mapping of koklass for
[illegible] of
habitats

CHAPTER 1

INTRODUCTION

1.1. The Pheasants

Pheasants are large, ground dwelling birds with brightly coloured plumage and represent the family *Phasianidae* of the order *Galliformes*. The word pheasant comes from Greek *phasianos* meaning 'Phasian bird' and it was perhaps because, the ring-necked pheasant (*Phasianus colchicus*) was first described from the River Phasis in Colchis, an ancient territory in Asia situated between the Black Sea and the Caspian Sea (Gotch 1981). Generally, the 'pheasants' are referred to those members of subfamily *Phasianinae*, which are characterized by greater sexual dichromatism and dimorphism, and largely possess chicken-like morphological and behavioural traits. Males are distinctly bright and possess well-developed/elongated tails, crests and specialized fleshy structures such as lappets. Marked differences are discernable within each group of pheasants in anatomical, morphological and biological characteristics. The main morphological characteristics that differentiate various genera of pheasants include general pattern and color of feathers, presence or prominence of wattles, crest, hackles and spurs, shape and structure of tail, wings and bill (Delacour 1977). In comparing pheasants to mammals, their internal structures are analogous to ruminants. Although they consume insects and other invertebrates, they primarily feed on vegetative materials such as seeds, leaves, fruits, shoots and tubers (McGowan 1994). Anatomical characteristics within pheasants vary only to a small extent. Biological characters such as habit, voice, courtship display, mating and nesting hold greater value in separating among the groups and also from other birds (Delacour 1977).

Fifty-one species belonging to 16 genera have been recognized so far in the world. Interestingly, 50 of them are Asian in origin, the lone exception being the Congo peafowl (*Afropavo congensis*) confined to a small area in the virgin forests of east central Congo basin (Delacour 1977). The natural range of pheasants spreads from

Java through forests of Malaysia, Indochina and China, and westwards along the Himalaya to Caucasus in west Asia, and also in Peninsular India, Myanmar, Bangladesh and Sri Lanka (McGowan 1994). Also, several species of pheasants including Ring-necked pheasant and Reeves's pheasant (*Syrmaticus reevesi*) have been introduced in various parts of Europe and America (Lowe 1933, Bump 1941, Pokorny and Pikula 1987, Moynihan 1995). Most of the pheasants are associated with woody and diverse vegetation types that include lowland tropical rainforest (e.g. Crested fireback *Lophura ignita*, Congo peafowl *Afropavo congensis*), montane tropical forest (e.g. Mountain peacock-pheasant *Polyplectron inopinatum*), temperate coniferous forest (e.g. Western tragopan *Tragopan melanocephalus*), subalpine scrub (e.g. Blood pheasant *Ithaginis cruentus*), alpine meadows (e.g. Chinese monal *Lophophorus lhuysii*), tropical dry-deciduous forests (e.g. Grey jungle fowl *Gallus sonnerati*) and agricultural lands (e.g. Indian peafowl *Pavo cristatus*) (McGowan and Garson 1995).

Pheasants, along with other game birds such as partridges and quails, have long been associated with social and religious status of people living in Asia and Europe. The use of term the 'game' in British law in an Act of 1389 in the reign of Richard II was linked directly with the defining of property qualification and/or social status necessary for anyone who wishes to hunt in a gentlemen's game (McKelvie 1985). Use of feathers is considered significant in rituals and local ceremonies among the people across Asia. For example, men in Himachal Pradesh (India) highly value ornamenting traditional cap with crest feather of Himalayan monal during local religious activities and marriage rituals. Pheasants as source of food and aesthetic for human is irrefutable, for chicken provide stable diet of several million people across globe and sport hunting is popular entertainment in Europe and America. Interest for several of these factors have collectively contributed to the removal of wild populations in their native range. As a result, the pheasant populations in most part of their range have undergone heavy depletion and also due to loss of their habitats to human encroachment/development (Mcgowan and Gillman 1997). Currently, a total of 29 species (57%) of the entire group are listed as either rare, endangered or vulnerable in the action plans developed by IUCN/Species Survival Commission/Pheasant Specialist Group (PSG) (McGowan and Garson 1995, Fuller and Garson 2000). The proportion of species in *Phasianidae* that are threatened as a result of man's activities is highest amongst in any bird family and there is a chance that many species will become extinct during the next 100 years (McGowan 1994).

1.2. The Himalaya and its pheasants

The Himalaya, the highest and one of the youngest mountain systems in the world, extends over 2400 km as an arc from northwest to southeast and 150 - 250 km in width (Devan 1988). Well recognised for its ecological, socio-cultural and aesthetic values, the Himalayan range is one among the most important bio-geographical zones in India (Rodgers and Panwar 1988). It is situated at the junction of three bio-geographical realms *viz.*, Palaearctic, Africo-tropical and Indo-Malayan (Mani 1974) and this unique feature has allowed proliferation of a wide variety of floral and faunal elements. Since the Himalayan ranges are of relatively recent origin, the endemics (that include several species of pheasant) found in this mountain system could have colonised later than Pliocene. Pheasants enjoy special status in this landscape as the most charismatic and conspicuous of all the fauna. They are also regarded as the most distinctive bird family of the Himalaya due to their high endemism and brightly coloured plumage (Ali 1981). Their role as prey-base for carnivorous birds and mammals provide a significant identity in the functioning of high altitude ecosystem (Johnsgard 1986).

Of the 51 species of pheasants, 20 (39%) are endemic to the Himalaya, which include the genera of *Ithaginis* (blood pheasant), *Tragopan* (tragopans or horned pheasants), *Lophophorus* (monal pheasants), *Lophura* (kalij pheasant), *Pucrasia* (koklass pheasant), *Catreus* (cheer pheasant), *Crossoptilon* (eared pheasant) and *Polypectron* (peacock pheasant). The Indian Himalaya harbour 16 species of pheasants (Table 1.1) that form 94% of the total pheasant species (17) found in India. These species occupy various vegetation types and altitudinal gradients as presented in Table 1.1. Winter season in this region plays a major role in their survival and also determines the brood size of individual birds. The large size and heavily built plumage in these birds are possibly due to the physiological requirements to withstand the harsh climatic condition in high altitudes. During winter, when much of the ground is snow covered and resources are limited, they are forced to descend to lower elevations where they face density dependent and intra-specific competition, increased predation and threats from poaching.

Table 1.1. Ecological distribution of the pheasants found in the Indian Himalaya

No.	Species[a]	Vegetation types[b]	Altitudinal range (m) [b]	Status[c]
1.	**Blood pheasant** *Ithaginis cruentus* Hardwicke 1822	Temperate fir and sub-alpine rhododendron, birch and juniper patches	3200-4400 (1500 in winter)	V
2.	**Western tragopan** *Tragopan melanocepahlus* Gray 1829	Upper temperate conifer and sub-alpine oak forests with dense under growth and bamboo patches	2400-3600 (2000 in winter)	V
3.	**Satyr tragopan** *Tragopan satyra* Linn 1758	Temperate conifer and sub-alpine oak forests with dense under growth and bamboo patches	2590-3800 (2000 in winter)	V
4.	**Blyth's tragopan** *Tragopan blythii* Jerdon 1870	Moist evergreen broad-leaved forests with thick under storey of ringal bamboo	1800-3500	E
5.	**Temminck's tragopan** *Tragopan temminckii* Gray 1831	Dense under growth in damp, evergreen broadleaf and sub-alpine forests	2100-3600	S
6.	**Koklass pheasant** *Pucrasia macrolopha* Lesson 1829	Temperate broadleaf, conifer and sub-alpine oak forests with dense under growth	2100-3300	S
7.	**Himalayan monal** *Lophophorus impejanus* Latham 1790	Upper temperate conifer forests, sub-alpine oak and alpine scrub and meadows	2400-4500 (2000 in winter)	S
8.	**Sclater's monal** *Lophophorus sclateri* Jerdon 1870	Upper temperate fir forest and alpine scrub	3000-4000	E
9.	**Red junglefowl** *Gallus gallus* Linn 1758	Moist mixed forest and scrub jungle with dense under growth, habitations	Up to 800	S
10.	**Kalij pheasant** *Lophura leucomelanos* Latham 1790	Tropical and subtropical and secondary forests with dense under growth, habitations	245-3050	S

11.	**Tibetan eared-pheasant** *Crossoptilon harmani* Elwes	Upper temperate, sub-alpine forests and alpine scrub	2800-4600	E *
12.	**Cheer pheasant** *Catreus wallichi* Hardwicke 1827	Rocky slopes with bushes, long grasses, *nullas* and open oak and pine forest	1500-3050	V
13.	**Hume's pheasant** *Syrmaticus humiae* Hume 1881	Rocky slopes with bushes, long grasses and open oak and pine forest	1200-3000	E
14.	**Grey peacock pheasant** *Polypectron bicalcaratum* Linnaeus 1758	Tropical moist, broad-leaved evergreen and semi ever green forest	Up to 1200	S
15.	**Indian peafowl** *Pavo cristatus* Linnaeus 1758	Deciduous forests, agricultural lands, habitations	Up to 1800	S
16.	**Green peafowl** *Pavo muticus* Linn 1766	Dense forest near streams	Up to 1000	? *

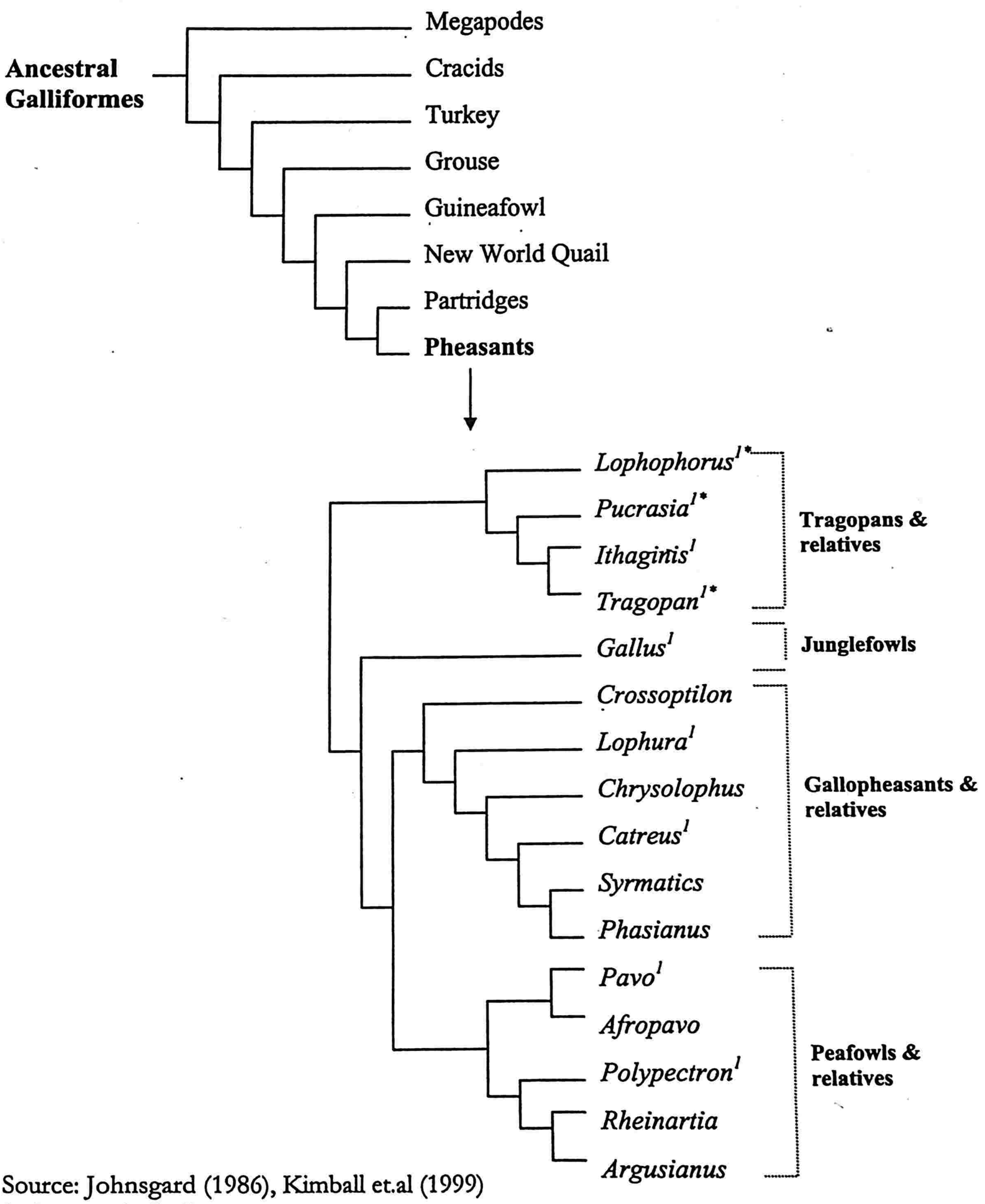
a – Johnsgard (1986); b – Grimmett, et al. (1998) c –McGowan and Garson (1995)
*(V = Vulnerable, E = Endangered, S = Safe, ? = Not known * - no recent records from India)*

1.3. Classification and Systematics

There has been a general acceptance in the classification of pheasants under family *Phasianidae* within the order Galliformes, but there are differences of opinion among taxonomists in the placement of partridges and quails along with pheasants (Peters 1934, Mayr and Amadon 1951, Verheyen 1956, Wetmore 1960, Johnsgard 1973, Delacour 1977, Johnsgard 1986, Sibley and Monroe 1990, Kimball et al. 1999). Although the pheasants and Old World partridges are considered closely related taxa, Johnsgard (1986) suggests a separate tribe *Phasianini* exclusively for pheasants and tribe *Perdicini* for Old World partridges, quails and francolins. However, a recent study on molecular phylogeny of the pheasants and partridges contradicts that these two lineages are not monophyletic (Kimball et al. 1999). Based on the DNA comparison techniques, 57 genera and 214 species representing three families have been recognized under the order Galliformes. This includes the family *Phasianidae* (pheasants, turkeys, grouse and partridges), *Numididae* (guinea fowls) and *Odontophoridae* (New World quails) (Sibley and Monroe 1990). This classification has placed the family *Cracidae* (guans, chachalacas and curassows) and *Megapodiidae* (megapodes) in separate order Craciformes, which had otherwise been classified under Galliformes. The most recent literature available on taxonomy of Galliformes still considers these two families within the order Galliformes and more over, the turkeys and grouses have been placed in separate families *Meleagrididae* and *Tetraonidae* respectively (McGowan 1994). Therefore, presently the family *Phasianidae* includes only pheasants, quails and partridges.

The evolutionary history of pheasants, like other groups of birds, is less clear. Even the relationships within groups appear to be very complex, as has been exposed by recent DNA based studies (Sibley and Ahlquist 1990, Kimball et al. 1999). It is believed that Galliformes, along with several groups of birds, had established on the earth during Eocene epoch of the Tertiary period. Fossil evidences, which are relatively numerous in the case of Galliformes, reveal the occurrence of first known turkeys during Oligocene in mid-Tertiary period (Pettingill 1970). The earliest fossils deposited during lower Eocene indicate the presence of pheasant or partridge-like life forms in Europe during the Tertiary period. However, these birds are considered extinct now (McGowan 1994). Jonhsgard (1986) hypothesizes that the pheasants that exist today evolved from generalized partridge-like ancestors and that early radiation of the partridge and pheasant lineages perhaps occurred in Southeast Asia. He has also postulated four major pheasant lineages based on ecological, structural and distribution evidences. The four lineages are (a) the tragopans and their relatives, (b) the junglefowls, (c) gallopheasants and their relatives and (d) peafowls and their relatives (Fig. 1.1). These lineages are largely supported in at least some of the DNA based analyses done by Kimball et al. (1999), with minor differences in branching patterns. Kimball et al. (1999) conclude that the pheasants and partridges cannot be monophyletic. Further, they have placed turkeys and grouses along with pheasant-partridge clade suggesting that turkey and grouse evolved during the same period as that of pheasants and partridges (Kimball et al. 1999).

Figure 1.1. Phylogenetic relationships among Galliformes and the Pheasants



Source: Johnsgard (1986), Kimball et.al (1999)
1 - Present in India
* - Genera representing the study species

1.4. Current state of knowledge

Despite considerable number of surveys conducted over the years, the present knowledge on individual species of pheasants is still poor. This may be partly because many of the surveys were attempted to establish distribution and population status of these birds and that these attempts had limited scope for quantitative description of species biology. Excluding the ecological studies undertaken by Islam (1985), Hill and Robertson (1988), Kaul (1989), Ahmed and Musavi (1997), Khaling (1997), Kumar (1997), Young et al. (1991) and McGowan (1992), most information available is anecdotal. This information largely comes from surveys, adlibitum records and observations while studying other taxonomic groups (Severinghaus 1979, Garson 1983, Gaston et al. 1983a, Duke 1990, McGowan 1990, Kaul and Ahmed 1993, Balen and Holmes 1993, Choudhry 1993, Cu and Eames 1993, Gaston et al. 1993, Guang-Mei and Zheng-Wang 1993, Kaul and Garson 1993, Pandey 1993, Prasad 1993, Sathyakumar et al. 1993, Shah 1993, Sharma 1993, Shrestha 1993, Yatim 1993, Pandey 1994, Ramesh 1995, Kumar and Singh 1999, Kumar and Singh 2000). More over, these surveys were carried out in small isolated pockets, usually over a short duration of time and a vast area of distribution range of pheasants is still unexplored for scientific purpose. Such situation remains the same in the Indian Himalaya as well, with very few notable studies on pheasants. Prior to initiation of this study, only a handful of intensive ecological studies have been carried out in India that include Kaul (1989) on cheer pheasant, Ahmed and Musavi (1997) on kalij, Khaling (1997) on satyr tragopan and Kumar (1997) on Himalayan monal. Lack of information on many of the pheasants has been the biggest limitation to plan effective conservation of these species in this region. However, there has been an increasing realization, among the biologists and conservationists, for enhanced efforts to bridge the hiatus. As a result, concurrently, few other studies were initiated on western tragopan in Chamba District of Himachal Pradesh (Khan et al. 2000), kalij and koklass in the Kumaon Himalaya (Hussain et al. 2001) and blyth's tragopan in Mizoram (Ghose et al. 2000).

In the Great Himalayan National Park (GHNP) where this study was carried out, five species of pheasants are present. These are Himalayan monal, koklass, western tragopan, cheer and kalij. Indian peafowl has, however, occasionally been recorded in the ecodevelopement project area bordering GHNP along the western side. Incidentally, this Park is one of the only three National Parks in the world and the only National Park in India to support a sizable population of the endangered western tragopan (Collar and Andrew 1988, Birdlife International 2001). It requires no special emphasise that adequate knowledge on species status, distribution and habitat requirements are fundamental for effective management and conservation of any species. The series of surveys conducted under the banner of Himachal Wildlife Project I, II and III from 1979 to 1991 attempted to gather information on abundance and ecological distribution of these pheasants in this park (Gaston et al. 1981, Gaston et al. 1983a, Gaston and Garson 1992). However, these surveys were of very short term in nature (10 days to one month) and conducted only during the summer months. Due to uncertain data quality, results of these surveys are limited to draw any direct ecological interpretation and to influence management implication. Further study with more quantitative approach was suggested imperative by the authors themselves (Gaston and Garson 1992) and it provided the impetus and foundation for the present intensive attempt. Since cheer and kalij were less represented (in both abundance and distribution) in this park and also, have been studied in detail elsewhere, this study focussed only on Himalayan monal, koklass and western tragopan. This study holds an additional value as it involves the western tragopan, which is among the rarest of the birds.

1.5. On the study species

The study species are typical to upper temperate region of the Himalaya and are known to use similar vegetation types during most part of their life (McGowan 1994, Table 1.1). The information available on the evolutionary history of the pheasants reveal that these species are sympatric (Johnsgard 1986), which has further been substantiated by a recent genetic study (Fig. 1.1, Kimball et al. 1999). Occurrence of these species together is, however, limited to the northwest and part of the western Himalaya. Towards east along the Himalaya, Himalayan monal and western tragopan are replaced by Sclater's monal and satyr tragopan respectively. Koklass diverge towards northeast into china. Mace-Lande threat category adopted by Pheasant Specialist Group (PSG) considers western tragopan as 'Vulnerable' and Himalayan monal and koklass as 'Safe' (McGowan and Garson 1995, Fuller and Garson 2000, Table 1.1). However, in India, attributing to local threats, all these pheasants have been listed together in Schedule I of the Indian Wildlife (Protection) Act 1972 (Anon 1972), which invokes legal protection from the Government. Further details specific to these species are compiled below.

1.5.1. Himalayan monal

Himalayan monal is one of the three species under the genus *Lophophorus*, the other two being Sclater's monal and Chinese monal (*Lophophorus lhuysii* Hilaire 1866), which are distributed in northeastern hills of India and southeast China respectively. Recently, a survey carried out in Arunachal Pradesh discovered a new type of *Lophophorus* species and its identity, though believed to be a subspecies of Sclater's monal or a potential new species, is yet to be confirmed (Kumar and Singh 1999). There is, so far, no confirmed record of subspecies in the Himalayan monal. It is a relatively large sized bird with reference to family *Phasianidae*. About 70 cm in length, the weight of males and females range between 1980-2380g and 1800-2150g respectively. An adult male possess a long crest, are feathered with multicoloured plumage throughout its body, while the females, like in other pheasants, are dull in colour with the upper parts covered with dark brownish-black feathers. Notable features in males are a long crest that is metallic green, changeable reddish copper on the back and sides of the neck and, a prominent white back and rump while in flight. Tail feathers of males are uniformly rufous being darker towards the tips, where as the lower tail coverts of females are white, barred with black and rufous. Females have a prominent white patch in the fore neck and a white strip on the tail. First year males and immatures resemble females, but first year males are larger and the immature are less distinctly marked (Delacour 1977).

The Himalayan monal secures a distinct position among pheasants due to its prominent built, brilliant plumage and strong association with local folklore (Delacour 1977). Because of this, Himalayan monal has been declared as the national bird of Nepal and the state bird of Uttaranchal and Himachal Pradesh in India. Its natural range spreads from eastern Afghanistan through the Himalayas including countries of Pakistan, India (states of Jammu & Kashmir, Himachal Pradesh, Uttaranchal, Sikkim and Arunachal Pradesh), Nepal, Southern Tibet and Bhutan (Fig. 1.2). There is also a report of its occurrence in Myanmar (Yin 1970). It occupies upper temperate oak-conifer forests interspersed with open grassy slopes, cliffs and alpine meadows between 2400 – 4500m, mostly concentrating in a narrow belt of 2700 – 3700m (Table 1.1). They seem to exhibit clear and fluctuating altitudinal migration reaching as low as 2000m in winter (*pers. observ.*). They, however, show tolerance to snow and have been observed to dig through snow for roots, tubers and other plant parts, and also invertebrates (McGowan 1994, Kumar 1997). Seen in pairs during the breeding season (April to August), they form large coveys and involve in communal roosting during the winter (*pers. observ.*). Population of this species in most of its range is threatened due to poaching and other anthropogenic factors. Male monal had been under heavy hunting pressure for its crest feather, which as described above was used to ornament hats of Himachal men, until 1982 when legal hunting was banned in the state.

1.5.2. Koklass

Koklass is a monotypic species of genus *Pucrasia* with nine subspecies recognised so far (Johnsgard 1986). These are (1) Indian koklass (*P. m. macrolopha)*, (2) western koklass (*P. m. castanea*), (3) Kashmir koklass (*P. m. biddulphi*), (4) Nepal koklass (*P. m. nipalensis*), (5) Meyer's koklass (*P. m. meyeri*), (6) orange-collared koklass (*P. m. rufficolllis*), (7) yellow-necked koklass (*P. m. xanthospila*), (8) Joret's koklass (*P. m. jorentiana*) and (9) Darwin's koklass (*P. m. darwini*). This study deals with the subspecies *P. m. biddulphi,* which is resident from Kashmir east to Kullu in India. With exception of the subspecies *nipalensis, castanea* and *macrolopha,* which are endemic to the southern side of northwest and western Himalaya, other five are confined to China and Mongolia (Johnsgard 1986). The koklass is a medium sized elusive bird confined to high altitude forests from Afghanistan to central Nepal, and in north-eastern Tibet to northern and eastern China (Fig. 1.3).

Upper parts of male koklass are covered with silver-grey plumage streaked velvety-black down the centre of each feather, and it has the unique feature of a black head, chestnut breast and prominent white patches on the sides of neck. The females differ from males in above characters and instead their upper parts are covered with pale brown plumage. Both sexes, however, have distinct elongated tails tipped with pale feathers. The males are known to weigh about 1135 – 1415g and the females, about 1025 – 1135g, with the body length varying from 58 – 64cm and 18 – 22cm respectively. Immature and juveniles resemble adult females in plumage pattern (Johnsgard 1986). Like the western tragopan, it does not extend its range above the tree line. One of the less colourful pheasants, the koklass exhibits moderate sexual dimorphism. Though they skulk under bushes, which makes direct sighting difficult, they give loud chorus/predawn calls during the breeding season and during autumn, revealing their presence. They remain in pairs or small family groups throughout the year. Nest on the ground and spend the nights roosting on trees, or under rock overhangs (*pers. observ.*).

1.5.3. Western tragopan

There are five species recognised under the genus *Tragopan viz.*, Western tragopan, Satyr tragopan, Blyth's tragopan, Temminck's tragopan and Cabot's tragopan. Except for the Cabot's tragopan that is restricted to China, all other tragopans are found in the Indian Himalaya. No subspecies has so far been recognised for western tragopan. It is a medium sized brightly plumaged bird with males and females weighing 1800 – 2200 g and 1300 – 1400 g respectively. Length of males varies between 65 and 75cm and that of the females 60 – 65cm. Male possesses a red-tipped long crest, feathered with reddish back, and the sides of the neck and face are red. Upper parts are covered with buffish grey and black with prominent white spots. Crest feathers are absent in females and they lack the red colour excepting on the face and legs which are pinkish. Females have pale brownish grey upper parts finely vermiculated and spotted with black, and most of the feathers have black patches and central white streaks. Immature males resemble females, but are larger in size with longer legs and variable amount of black on head and red on neck. Males possess unique feature in the form of a naked throat which, during breeding, is called as lappet and is displayed for attracting females. Moreover, they call loudly during the breeding season to attract females and to defend territories.

Western tragopan, also known as western horned tragopan is considered to be the rarest of all living pheasants. This endangered pheasant is endemic to the northwest Himalaya with a narrow range from Hazara in north Pakistan through Jammu & Kashmir, Himachal Pradesh to the western part of Garhwal in India (Fig. 1.2). Due to its beautiful plumage and large size, this bird is locally called "***Jujurana***" which means "King of Birds". It is reported to inhabit upper temperate forests between 2400 and 3600m in summer, and in winter, dense coniferous and broad leave forests between 2000 to 2800 m elevations (Table 1.1). They mostly feed on leaves, shoots, seeds, but also consume insects and other invertebrates. Like most of the pheasants, they roost on trees singly or in pairs except during nesting, which is reported to be on ground and also on tree. Population of western tragopan is threatened by several anthropogenic factors throughout its range. The declining world population of this species has been estimated to be varying from 1600 to 4800 individuals (Gaston *et al.* 1983b, Johnsgard 1986), including captive population which is less than five at the moment. CITES has listed this species in Appendix I in order to discourage selling of its feathers. Representing the endemic bird area D02 (Western Himalaya), western tragopan has been described as a range-restricted species (ICBP 1992).

Himalayan monal (*Lophophorus impejanus*) - Male

Koklass (*Pucrasia macrolopha*) - Male

Western tragopan (*Tragopan melanocephalus*) - Male

Himalayan monal - Female

Koklass - Female

Western Tragopan – Female

Plate 1. The study species

Figure 1.2. Global distribution range of Himalayan monal and western tragopan (source: Johnsgard 1986, Grimmett et al. 1998)

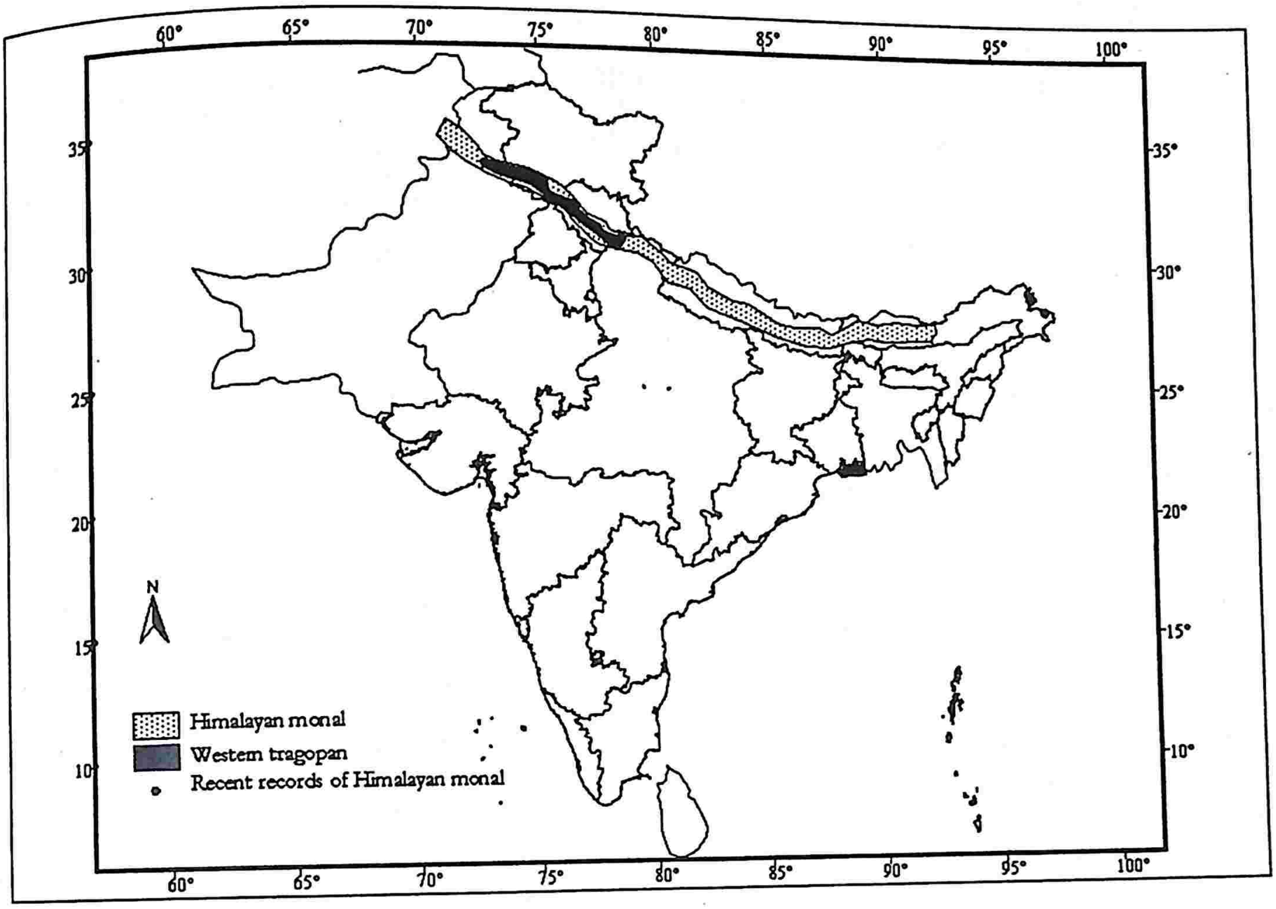
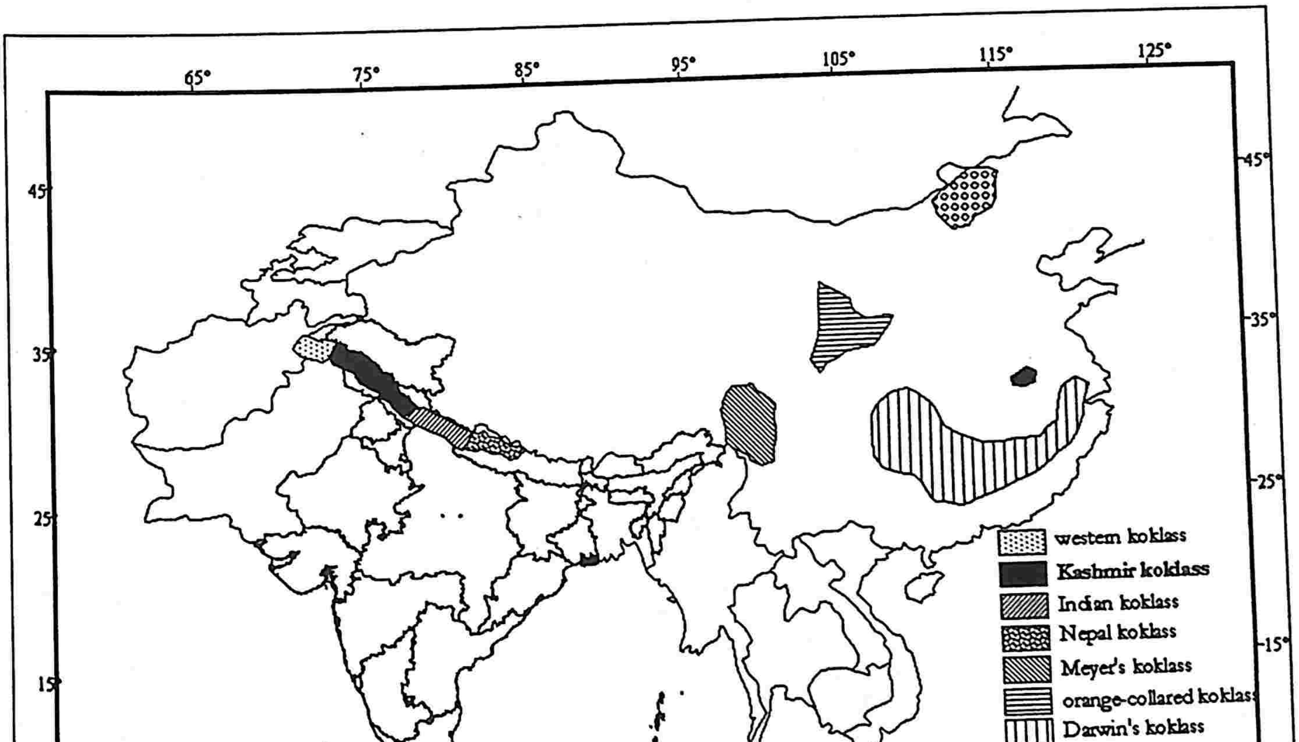


Figure 1.3. Global distribution range of koklass (with details of subspecies) (source: Johnsgard 1986, Grimmett et al. 1998)



1.6. Literature review

Gleaning of literature specific to the study species reveals that studies on the ecology of these species are vastly wanting. The series of surveys conducted by Himachal Wildlife Project I, II, III was the first ever attempt to document the population status and ecological distribution of this species (Gaston et al. 1981, 1983a, Gaston and Garson 1992). Although the information gathered formed the base line source on the ecology of Himalayan monal (Johnsgard 1986, McGowan 1994, McGowan and Garson 1995, Fuller and Garson 2000), it is constrained by short-term nature of the surveys and also was restricted to summer seasons. Kumar (1997) did the first ever intensive study focussing on the ecology of Himalayan monal in Kedarnath Wildlife Sanctuary, Western Himalaya. This again was a short-term study (6 months), had limited scope for wider understanding of the species ecology, rather it provided detailed information only on winter habitat use. Other ecological information that come as short notes and adlibitum records are beyond the scope of review. There were, however, few notable surveys and short-term attempts that provide useful information on ecology and population status of this species (Gaston et al. 1981, Lelliott 1981, Gaston et al. 1982, Lamba et al. 1982, Sharma and Pandey 1989, Choudhry 1993, Gaston et al. 1993, Kaul and Garson 1993, Pandey 1993, Sathyakumar et al. 1993, Sharma 1993, Yahya 1993a, Jandrotia 1999).

Koklass has been relatively poorly studied species, possibly due to its skulking behaviour and not being under any threat category for priority conservation. The attempt to monitor the population between 1976 and 1981 in Pakistan by Khan and Shah (1982) has been the lone intensive effort on this species. However, the surveys conducted by Howman (1976), Severinghaus (1979) and Shah (1993), Gaston et al. (1981), (1983), Gaston and Garson (1992) present certain ecological facts, besides relative abundance. There are also anecdotal records of this species during the surveys conducted in the recent past (Gaston et al. 1981, Gaston et al. 1993, Choudhry 1993, Kaul and Garson 1993, Pandey 1993, Sharma 1993, Yahya 1993b and Jandrotia 1999).

In the case of western tragopan, there was only one ecological study done before this study. The study by Islam (1985) in Pakistan was part of his MS dissertation and was able to document only the summer habitat use by this species. Other attempts that aimed to estimate and monitor the population of western tragopan in Pakistan include Mirza et al. (1978), Islam (1982), Duke (1989), (1990), Whale (1996) and Nawaz et al. (2000), but is mostly of status survey nature. It is noteworthy that before the initiation of the present study, no attempt had been made to study the ecology of western tragopan in India. Nevertheless, considerable number of surveys had been undertaken to obtain empirical data on status and distribution of this species (Gaston et al. 1981, Lamba et al. 1982, Gaston et al. 1983a, Gaston and Garson 1992, Sharma and Pandey 1989, Narang 1993, Pandey 1993, Prasad 1993, Sharma 1993, Pandey 1994 and Jandrotia 1999). Secretive behaviour compounded with low density was reportedly the difficulty in understanding the ecology of this species. A parallel study in Chamba District of Himachal Pradesh (Khan et al. 2000) that was initiated a year after this study, identified several new populations of western tragopan, mostly outside PA network. Its focus on ecological aspects provides spatial replicate of the present study, as it had similar objectives and was carried out in similar environment.

This study is essentially an attempt to provide a comprehensive account on ecology of these species. In particular, it presents quantitative description on count techniques (both for studying habitat use and monitoring), abundance and group size characteristics, habitat association at macro and micro scales, and GIS (Geographical Information System) based model to predict spatial distributions. The specific objectives of the study are as follows.

1.7. Objectives

1. **Review and field test the available count techniques, and provide estimate of relative abundance of the species across space and time.**

2. **Document group size characteristics of the species and their response to different seasons.**

3. **Describe habitat use/relative preference and species coexistence at both macro and micro scales and along seasonal gradients.**

4. **Develop spatially explicit model to establish potential habitats and the probability of occurrence at landscape scale.**

1.8. Organization of the thesis

The entire efforts for the thesis work and its outcomes have been synthesized into six chapters *viz.* 1) Introduction, 2) Study Area, 3) Study Design and Methods, 4) Count Techniques and Relative Abundance, 5) Habitat Use and Coexistence and 6) Spatial Distribution. Chapter 1 discusses the biological, behavioural and conservation attributes of the pheasants in general and the species under study in particular. It essentially provides the background to the research, highlighting the lacunae in the current status of species biology and the necessity to undertake the present ecological study. Chapter 2 describes the study area (including intensive study area) in terms of both physical and biological characteristics and substantiates the justification for carrying out this study in the Great Himalayan National Park. Quantitative description to these physical and biological characteristics were mostly based on spatial data base developed using Geographical Information System and intensive field studies concurrently carried out on various taxonomic groups in this park. The broad approach or in other words, sampling and analytical framework adopted to achieve the objectives of the study is given in the Chapter 3. Methods mentioned in this chapter are only cursory and further details have been adequately elaborated in the relevant technical chapters. Chapters 4-6 maintain independent identities in the form of research papers and the issues involved in the individual chapters are dealt in separate Introduction followed by detailed Methods, Results and Discussion. Available literatures on bird census techniques that are potentially relevant for the study species have been reviewed, field validated and modified, and these details are given in the Chapter 4. Using the appropriate methods (both available and developed), the abundance estimates obtained across localities, seasons and years are presented in this chapter. In addition, descriptive details on the group size and composition of the study species in response to seasonal changes have also been documented. Chapter 5 deals with pheasant-habitat association and the factors that affect ecological distribution of the species. Preliminary analysis of ecological separation among the study species or in words, description to the factors that enable coexistence of these species in the same area has also been attempted. Information gathered in the field on habitat correlates and the spatial data base in GIS were combined to establish spatial distribution of the species at landscape scale, in this case, the entire area of GHNP. Details of spatial analysis and the results obtained on the potential habitat availability for the species and probability of distribution within potential area are given in Chapter 6. Though these chapters stand independent to a large extend, they certainly maintain a logical order. First three chapters provide foundation and approach to the study, chapter 4 and 5 look into intricacies of issues in the field and establish relationship with the species respectively, and the relationship established based on empirical data has been taken to GIS for wider utility in chapter 6. The literatures that were referred to and cited in all these chapters have together been compiled and listed at the end under References.

CHAPTER 2

STUDY AREA

2.1. Introduction

The Great Himalayan National Park is identified to be one among the important Protected Areas in the Himalaya for supporting rich and abundant western Himalayan elements particularly the high altitude pheasants and ungulates. Popular use of the name 'Great Himalayan National Park or GHNP' does not strictly refer to the legal area designated under National Park, but for the large, contiguous area together constituted by the Great Himalayan National Park (GHNP), Tirthan Wildlife Sanctuary (TWS), Sainj Wildlife Sanctuary (SWS) and the Ecodevelopement Project Area (EPA) or the buffer zone. The National Park attained its name 'Great Himalayan' due to its location in the Greater Himalayan range. Due to its close proximity to the Trans Himalayan region, the faunal and floral assemblages have representation from both the regions. The relatively less disturbed forests, extensive meadows, high mountains with snow-covered peaks, inaccessible terrain and the associated endemic and endangered fauna and flora are the characteristic features of GHNP. Further, presence of the rare bird, western tragopan has given this area a distinct identity and is responsible for its worldwide popularity.

GHNP became the natural choice for the present study since it was a part of the multidisciplinary research project carried out by Wildlife Institute of India in this Park. More over, the earlier surveys conducted by the Himachal Wildlife Project (Gaston et al. 1981, Gaston and Garson 1992) and the reconnaissance surveys during this study revealed a substantial population of the study species in this area. This together with the information that was to be generated by other components of the project provided an ideal platform to understand the ecology of the study pheasants.

2.2. History

The GHNP has come into existence after having undergone a series of eventful developments. The Government of Himachal Pradesh, after achieving autonomous statehood in 1971, was proactive in preserving the natural wealth of the state, and initiated steps towards establishment of Protected Areas. Shri Dilaram Shabab, the then legislator from Seraj region, was the first one to support the initiative. He proposed parts of Tirthan and Sainj valleys as Protected Area in 1971 (Shabab 1997). Consequently, an area of 84 km^2 was notified as Tirthan Wildlife Sanctuary (TWS) on 17th July 1976, but 23 km^2 was later upgraded to National Park along with additional areas, which brought down the area of TWS to 61 km^2. During 1978 – 80, the Himachal Wildlife Project I led by a team of biologists carried out extensive surveys in most localities within the state to identify a suitable area for establishing a National Park. The team, convinced by rich wildlife assemblages and minimal biotic disturbances, recommended parts of Tirthan and Sainj valleys as a potential site for the creation of a National Park (Gaston et al. 1981). On 1st March 1984, the Government of Himachal Pradesh issued a notification declaring the Great Himalayan National Park in these valleys with 620 km^2 under the core zone.

Presence of villages inside the proposed National Park particularly in Sainj valley posed legal constraints. There fore, in 1990, the Government of Himachal Pradesh excluded the parts of lower Sainj valley from the National Park and added to buffer zone. Again on 22nd February 1994, the Government issued a notification for adjusting boundaries with the addition of 145 km^2 from Parvati valley to the park, but 90-km^2 areas comprising the villages of Shakti and Marour was carved out to create Sainj Wildlife Sanctuary. Mean while, for the first time in India, the FREE Project with ecodevelopement as the key strategy was initiated in this area along with Kalakad Mundanthurai Tiger Reserve in Tamilnadu. Since the project had to address the issue of dependency on natural resources by local people, there was a necessity to demarcate a buffer zone or ecozone containing the dependent people for the implementation of ecodevelopement program. As a result, a stretch of 5 km^2 along the western boundary of the National Park and Wildlife Sanctuaries was established as ecozone / ecodevelopement zone.

The Supreme Court's directive to all State Governments to expedite the settlement of resource use rights of locale people and to issue final notification of National Parks was a very crucial development in GHNP. On 23rd June 1999, the Government of Himachal Pradesh hurriedly issued the final notification legally constituting the National Park. This notification also excluded 10.6 km^2 from Jiwa valley, which was within the proposed National Park in the initial notification.

2.3. Physical attributes

2.3.1. Location

The GHNP is situated in the Kullu District of Himachal Pradesh, India and lies between 31° 33' 00" - 31° 56' 56" latitudes and 77° 17' 15" - 77° 52' 05" longitudes. It comes under the Nohanda *kothi* of inner Seraj division. The Pin Valley National Park, Kanawar Wildlife Sanctuary and Rupi Bhaba Wildlife Sanctuary surround the Park on the north, the northwest and the east respectively (Fig. 2.1). Located at the junction of two great faunal realms *viz.*, Palaearctic to the north and Oriental to the south (MacKinnon et al. 1986), this area falls under the biogeographic zone 2A - Northwest Himalaya (Rodgers and Panwar 1988). It is also part of the important endemic bird area (D02, Western Himalaya) designated by the International Council for Bird Preservation (Anon 1992).

2.3.2. Area

The study area encompasses a total of 1,171 km^2, represented 754.4 km^2 of GHNP, 90km^2 of SWS, 61km^2 of TWS and 265.6 km^2 of EPA. These areas spread across four major valleys or sub-water sheds viz. Tirthan, Sainj, Jiwa and Parvati. Representation of the above administrative units in each of the valleys is presented in Table 2.1. Of the total of 343.6 km^2 in Tirthan valley, 53.5 % area is covered by forest, where as the Sainj and Jiwa valleys support more of blanks and snow-covered mountains than forests (Fig. 2.2, Fig. 2.3). Open rocks (52.7%) and permanent snow (47.5%) occupy the entire Parvati valley (235 km^2) represented in GHNP.

Figure 2.1. Location and composition of Great Himalayan National Park (showing the intensive study area)

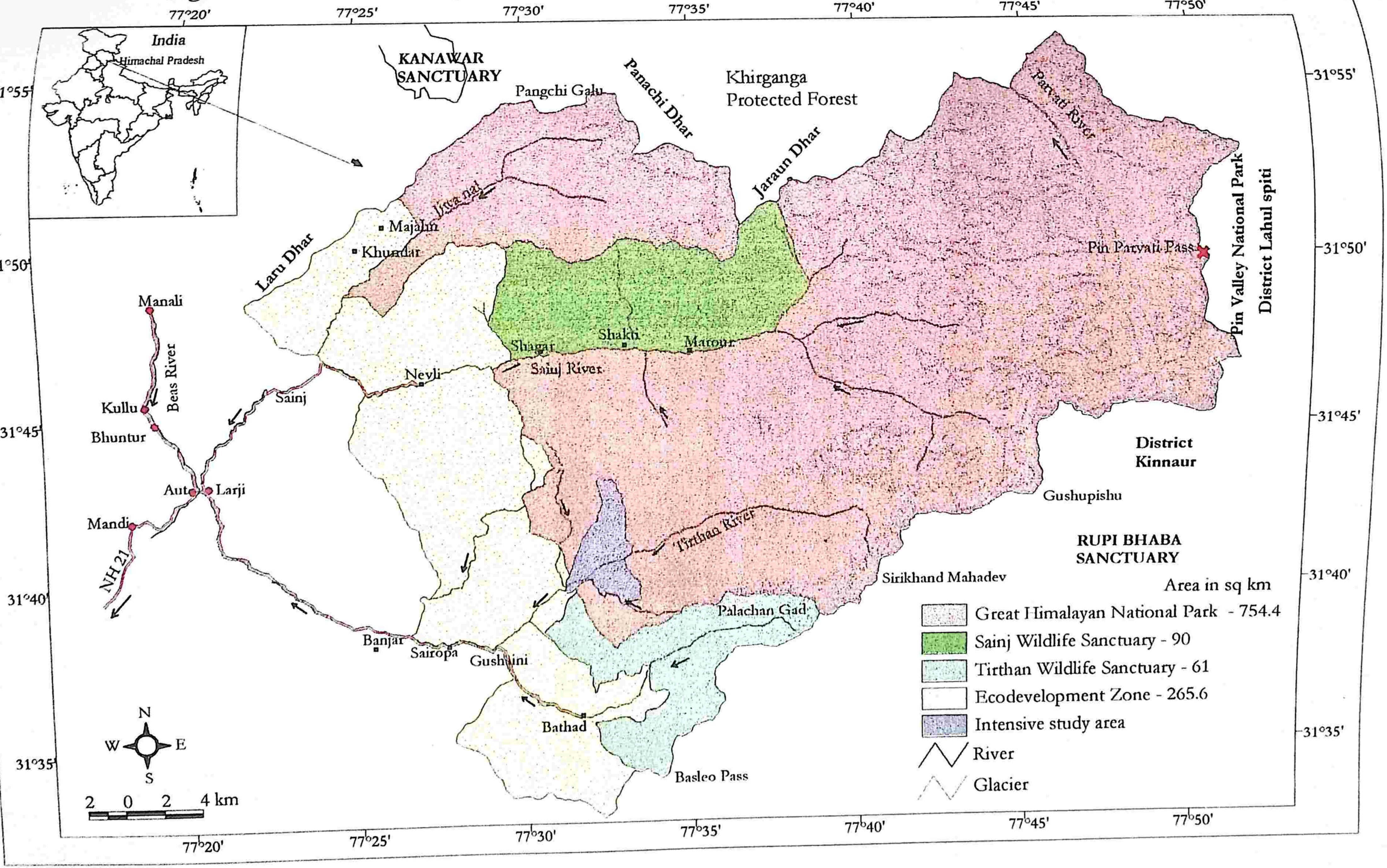
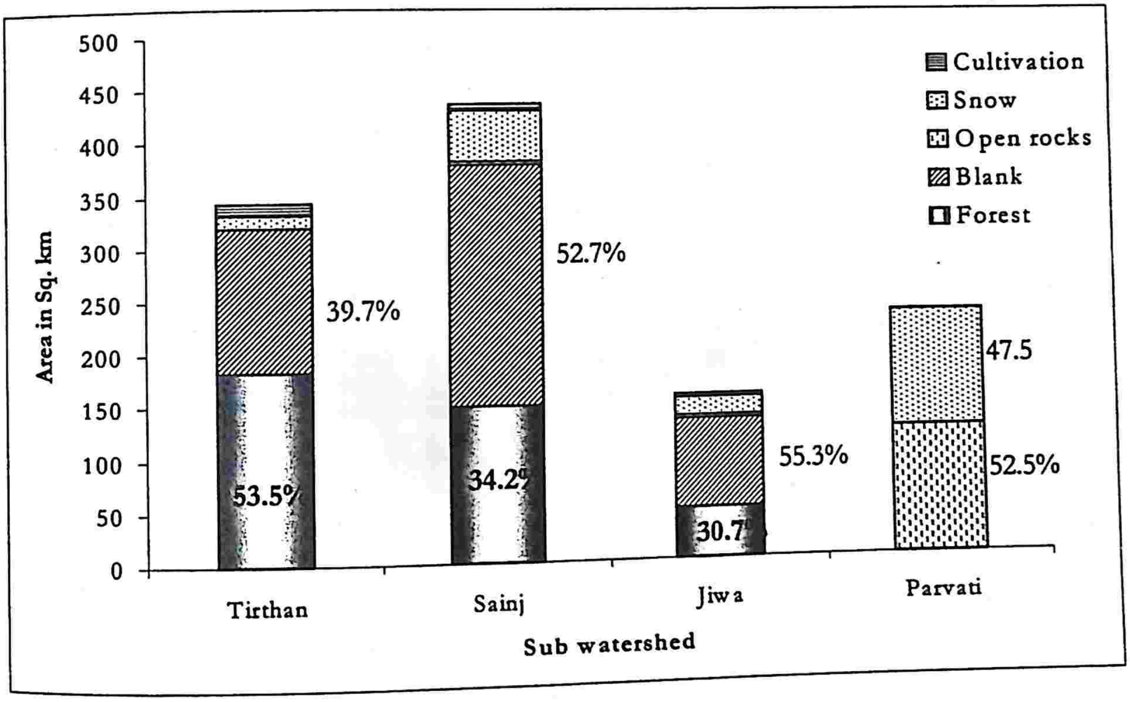


Table 2.1. **Distribution of the sub watershed-areas under different administrative units** (*Source: Negi 1996*)

Valleys Administrative units	Tirthan[1]	Sainj	Jiwa	Parvati	Total
National Park	157.3	240.0	132.7	235.0	**754.4**
Tirthan Sanctuary	61.0	-	-	-	**61**
Sainj Sanctuary	-	90	-	-	**90**
Ecozone	125.3	106.2	23.5	-	**265.6**
Total*	**343.6**	**436.2**	**156.2**	**235.0**	**1171.0**

([1] – including the Plachan sub-watershed, * - area in km^2)

Figure 2.2. Proportion of forests and other land use categories in different valleys (*Source: Negi 1996*)



2.3.3. Topography

Highly undulating, rugged and steep slopes characterize the topography of GHNP. The elevation ranges from 1,344 m (Seund at the confluence of Jiwa Nal and Sainj River near Sainj) to 6,248m (*Jujurana* Peak in Parvati valley). However, majority (91%) of the area lies between 2400 – 5600 m elevations. The mountains exhibit greater diversity of aspects. Except the northern aspect that covers the maximum of 20%, there is little difference in the proportion of area under other aspect categories (Table 2.2). Besides, relatively flat alpine meadows and valley bottoms, the slopes are generally steep, most of which are inaccessible. Over 68% of the area above 3,200m elevation and 45% with the slope angle of 41-90° illustrates the steepness and inaccessibility (Table 2.2).

The late Pleistocene glaciation has had considerable effect on the topography of the region. The extensive moraines, glaciers, river terraces and hanging valleys found in GHNP are the result of this glaciation (Gaston and Garson 1992). Distinctively, 228 km^2 (19%) is together covered by permanent snow (184 km^2), moraines (25 km^2) and glaciers (19 km^2) (Mathur and Naithani 1999). Frequent landslides caused by heavy monsoon rains and avalanches during post winter season have further modified the topography. Of the total area, 38 % are in the form of exposed rocks, escarpments, moraines, perpetual snow, etc.

Table 2.2. Area distribution under different elevation, aspect and slope categories in GHNP *(parentheses are percentages)*

Elevation category	Area (km^2)	Aspect category	Area (km^2)	Slope category	Area (km^2)
<1600	5.0 (0.4)	North	227.1 (20)	0-10	95.4 (8)
1601-2400	98.6 (8.5)	Northeast	125.2 (11)	11-20	125.3 (11)
2401-3200	267.0 (22.8)	East	119.4 (10)	21-30	188.5 (16)
3201-4000	218.0 (18.6)	Southeast	127.6 (11)	31-40	239.7 (21)
4001-4800	332.4 (28.4)	South	138.9 (12)	41-50	195.0 (17)
4801-5600	246.0 (21.0)	Southwest	151.7 (13)	51-60	107.2 (9)
5601-6400	5.0 (0.4)	West	141.0 (12)	61-70	80.3 (7)
		Northwest	130.1 (11)	>70	139.6 (12)
Total	**1171.0**		**1171.0**		**1171.0**

2.3.4. Drainage pattern

Major tributaries of river Beas *viz.*, Tirthan, Sainj, Jiwanal and Parvati drain the GHNP, and flow out in east-west direction meeting the Beas near Larji. There are 2787 streams, both perennial and transitory, covering a total distance of 2074.2 km in

GHNP. Number of streams and the distance covered in each of the administrative units are given in Table 2.3. Although the streams are distributed in large number in the National Park, the estimated drainage density (both number/unit area, and distance/unit area) indicates a homogenous distribution pattern (Table 2.3). Interestingly, 78% (2169) streams belong to 1st order streams, which are defined as a single smallest stream originating in a micro watershed (Negi 1996). Availability of water in most of these streams is directly linked to monsoon and occasional showers. The remaining 22% of the streams have greater conservation implication since distribution and abundance of several wildlife species are known to revolve around these water sources.

Table 2.3. Drainage pattern and distribution in different administrative units in the study area *(Source – Negi (1996), percentage in parentheses)*

Administrative units	Number of drainage	Distance covered (km)	Drainage density	
			No./ km²	Mts./km²
GHNP	1416 (50.8)	1208.5 (58.3)	1.9	1.6
Tirthan Sanctuary	282 (10.1)	161.0 (7.8)	4.2	2.5
Sainj Sanctuary	255 (9.1)	155.0 (7.5)	3.1	1.8
Ecozone	834 (29.9)	549.7 (26.5)	3.3	2.2
Over all	**2787**	**2074.2**	**2.4**	**1.8**

2.3.5. Geology and edaphic characters

The GHNP including other parts of Himachal Pradesh represents Central Crystalline belt, one of the four geological belts classified on the basis of geological characters. The others are Siwalik, Lesser Himalaya and Tethyan. Named as Vaikrit series, the rocks are quartzite, schists, phyllites, dolomites, limestones, shales, slates, gneisses and granites. These rocks play a significant role in the formation of soils and are greatly responsible for different vegetation types (Negi 1996). There are three soil types found in GHNP *viz.*, alluvial, podsolic and brown soil. The soils are mostly acidic in nature and pH values show negative correlation with increasing altitude (Table 2.4). The mean soil temperature varied from 3.6 ± 2.2 in alpine zone to 15.8

± 3.7 in lower temperate forests. Although there are marginal differences in the soil characteristics of various climatic zones, temperate and alpine zones can be differentiated based on these characters (Table 2.4.)

Table 2.4. Characteristics of soil in different climatic zones
(Source – Singh and Rawat 1999)

Climatic zone	pH	Soil temperature (°C)	Soil moisture (%)	Organic matter (%)
Lower temperate	6.3± 0.8	15.8 ± 3.7	21.5 ± 3.8	68.6 ± 10.5
Temperate	6.2 ± 0.4	12.6 ± 3.1	25.3 ± 5.3	71.0 ± 12.1
Upper temperate	6.2 ± 0.5	9.3 ± 2.1	37.8 ± 6.1	65.5 ± 11.5
Sub alpine	6.0 ± 0.2	5.4 ± 2.0	45.2 ± 5.5	62.8 ± 9.4
Alpine	5.5 ± 0.3	3.6 ± 2.2	43.8 ± 7.3	64.7 ± 10.2

2.4. Ecological attributes

2.4.1. Climate

The climate is typically the western Himalayan temperate and alpine type. There are four distinct seasons recognized for GHNP *viz.*, spring (April – June), rainy/summer (July – September), autumn (October – November) and winter (December – March). Precipitation is moderate over most of the year and abundant during monsoon from mid-June to mid-September. During winter, the precipitation is in the form of snow even in lower elevation (1,560m) and higher elevation areas experience heavy snowfall of over 2m depth.

Mean annual rainfall recorded at Niharni and Sainj in Sainj valley for the years 1992-1994 was 1155.7 mm and 1158.3 mm respectively. The maximum rainfall recorded during the study period was 1298mm, which is not significantly different from the previous records. The ambient temperature varied from -10° to 40° C, January and June being the coldest and hottest months of the year respectively.

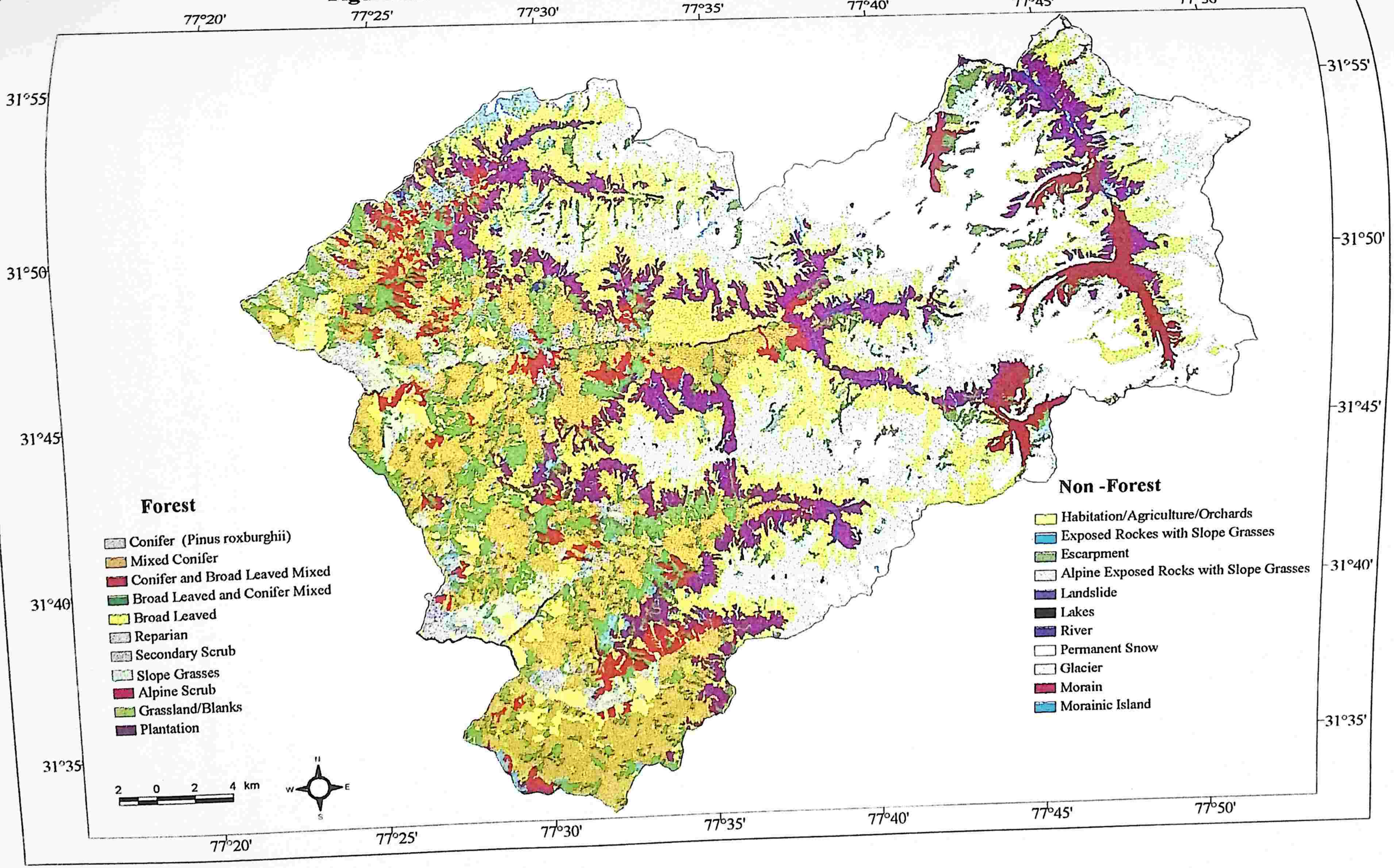
2.4.2. Floral diversity and vegetation types

Forested area of GHNP is relatively less and covers only about 32.5% of the total area. The National Park supports only 17% forest cover, while Tirthan Wildlife Sanctuary, Sainj Wildlife Sanctuary and ecozone have 47.1%, 35.1% and 74.6% of their respective area under forest (Negi 1996). The plant communities are representatives of the temperate, sub alpine and alpine regions, which include oak and coniferous forests, high altitude mixed forests and subalpine and alpine pastures. Fourteen forest types of Champion and Seth (1968) classification are found in the Park. They are, 1. Ban oak forest, 2. Moist deodar forest, 3. Western mixed coniferous forest, 4. Moist temperate deciduous forest, 5. Kharsu oak forest, 6. Western Himalayan upper oak-fir forest, 7. Montane bamboo brakes, 8. Himalayan temperate parkland, 9. Himalayan temperate pastures, 10. Western Himalayan sub-alpine fir forest, 11. Sub-alpine pastures, 12. Birch /rhododendron scrub, 13. Alpine scrub and 14. Alpine Pastures. Based on visual interpretation of (IIRS IB/LISSII/ FCC, 1993) remote sensing data, 11 types of vegetation classes have been documented in GHNP (Mathur and Naithani 1999) (Fig. 2.3).

However, Singh and Rawat (1999) have recognised following nine broad vegetation types on the basis of physiognomy and dominance of plant species.

1. Temperate broad-leaved forests,
2. Temperate conifer forest,
3. Upper temperate broad-leaved and mixed conifer forest,
4. Sub alpine birch-rhododendron forest,
5. Alpine scrubs,
6. Alpine meadows and *Thaches*,
7. Riverine forests,
8. Temperate grassy slopes and
9. Temperate secondary scrub.

Figure 2.3. Land cover characteristics of Great Himalayan National Park



Very little information was available on flora of the GHNP prior to initiation of the multidisciplinary project. Mehta et al. (1993) had reported a list of 309 species of flora from the GHNP. This has now been increased to 1,174 species, represented by 794 species of angiosperms, 11 species of gymnosperms, 27 species of ferns, 192 species of lichens and 150 species of bryophytes (Singh and Rawat 1999, Upreti 1999). Herbaceous plants dominate the floral diversity with 493 species, many of which possess high aromatic and medicinal properties. Tree diversity is higher in middle temperate forests (62 species) followed by lower temperate zone (59 species). Besides, the temperate zone also accounts for the highest species richness harbouring 624 species. Of the total of 45 communities identified in both Tirthan and Sainj valleys, there is less similarity in the vegetation communities between these valleys (Singh and Rawat 1999).

2.4.3. Faunal diversity

GHNP is bestowed with a wide variety of fauna, including several charismatic, endangered and endemic species. Mammalian fauna is represented by over 31 species belonging to six orders *viz.*, Primates, Carnivora, Artiodactyla, Insectivora, Rodentia and Lagomorpha (Ramesh and Sathyakumar 1997, Vinod and Sathyakumar 1999). Endangered Himalayan musk deer (*Moschus chrysogastor*), endemic Himalayan tahr (*Hemitragus jemlahicus*) and elusive Snow leopard (*Uncia uncia*) are among the few notable mammals found here. Birds form a significant constituent of the biodiversity of the study area. 183 species of birds (both resident and migrant) were reported by Gaston et al. (1993). This study added 26 more species to the list, making the total number of species confirmed to 209 (Ramesh et al. 1999).

Pheasants occupy a prominent place in the bird communities of the area on account of their large size, charismatic and conspicuous appearances, besides being indicators of habitat types and being threatened. Of the seven species of pheasants found in the western Himalaya, GHNP holds six species. Herpetofauna are represented by 12 species of reptiles and 9 species of amphibians (Dutta 1999). Surveys conducted to document the diversity of other life forms have indicated high species richness and abundance of lower invertebrates. There are 125 species of insects representing 6 orders and 111 genera reported by Uniyal and Mathur (1999). Julka (1999) has reported 11 species of earthworms, 3 species of leeches and 14 species of molluscs from the area. Given the vast area with diverse habitat types and inaccessible topography, the faunal diversity seemingly will have interesting additions.

2.5. Anthropological attributes

2.5.1. Human population

People living in and around GHNP are distributed in eight *Kothis* (blocks) and 13 *Phantis* (revenue villages). There are 123 hamlets with a total of 14,025 people located in these revenue villages (Nangia et al. 1999). However, the park authorities have recognized 141 villages including scattered hamlets so as to implement the ecodevelopement programme effectively. With the exception of three villages that are located in Sainj Wildlife Sanctuary, all others are concentrated in ecozone. Male and female population is divided into 52% (7,248 individuals) and 48% (6,777 individuals) respectively. Age class of the local people reveals that maximum people are in the age class 16-30, which is similar to natural human population (Nangia et al. 1999). Literacy of the local population is 31%. There were only 1202 female literate as compared 3183 male literate in whole of the ecozone during 1998.

2.5.2. Resource use by people

Although agriculture has been the primary source of subsistence for the local people, they have enjoyed unrestricted access to nearby forests for firewood, timber, bamboo and several medicinal herbs. Between the years 1886 and 1896, the then Commissioner of Kullu Alex Anderson, issued legal settlement of the forests of Kullu, which limited the open access (Anderson 1886). However, the people continued to use the forests including the National Park for timber, medicinal herbs/non timber forest produces (NTFP) and for pastoralism. Singh and Rawat (1999) and Nangia et al. (1999) have given detailed information on the resource use by local people.

Mass hunting during festival periods for meat of ungulates and pheasants was common till 1982 when the hunting was legally banned in Himachal Pradesh. Besides for meat, pheasants were also trapped and killed using snares for their brightly colored plumage, which was used to ornament the hat of the people. Himalayan musk deer and black bear were poached for musk and gall bladder respectively, which fetch a considerable amount of money from the illegal trade in both national and international markets. Traditionally, the people have also been using certain parts of the GHNP for pilgrimage.

2.5.3. Pressure on wildlife

The aforesaid resource use by local people, coupled with poaching and habitat destruction has threatened the future of the endangered species of this park. However, collections of NTFPs and grazing have been the major pressure on the natural resources of GHNP during the present study. Over 60 species of plants including those listed under IUCN threat category were being collected for commercial use (Singh and Rawat 1999). Digging and uprooting of medicinal herbs by a large number of people over several decades have caused drastic decline in their population. The habitats have undergone depletion due to camping of livestock and other practices such as burning. Branches of tree species such as kharsu oak (*Quercus semecarpifolia*) and blue pine (*Pinus wallichiana*) and several other shrubs are cut for collection of lichens.

Circumstantial evidences reveal that mushroom collection has serious negative impact on pheasants (Ramesh et al. 1998). Grazing by about 20,000 migratory sheep and goats during summer season in alpine and sub alpine region has greatly changed the vegetation composition in these pastures (Singh 1999). Presence of a large number of people and livestock in alpine pastures are suspected to play negative role in the life of mountain ungulates. Although hunting was prevalent during 70s, currently there is no evidence of severe hunting or poaching possibly due to the law imposed against hunting in 1982 by Himachal Pradesh Government and also due to declaration of National Park. The final notification given on 23rd June 1999 is, however, expected to diffuse at least part of the above problems in due course of time.

2.6. Administrative units

GHNP is divided into three forest ranges namely Tirthan, Sainj and Jiwa. However, the whole area is further divided into several smaller, manageable units called 'beats'. Each range covers the respective catchment areas, which form part of Great Himalayan National Park, Tirthan Wildlife Sanctuary, Sainj Wildlife Sanctuary and ecozone (Fig. 2.1). Although ecodevelopement area as such does not have any legal validity, some of the forests have been designated as reserved forest and second-class Protected Forest. Apart from bridal paths managed by graziers and the Park management, there is no network of motor roads inside the Park. There are few patrolling huts available inside the area, which help accommodating at least four persons at a time. Landslides caused by heavy monsoon rain prevent accessibility to the park during the rainy season. Upper ridges cannot be approached during winter due to heavy snow up to 2m depths.

2.7. Intensive study area

Several aspects of the study did not require the entire area of GHNP, instead warranted a manageable representative area. Accordingly, a 16-km^2 area was identified in Tirthan valley based on reconnaissance surveys and field study conducted in this area on mammals (Ramesh and Sathyakumar 1997). It was ensured that the area supports substantial population of the study species and has less human intervention. Besides, it has maximum possible representation of GHNP in terms of vegetation composition and topography. The intensive study area lies in the National Park area with close proximity to ecozone in Tirthan valley (Fig. 2.1). The river Tirthan flows down in the southern part of the area and forms the boundary of Rekhundi Second-class Protected Forest on the north and Rolla Reserved Forest on the south. Excepting for the people of three villages (Dhar, Shungcha and Shalinga) who have resource use rights in Rekhundi Forest, no other people have legal rights for resource use in the intensive study area (Nangia et al. 1999). Nevertheless, the local people had unrestricted access to resources in the area till the final notification of the park on 23rd June 1999, which prevented open access to the people.

The altitude of the intensive study area ranges between 1,890 and 3,710m. Majority of the area (87%), however, falls between 2150 and 3450 elevation (Fig. 2.4). Temperate and sub alpine regions that provide ideal habitats for pheasants are represented by 67.9% and 31.5% respectively (Fig. 2.4). Alpine region with only 0.6% is under-represented in the intensive study area. In comparison, GHNP as a whole has only 32% under Temperate Zone, while 13% fall in sub alpine region. Although the intensive study area supports diverse aspects, north-facing slopes dominate the topography. Southeast, south and southwest aspects together account for 54% of the total 16 km^2 in intensive study area (Fig. 2.5). The slopes are largely gentle and only 18% of the area have above 51-degree slope (Fig.2.5).

Significantly, the intensive study area has 70% of its land covered by closed canopy forests (Fig. 2.6). It is uncommon that even south facing slopes support substantial forests, which are otherwise expected to have dry environment due to direct solar radiation. This unique feature has perhaps been influenced by the high hill shade compounded with high drainage density in this area (Fig. 2.7). The plant communities here are mostly of temperate types. Five major vegetation types have been recognized based on remote sensing data (Figure 2.6). However empirical data collected during the study period reveals that there are 15 plant communities in the intensive study area (Singh and Rawat 1999). The kharsu oak and blue pine trees with 40.2 and 36.1 IVI (Important Value Index) respectively dominate the tree species.

Figure 2.4. Area distribution of climatic zones and elevation categories in the intensive study area

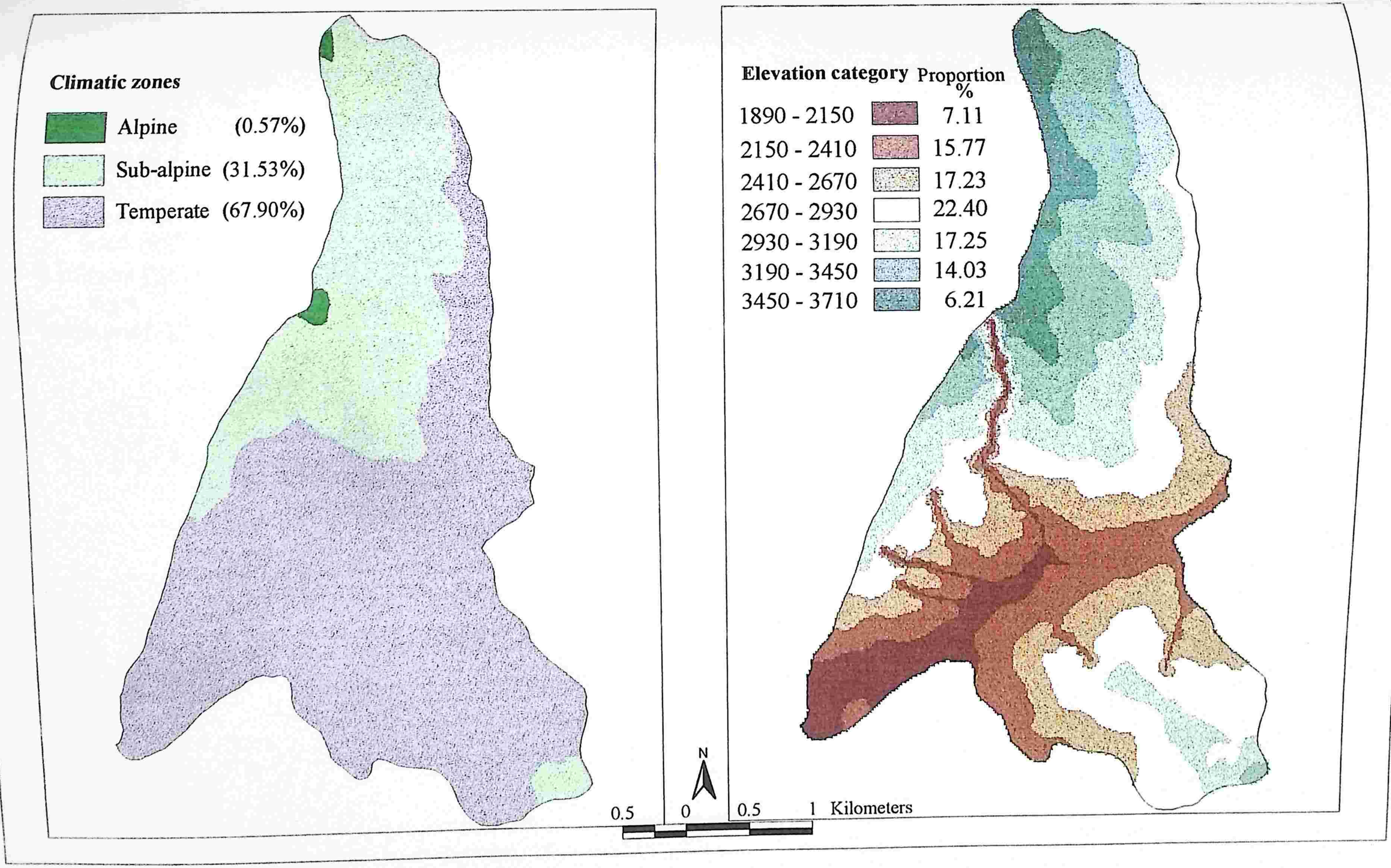


Figure **2.5. Area distribution of slope and aspect categories in the intensive study area**

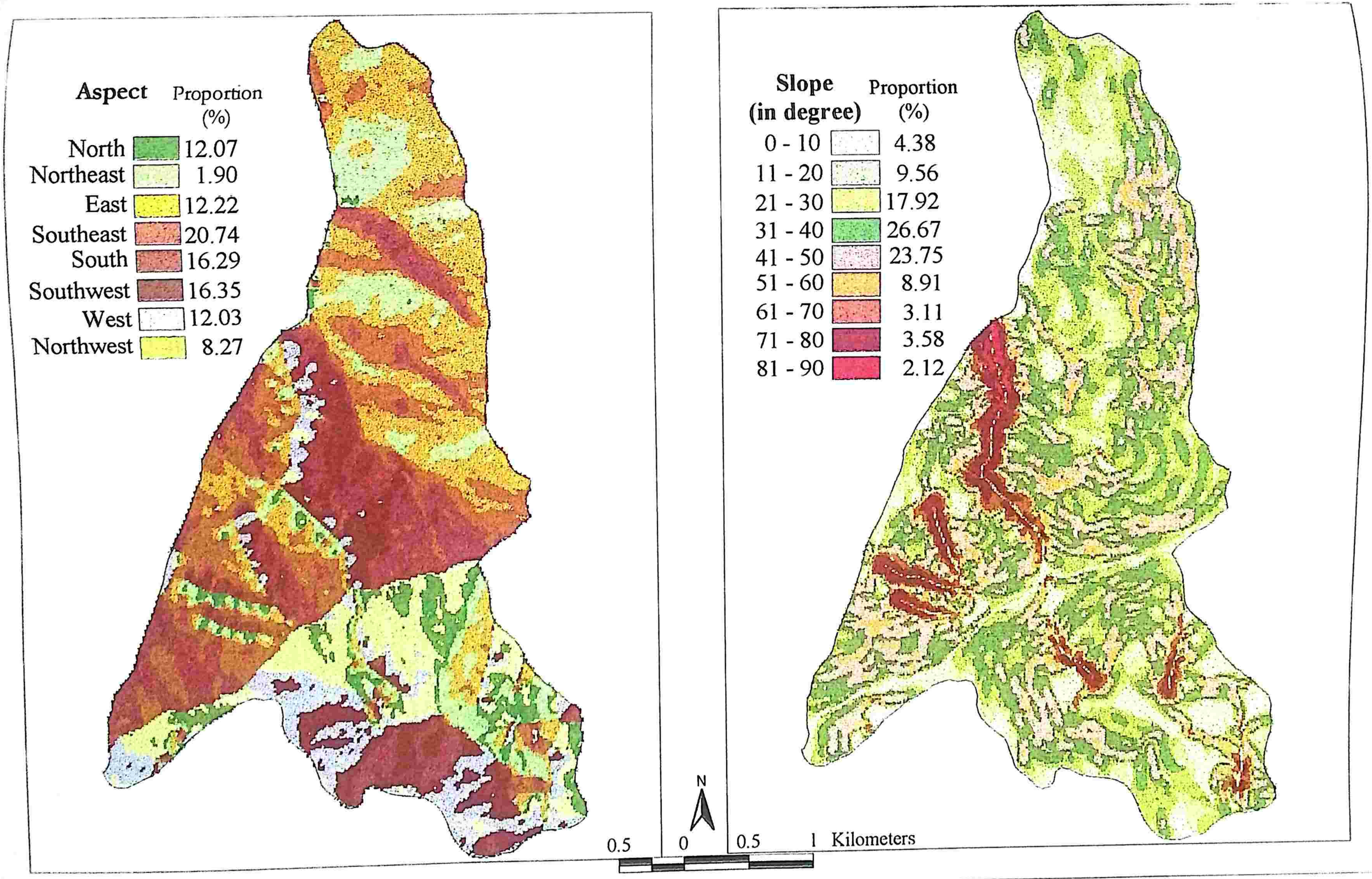


Figure 2.6. Vegetation characteristics of the intensive study area

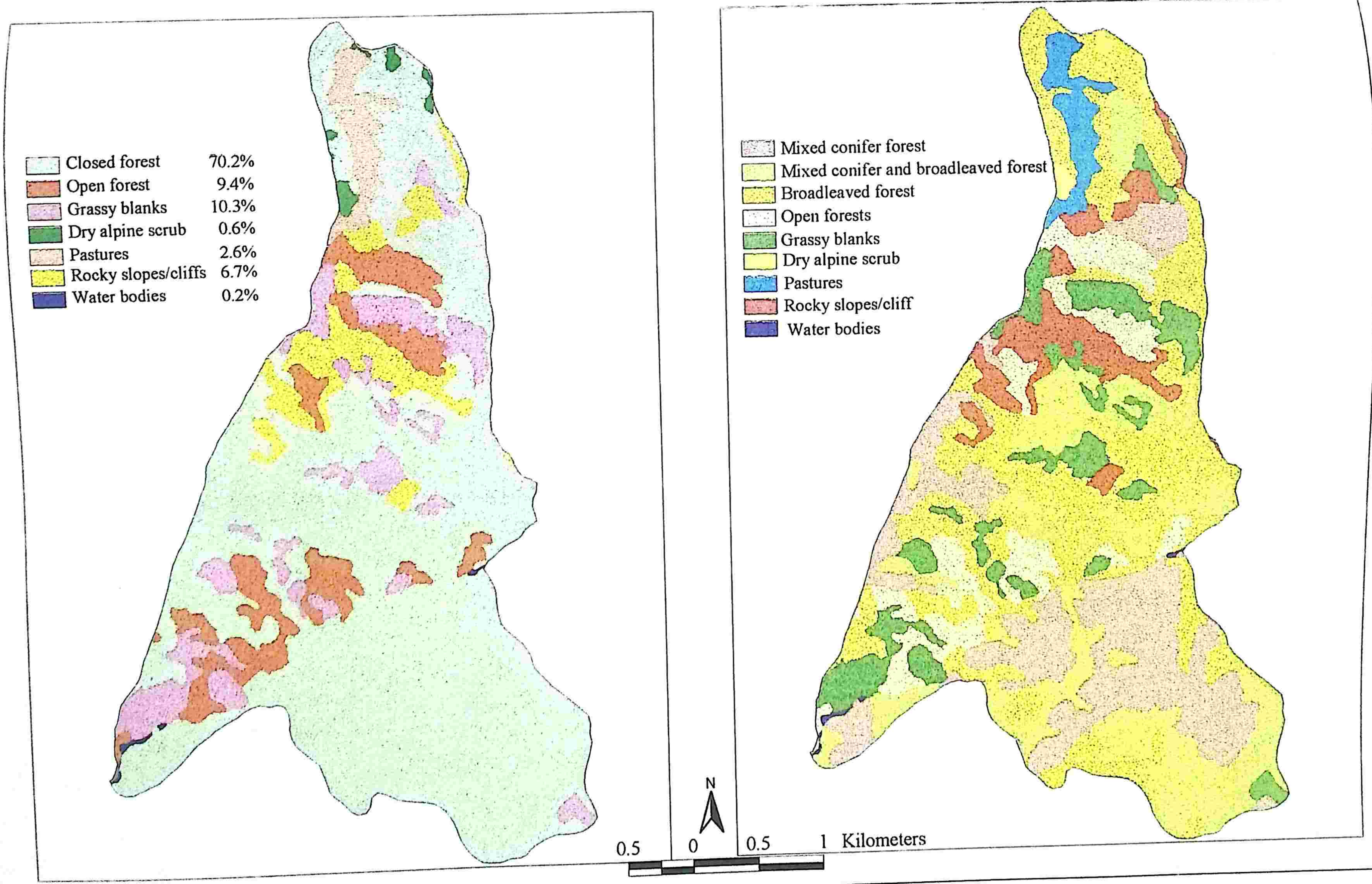
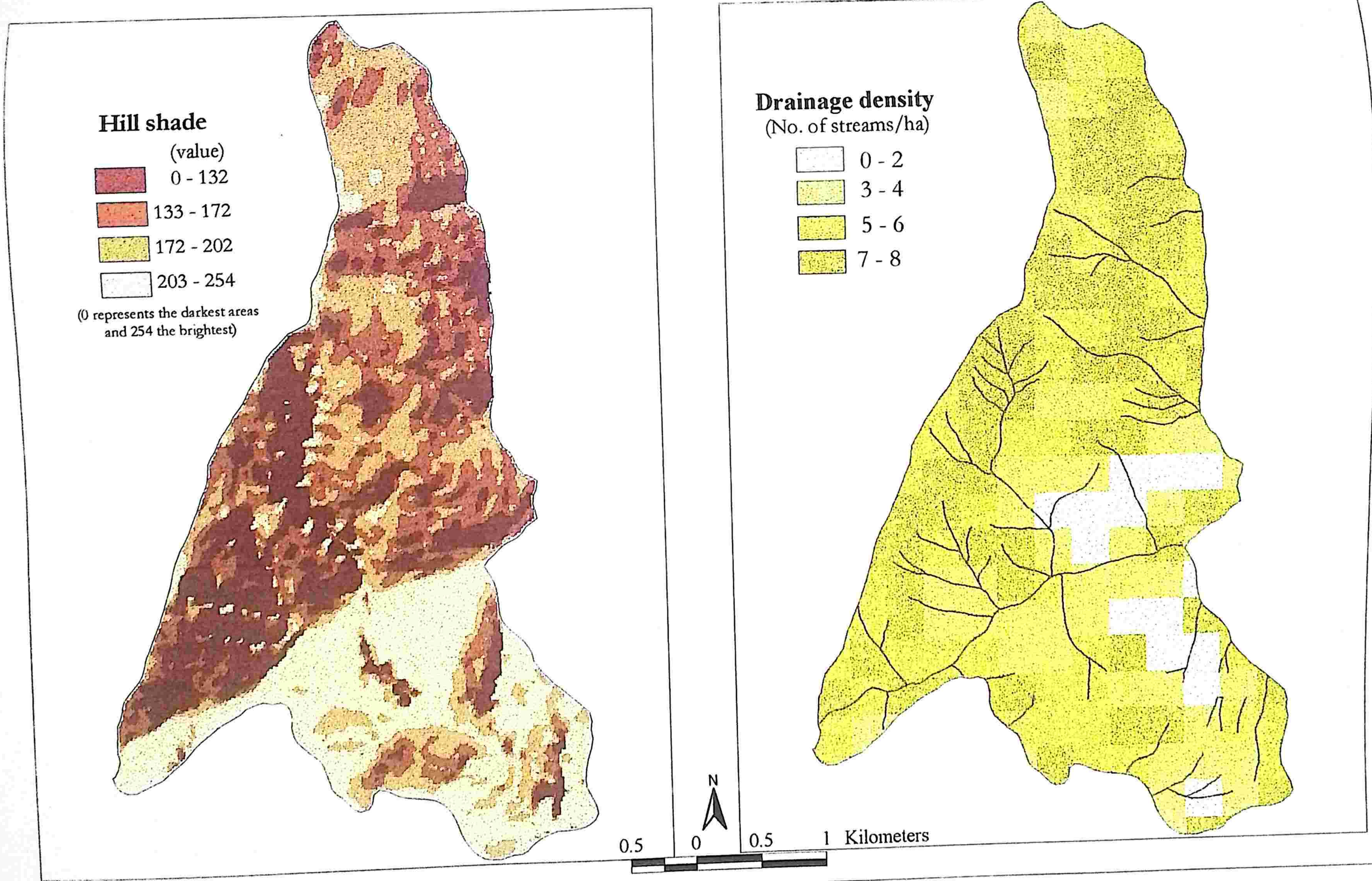
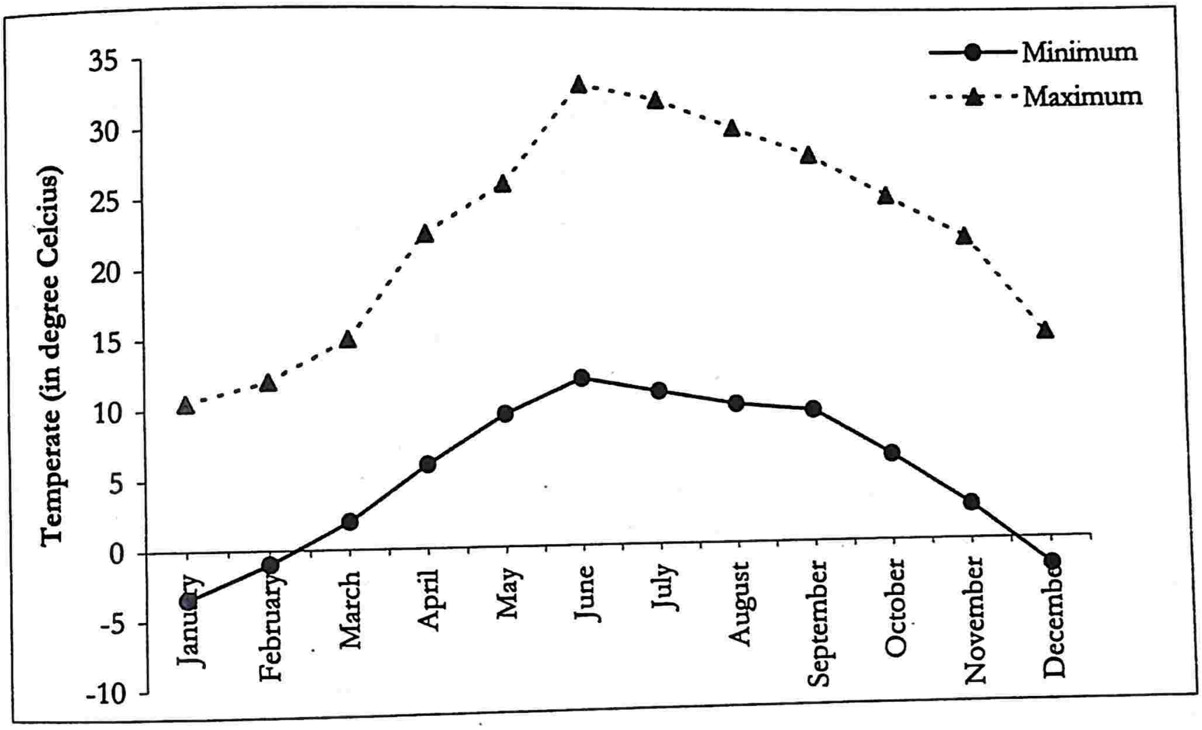


Figure 2.7. Hill shade and drainage density in the intensive study area



The temperature showed high fluctuation depending on the local climatic condition and varied from -3.5° C to +33.1°C during the entire study period. However the mean minimum and maximum temperature followed a steady pattern as shown in Fig. 2.8.

Figure 2.8. Mean monthly temperature recorded at Rolla (2000m) in the intensive study area during 1996-1999



CHAPTER 3

STUDY DESIGN AND METHODS

3.1. Introduction

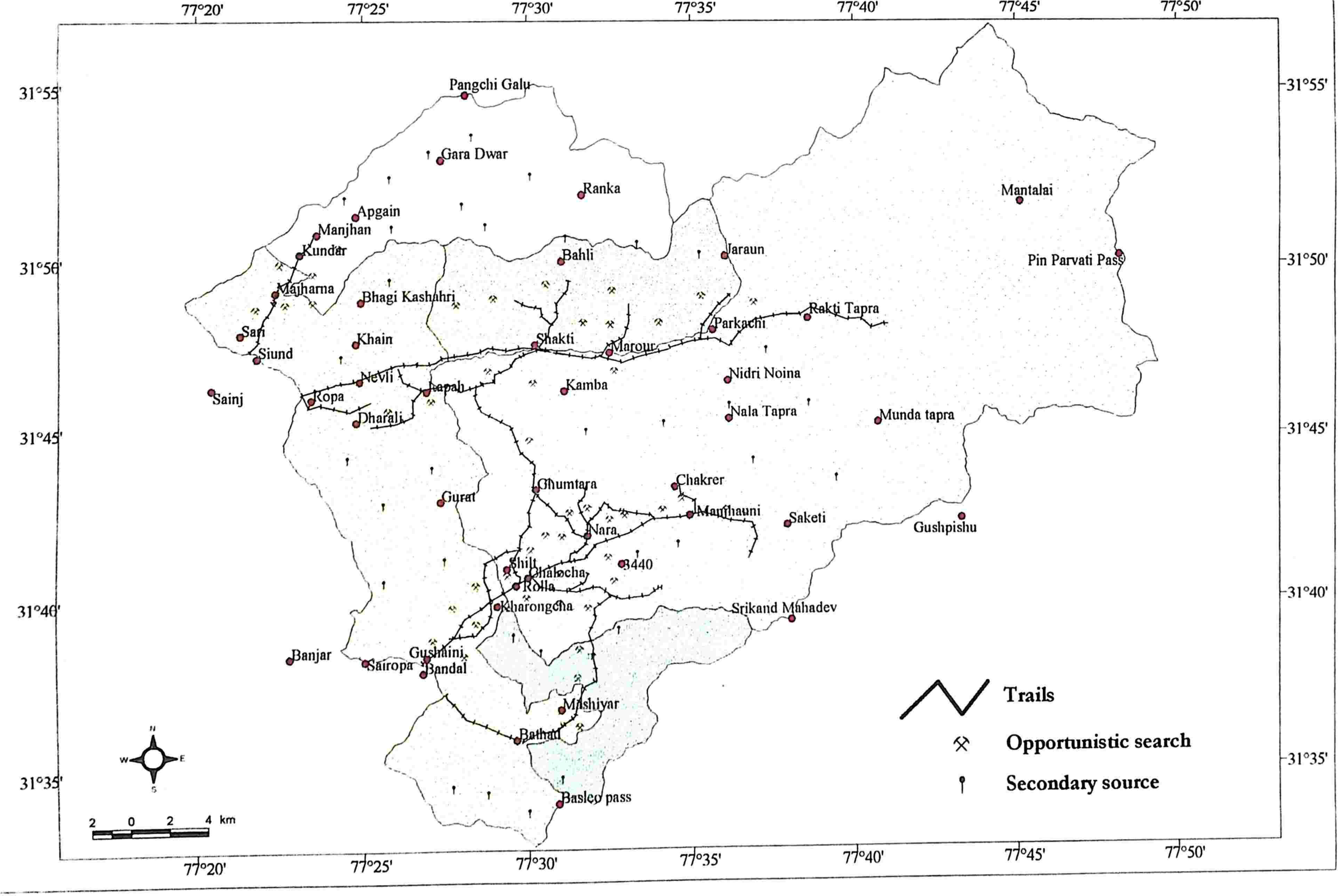
There has been considerable advancement in the field of wildlife ecology during the past few decades with several workers attempting to develop new methods and redefining the existing ones to acquire reliable empirical data. As a result, several standardized techniques are now available to study ecology of birds (Emlen 1956, James and Shugart 1970, Muller-Dembois and Ellenberg 1974, Caughley 1977, Burnham et al. 1980, Anderson and Ohmart 1981, Manuwal and Carey 1991, Bibby et al. 1992, etc). However, with the exception of ring-necked pheasant that has been well studied in Europe and America, studies on all other pheasant species particularly in their native range have proved to be challenging. Ring-necked pheasants occur in high densities and in relatively open habitats, and using advanced technologies such as radio-telemetry, the pheasant biologists have been able to accumulate finer details of ecology and behaviour of this species (Hill and Robertson 1988). In contrast, many of the pheasants found in Asia live in closed canopy, were secretive, with small populations and more significantly, these birds inhabit tough terrain in the mountains. These factors have collectively posed constraint to plan and execute studies effectively and more over, there is incredible variation among individual species in behaviour and microhabitat selection, which further limits the scope of applying a common sampling protocol. For example, in the present case, Himalayan monal is more conspicuous and take relatively extended flight when disturbed. Koklass is very secretive, living mostly in closed environment and their abundance can effectively be assessed only during the breeding season when the males indulge in vocal advertisement. Western tragopan though secretive, does reveal its presence by responding with alarm call and the males give loud calls during breeding season. However, low density compounded with its preference for well-developed understorey precludes direct sighting of the species. Studies involving more than one such species, therefore, require additional efforts and demand field techniques targeting individual species separately. The present study has involved a combination of field techniques, both common and species specific ones and this chapter present an overview of the approaches made to answer the study objectives. Further elaboration and in-depth analysis of the methods (both field and analytical) pertaining to individual objectives and species are given in the respective chapters.

3.2. Study design

This study was attempted on three broad approaches, with each complementing the other either during field sampling or analysis phases, and included specific field sampling protocol for individual species. The three approaches are 1) field sampling at predetermined intensive study site for assessing count techniques and to estimate relative abundance, 2) associative approach that is to establish relationship between the study species and the bio-physical characteristics and 3) GIS based spatial modeling. Prior to evolving specific study plans, the entire area of GHNP was extensively surveyed (between October 1995 and December 1996) to select an appropriate intensive study site (Fig. 3.1). The study site was envisaged as the best representative unit in terms of species distribution, abundance, low biotic disturbances and habitat characteristics, and also logistically suited to carry out an intensive study. Consequently, an area of 16 km^2 was identified in the National Park area within Tirthan valley.

Trails/human use paths already available or maintained by the Forest Department formed basis for field sampling strategy, as cutting of new transects or any other sampling scheme was practically impossible, given the inaccessible nature of terrain and limited resource availability. Sampling plots such as call count stations (details in Chapter 4) and focal bird plots (details in Chapter 5) also depended on the trails. Intensive field sampling was done from April 1997 and March 1999, which included efforts for field validation of count techniques and, data collection for estimating relative abundance and establishing pheasant-habitat associations. Radio-telemetry was involved specifically for western tragopan and was carried out during April-November 1999. Field sampling was extended in winter 2000 to collect data on relative abundance so as to provide additional data point for assessing relative

Figure 3.1. Efforts for identifying intensive study site and for generating distribution maps for the study species



abundance over years. Grid based study scheme was adopted for spatial modeling using GIS and a model developed based on data from intensive study sites was extrapolated for the landscape unit (see chapter 6 for details).

The intensive study area was stratified into different habitat types represented by various elevation, slope and aspect categories. Trails were identified (Fig. 3.2, Table 3.1) within the habitat types, and if the trail extended to another habitat (which was largely the case), the trails were divided to represent different habitat types and sampling was restricted to particular habitat type. Extensive surveys and opportunistic searches were also made within the intensive study area and also in other parts of GHNP to collect additional information on space use and group size characteristics of these species (Fig. 3.1).

Figure 3.2. Location of trails (available and sampled) and call count stations in the intensive study site

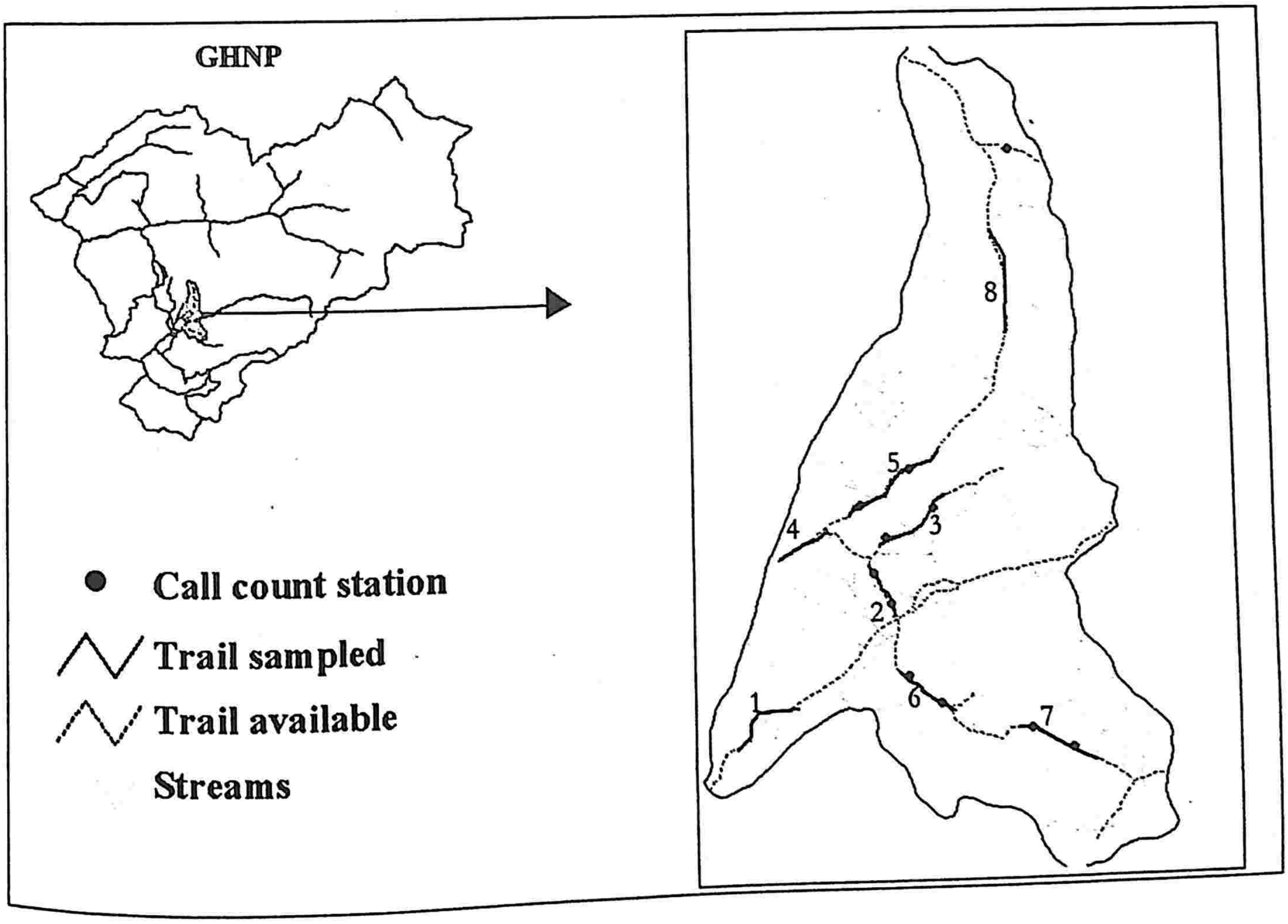


Table 3.1. Characteristics of trails in the intensive study site
(* - *Discarded transects*).

Trail No.	Trail Name	Dominant vegetation type	Length (Km)	Elevation (m)	Aspect
1*	Karoangcha	Broad-leaf forest	1	1600-1800	South
2	Rolla	Broad-leaf forest	1	2290-2640	South East
3	Dulunga	Mixed broad leaf and conifer forest	1	2700-2770	East
4	Shilt	Mixed broad leaf and conifer forest	0.7	2900-2920	South
5	Chordhuar	Sub alpine oak forest	1.2	2900-3010	South
6	Basu	Conifer forest	1	2420-2655	North
7	Koilipoi	Conifer forest	1	2710-2870	South East
8*	Gumtharao	Alpine	1	3200-3300	South East

3.3. Methods

3.3.1. Field methods

Trail walk, call count and spot mapping were the basic data collection strategies for field testing count techniques and estimating relative abundance (see Chapter 4 for details). The identified trails (Fig. 3.2, Table 3.1) were walked in morning hours within the standardized time schedule (one hour per km and sampling of 2 hours from sunrise) and data on bird species, number, sex, composition, sighting angle and sighting distance were recorded. Koklass and western tragopan that are more secretive, but produce advertisement/breeding calls, were counted also from fixed and open radius circular plots laid at 500m interval along the trail. The trails inclusive of call count stations were sampled sequentially so that time gap between sampling plots/trails would be constant. Locations of western tragopan recorded from direct count during trail walk and opportunistic searches, and call count were plotted on a map. Description to habitat association was attempted at hierarchical scales, represented by major vegetation types, elevation, aspect and slope categories at macroscale and the microhabitat features that formed immediate environment of the pheasants at a microscale. Abundance derived from the data collected based on trail walk and call count was related with the macrohabitat features, while microhabitat variables were quantified at the location where the bird was found feeding/resting. Efforts were concentrated within the intensive study area to trap and radiocollar western tragopan, as a means to gather maximum possible information on the rare bird. Locally designed live traps were used to capture the birds and radiolocations were obtained based on triangulation and modified home-in methods (Chapter 5 for details). Field data on sighting locations were plotted on 1:50,000 scale topographic maps for GIS based spatial analysis.

Sampling efforts and intensity: Field data collection was done fortnightly in all months except monsoon (because of difficulties in accessing field due to landslides and also bird detection was highly biased in rainy days in this season). Eight trials were initially identified for sampling, but the trails in alpine meadows and lower altitude (<1800m) were later discarded due to virtual absence of the study species (Fig. 3.2, Table 3.1). However, the six trails ranging from 0.7 to 1.2 km. constituted 70% of the total trails available within potential pheasant habitat in the intensive study area. Ten call-count stations were established on the trails (maximum of two stations per trail) and sampling was done twice a month during early part of breeding season when the males were calling. These efforts together translated into 6 replicate trails and 36 pseudo-replicates/repeated measures per seasons or a total of 214 km of sampling intensity within the intensive study area in the two years. Similarly, the total sampling intensity for the call counts from 10 calling station with minimum radius of 300m and sampled twice a month (total of 40 measures, as majority of the calling was in April and May) accounted for minimum of 2260 ha efforts in the two years. In addition, trails were also walked during winter 1996 and 2000.

Measurement of habitat and environmental variables: Materials used to measure/ quantify various habitat and environment variables are as follows;

1. Altimeter with 1m accuracy for Altitude.
2. Sunnto compass with 1° accuracy for sighting angle and aspect categories
3. Slope and canopy cover by ocular estimation.

4. Digital thermometer with the range between -10°C and 50°C for temperature measurement.
5. Spring balance weighing a maximum of 1 kg for soil (wet & dry) weights.
6. Anemometer for wind velocity.
7. Binoculars - 7 x 36 for field identification of the birds.
8. SLR Camera with 35 - 70 mm lens for recording purposes.
9. Spatial variables include (a) vegetation types - classified from IRS/LISSII/ FCC- 36.5m pixel, (b) Normalized Difference Vegetation Index - IRS LISSIII digital data – 23.5m pixel, (c) Digital Elevation Model (DEM) derived from contour, (d) Aspect - derived from DEM, (e) Slope - derived from DEM and (f) Distance to water – measured from drainage map.

3.3.2. Analytical methods

Count data from trail walk and call count was pooled to calculate abundance index based on detection rate/encounter rate *i.e.* number of birds seen per km distance or number of calling males per call count station (Caughley 1977). Density (number/km^2) was also computed from trail walk and call count. Non parametric statistical techniques such as One-way ANOVA, Kruskal-Wallis test, Mann-whiney U test and Wilcoxon Sign Rank test were performed using statistical software SPSS 8.0 for windows for comparing encounter rates across localities, habitat, seasons and years. Ninety five percent Confidence Limit was also computed and plotted graphically for comparison of abundance estimates and mean group sizes. Descriptive statistics was computed for macro and microhabitat variables. Relative use of macrohabitat features were assessed based on graphical representation, while Classification Tree (De'ath and Fabricius 2000) was constructed for describing microhabitat association of the pheasants. Boolean logic (or rule based model) and logistic regression (predictive or probabilistic model) were adopted for spatial analysis using GIS software such as Arc/Info and Arcview.

3.4. Organization of fieldwork

Fieldwork for the whole study was operated from one Base Camp (located at Banjar, Kullu District, Himachal Pradesh) and two field stations, one at Rolla (ca. 2000m) and another at Shilt (ca. 3000m), both in Tirthan valley. On an average of 22 days in a month was spent in the field, which amounted to 396 days of fieldwork (excluding monsoon) from April 1997 to March 1999. Surveys (reconnaissance and between intensive study) in other parts of GHNP and trail walk in 1996 and 2000 included additional 105 days of fieldwork. During the telemetry study, transition camps were established in three localities (Shilt, Chordhuar and Grahani) and trapping was attempted for 90 days between April and June 1999. Radiotracking was continued till November 1999 with average field working days of 15, contributing to a total of 75 days between July and November 1999. Camped at Rolla field station, fieldwork was conducted in Rolla, Basu and Dulunga trails. Fieldwork for Chordhuar and Shilt trails was conducted from Shilt field station and for other trails, tents and patrolling huts were used. Two local men were hired to assist in the fieldwork during intensive study period and two more during trapping.

3.5. Limitations of the study

Sampling was limited by steep and rugged terrain compounded with harsh climatic condition and hence, the methods that are used in plains could not be adopted. Selection of desired number of replicates and sampling at random fashion was not feasible and had to solely depend n the existing trails. More over, the available trails were very few and it was difficult to arrive at a reliable population mean of the estimates. Consequently, there was an element of uncertainty in establishing strong relationship with the pheasants and the biophysical characters and therefore, wider extrapolations of the observed pattern need to be done accordingly and may be viewed that it is limited to the study area. Also, the study was carried out in one of the better areas in GHNP in terms of abundance and habitat quality and the results essentially provide an overestimate of abundance of these species.

CHAPTER 4.

COUNT TECHNIQUES AND ABUNDANCE

4.1. Introduction

How many individuals are there in this area? Is the population stable, increasing or decreasing? These are among the basic and crucial questions that concern most wildlife managers and conservationists. When wildlife populations suffer deterministic decline due to sustained pressure or stochastic events, it is of high conservation concern. More so, because if populations decline to critical levels it reduce genetic variation leading to genetic drift, genetic bottlenecks, inbreeding and related problems, which can potentially drive the species to extinction (Caughley 1994). In this context, the information on population parameters of the species (e.g. total or relative numbers/abundance or densities) becomes imperative for conservation and management inputs. Ecologists relate the abundance values with the biotic and abiotic features as a means to understand the patterns of space and time use by species (e.g. Begon 1979, Blower et al. 1981). What causes the species to be at high or low densities in one area than others? What makes the population to fluctuate? Ecologists or conservation biologists are interested in such questions and more often, the abundance provides the basis for hypotheses testing.

The number of individuals of a species in an area is generally assumed to be strongly associated with the size of the geographical range of the species, availability of suitable habitat and the mean density achieved by the species (Newton 1998). Specifically, the ultimate factors such as food supply, competitors, disturbance, predators and parasites, and consequent demographic characteristics such as birth and death rates, immigration, emigration and population structure largely determine the abundance. Therefore, any strategy that deals with studying the species ecology or evolving conservation plans entail appropriate design that can accurately capture the functional attributes of the abundance. It is this necessity that drives biologists to be concerned about properly estimating populations and has lead to consideration of censusing methodology and analysis in greater detail (Wiens and Rotenberry 1981). Selection of appropriate count techniques has always been considered a methodological problem, and it is more so for the species that are mobile and inconspicuous having wide distribution. Counting all the individuals of a species in an area is often difficult or impossible and in some cases, expensive and inefficient. Further, the estimates obtained for the free ranging species are expected to have considerable amount of error due to inherent variation in the distribution patterns and behaviour of the species, and also due to inaccessible habitat condition that hinders proper sampling. These impediments have necessitated the development of several practical count methods and there have been specific count methods developed for specific species and for specific conditions. The approaches include direct counts based on directly spotting the species or recording indirect evidences such as tracks, droppings, calls, nest sites, etc, which have varying efficiency and reliability. These techniques range from a simple count by walking on an existing trail to highly expensive and sophisticated aerial surveys. Nevertheless, an acceptable method is always the one that is reasonably efficient to use in the field, provides relatively reliable results and rely upon as few assumptions as possible (Franzreb 1981).

Depending on the study question and necessity, the abundance is measured as either total count (the number of animals in a population) or absolute density (number of animals per unit area) or relative density (density of one population relative to another) (Caughley 1977). Unless it is very important (for instance, need to know the number of rare species with very small population size), total count is often unnecessary given the efforts and money required for such attempts, and also cause greater disturbance to the study population. On the other hand, the same question can be answered based on relative measurements that would require substantially less efforts and money. Information on the relative abundance of species with respect to various habitats or on temporal scale would be sufficient for management and conservation planning. In such a situation, the relative measurements provide an index to the population size (Bull 1981). It is also possible to use indirect signs of animals as an index of the abundance and thereby, to be able to understand relative use of habitat by the species.

In the development of censusing methodology, birds have contributed significantly by providing ample opportunities and challenges. Their conspicuous nature (both vocal and readily detectable plumage pattern), large flock size and living in open habitats have provided easy option to develop and validate several count techniques. Species that skulk, are camouflaged, prefer closed habitats or highly mobile have posed challenge in terms of obtaining an unbiased estimate of abundance. Pheasants represent one such group. Despite their large body size, conspicuous plumage pattern and ground dwelling habit, estimating their abundance in their natural habitat has been full of challenges. Inhabiting a high altitude environment, which is characterized by undulating, rugged terrain and harsh climatic conditions, the Himalayan pheasants defy reliable population estimates. Besides, these birds are very sensitive to human presence and have the habit of either flushing at greater distances or skulking under bush, which further complicate issues.

Gaston (1980) has provided a comprehensive account on count methods for Himalayan pheasants. However, the effectiveness of these methods is highly variable depending on the local topography and behaviour of the individual bird species. Several studies on Galliformes have used the methodologies employed in the western countries to study quails and ring-necked pheasants. Some of these techniques require further validation and standardization for the Himalayan pheasants, particularly for the ones that thrive in the rugged and inaccessible areas. During the present study, attempts were made to identify appropriate count methods for the study species, and using the efficient methods, abundance estimates were obtained for these species across localities, seasons and years.

With the exception of a few species, the pheasants are generally seen as group living birds interacting with other individuals at least during some time of a year. Himalayan pheasants, in particular, display such behavioral patterns with varying group size, group composition and sex ratio in response to climatic changes. Most of the Himalayan pheasants are reported to form flocks during the winter. Living in groups arguably benefits the birds in great deal to procure food more easily and helps in minimizing the risk of predation (Hill and Robertson 1988). Changes in the group size and sex ratio provide an insight to the interacting nature of the population and would augment the cope for further management implications. Research work on this aspect of ecology is deficient for Himalayan pheasants and the available information is confined to limited seasons (Kaul 1989, Islam and Crawford 1993, Sathyakumar et al. 1993 and Kumar 1997). Though it is not the main part of the thesis, attempts were made to document group size characteristics of the species in this area.

In brief, this chapter attempts to answer the following basic questions pertaining to abundance and social organization of the three pheasant species.

1. What are the appropriate count methods for the study species?
2. How variable the pheasant abundance in space and time, and between species?
3. What are the group size characteristics of the species and are there any apparent variations in these characteristics between seasons?

4.2. Methods

The methods described by Bibby et al. (1992) and, Manuwal and Carey (1991) for main land birds and those by Gaston (1980) for Himalayan pheasants were taken into consideration while designing methods to estimate the abundance of the species. Line transect (both fixed width and open width), point count and spot mapping methods were the options available. Though mark-resighting technique was another potential method, the efforts involved in terms of trapping the birds or color marking by any other means made this option extremely difficult to include in this study. Utility and effectiveness of the above methods considered in this study have been discussed below.

4.2.1. Open-width line transect

The line transect method involves walking on a straight line and counting the individuals on both sides of the line. Burnham et al. (1980, 1981) has given a detailed account of this method. It is proven that this technique is effective and gives unbiased estimate of abundance only when the associated assumptions are addressed adequately and appropriately. Burnham et al. (1981) lists four basic assumptions involved in this technique; 1) ***Animals directly on or very near to the line will always be detected,*** 2) ***There is no movement of animals in response to the observer and none are counted more than once during a given transect walk,*** 3) ***All distances and sighting angle can be measured accurately,*** and 4) ***Sightings of different individuals are statistically independent events.*** Since the mountainous landscapes do not support linear transects, it is not possible to obtain accurate distance measurements. The assumptions associated with the line transect method were further violated by the behaviour of the study species. Koklass and western tragopan have the habit of skulking under the bush or running upwards to evade the observer. This is likely to result in high variation in detection and chances of double counts. Himalayan monal, on being disturbed or sensing the presence of observer, not only flush at greater distances, but also influence the other birds with their loud alarm calls, thus making the detection biased. It was due to these reasons, the line transect was ruled out in this study.

4.2.2. Closed width line transect or strip transect

After considerable amount of fieldwork, it was evident that strip transect can produce useful estimates of abundance for Himalayan monal. Like line transect, the strip transect deploys the following assumptions (Bibby et al 1992). 1) ***All birds within the strip are detected,*** 2) ***No bird moves into or out of the strip in response to the observer's presence before being detected,*** 3) ***No bird is counted*** *more than once during the same transect walk,* and 4) ***Detections are independent events***. Use of this method for counting koklass and western tragopan involves a lot of uncertainty, as these birds are likely to be missed within the strip because of their characteristic behaviour of skulking or running uphill. Further, their secretive behaviour posed difficulties to establish whether or not the birds moved out of the strip or if they were counted twice. Therefore, this technique was found unsuitable for these species. On the other hand, Himalayan monal is highly conspicuous from bright colored plumage and group living habit and their behaviour to give alarm call in response to even slightest of disturbance. This meets the assumption 1. When disturbed, they fly off from the feeding/resting area, but will make a characteristic semi-circular flight at down slopes and most often would return towards the same habitat types. This essentially qualifies for the second assumption that the birds do not move out of the strip. Since the birds move down wards, there is less likelihood that they will be counted twice during the same transect walk. However, there was a problem in obtaining independent sightings wherever the population was in high densities and also it was not possible to accurately measure the transect width in the rugged terrain. It required considerable amount of experience in the field to over come these problems, and hence this method was used only to estimate the overall density of Himalayan monal, and was not used for relative abundance.

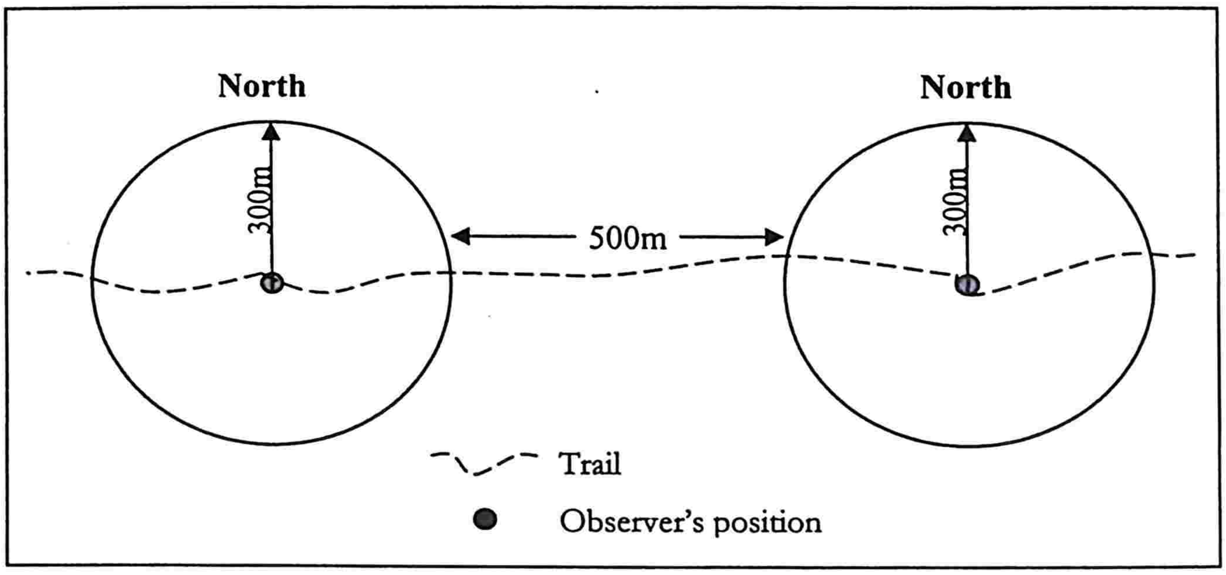
4.2.3. Trail count

Bird count along existing trails is a useful alternative when there are difficulties in employing line transect methods. Simple count with an estimate of efforts (either distance or time) will produce a reliable index of abundance. The most commonly used abundance index is **Encounter rate**, which is expressed as number of individuals counted per unit effort (Caughley, 1977). In this case, distance was used as the sample effort and the encounter rate estimate was obtained using the formula, Encounter rate = n / L, where as n = Number of sightings and L = Distance involved. Encounter rate was also estimated for calling birds as described in the point count/call count methods below. The usage of this technique for estimating and monitoring population trends of Galliformes has been common since the recent past (Islam 1982, Gaston and Garson 1992, Kaul and Ahmed 1993 and Sathyakumar et al. 1993). However, use of encounter rate for describing relative abundance is arguably problematic if the detection probability is significantly variable across space and time. This is often the case as the visibility in different habitats is likely to vary and also the behavioural responses of the species (for instance, secretive birds) hinder equal probability of being sighted. However, this method is still effective for monitoring the trend in abundance and for conspicuous species as the bias caused by the visibility factor or differential detection probability is largely taken care of or is constant over repeated counts. The bias is expected to be consistent when the count is repeated on the same trail during the same period of a year, and the conspicuous species is less likely to be missed (for example, loud alarm call by Himalayan monal) regardless of the differences in the visibility.

4.2.4. Point counts or call counts

In this method, the birds are counted from a predetermined point and the radius within which the counts will be made are kept either fixed (known as ***Fixed-radius circular plot***) or variable (known as ***Variable-radius circular plot***) depending on the objective of the study or applicability of the technique. Both the techniques were used to record the relative abundance of calling birds (koklass and western tragopan), which were otherwise difficult to detect. The males produce characteristic loud calls at dawn during their breeding season, as a display mechanism to defend their territory or to attract females for mating. These calls were counted from fixed points (or call-count stations) positioned 500 m apart, and depending on the length of the trail available in a given habitat or strata, more than one calling stations were established for the count (Fig. 4.1). In such cases, starting time of the count was synchronized and for each record of calling, location (distance from the point and direction) of the calling bird and time were marked on the data sheet. These details were necessary to avoid double counts and this also helped in delineating an appropriate radius for enumerating density of the population. Considering the audibility and relative accuracy of recognizing the boundary of the radius, a 300m radius was found to be effective for density estimation. Weather conditions, wind velocity and topographical features such as slope, aspect, altitude etc. were also recorded to control for the variability caused by these potential factors. The observers needed to take their position at the calling station well before first fall of the light, so as to ensure that the birds do not get disturbed by the observer and that the counts were independent.

Figure 4.1. Diagrammatic representation of call count stations



The counts were translated into an abundance index expressed as number of calling males per calling station or point. An estimate of density was also derived from the data. It was assumed that each calling male is likely to be associated with one female bird, and hence, the density estimate was converted for the breeding pair.

4.2.5. Spot mapping

During the breeding season, presence of the territorial birds is usually conspicuous by their characteristic display behaviour, such as songs (crowing in Galliformes), nuptial dance/flight, and some deliberately expose their breeding plumage (which grows only during breeding season) and other body parts. Such birds are easy to detect in the field and systematically plotting of records species occurrence on a gridded spatial map would provide a useful index of relative abundance. This method, known as spot mapping, is useful for territorial birds (Manuwal and Carey 1991). Once the observations obtained through several visits to the locality are marked on the map, territorial boundaries are subsequently delineated to obtain an estimate of abundance, *i.e.* number of territorial males per plot. This method is clearly efficient and can even be used for estimating population size particularly for those birds that maintain small, non-overlapping territories and are monogamous. However, there are several assumptions that need to be considered before employing this technique. They are: 1) ***populations are stable during the time of the study, and that birds remain in territories during sampling period,*** 2) ***birds are correctly identified,*** 3) ***one bird per territory produces a sufficient number of songs to be recorded on successive visits,*** 4) ***an accurate estimate of the population is made of the mean number of birds represented by each cluster, and*** 5) ***observers do not differ in ability to detect and identify birds.*** In this study, it was possible to use this method for western tragopan since the above assumptions were met only for this species. Although this method was not visualized at the beginning of the study, all the observations plotted on a spatial map to generate distribution map were helpful in adopting this method to estimate abundance of western tragopan.

4.2.6. Opportunistic searches

Besides the systematic data collection using the above-described methods, data on abundance and distribution were also collected during visits to different localities. Areas that are not supported by trails were randomly searched for presence and abundance of these species. The efforts spent (either time or distance) were recorded accurately, and such data can still be used to estimate encounter rate. However, results from these data are subject to bias and are not comparable. This is because efforts required for different areas even by the same person are not consistent. Moreover, the observers end up spending more time searching for the path, rather than searching for birds. This data was used mainly to substantiate explanation on spatial and seasonal distributions, and group size characteristics of the pheasants.

4.2.7. Data collection

In order to avoid biases that might arise from temporal movement of the birds, counts were done only in mornings. These morning estimates were most reliable as the birds seen in the mornings in any particular habitat indicate preference for roosting in the area. Six trails and 10 call count stations were identified for sampling and were sampled as described in Chapter 3. Time and walking pace was standardized considering the activity of the birds and steepness of the slopes respectively. For each sighting of the pheasants, data on species, number, sex, sighting distance, sighting angle and flushing distance were recorded for further analysis. For comparisons between different areas, seasons and years, the data was pooled from the sample plots represented in the respective habitat types, seasons and years. A conservative estimate of density was attempted for koklass based on calling males counted within the 300m radius from the center of the sample points. 300m radius was fixed on the basis of field experience that all the males calling within this radius could be mapped and that this radius was found sufficient to obtain a fairly good estimate of density. Observations (both direct and indirect evidences) made on western tragopan during trail walks, call counts and opportunistic searches were plotted on a topographic map for obtaining abundance estimates of the bird based on spot mapping method. Data collected from trail walk and opportunistic searches were synthesized for describing group size and composition of these species.

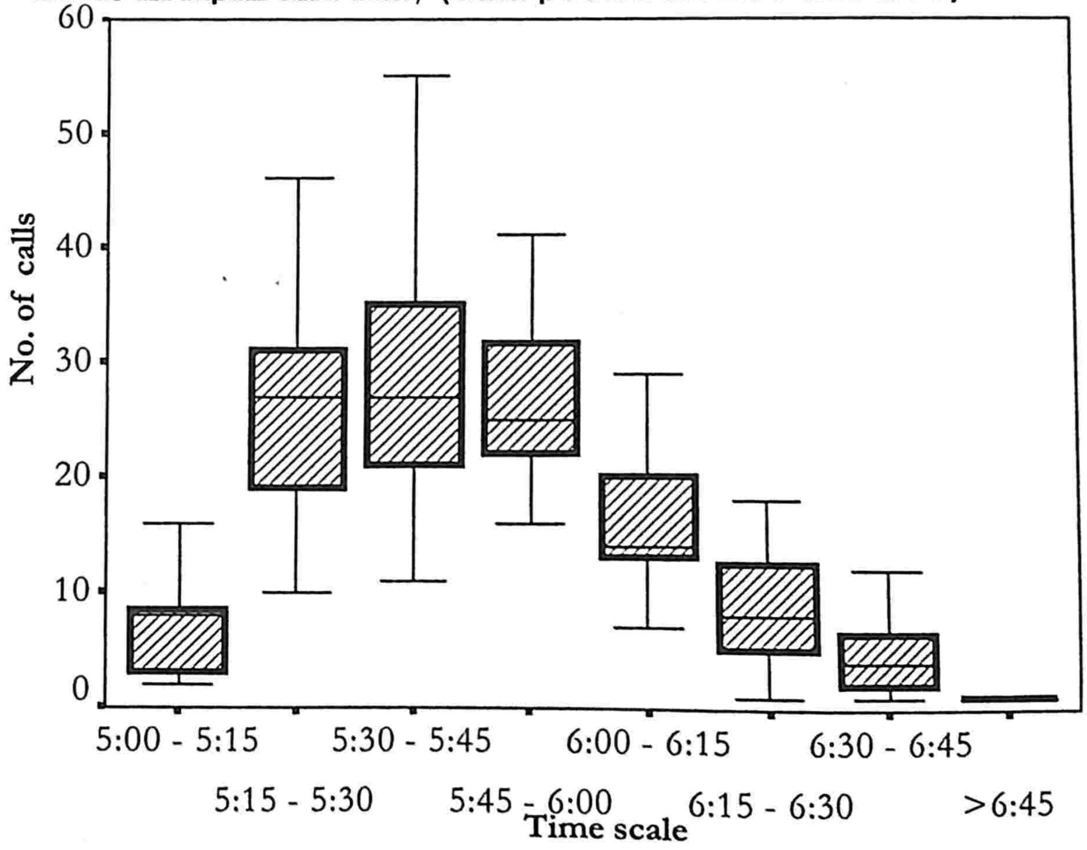
4.3. Results

4.3.1. Count techniques

As discussed in the previous chapters, specialized techniques were required for an effective estimation of relative abundance of these pheasants. Trail count for enumerating the encounter rate was found to be the only efficient method presently available for studying the relative abundance of Himalayan monal. Crude estimate of density was possible using strip transect technique, after having studied the effective strip width for the count.

Call count was found to be the most practical method for estimating relative abundance of koklass. Call count from open width and fixed width provided an index of abundance (i.e. calling males/sampling plot) and a conservative estimate of density (Number/km^2) respectively. Prior to abundance calculation, it was necessary to recognize the effective calling period when call counts would provide unbiased estimate of relative abundance of these calling birds. During the study period, first call of koklass was recorded at 5:05a.m. and the birds continued to call till 7:17 a.m., though less in frequency as the time of the day increased. The crowing was consistently higher between 5:30a.m. and 6:00 a.m. irrespective of the area (Fig.4.2.). Of the total calls recorded (1769) over two years, >800 calls were recorded during this time period, indicating that peak activity of calling was this time period of 5:30-6:00am. The observed pattern of calling was non-linear and significantly negatively correlated with time (Spearman's Correlation, $r = -0.44$, $p < 0.01$). Data collected for the first season (i.e. April 1997) on both call count and trail count was assessed for the efficiency of counting the koklass. The encounter rate obtained based on trail count was significantly lower (mostly less than two birds per km walk) and had high variability across all areas (Fig. 4.3). Call count provided a much higher encounter

Figure 4.2. Frequency of calling by koklass across sampled times in April and May (data pooled for 1997 and 1998)



rate (over 3 calling males/sample point) (Fig.4.4). The higher counts together with low variance suggested that the call count could best represent the number of koklass present in an area more efficiently, and that the results obtained have greater precision.

Figure 4.3. Mean encounter rate of koklass in spring 1997, enumerated based on trail count (Error bar denotes SE)

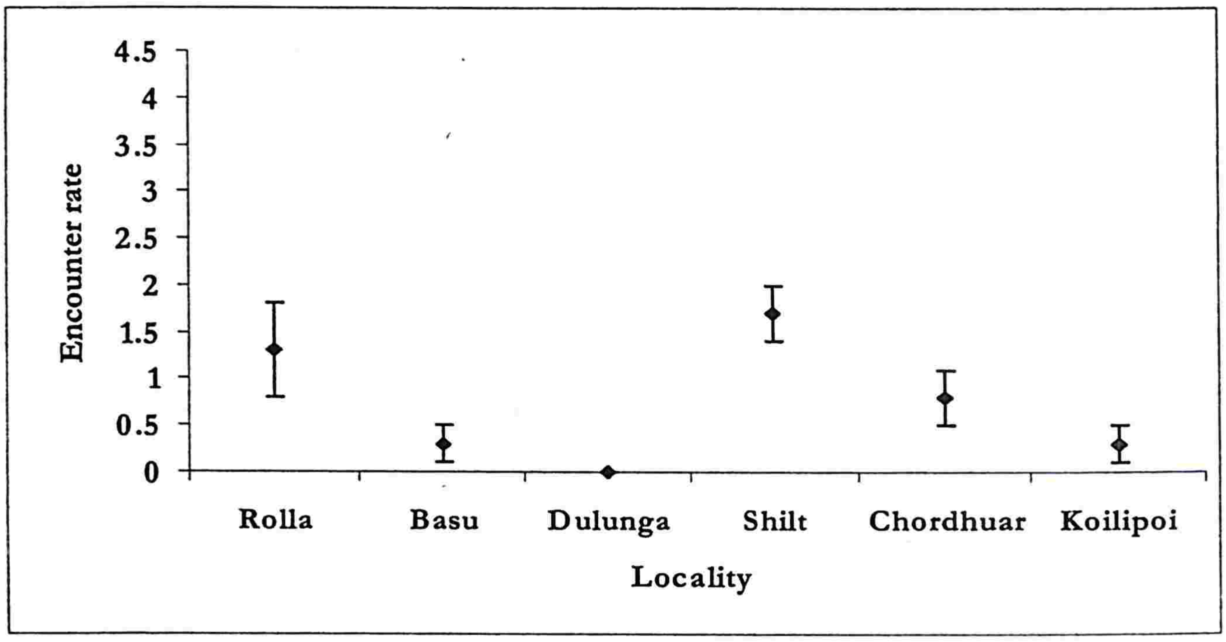
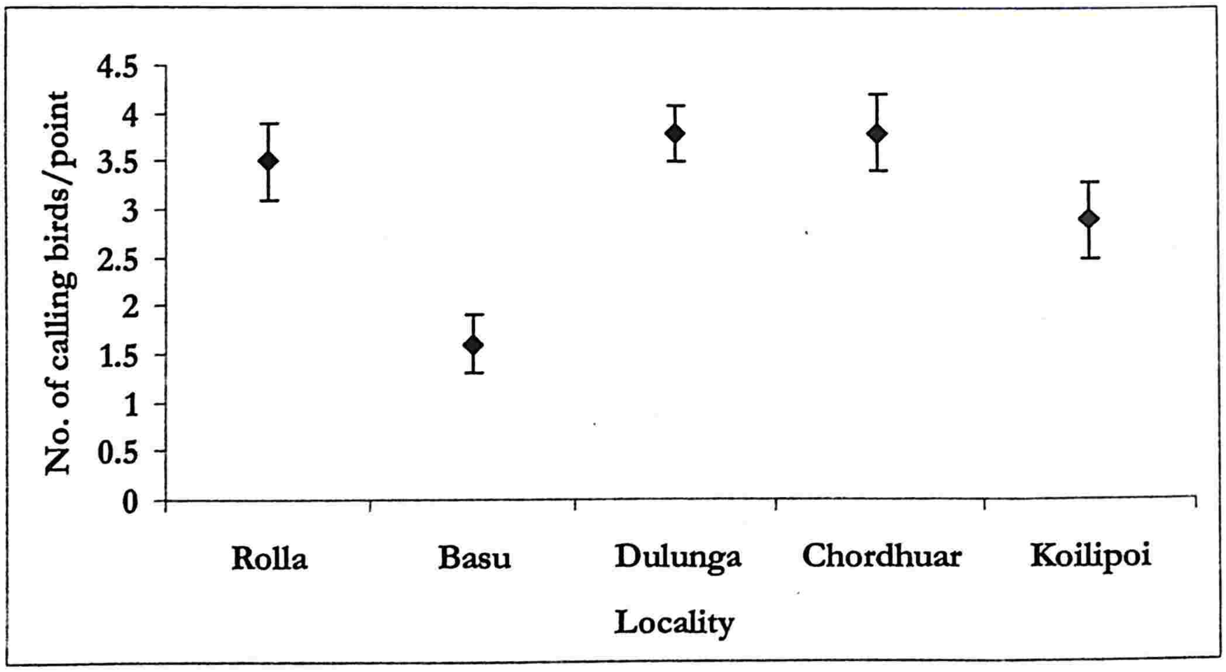


Figure 4.4. Mean encounter rate of koklass in spring 1997, enumerated based on call count (Error bar denotes SE)



Trail count and call count methods were useful in obtaining relative abundance estimate of western tragopan, while spot mapping was found to be suitable for estimating population size of this rare species. Details of the results obtained from different methods have been presented below.

4.3.2. Relative abundance across localities

During the intensive study period between April 1997 and March 1999, there were 320 sightings of Himalayan monal, 90 sightings of koklass and 30 sightings of western tragopan. Opportunistic records accounted for another 204 sightings of Himalayan monal, 36 sightings of koklass and 15 sightings of western tragopan, thus making the total sighting to 524, 126 and 45 respectively.

Himalayan monal: Himalayan monal was the most frequently sighted of all the species during the study. Encounter rates obtained for the Himalayan monal ranged between 0.6 and 6.5 birds/km, with a pooled mean of 2.5 (± 0.26 SE, $n = 35$) birds/km. Each of the trails sampled did represent different localities as given in the Table 4.1. Encounter rate obtained for these trails indicated variability in the abundance of the study pheasants in these localities. Trails in Chordhuar and Dulunga area accounted for relatively high encounter rate in all the three seasons studied (Table 4.2). The differences in the encounter rate between the localities were observed to be statistically significant in spring (One Way ANOVA, $F = 4.58$, $df = 5$, $p < 0.001$, $n = 11$) and winter (One Way ANOVA, $F = 2.27$, $df = 5$, $p < 0.06$, $n = 12$). There was a high variability in the encounter rate in all the localities during autumn and the differences in the encounter rates across localities were statistically insignificant in this season (One Way ANOVA, $F = 0.80$, $df = 5$, $p < 0.56$, $n = 8$). The encounter rate was clearly higher in localities such as Chordhuar (3.9 ± 0.45), Dulunga (2.4 ± 0.45) and Shilt (2.5 ± 0.55) in spring. The encounter rates during autumn were around 2.5 birds/km (Table 4.1), with marginally higher estimate for Dulunga (3.3 ± 0.76) and Chordhuar (3.2 ± 0.40). The birds were sighted in large numbers in all the localities during winter. On an average, the encounter rates in these localities were about 3.5 (± 0.65) birds/km. There was high fluctuation in the encounter rate of Himalayan monal in Rolla area, and though the mean encounter rate was 1.4 ± 0.63, the records ranged from 0 to 8/km. It was clear from the results that the Himalayan monal was concentrated in middle and higher elevation areas, and as the winter progressed, they were seen in higher numbers, particularly in lower elevation areas. However, Chordhuar was an exception to this observed pattern with constantly higher encounter rates regardless of seasons. This perhaps was due to the availability of preferred habitat in this locality and this area could be a transition for the altitudinal movement of the species in response to climatic conditions.

Table 4.1. Mean (± SE) encounter rate of Himalayan monal in different trails/localities during the study period between April 1997 and March 1999

Season (n)	Rolla	Basu	Dulunga	Shilt	Chordhuar	Koilipoi
Spring (11)	0.8 ± 0.26	1.5 ± 0.78	**2.4 ± 0.45**	**2.5 ± 0.55**	**3.9 ± 0.45**	1.4 ± 0.36
Autumn (8)	2.6 ± 0.84	2.5 ± 0.65	**3.3 ± 0.75**	1.6 ± 0.63	**3.2 ± 0.40**	2.3 ± 0.80
Winter (12)	1.4 ± 0.63	3.8 ± 1.07	**4.8 ± 0.62**	3.6 ± 0.92	**4.2 ± 0.67**	2.5 ± 0.76*

(** n = 6 for this trail*)

Koklass: It was apparent that the abundance of koklass was underestimated by trail counts. Pooled mean of encounter rates obtained based on trail counts was 0.7 (± 0.87 SD, n = 180) bird/km. Except for Rolla with an encounter rate of over 1 bird/km, the estimates in other areas were always less than one (Table 4.2). Kruskal-Wallis ANOVA performed on the encounter rates (pooled data across seasons) revealed that the variations in the encounter rates between areas were significant (K-W test, $\chi^2 = 36.54$, df = 5, $p < 0.01$, n = 26 for Koilipoi and for the rests, n = 31). This statistical test was performed only after having established that there was no significant difference in the encounter rates between seasons and that there was no bias introduced to the analysis from the seasonal variation in the distribution of koklass. Despite the fact that trail count was inferior to call count in estimating relative abundance of koklass, these estimates were still obtained expecting that a correction factor could be developed to account for the bias arising from differential detection caused by visibility factor and the skulking behaviour of the koklass.

Table 4.2. Mean (± SE) encounter rate of koklass in different trails /localities during the study period between April 1997 and March 1999 ([a]n = 6, [b]n = 25)

Season (n)	Rolla	Basu	Dulunga	Shilt	Chordhuar	Koilipoi
Spring (11)	1.2 ± 0.30	0.3 ± 0.14	0.2 ± 0.12	1.2 ± 0.33	0.7 ± 0.22	0.4 ± 0.15
Autumn (8)	1.4 ± 0.26	0.1 ± 0.13	0.3 ± 0.16	0.9 ± 0.63	0.5 ± 0.27	0.5 ± 0.27
Winter (12)	1.5 ± 0.36	0.4 ± 0.19	0.4 ± 0.15	0.6 ± 0.28	0.2 ± 0.11	1.7 ± 0.61[a]
Pooled (31)	**1.4 ± 0.18**	**0.3 ± 0.09**	**0.3 ± 0.09**	**0.9 ± 0.17**	**0.5 ± 0.12**	**0.7 ± 0.20[b]**

Abundance index obtained using call counts provided a much higher estimate of koklass in the given area. The mean (± SD) encounter rate (i.e. no. of calling males per sample point) calculated based on 10 replicate points (with 8 pseudo-replicates for each point) was 2.9 ± 1.2. If the assumption that all the calling males are likely to have a female partner is true, then the encounter rates for koklass would be significantly higher (about 6 birds/count station) as compared to Himalayan monal. Since the counts were made only in spring season, it was possible to combine the data from both the years (1997 and 1998) to obtain a pooled estimate of abundance index. During the study period, the abundance index obtained for different areas ranged between 1.9 (± 0.30 SE) and 3.4 (± 0.32) birds/station (Table 4.3).

Table 4.3. Mean (± SE) encounter rate (Number of calling birds / count station) of koklass during spring 1997 and 1998 in the study area

Year	Rolla	Basu	Dulunga	Chordhuar	Koilipoi
1997 (n = 8)	3.5 ± 0.38	1.6 ± 0.32	3.8 ± 0.31	3.8 ± 0.41	2.9 ± 0.44
1998 (n=8)	2.8 ± 0.45	2.1 ± 0.50	3.3 ± 0.31	3.1 ± 0.48	1.4 ± 0.38
Pooled (n = 16)	**3.1 ± 0.30**	**1.9 ± 0.30**	**3.3 ± 0.25**	**3.4 ± 0.32**	**2.1 ± 0.34**

The differences in the abundance index across areas were statistically significant (One Way ANOVA, F = 5.45, df = 4, $p < 0.001$, n = 16). Chordhuar and Dulunga accounted for consistently higher estimate, over 3 birds/station in both the years. This was contradictory to the results obtained based on the trail count, which provided a much lower estimate for these areas as compared to the rest (Table 4.2). Only Rolla area was revealed to be supporting relatively high abundance of koklass from both the trail and call counts.

Western tragopan: Western tragopan was sighted occasionally and they showed site fidelity towards some areas. They were mostly recorded in Dulunga (2700m), Chordhuar (3000) and Koilipoi (2800) areas with a mean encounter rate of about 0.3 bird per km walk (Table 4.4). However, during the peak winter, Rollà area (2000m) had the highest encounter rate of 1.0 (± 0.30 SE), possibly due to heavy snow at higher altitude. Based on call counts, **three calling males** were identified, one each in Dulunga, Chordhuar and Koilipoi. These observations (both direct sightings and call counts) provided an indication of a positive relationship between trail count and call count for this species. Further analysis to establish such a relationship could not be done due to insufficient replicates and low sample size. Plot mapping method revealed **three clear territories** of western tragopan in Dulunga, Chordhuar and Basu-Koilipoi areas respectively. The observations made in Kodthach area were not distinguishable as to whether this pair was a part of the Dulunga one or it had a separate territory due to overlapping observations between these areas. Despite the fewer records of western tragopan during the entire study period, all three methods showed a similar relative abundance of this species. Considering the effort both in terms of sample size (6 trails with 31 repeated measures each and 10 call count stations with 8 repeated measures each) and time invested (2 years), the low number of records clearly indicated that the western tragopan was in low abundance.

Table 4.4. Mean (± SE) encounter rate of western tragopan in different trails/localities during the study period between April 1997 and March 1999

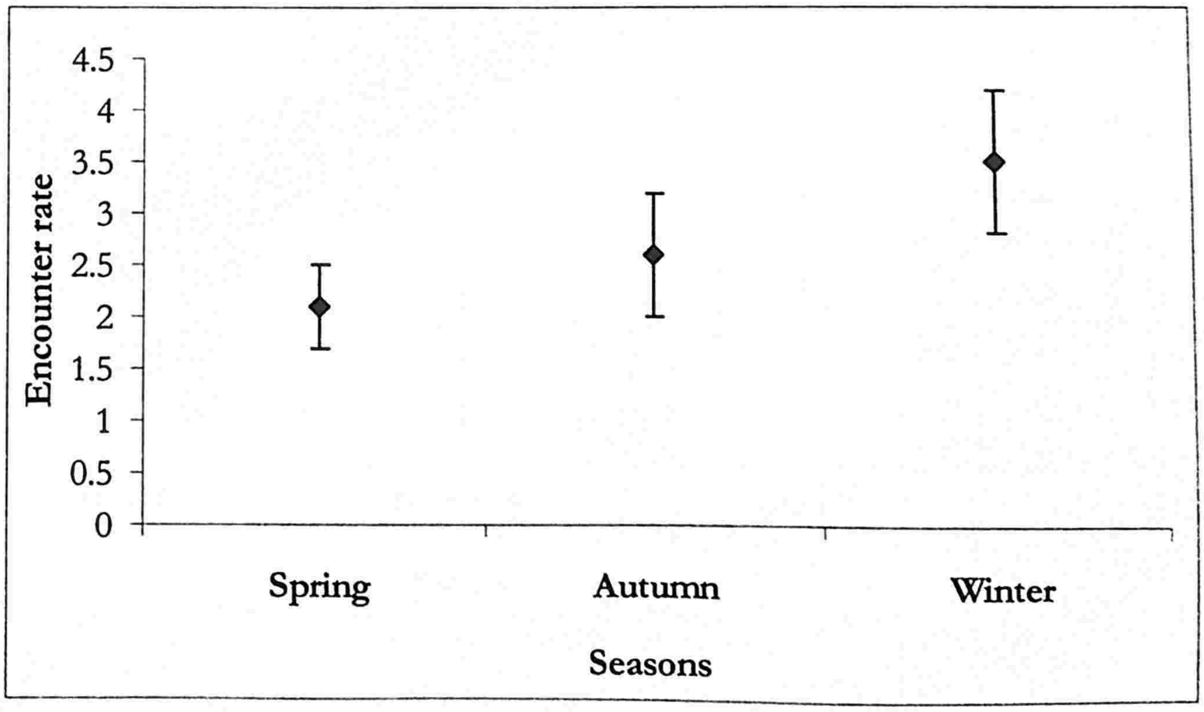
	Rolla	**Basu**	**Dulunga**	**Shilt**	**Chordhuar**	**Koilipoi**
Spring (n = 11)	0	0	0.4 ± 0.15	0	0.4 ± 0.13	0.2 ± 0.12
Autumn (n = 8)	0	0.1 ± 0.13	0.3 ± 0.25	0	0.2 ± 0.21	0
Winter (n = 12)	1.0 ± 0.30	0.1 ± 0.08	0	0	0.3 ± 0.19	0*

*$n = 6$

4.3.3. Seasonal variation in relative abundance

There was a distinct seasonal variation in the encounter rates for Himalayan monal (Fig. 4.5) and western tragopan, as these two species were found to show immediate response to the climatic changes in the higher altitudes. Consequently, they were seen congregating at lower elevations in winter. The pooled mean of encounter rates obtained for Himalayan monal were 2.1 (± 1.7 SD) in spring (n = 6 replicates and 11 pseudo-replicates each), 2.6 (± 2.0 SD) in autumn (n = 6 replicates and 8 pseudo-replicates each) and 3.5 (± 2.7 SD) in winter (n = 6 replicates and 12 pseudo-replicates each). Despite the local variations in the observations, encounter rates in winter was significantly higher as compared to spring (as depicted by non-overlapping confidence limits in Fig. 4.5. for these seasons), but there were no clear differences between spring and autumn, and autumn and winter. There was no apparent seasonal difference in the encounter rates of koklass (Fig. 4.6), and the pooled means were almost similar in all the seasons, as similar was the case for western tragopan. Though there were consistently higher encounter rates in Rolla area during winter, the overall differences in the encounter rates between seasons were insignificant (Fig, 4.7). However, there was one common pattern observed in

Figure 4.5. Seasonal variation in the encounter rates of Himalayan monal (pooled mean with 95% Confidence Limit)



the encounter rates in all the three species. The mean encounter rates in winter were relatively high, suggesting that there was an increased detectability in winter perhaps due to high visibility and/or high concentration of individuals in the sampled areas.

Figure 4.6. Seasonal variation in the encounter rates of koklass (pooled mean with 95% Confidence Limit)

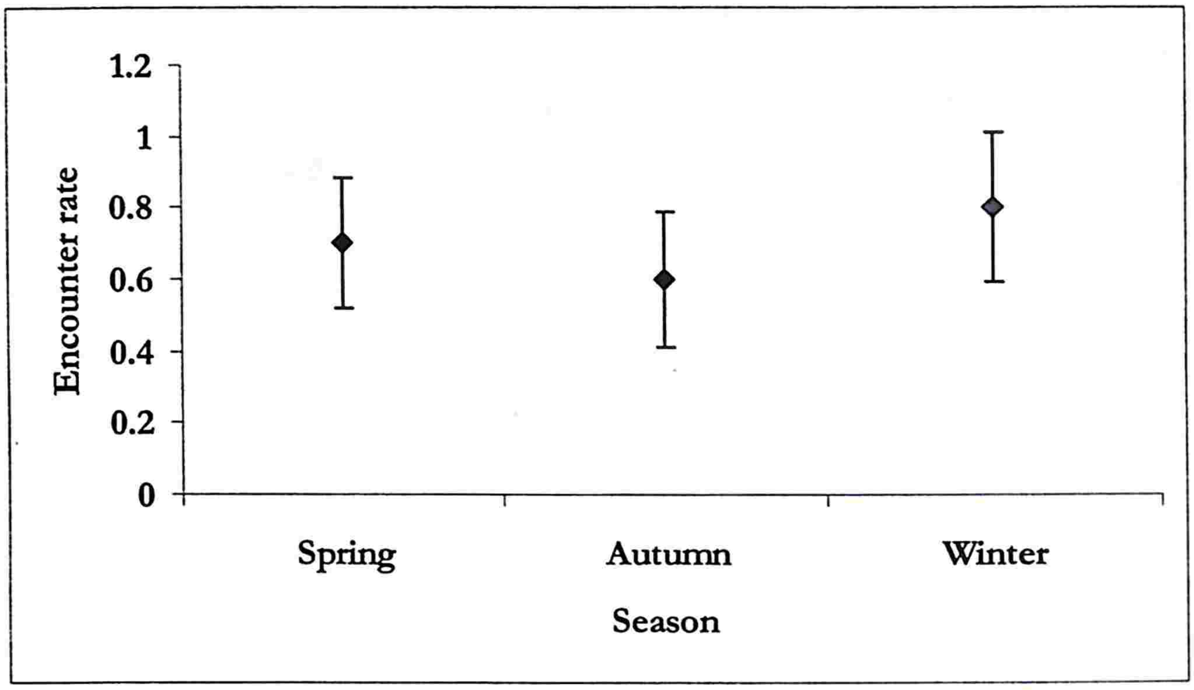
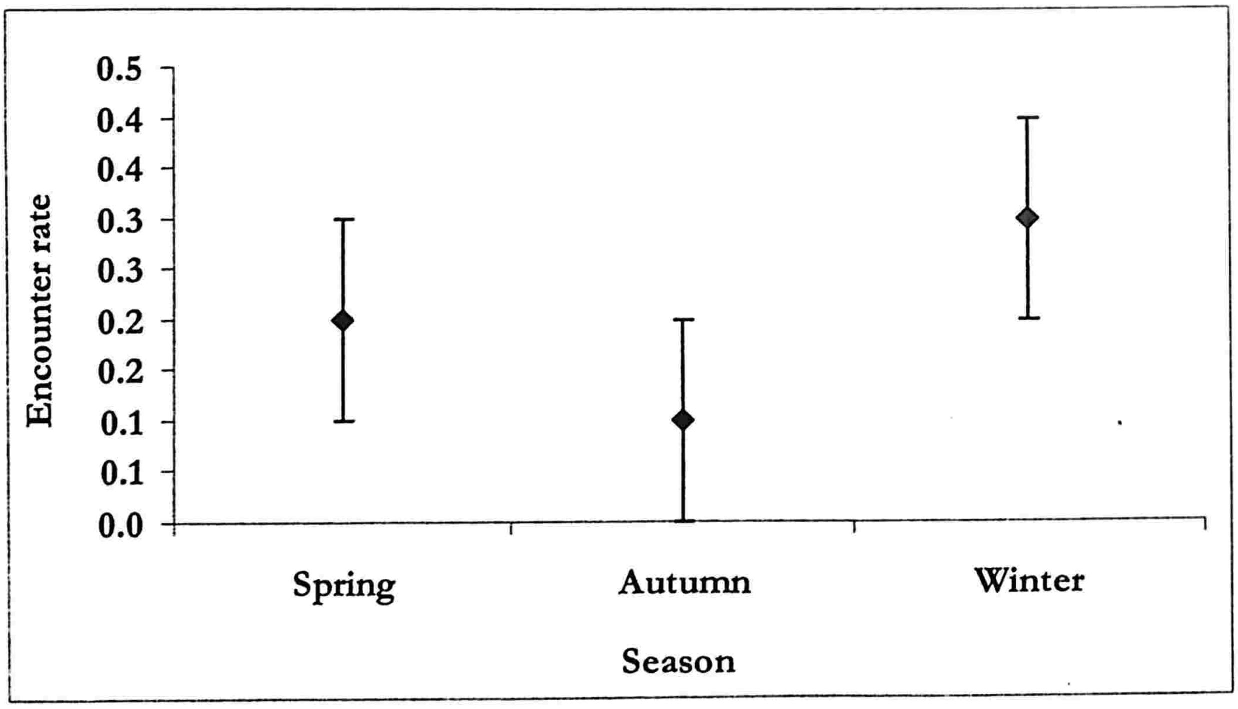


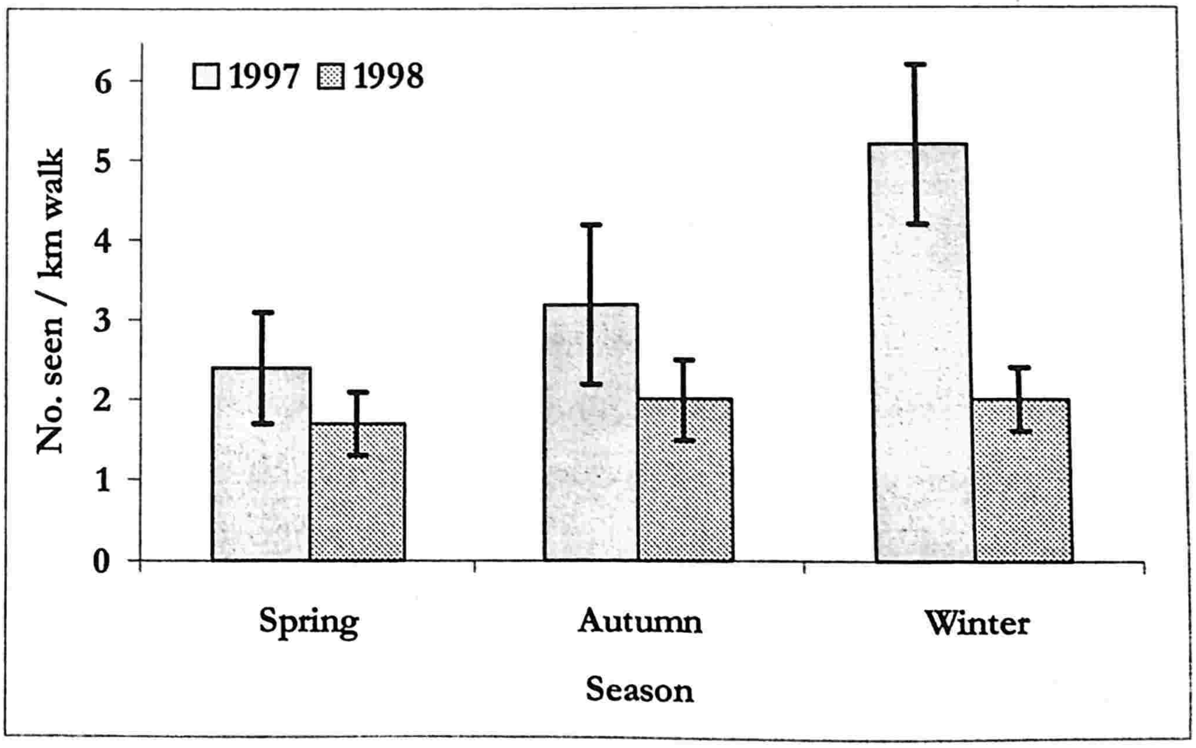
Figure 4.7. Seasonal variation in the encounter rates of western tragopan (pooled mean with 95% Confidence Limit)



4.3.4. Annual variation in relative abundance

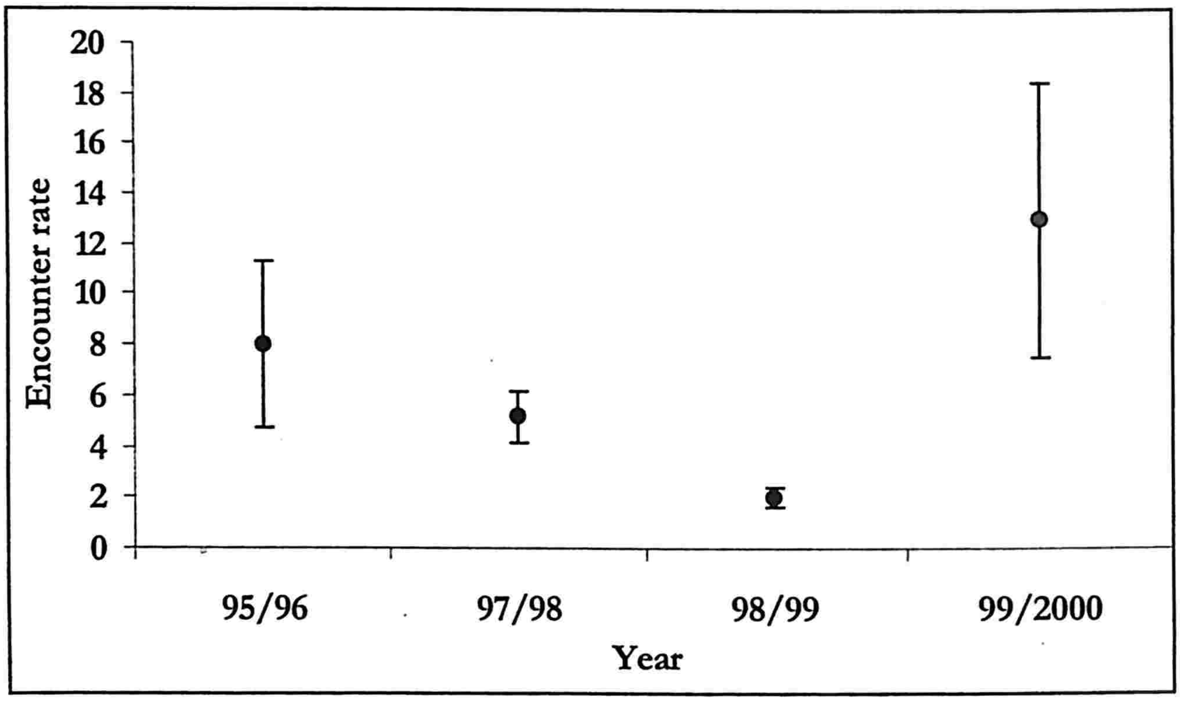
Noticeable differences were recorded in the abundance of the study species over successive years, primarily indicating a declining trend in the population. The number of Himalayan monals encountered in 1997 showed a consistent reduction in all the seasons during 1998 (Fig. 4.8). Because of the apparent seasonal variation in the distribution patterns of the Himalayan monal, the seasons were treated as different groups and test for statistical significance in the encounter rates between 1997 and 1998 was done separately for each season. Wilcoxon Signed Ranks Test detected a significant difference, indicating a decline in the successive estimates from spring 1997 to spring 1998 ($Z = -2.207$, $p < 0.05$, $n = 6$). The Himalayan monal was seen in good numbers during winter 1997, with the pooled mean of 5.2 (± 2.8 SD) birds/km, and the sightings dropped to significantly low numbers in 1998 measuring just 2.0 (± 1.3 SD) birds/km ($Z = -2.023$, $p < 0.05$, $n = 6$). Though the decline was apparent in autumn seasons too, the difference was detected at only 90% confidence level ($Z = -0.787$, $p < 0.1$, $n = 6$). The declines in winter count could be considered as the decline in the overall population of Himalayan monal. Unless there is a

Figure 4.8. Pooled mean encounter rates (with 95% Confidence Limit) of Himalayan monal in 1997 and 1998



significant variation in the snow condition, such inference was possible considering the fact that the birds are confined to a narrow belt in the lower elevation areas, thus increasing the likelihood of accurately assessing the abundance of the birds occurring in the given area. The winter estimates obtained for four years (including the data obtained in 1996) indicated a declining pattern in the encounter rates over the years until 1999, and there was a sudden increase in the encounter rates during winter 2000 (Fig. 4.9). Over 60 Himalayan monals including several chicks and sub-adults were seen during this field trip and the counts in five trails produced an average encounter rate of 13.3 (± 3.3 SE) birds per km walk, which was the maximum ever recorded during the study period.

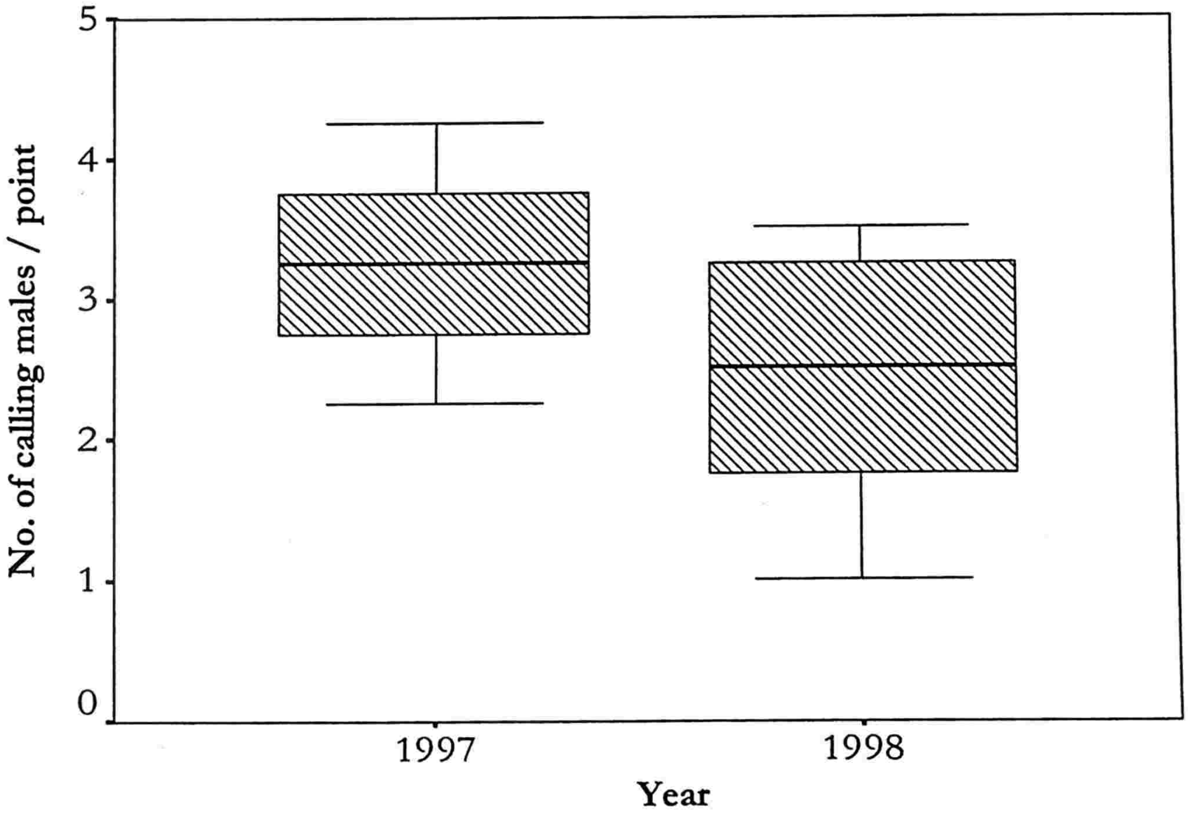
Figure 4.9. Winter estimate of encounter rates of Himalayan monal in the recent years



The encounter rate obtained for koklass based on call counts also indicated a decline in the population in the year 1998 (Fig. 4.10). Of the 10 paired observations (*i.e.* mean calling males in sample plot in year 1997 *versus* 1998), 80% showed a declining tendency, and that the mean number of calling males recorded in the year 1998 was consistently less in most of the sample plots. The overall difference in the encounter rates of koklass between the years was observed to be significant at 90% confidence limits (Wilcoxon Signed Ranks Test, $Z = -1.78$, $p < 0.1$, $n = 10$).

Sighting of western tragopan was too low for any meaningful statistical tests to compare the annual difference. However, there was an indication of decline from the reduced sightings of 18 individuals in 1997 to 15 individuals in 1998 (pooled data). And, only one calling male was recorded during the year 1998, indicating that there was a problem in the western tragopan population. However, like Himalayan monal, there was a substantial increase in the sightings of western tragopan in winter 2000, with the mean encounter rate of 0.9 (± 0.8 SE) birds per km walk, which also included three chicks/sub-adults. Interestingly, it was for the first time that chicks or sub-adults of western tragopan were recorded in the entire study period.

Figure 4.10. Box plot depicting the number of calling males recorded per sample point in 1997 and 1998



4.3.5. Density and population status

Himalayan monal: Based on the data on sighting distance estimated for each observation, 100m width (50m on both sides from the trails) was identified to be effective in counting the Himalayan monal. Only spring count was considered for density estimation assuming that these birds occupy their breeding habitats during this time and that the estimate obtained during this period is likely to have a less bias. The density estimate for each trail was pooled across the season and the years, and the mean and median densities for spring were 20. 5 (± 3.1 SE, ± 6.2 at 95% CI) and 20 birds/km^2 respectively. This translated to a population range between 14 and 27 birds/km^2. If this figure is extrapolated to the available potential habitats for Himalayan monal in GHNP (Table 6.4. of Chapter 6), then the total population size of Himalayan monal in the park area would be around 2500 individuals (mean = 1900, range at 95% confidence interval = 1300 to 2500 birds). Similarly, based on such extrapolation, the estimates obtained on the population size of this species were approximately 500 birds in Tirthan Wildlife Sanctuary (mean = 600, range = 400 to 800) and Sainj Wildlife Sanctuary (mean = 450, range = 300 to 600). However, surveys carried out in several parts of Tirthan Wildlife Sanctuary and Eco-development area revealed that despite the availability of the potential habitats, the abundance of this species in these areas were either low or were absent in most parts of this zone. It is important to note that the estimates on the density and population size could be an over estimate since the data collection was done in one of the best habitats of Himalayan monal in GHNP. Therefore, the estimates could essentially be treated as the maximum number of birds expected to occur in the area.

Koklass: Call counts obtained within a 300m radius provided a density estimate of 8.6 (± 2.9 SD) calling males/km^2. Assuming that the males do have or are likely to have a female partner, the mean density was translated to be 17.2 (± 5.8 SD) individuals of koklass per km^2, with a range of 14 to 21 birds at 95% confidence limit. Given the availability of potential habitat in GHNP (42 km^2), the total population size (within 95% confidence limit) is expected to range between 300 and 450 pairs in GHNP. Similarly, the potential areas in Tirthan (15 km^2) and Sainj (11 km^2) Wildlife Sanctuaries is likely to accommodate around or less than 125 (range = 100 to 150) and 100 (range = 70 to 110) pairs of koklass respectively. Though the density is not very different from the Himalayan monal, the overall population of koklass is considerably less, primarily attributed to low availability of its preferred habitats in GHNP.

Western tragopan: The plot mapping and call count method independently revealed about three to four pairs of western tragopan within the intensive study area. It was identified from the GIS based map and intensive field work that within the study area of the 16 km^2, only about 8 km^2 had the potential habitat to support this species in terms of the availability of preferred vegetation types and other habitat requirements. These observations were used to enumerate density for this species and it provided a density estimate of 1.5 to 2 birds per km^2 in this area. Extrapolation of this estimate to the potential habitat in GHNP (36.6 km^2) revealed that there could be not more than 40 pairs in the entire park area, unless the current population level increases substantially. The potential habitats in Sainj Wildlife Sanctuary (9 km^2) is likely to support another 8 to 10 pairs. If the Trithan Wildlife Sanctuary area also supports the western tragopan population to its potential, which seemed unlikely, then the total population size together in these areas could be expected to be about 65 pairs. It is apparent that limited availability of potential habitat (for instance, it is just 5% of the total area in the GHNP) compounded with low population size has clearly placed this species to be rare among the study species.

4.3.6. Group size and composition

Group size: Group size of Himalayan monal ranged from 1 to 11 individuals with a mean of 1.61 ± 1.21 individuals (Table 4.5). Mann-Whitney U test revealed that group sizes of Himalayan monal varied significantly between seasons (autumn versus spring $Z = -1.969$, $p < 0.049$; summer versus winter $Z = -2.533$, $p < 0.011$; and spring versus winter $Z = -4.886$, $p < 0.001$). Larger groups of up to 11 individuals

Table 4.5. Group size characteristics of Himalayan monal in different seasons

Seasons	Mean	Std. Deviation	Minimum	Maximum	N	% Sightings
Spring	1.3	0.5	1	4	142	27.1
Summer	1.4	0.9	1	6	38	7.3
Autumn	1.5	0.9	1	7	67	12.8
Winter	1.9	1.5	1	11	277	52.8
Overall	**1.6**	**1.2**	**1**	**11**	**524**	**100.0**

were seen in winter and the groups were consistently small in spring, which is the breeding season of the pheasants. Koklass, however, did not show significant seasonal variation in group sizes (Kruskal-Wallis test $\chi^2 = 1.860$, $p < 0.602$). A group consisting of three individuals was the maximum group size recorded for this species. Other group size characteristics of koklass are given in Table 4.6. Like koklass, group size of western tragopan did not exceed more than three individuals and the estimated mean group size for this species was 1.1 ± 0.29 birds (Table 4.7). Due to deficient data, the sightings were grouped into two seasons *viz.*, winter and summer (this includes spring, summer and autumn) for statistical analysis. There was no apparent difference in the group size of this bird in response to seasons (Kruskal-Wallis test $\chi^2 = 0.402$, $p < 0.526$).

Table 4.6. Group size characteristics of koklass in different seasons

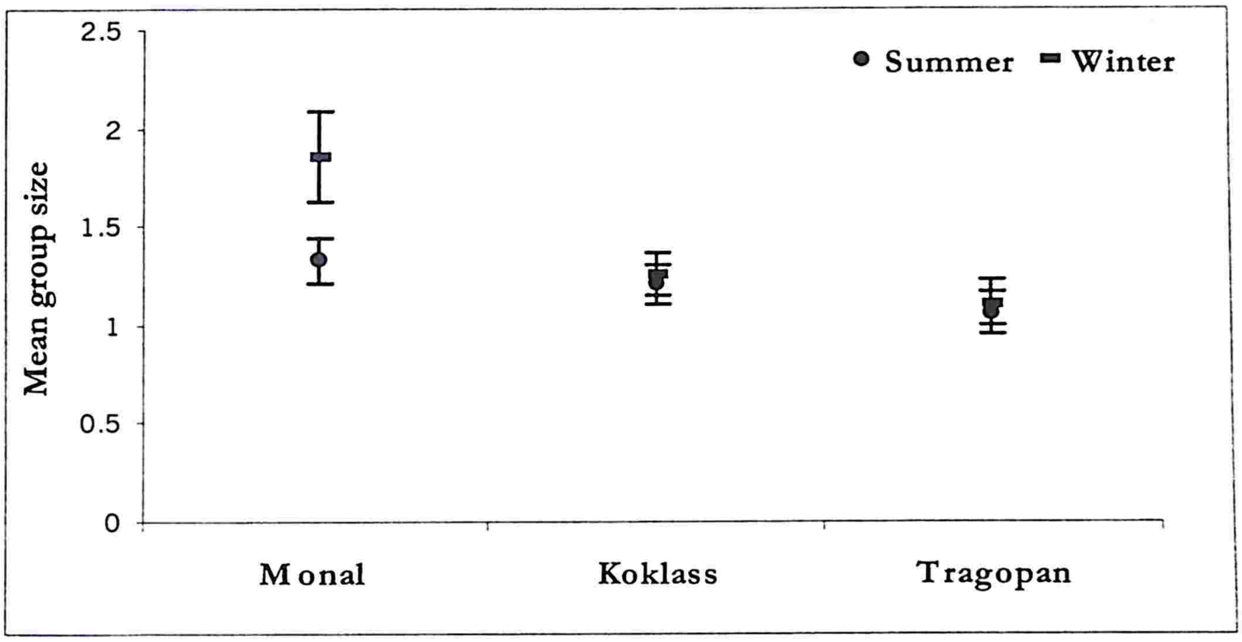
Seasons	Mean	Std. Deviation	Minimum	Maximum	N	% Sightings
Spring	1.2	0.4	1	3	47	37.3
Summer	1.4	0.7	1	3	8	6.3
Autumn	1.2	0.6	1	3	17	13.5
Winter	1.3	0.4	1	2	54	42.9
Overall	**1.3**	**0.5**	**1**	**3**	**126**	**100.0**

Table 4.7. Group size characteristics of western tragopan in different seasons

Seasons	Mean	Std. Deviation	Minimum	Maximum	N	% Sightings
Spring	1.1	0.3	1	3	15	33.3
Summer	1.0	0.0	1	1	2	4. 5
Autumn	1.0	0.0	1	1	1	2. 2
Winter	1.1	0.3	1	2	27	60.0
Overall	**1.1**	**0.3**	**1**	**3**	**45**	**100.0**

Confidence interval constructed using bootstrap statistics also reflected the foreseen observations on the seasonal variation in group sizes of these species. Overlapping confidence limits in koklass and western tragopan reveal a insignificance difference in the group size between summer and winter, while for Himalayan monal the difference was apparent as depicted in the Fig. 4.11.

Figure 4.11. Estimated mean group sizes of the study species in summer and winter (Error bar denotes 95% confidence limit)



Group composition: Himalayan monal was seen solitarily more often than in groups. Of the 524 sightings, 336 (64%) were solitary records and 124 occasions (24%) were in pairs. Although a flock could consist of up to 11 individuals, the group sizes with more than three individuals were relatively few (Fig. 4.12). Interestingly, there were several considerable records of unisexual groups, represented by males in 228 occasions and 216 by females. Only 80 records consisted of mixed sex. Male groups were relatively high in all, but winter season when female groups dominated with 133 records (Table 4.8).

Figure 4.12. Frequency of group size classes in Himalayan monal

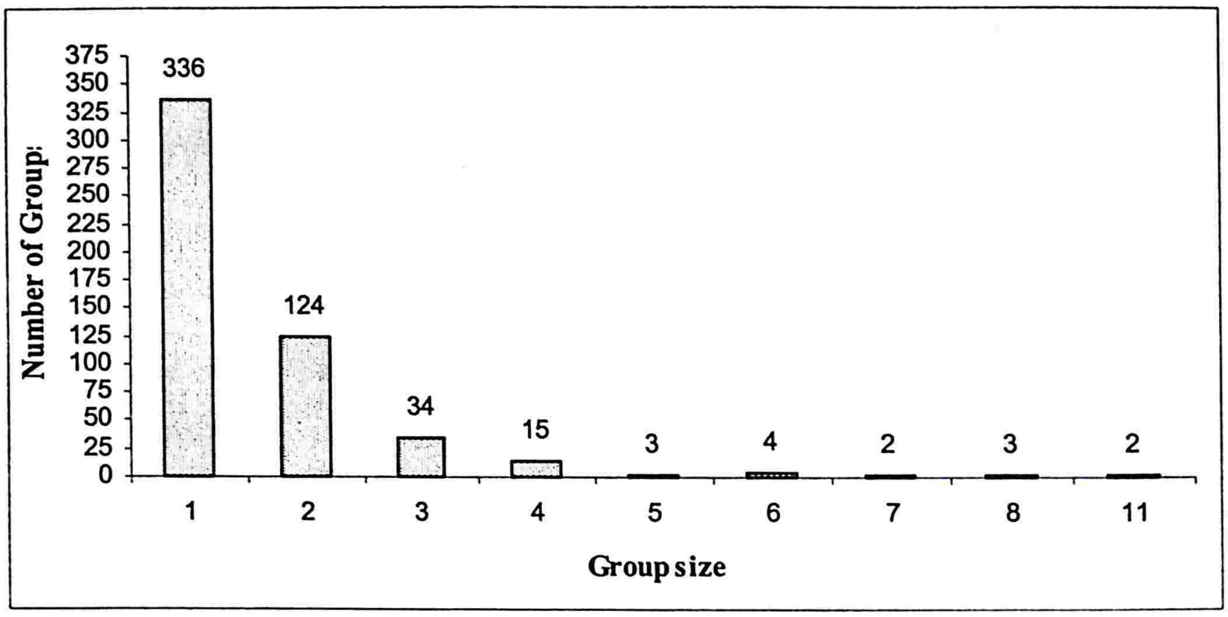


Table 4.8. Frequency of unisexual and mixed groups in Himalayan monal

Seasons	All male	All female	Mixed	Total
Spring	73	46	23	142
Summer	19	14	5	38
Autumn	35	23	9	67
Winter	101	133	43	277
Overall	**228**	**216**	**80**	**524**

As expected, koklass was mostly seen either singly or in pairs. Of the 126 observations, 79% (100 records) were of solitary birds and the remaining 21% consisted of mostly breeding pairs (23 records) and one records of three individuals. The notable observation was that a male koklass was in association with two females at the time of the peak breeding season, otherwise koklass is thought to be strictly a monogamous species. Western tragopan was seen mostly as a solitary bird and only during breeding season, did these birds tend to ·form pairs. Family parties of not more than 3 individuals were also seen during the winter season. In the study period, 91% (i.e. 41 records) of the sightings were of single birds and the rest were either pairs or group of three.

Sex ratio: The estimated sex ratio for Himalayan monal and western tragopan was found to be skewed, favouring towards females, but it was towards males in the case of koklass (Table 4.9). For every 10 males, there were 13 females recorded for both Himalayan monal and western tragopan, but for koklass, there were only 7 females per 10 males. However, these estimates are likely to have an error since subadult males are usually difficult to distinguish from females.

Table 4.9. Estimated sex ratio for the pheasants in the study area
(Data pooled across seasons and areas)

Species	No. of Males	No. of Female	Sex ratio *(Male : Female)*
Himalayan monal	342	456	10 : 13
Koklass	77	51	10 : 7
Tragopan	17	22	10 : 13

4.4. Discussion

The study area, like most of the Himalayan landscape, was characterized by rugged, undulating and not so easily accessible terrain. These landscape characteristics played a decisive role in structuring the sampling framework. This is an inherent problem associated with the Himalayan landscape and the previous studies carried out in the Himalaya have also had to be content with the trails for field sampling (Islam 1985, Kaul 1989, Mishra 1993, Sathyakumar 1994, Bhatnagar 1997, Kumar 1997, Vinod 1999). In this study, attempts were made to ensure maximum possible sampling within available options in the field. The fact that 70% of the available trails were utilized for the study underscores the intention of obtaining adequate sample size. Moreover, the trails sampled passed through almost all the habitat types and elevation zones within the study area, and hence, sampling represented these macrohabitat features. Further, the variability in abundance or conversely, the precision of the estimates was addressed by maximum possible number of pseudo-replicates.

Another major confounding factor that was typical to studying pheasants was their characteristic behavioural responses to the observers. On sensing the observer, invariably the birds either went skulking under the bush (e.g. koklass and western tragopan) or flew away to greater distances (e.g. Himalayan monal). These responses were likely to skew detection probability and it becomes biased to use these estimates for making comparison between species and area. This coupled with the inaccurate distance measurement caused non-linear trails and inaccessible terrain posed limitations in adopting some of the established count methods (e.g. line transect methods), which are otherwise useful for estimating abundance of terrestrial birds. Consequently, count techniques prescribed for these terrestrial birds including Galliformes (Gaston 1980, Manuwal and Carey 1991, Bibby et al. 1992) were modified to suit the condition and requirement of this study. Besides, point count and plot mapping were directly adopted, after establishing that the key assumptions associated with these techniques could adequately be met. Though constrained by availability of trails and time to negotiate with the strenuous terrain, the number of replicates and pseudo-replicates used in this study still provided a reliable estimate of abundance.

4.4.1. Count techniques

Selection of appropriate count techniques has often been of concern to field biologists. Constant debates and criticism over this important subject have resulted in voluminous literatures providing details on various count methods for studying bird abundance (*e.g.* Emlen 1971, Ralph and Scott 1981, Verner 1985, Manuwal and Carey 1991, Bibby et al. 1992, Buckland et al. 1993, Sutherland 1996). Seber (1982) has provided further details on sampling approach and statistical analysis related to these methods. Mark-recapture/re-sighting, spot-mapping, circular plot and line transect are among the commonly used count methods in bird studies. However, no count techniques proved effective in every instances and some techniques provide best estimate if carried out during a particular time of year or if it is based on indirect evidences such as recording of calls or count of feces. For instance, spot mapping and transect counts, if carried out during the breeding season, have been found to be efficient to obtain a reliable estimate of abundance in some bird species (O'Mehra 1981, Redmond et al. 1981). Call counts, mostly carried out during the breeding season, has been the most common count method for several species of Galliformes (e.g. Kimball 1949, Howman 1976, Severinghaus 1979, Khan and Shah 1982, Young et al. 1987, Hill and Robertson 1988, Duke 1990, McGowan 1990, DeMaso et al. 1992, Khaling 1999). Given the limited resource and time, effectiveness and reliability of these techniques needed to be combined with practical knowledge of the birds' biology and behaviour along with sampling protocols (Conroy and Carroll 2000). Extra care is required if the terrain is rugged like the Himalayan landscape, as one has to deal with many other confounding factors that can potentially inflate the bias in the estimates (Dawson 1981).

4.4.1.1. Trail count

Despite their coexistence and almost similar living habits, there was no single method that could commonly be applied to these pheasant species studied during the work. Detection was largely dictated by the birds' behaviour and therefore, strategies had to be worked out based on any one or a combination of methods that would be relatively efficient in recording the number of birds present in the given area during sampling. Trail count proved effective for estimating abundance of Himalayan monal, regardless of seasons. However, if the objective of the counts was to understand the ecological distribution of the species, then the counts carried out during spring season would be more reliable as the birds tend to disperse to wider areas, occupying their breeding habitat during this season. Unless there is high amount of inter-specific variation due to social dominance of some individuals over the other, the habitat occupancy during this period is known to indicate their preference to such areas. There is a potential bias in comparing the estimate between habitats that have high variation in visibility. The concern is that low numbers counted in closed or dense habitat need not necessarily indicate that the habitat supports low population, rather it could be a function of low detection probability in this habitat. Besides the vegetation composition and community structure, skulking or secretive behaviour of the birds also influence unequal detection between different habitat. Therefore, any abundance indices, such as the encounter rates, that do not address the visibility issue need to be viewed carefully, particularly while comparing abundance between two or more different habitats. This is why the methods such as line transect and variable width circular plots described by Burnham et al. (1980) and Buckland et al. (1993) are considered superior as they conform to such requirements.

Line transect technique is among the most commonly used methods for estimating abundance of terrestrial birds (e.g. Emlen 1971, Burnham et al. 1981, Guthery 1988). This has been recommended as a viable option for Himalayan pheasants (Gaston 1980). On the contrary, this method was unsuitable for the study species as the terrain and the typical behaviour of the species served to violate all the assumptions associated with this method. Therefore, line transect was ruled out because of the apprehension that the results and further interpretation would be plagued by uncertainty. However, several studies have proceeded ahead with this method despite violation of assumptions (Verner and Ritter 1988). Though it is also unrealistic to expect to meet all the assumptions of the line transect method particularly while dealing with terrestrial bird communities, any compromise in accepting the bias that stems from unequal detection and inaccurate distance measurement would lead to invalid results.

Though most of the estimates were encounter rates, visibility was not a major problem for Himalayan monal as the birds were clearly conspicuous by their large size and characteristic alarm call. It was highly certain that majority of the birds within about 100m belt (50m either side) could not have been missed during the trail walk. These observations provided a basis for considering belt transect method to be able to come up with a crude estimate of density for Himalayan monal. Even if there is a significant difference in the variability across habitats, the encounter rates from adequately replicated trails would still be effective for estimating population trends if the potential biases caused by visibility is constant across years. This is likely in most of the cases unless the habitat undergoes significant changes simultaneously or stochastic events change the habitat condition. Trained dogs have been used to flush out birds to overcome the detection problem (Islam and Crawford 1987). Use of dogs, in such a hilly terrain and that too for a sensitive group of birds, was problematic. Because such exercises create a high degree of disturbance to the species (can be detrimental during breeding season), and it is not repeatable at the required scales and frequency to arrive at any meaningful abundance measures. This method could still be of good use for population monitoring, if carried out during non-breeding season from adequately replicated samples spread across large areas.

Winter was the ideal season to document overall abundance of the Himalayan monal as they were restricted to lower elevation areas, including those from inaccessible areas where the birds could otherwise have been missed during other seasons. This also augments the scope for obtaining more replicate trails across wider areas since the effort required in the higher altitudes can be channelised to much larger areas in the lower altitudes. Counts in the marked trails carried out over years would form an effective basis to track trends in population and status of the population of this species. While doing so, yearly variation, if any, due to snow conditions need to be accounted for, since snow plays an important role in limiting winter distribution of most pheasant species, including the ones studied (Hill and Robertson 1988, Kumar 1997). The observations made on the species across seasons and the estimates of abundance obtained suggested that trail counts, with or without a closed width, is an effective method to estimate the abundance of the species.

Trail count was identified to be useful for western tragopan, although relatively very few birds were recorded. The low abundance was perhaps due to two reasons; firstly, the study area was small to accommodate more number of territories of the species and secondly, the actual population size was too small during the study period. Trail counts have also been used as effective method elsewhere to document the abundance (Islam 1982, Gaston and Garson 1992, Kaul and Ahmed 1993, Sathyakumar et al. 1993, Khan et al. 2000, Nawaz et al. 2000), distribution (Gaston et al. 1983, Sharma and Pandey 1989) and habitat use (Islam 1985, Kumar 1997) of the species. Like the Himalayan monal, western tragopan also responded quickly to the observer presence with a characteristic alarm call and subsequently, was seen walking uphill or skulking. Upon close proximity, these birds took off to down slopes. Though it was not certain that all the individuals present in the area were detected during the given trail walk, results obtained based on the other two methods *viz* call count and plot-mapping suggested that trail count can be a viable option to record the abundance of the species.

If a correction factor could be worked out to control for the detection bias, the trail count might be a useful index of abundance for koklass, which can further be used to study the relative population status across areas/habitats, and over years.

4.4.1.2. Call counts

Birds use auditory signals as a primary means of communication amongst the members of their families and produce a variety of calls to serve different purposes of communication. The vocalization is known to be stronger during the breeding season as the birds indulge in display behaviour through loud breeding calls so as to attract suitable females for breeding. It is also a defensive signal to a potential competitor to keep away from the already occupied territory. Termed as point count, many studies have effectively converted these calls to an abundance index to monitor the population change across space and time (Lancia et al. 1994, Farnsworth et al. 2002). Recording of calls to obtain population estimate has been found to be advantageous. By using this approach, the birds are disturbed less and a larger area could be covered with minimal effort (Bull 1981). This method is particularly useful for birds such as pheasants that are difficult to sight, but are conspicuous by their calling behaviour. With the exception of a few species that do not give breeding or advertisement calls (e.g. Himalayan monal), studies carried out so far on pheasants have invariably considered adopting call count to obtain population estimates and for subsequent ecological interpretation. Specifically, this method has been effectively used for cheer pheasant (Gaston and Singh 1980, Young et al. 1987), koklass (Howman 1976, Severinghaus 1979, Khan and Shah 1982), western tragopan (Duke 1990, Pandey 1993), satyr tragopan (Lelliot 1981, Khaling 1999, Baral et al. 2001) and the Malaysian peacock pheasant (McGowan 1990).

The major assumption of this population index is that detection probabilities are constant across space and time, meaning that all the birds (or in some species only males) in the given area are likely to call during the sampling time and that none of the calling birds were missed. This detection probability is a function of calling rates and the observer's ability, which are often influenced by climatic condition and topographic features; extreme condition would limit the calling rate (Wellendorf et al. 2000) and dense habitats or obstruction by steep slopes would limit the audibility. Also, unless the sex ratio of the birds is close to or equal to unity, the results obtained based on call counts would overlook the female population. However, the evaluation whether or not the detection probability is constant and understanding the proportion of calling males in the total population and sex ratio, would require a careful monitoring of representative number of marked individuals preferably by radio-tags. Because such exercises are expensive and would involve great amount of field difficulties and risk to the birds, none of the above studies on pheasants in Asia attempted to incorporate the detection probabilities and calling males ratio. Instead, equal probability has been assumed for those species that are monogamous or live in pairs or the estimates have only been used for monitoring the population over years. Observations carried out on western tragopan and koklass in Sarahan Pheasantry (Captive Breeding Centre), Himachal Pradesh indicate that calling is done by all male birds including sub-adults (*pers. observ.*) It was also possible to substantiate such observation in the field for western tragopan from the spot-mapping method that the males in three of the territories identified gave breeding calls during the breeding season.

Call count produced higher abundance value for koklass and the standard error associated with the mean was consistently low, suggesting that greater precision could be achieved of the calling birds in a given area. In the case of western tragopan, the estimates from the call counts complimented the spot-mapping method. Koklass's calling activity showed a peak in the months of April and May, though there were few sporadic calls in late March and early June, where as the western tragopan was vocally active mostly during the month of May when the activity of koklass was settling down. Similar calling patterns have been observed elsewhere for koklass (Severinghaus 1979, Khan and Shah 1982) and the western tragopan (Duke 1990, Khan S.B. *pers. com.*). Interestingly, peak calling activity of satyr tragopan (the congener of western tragopan) was observed to be during April in both Nepal (Lelliot 1981) and India (Khaling 1999). In these areas, koklass was either absent or they were in very low density. These observations could be an indication that the western tragopan might be adjusting the peak calling activity wherever it shares the habitat with koklass as the loud chorus of koklass could mask the western tragopan calls. It is important for koklass to call as early as possible to be able to establish breeding territories, as they have to compete with a large number of potential males who are also trying to establish breeding territories. High density in satyr tragopan could perhaps be the reason for extended period of calling starting from April until June. In the case of western tragopan, site fidelity indicated permanent breeding territories. Low density of these birds compounded with the availability of sufficient area of suitable habitats appears not to impose high competition amongst individuals in the study area. So, the calls produced during May month could just be to reconfirm its occupation in the territory during the particular breeding season. This trend is likely to change only when the western tragopan population increases to substantially high densities and there are more males to compete for the same resources. However, these explanations are merely hypothetical or speculative and only further research based on experimental study design would reveal decisive reasons for the differential calling behaviour in these species.

During the study period, the birds were observed to call from elevated positions (hill slopes) or from roosting trees during the early hours of dawn and as the day progressed, they would begin moving around various directions, continuing to call, though with less frequency. Call counts carried out at this particular time period would be more reliable to estimate abundance and for long-term monitoring. The field observations suggest that future workers in GHNP can consider carrying out call count during April and May, and between 5:30 – 6:00a.m. Since the calling activities could severely be affected by poor weather conditions such as very cold or rainy days (Bull 1981, Khaling 1999, Wellendorf et al. 2000), counts should be avoided in these periods. Considering the peak vocal activity, western tragopan could be counted effectively during the months of May. The fact that the males in the three identified territorial pairs called during the breeding season provided support to the assumption that all the males in the population do call during sampling.

4.4.1.3. Spot-mapping

Spot mapping is among the more popular survey methods to quantify abundance of territorial, non-colonial bird species (Ralph and Scott 1981). Several ornithologists have considered this way of sampling to be more efficient and accurate for density estimation (O'Mehra 1981, Verner and Milne 1990) and also for explaining bird-habitat interactions (Rangen et al. 2000). It has also been considered to be an effective tool in large-scale land bird monitoring programme such as the Common Birds Census of Great Britain (Willamson and Homes 1964). However, like any other count methods, spot mapping is also constrained by certain limitations. To begin with, this method is effective only for territorial birds and that too during breeding seasons when the birds are conspicuous by their high vocal activities. More over, if the counts are made based on only singing males, it would only provide abundance index for the male population, unless the proportion of non-singing birds in the group is known. Also the other disadvantage of the method was that one has to find other suitable methods for measuring the non-breeding population. Oelke (1981) has pointed out several major issues that potentially challenge the efficacy of this method. The concerns have largely been related to the accuracy of measuring all individuals at any one sampling time and such a problem is likely to get inflated while counting several species at a given sampling time, an exercise common in bird community studies and large scale monitoring programme. Alternately, attempts focussing on single species would be more efficient to carry out and would amplify the options for finding alternative strategies to over come key methodological problems.

Among the study species, spot mapping method could effectively be used for identifying different populations of western tragopan in the intensive study area and for subsequent population estimation. Low density, territorial behaviour, monogamy and ability to produce loud calls during the breeding season led to consideration of this method. Low density perhaps allowed the species to occupy segregated territories and there was no measurement error in terms of recording the occurrence of the species. These records were mostly of singing males and the probability of recording females during breeding season was very low since they become secretive for nest building. However, this problem was not expected to contribute to a significant bias and the estimates can still serve the purpose of monitoring breeding populations. This estimate can also help understand the population status of the species at a large scale, since the breeding populations are positively related to good habitat conditions. The estimates can also be extrapolated to obtain total population size, if established that the sex ratio remains largely 1:1 and if the proportion of non-signing males in the population is estimated. Since the clutch size of the western tragopan is reportedly not more than 3 (Ali and Ripley 1983) and the possibility of achieving 100% breeding success was low, even if they do, it is unlikely that the sex ratio would consistently be biased towards females. During the field survey, the sex ratio was close to 1:1 and except for winter 2000, there were no sighting of sub-adult males (which are thought to be non-singing). Therefore, the bias potentially incited by these two factors (skewed sex ratio favoring females and large number of sub-adult males) could not have been significant.

The techniques discussed above are primarily based on empirical data from a small area and for a limited time. Though each of the methods discussed could be useful for specific conditions and were useful to address the study questions, there is scope for refinement and validation of certain assumptions regarding detection probability and the level of accuracy in distance measurement. A carefully planned study with adequate number of marked birds preferable with radio-tags seems to be the only viable option available at the moment to test or validate these issues in the field. Strategies for filed sampling that would help explain ecological questions and methods for long-term monitoring of Galliformes species have been discussed in the previous publications (Woodburn 1993, Conroy and Carroll 2000).

4.4.2. Relative abundance

Number of individuals encountered in an area is generally related to the population status of the species in that area, because sighting probability is considered to be a function of population density. However, this is valid only if the detection probabilities of species remain constant in the area and that the count methods used to sample their abundance is efficient enough to account for the relative proportion of the abundance. In this study, though the sighting frequency of Himalayan monal was substantially higher as compared to the other two species, the mean encounter rate of the species during spring season (2.6 ± 2.0 SD/km) was comparable with the call count estimate of koklass (2.9 ± 1.2 SD calling males/station). In fact, the abundance of koklass is likely to be higher if the call count estimate is to be extrapolated by including females, which was otherwise not represented in the estimate. Similarly, the density estimates obtained for these two species were almost similar (14-27 Himalayan monal/km^2 and 14-21 koklass/km^2). It is arguable that the abundance indices obtained for Himalayan monal and koklass are not comparable as these estimates were based on two different count methods/sampling efforts (trail walk for Himalayan monal and point count for koklass). However, the estimate of population was standardized to a uniform unit and so, the results were supportive of the fact that both the species occur in almost similar abundance.

Most surveys carried out earlier on pheasants appear to have overplayed the abundance of Himalayan monal, largely attributed to higher sighting records during the survey (Gaston and Garson 1992, Pandey 1993). Because of the non-secretive habit and conspicuous body features, the Himalayan monal has perhaps been sighted more often than other pheasant species, thus giving the impression that this species could be occurring in higher abundance. This study proved that sighting alone is not the appropriate measure of abundance for these species since they display entirely different behaviours, being complete skulkers (koklass), readily conspicuous (Himalayan monal) and both secretive and rare (western tragopan). Therefore, it is important to address these behavioural issues while drawing interpretation based on sighting records. It appears that previous surveys could have overlooked the fact that potential habitat available (both altitudinal and geographical scale) for the Himalayan monal is much larger. Consequently, the probability of sighting Himalayan monal is a lot higher than the other two species, which in turn is reflected in the over all estimate of abundance.

Two major points that were apparent from the results: (1) Survey results need to be viewed carefully since results presented without appropriate measure of efforts would provide a biased estimate favouring conspicuous species and the ones that have a wide area of distribution, such as the Himalayan monal. (2) If the estimate obtained in GHNP is any indication about the relative population status, then Himalayan monal may not be as abundant as it has been thought to be, particularly when compared to koklass. It is worth mentioning that Himalayan monal is more prone to suffer population loss than koklass because of extensive poaching and high chances of predation faced by the species. Local people have long been poaching this species for the attractive plumage particularly the male's crest feathers that are valued in traditional ceremonies. Large body size having high meat value and large concentration of individuals in lower altitude areas during winter, even close to human habitation have often exposed the species to both avian and human predators, thereby increasing the chances of population reduction by predation. On the other hand, the recruitment to the population of Himalayan monal is likely to be much less than koklass given the small clutch size of 3 – 5 eggs as against 8 – 12 eggs in koklass (McGowan 1994, *pers. observ.*). In the case of western tragopan, the overall abundance of this species was very low in the study area, and surveys carried out in other parts of GHNP also indicated very low abundance of the species. Perhaps as a response to its high preference to certain habitat features (e.g. bamboo patches) which have limited spatial distributions, the populations of this species appeared to be divided into several small and isolated units.

Before this study, several surveys carried out in the past across the distribution ranges of the species have attempted to provide information on abundance of the species. However, perhaps due to inherent limitation of the study or inappropriate study design, many of the surveys/studies have reported the abundance in the form of total sightings recorded (e.g. Hume and Marshall 1879, Lelliott 1981, Gaston et al. 1983a, Sharma and Pandey 1989, Pandey 1993, Jandrotia et al. 1995) or number of birds seen per time effort (e.g. Gaston and Garson 1992, Jandrotia et al. 2000). Sighting records without the measure of effective unit effort or the abundance values reported in time as sampling unit do not provide a scope for repeatability and these values are not comparable due to inter observer variability. Also, the time taken by the same observer in an inaccessible area would be much higher than a relatively easily accessible area. These impediments have left few options to compare and ascertain the relative status of abundance of these pheasants in GHNP. Nevertheless, the reliable estimates available from other areas indicate that the GHNP supports relatively high abundance of these pheasants.

Sathyakumar et al. (1993) in Kedarnath Wildlife Sanctuary estimated encounter rate of Himalayan monal to be around 1.0 bird/km during off-winter period, which is half the estimate obtained in this study. There have been few density estimates available from other studies, which have projected the monal density to be around 10 birds/km^2, (Yonzon 1982, Gaston et al. 1983a, Sathyakumar et al. 1993), while in

GHNP, the density was estimated to be 14 – 27 birds/ km². Taking clues from the observations of Wilson quoted in Hume and Marshall (1879), Gaston et al. (1983a) observed during their survey that the density of Himalayan monal has declined over the past years. Similarly, density of koklass in GNHP was found to be relatively high (17.2 birds/ km²) or comparable with the estimates obtained elsewhere by Yonzon (1982) in Nepal (6 birds/km²), Green (1986) in Kedarnath Wildlife Sanctuary (10 birds/km²), Nawaz et al. (2000) in Hazara Forest Division in Pakistan (20 birds/km²) etc. However, Khan and Shah (1982) in Pakistan and Jandrotia et al. (2000) in one locality in Chamba District of Himachal Pradesh estimated a significantly higher density of over 30 birds /km². For western tragopan, the abundance indices and density estimates revealed that the forests in Pakistan support good number of western tragopan (Islam 1982, Nawaz 1999, Nawaz et al. 2000). In India, areas in upper Beas catchment were identified to support a large concentration of this species (Gaston et al. 1981, Gaston and Garson 1992). Density obtained in these areas (2 – 5 birds/km²) is comparable with the current estimate in the intensive study area (1.5 – 2 birds/km²). The point to be noted is that the estimate obtained in GHNP was from a high abundance area and so, it is possible that the current status of population might not be promising as it was in the 1980s. Recently surveys carried out in Chamba forests in Himachal Pradesh discovered new populations of western tragopan (Jandrotia et al. 1995, Jandrotia et al 2000) and it is reported that the abundance is significantly high in some areas that they are comparable with the estimates from Pakistan (Khan et al. 2000). However, the overall encounter rate obtained in these areas were around 3 birds per 10 km walk, which was similar to the estimate obtained in this study, suggesting that GHNP continues to have good number of western tragopan. Despite increasing level of disturbance (both direct and indirect) to these pheasants, the GHNP being under Protected Area with inaccessible terrain which limits easy human access to several parts, could perhaps be the reason for the relatively high abundance of the pheasants here. The overall impression of the abundance indices was that Himalayan monal and koklass are surviving in equally good numbers in GHNP. Though the abundance of western tragopan in GHNP is comparable with other areas, given the low records even after extensive efforts, it was possible to ascertain that western tragopan is not one of the common species and it is in very low abundance.

4.4.3. Population trend

The abundance indices indicated a declining trend in the populations of the study pheasants over the years. The decline was apparently recent and appeared to be related to the mushroom collection activities by local people in this area. Earlier estimates obtained for all these pheasants, presented a marginal decline of just 5% in the population between 1980 (0.9 birds/hour search) and 1991 (0.8 birds/hour search), suggesting that the overall abundance of these species is stable. The recent decline is, presumably, due to breeding loss as a result of extreme level of disturbance caused by uncontrolled mushroom collection activities (Ramesh et al. 1998). The mushroom, locally called *Gucchii*, represents morel mushroom and the particular one being collected in GHNP was *Morchella esculenta*, which is considered a table delicacy. The mushroom grows mostly in the temperate forests (Singh and Rawat 1999) that also happen to be the habitat of pheasants. The time of growth also coincides with the breeding season of the pheasants. Since the mushroom is camouflaged with ground cover and grows singly, people are required to put large amount of search efforts and they literally comb the entire forest floors. Ultimately there is no place in the forested area left unexplored. This is when the people are likely to disturb nesting activities of the pheasants. In addition, they are also reported to indulge in removing the eggs from the nest. The dogs that are supposedly taken along by the people for protection from wild animals are also seen to predate pheasant eggs (N = 2).

In the recent years, there has been an increasing number of people resorting to mushroom collection, because the mushroom has high economic value (US$500/kg of dry weight and around Rs. 2500 in local market, Singh 1997). This was found to be an easy and important source of money by the people. Also, since it is grown in gentle slopes, not far away from human habitation, people including women and children could earn from mushroom collection. 50-60 people were seen visiting the study area every day from late March to early June for mushroom collection. The level of dependency on this natural resource was evident. Out of 8 NTFP under extraction in GHNP, mushroom was the most preferred one, collected by 60% of the local population (Nangia et al. 1999). Since the typical climatic changes in the higher altitude do not permit a second brood, the disturbance can lead to a low breeding success. Secondary data collected by interviewing known mushroom collectors revealed that stealing of eggs of pheasants is taking place in GHNP. Though there was no control experiment to prove that the mushroom collection is solely responsible for the decline, there were circumstantial evidences to indicate that the mushroom collection have major influence towards the decline. A study on Brown-eared pheasant in China has confirmed that mushroom collectors reduced breeding success to a large extent (Zheng-wang 1995). During 1999, there was a total failure in the mushroom growth in GHNP and consequently, there was substantially low human activity in the study area. Substantial increase in the population of the pheasants in the subsequent year indicated a strong relationship between mushroom collection and abundance of the pheasants. After the final notification of the park in 1999, which ceases all human activity inside the park area, the status of pheasant population is likely to improve. However, in other part of the distribution range where mushroom collection has been a serious issue (Fuller and Garson 2000), immediate attention needs to be paid to restore the pheasant population in these areas. A decisive explanation is still due on the effect of mushroom collection on the pheasant population and it could be achieved by carrying out an experimental study.

4.4.4. Group size and composition

Mean group size of Himalayan monal in this study was relatively lower as compared to the estimates from Kedarnath Wildlife Sanctuary, where Sathyakumar et al. (1993) and Kumar (1997) have consistently recorded over 2 birds in a group. Significantly large mean group size along with flocking of more than ten individuals indicates that

Himalayan monal exhibit some amount of group congregation during the winter. Such flocking pattern during winter has also been reported in the ring-necked pheasants (Hill and Robertson 1988). Lack of similar data for koklass and western tragopan from other areas precludes comparative assessment of group sizes. The data brought out by this study with a large number of solitary individuals even for Himalayan monal which is supposedly group living, seem to suggest that resource crunch or disturbance factors are operating against the species. A male koklass with two females during the breeding season and continued pair bond (11 records) in Himalayan monal even after the chicks are hatched reveal that the common notion of koklass being strictly monogamous and the Himalayan monal is polygamous may not be true in all the cases. Skewed sex ratios favoring females have been reported elsewhere too for Himalayan monal (Kumar 1997) and western tragopan (Islam and Crawford 1993). The skewed sex ratios underrepresented by males in Himalayan monal and western tragopan appear to support the common believe that male populations are reduced by selective poaching for crest feather and by avian predators (as males tend to use more open areas). However, all these interpretation need to be substantiated with rigorous field experiments.

CHAPTER 5.

HABITAT USE AND COEXISTENCE

5.1. Introduction

Habitat, according to Odum (1975), corresponds to the address of an organism. Specifically, it refers to the physical and biological environment in which a species is usually found (Morrison et al. 1992). Interpreting species preference to certain habitat features from a human perspective is often ambiguous (Block and Brennan 1993) and also, describing habitat-animal association is scale dependent. Several studies have deliberately dealt with such issues and have focussed on the description from the species' perspective (Knick and Rotenberry 1999) and at appropriate hierarchical scales (Johnson 1980, Ritchie and Olff 1999). In reality, species distribution/habitat occupancy is primarily influenced by proximate and ultimate factors (Orians 1971). The proximate factors (otherwise called psychological factors) enable the species to motivate settling behavior, while ultimate factors influence the survival and reproductive success of individuals. In the absence of stochastic events and within the normal demographic processes, habitat conditions could reflect relative population status of the species. Local habitat factors also have an important role in determining abundance and geographical distribution of species. Brown (1984) has illustrated several scenarios, explaining the correlation between abundance and geographical distribution of the species. Therefore, a clear picture on how the species is (spatially and numerically) related to a given environment becomes essential to understand species biology and consequently, for management/conservation. Most of the habitat use studies, in effect, intend to provide initial steps towards understanding the complex issue by identifying and describing habitat correlates.

The pheasants, in general, are inhabitants of forested landscapes ranging from tropical scrub forests to alpine region and being ground dwellers, majority of them appears to show marked preference for ground cover (Johnsgard 1986, Fuller et al.

2000). Due to consumptive and sport hunting interests, a great deal of research has been carried out on Galliformes in western countries and in fact, some of these research works have made significant contributions in the early development of ornithology (Block and Brennan 1993). However, these studies represent different habitat conditions in the New World and on introduced populations, thus limiting the scope of extrapolating to natural populations elsewhere. With regard to pheasants specifically, much of the known quantitative information on ecology and population processes are from studies on introduced populations of Ring-necked pheasant (*Phasianus colchicus*) in Europe and United States (Hill and Robertson 1988). Surprisingly, studies on habitat use and selection by pheasants in Asia have been very few, even though 90% of the species are native to this region.

Current knowledge on pheasant-habitat associations remains largely limited to species association with broad vegetation types. Recent studies, with more focussed approach, have revealed that the availability of large extent of these broad habitat types may be irrelevant to some species, as microhabitat attributes act as stronger habitat determinants (McGowan 1994). Such relationships cannot be ruled out in other species, given our limited understanding and inadequate quantitative data. The study species, which inhabit typical temperate belt of the Himalaya, encounter additional complexity typical to temperate environment. The effects of altitude and aspect largely determine general vegetation here, and hence, distribution pattern of pheasant species is interrelated with these physical factors (Johnsgard 1986). Further, climatic conditions appear to be deterministic forcing species to select different habitats across seasons. These species descend to lower elevation areas in winter and spend a considerable amount of time in what is known as 'winter habitats' (Gaston et al. 1983a, Johnsgard 1986, Kumar 1997). Extensive snow cover combined with sub-zero temperature is believed to limit resource availability and compel them to compete with related species for resources during winter months (Hill and Robertson 1988). However, several of these facts are little understood and current knowledge on habitat selection in non-winter months is also very limited.

The study species largely resemble with each other in broad morphology (Ali and Ripley 1983), belong to the same clan in phylogenetic trees (Kimball et al. 1999) and are found in similar environments in temperate forests (Gaston et al 1983). Coexistence of closely related species is possible when they are separated ecologically either by specific habitat requirements or food, or both (Lack 1971). This exclusiveness or ecological isolation is a consequence of competition for resources, which becomes insufficient either due to overwhelming demand from corresponding increase in species populations or reduced by stochastic events and other dominant forces. The ability to coexist or share resources is an interesting subject that has strong roots in both ecological science and evolution. The study species are reportedly separated by altitude to some extent (Johnsgard 1986, Gaston et al. 1981), but wherever there is a spatial overlap which is obvious during winter, conditions that enable them to coexist or exclude each other remain unknown.

Kumar (1997) studied winter habitat use by Himalayan monal in the Garhwal Himalaya and found that dense *Kharsu* oak-rhododendron community in higher altitudes (2800-3100m) with high proportion of bamboo and litter cover was preferred by the species. Snow condition was proved to be the limiting factor for space use in winter, and there was a marked upward movement to higher altitude areas after the melting of snow, though *Kharsu* oak-rhododendron forest patches were continued to be used by few individuals. In koklass, a recent study carried out in select oak dominated forest patches in the Kumaon Himalaya described a positive relationship with well-developed and diverse ground vegetation (Hussain et al. 2001). Also, abundance was positively correlated with increasing altitude. In case of western tragopan, more than forest types or dominant plant species composition, structural components were responsible for habitat use during breeding season in Pakistan (Islam and Crawford 1987). These authors hypothesized that strong association with shorter life forms is relevant, because these provide nesting habitat, protection from predators and food resources. These studies were restricted to certain seasons and different climatic zones *viz.*, dry temperate region (Pakistan) and wet temperate region (Garhwal and Kumaon Himalaya). Nevertheless, they provide useful information on habitat use independently, but no inference could be made on ecological isolation. Further, in the case of western tragopan, ringal bamboo (*Thamnoclamus spathiflorus*) provides the required understorey in India, while it is replaced by *Vibunum* sp. in Pakistan (Islam and Crawford 1987).

The present investigation is an initial attempt to study these species together in the same environment and includes seasonal variation, which previous studies had either neglected or had limited information on. This study was essentially designed to describe habitat association of these species at both macro (major vegetation types and physical features) and micro (immediate environment such as tree, shrub and litter covers) scales, both in winter (snow) and summer (snow-free) seasons. As mentioned earlier, the study site supported all three species in sizable populations and occurrence of these species in the same area offered an opportunity to study factors responsible for coexistence in these species. Specifically, the study addressed the following questions.

1. Do the pheasants exhibit strong affinity towards certain vegetation types?
2. How do elevations, aspects and slope influence habitat use by these birds?
3. What are the microhabitat characteristics that govern habitat use of these birds?
4. What facilitates these species to coexist?

5.2. Methods

5.2.1. Macrohabitat use

Habitat association was quantified at hierarchical scales, based on correlative (relating abundance with major vegetation types, elevation, aspect and slope) and focal bird approaches (measuring habitat characteristics at bird locations) as described by Block and Brennan (1993). Four major vegetation types/habitat types were recognized within the intensive study area *viz*., 1) Broad-leaf forest (*Aesculus-Acer-Juglans*), 2) Conifer forest (*Cedrus-Pinus-Abies-Taxus*), 3) Mixed forest (*Abies-Pinus-Acer-Quercus*) and 4) Sub-alpine Oak (*Quercus semecarpifolia*). Abundance of the study species in each of the vegetation types was estimated based on trail monitoring or call counts (refer to Chapter 3 & 4 for details). Estimates from six trails and 10 call count stations were pooled to represent the vegetation types and the mean encounter rates associated with the standard errors were compared to describe relative habitat preference by the species in different seasons. Availability of absolute area under different elevation, aspect and slope categories was enumerated using Arcview software in GIS and, proportional availability and use of these habitat parameters by the study species were assessed graphically. Non-parametric Mann-Whitney U test was performed to assess statistical significance in macro habitat usage between seasons.

5.2.2. Microhabitat use

As and when the study species were sighted along the trail, the sighting points were flagged at nearest points. After completion of the walk, various microhabitat features (40) were quantified at the bird (flagged) locations. Quantification was made within circular plots of 10m and 5m radius respectively for tree and shrub associated variables. One-meter quadrats were laid at the center of bird location to measure herb, grass, and litter covers and soil depth. Soil samples within the quadrats were searched to record presence of potential invertebrate food sources. Physical variables such as elevation, aspect, slope, and distance to water sources were measured from the center of 10m circular plots. Redundant variables and auto-correlated variables were identified using correlation matrix computed in SPSS software and excluded for further analysis. Habitat associations with the microhabitat characteristics were described based on Classification Tree (De'ath and Fabricius 2000). Tree model was preferred because it is robust over several other statistical tools and the overriding advantage of this method is the ability to find patterns involving both categorical and discrete explanatory variables (De'ath and Fabricius 2000). The results are more descriptive and presented as a tree, each branch in the tree representing a homogenous group of variables together explaining habitat associations.

5.2.3. Radio-telemetry

Radio-telemetry was also used for western tragopan, since it is one of the important species of conservation value (Fuller and Garson 2000). Also, the ability to detect the species in natural habitat is constrained by its secretive behaviour and low density. Trapping efforts were made during April – June 1999, using indigenously devised fall nets (n=6) and leg-hold snares (n=9). Fall net was a combination of 'automatic fall net' and 'walk-in trap' described by Bub (1991). Measurement of the nets were 15 to 18m length and 6m width, with mesh size of 40 x 40mm. Nets were coloured to camouflage them, and were rigged such that 3m of the net was set lying on the ground and the remaining, stood at 50° angle supported by triggers made of bamboo sticks (Fig. 5.1). This set up would trap the bird upon release of trigger that is set free when the bird walks on the net. Leg-hold noose had a series of 40 – 50 independent nooses fixed at 15cm interval along a thin and strong rope (Fig. 5.2). The base of the noose, tied with a stick measuring 10 x 2cm was pressed into soft soil, leaving he noose at 90° to the ground. One end of the trap was roped with a strong support nearby, and the other end was left free. This setup prevents the bird from breaking away from the trap and at the same time, enables the bird to move around without inflicting injury to the leg. Traps were set in previously identified locations (12) in forest areas (n = 6), *thaches* (forest clearing used as campsite by pastoralists) (n = 2) and *nullahs* (small streams of both perennial and seasonal, n = 4). These locations were water holes, roosting sites and places where frequently sightings of birds occurred. The traps were monitored periodically twice a day. Besides, the bird was chased towards the net that was placed about 200m from the bird, immediately after hearing or spotting the bird. Trapping was attempted for 256 man-days (4 persons x 64 days in three months) in areas between 2600m and 3000m. The entire effort translated to 6694 trap hours, accounting to 3924 net hours and 2767 noose hours.

Figure 5.1. Diagrammatic representation of fall net

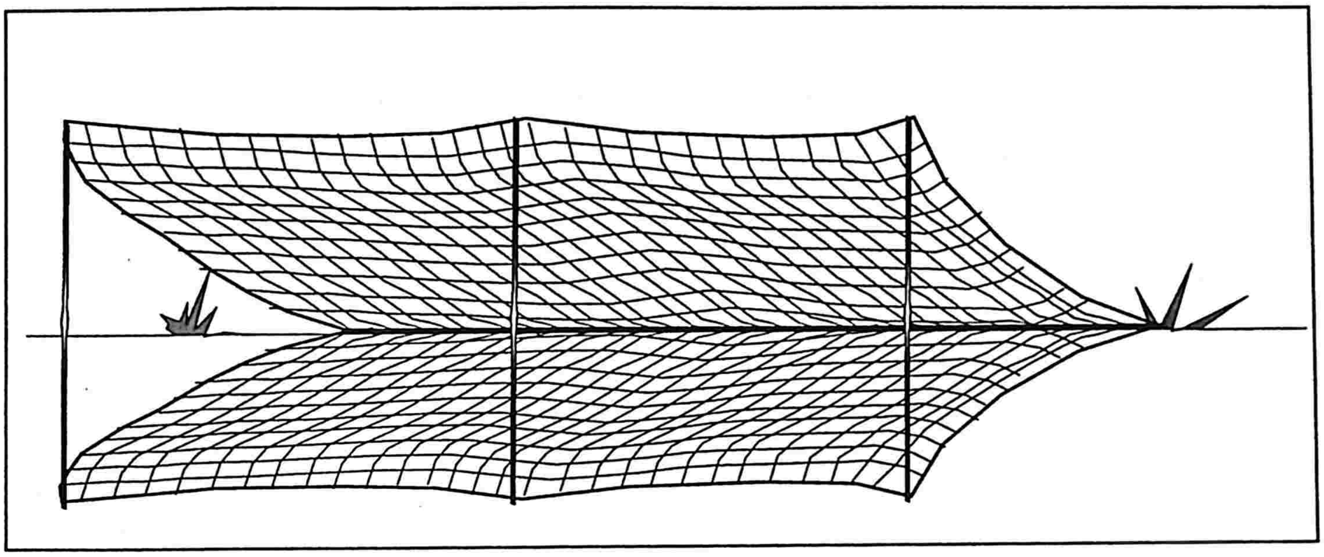
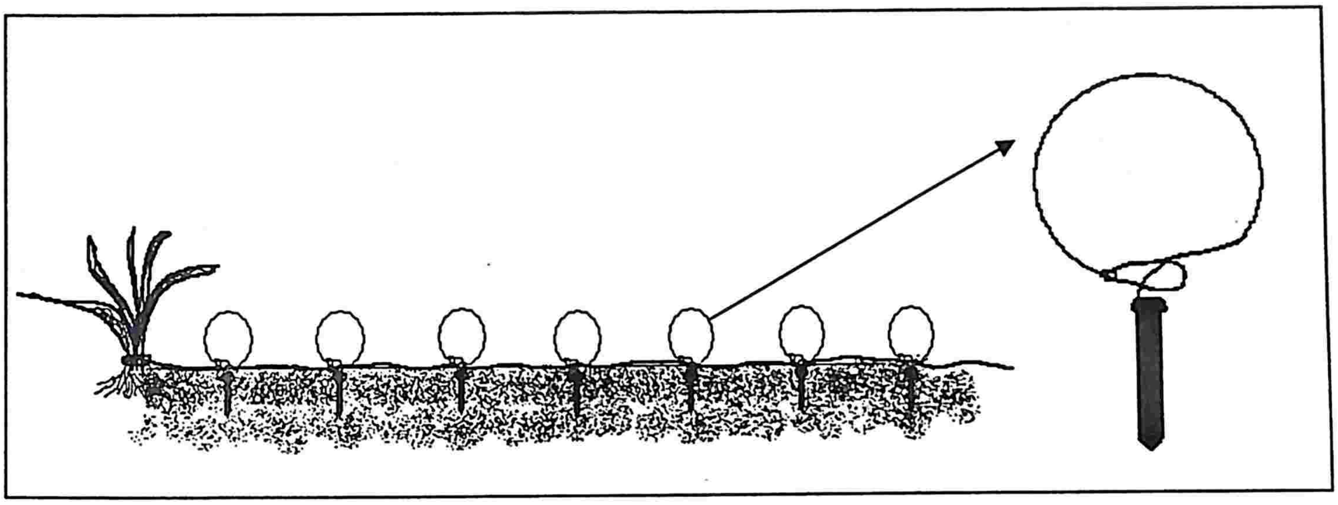


Figure 5.2. Diagrammatic representation of leg-hold noose



Only one female bird could be trapped in spite of an intensive attempt. The trapped bird was fitted with a radio transmitter using standard Biotrack necklace type collar weighing about 50g. Three element Yagi antenna and Mariner 57 Biotag receiver were used to record radiolocations. Home-in method to locate the bird was discarded after three sampling days, as the movement of the bird was found to be influenced by the observer. Rest of the data collection was done based on either triangulation or modified home-in method (taking location data from the closest distance that did not disturb the bird) and data was collected at three times (6 – 11 hrs, 10 – 15 hrs and 15 – 18 hrs) every third day. Collared bird was radio-tracked from May to November 1999 covering both summer (May – September) and autumn (October and November) seasons after which there was no signal obtained.

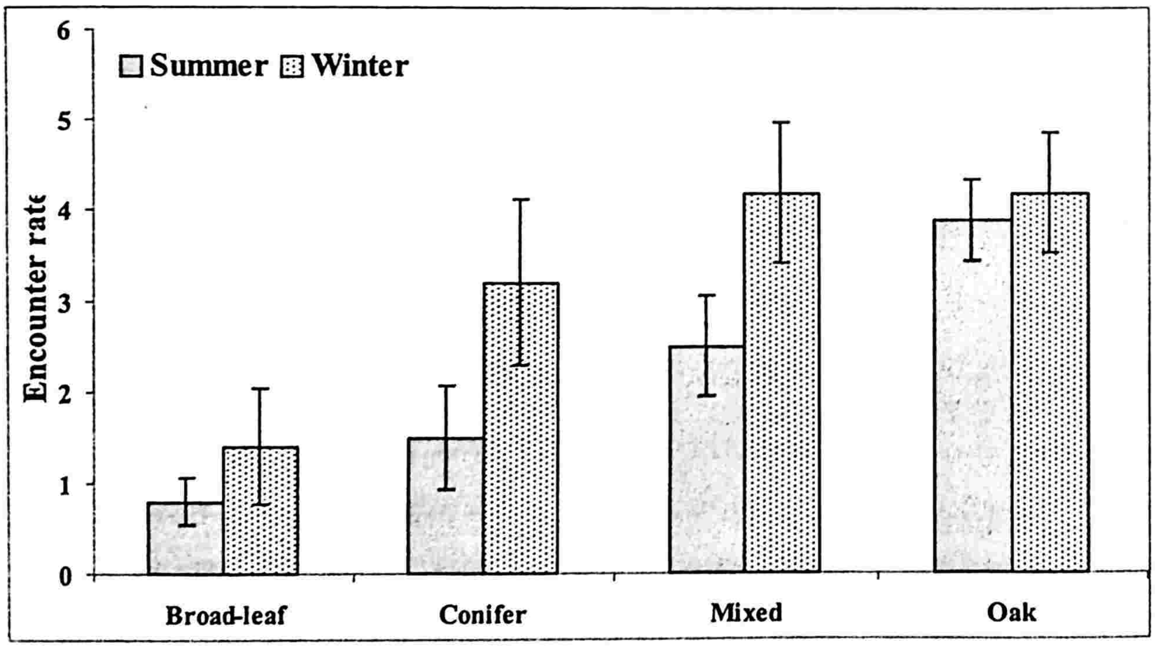
Locations were plotted on 1: 50,000 topographic map and home range was estimated based on 100% Minimum Convex Polygon (MCP) method in Arcview software. The location and home range polygon were plotted on habitat maps such as vegetation types, elevation, aspect and slope in GIS to relate tragopan association with these variables. Circular plots (n = 9) were laid randomly within the home range to study microhabitat features of the area used by the radio-tagged bird. Variables such as tree density, % canopy cover, ground covers, number of fallen logs and distance to water sources were measured within 10m radius. Composition and abundance of shrub species were quantified in 5m radius, and 1 x 1m quadrate was used to record ground parameters such as litter cover and litter depth.

5.3.Results

5.3.1. Macrohabitat use

Vegetation types: Broad leaf elements had a distinct effect in habitat use by these species, as indicated by relatively higher usage in broadleaf dominated forest types. Himalayan monal showed a gradation of preference from lower-altitude broad leaf forest to subalpine oak forests in both the seasons (Fig. 5.3.). However, marked preference to mixed and subalpine forests was conspicuous in summer, while

Figure 5.3. Use of vegetation types by Himalayan monal in summer and winter in the study area (mean ± SE)



conifer forests also were used substantially in winter. Koklass used broadleaf, mixed and oak forests indifferently and conifer forest was significantly less used (Fig. 5.4). Strong association with mixed and oak forests was discernable in western tragopan habitat use in summer, while in winter, higher encounter rate in lower-altitude broadleaf forest indicated its relative preference to such vegetation types in this season (Fig. 5.5).

Figure 5.4. Use of vegetation types by koklass in summer in the study area (mean ± SE)

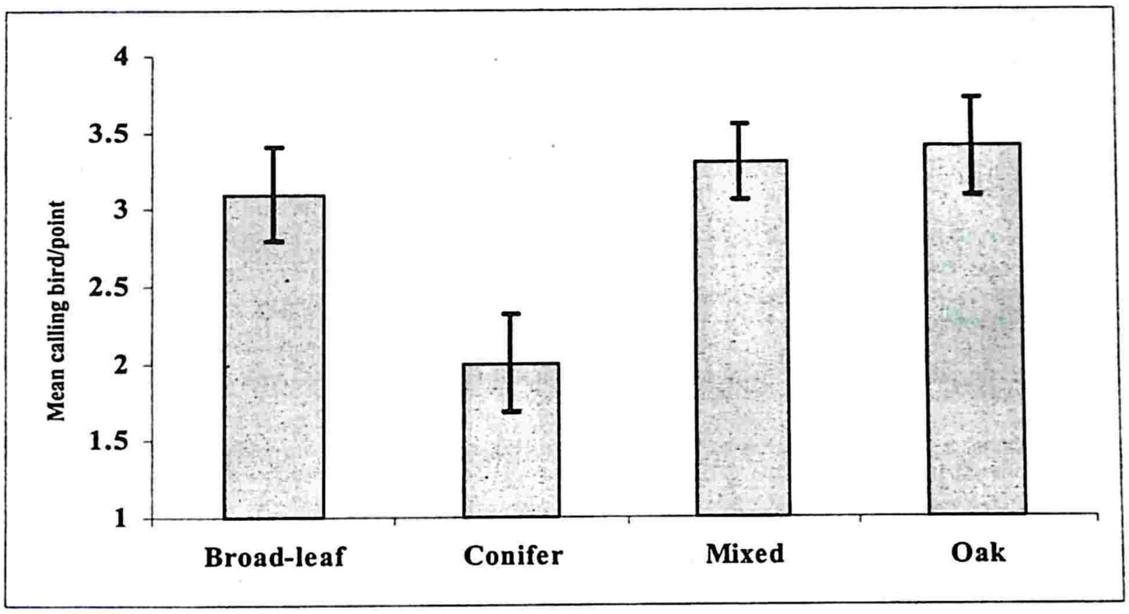
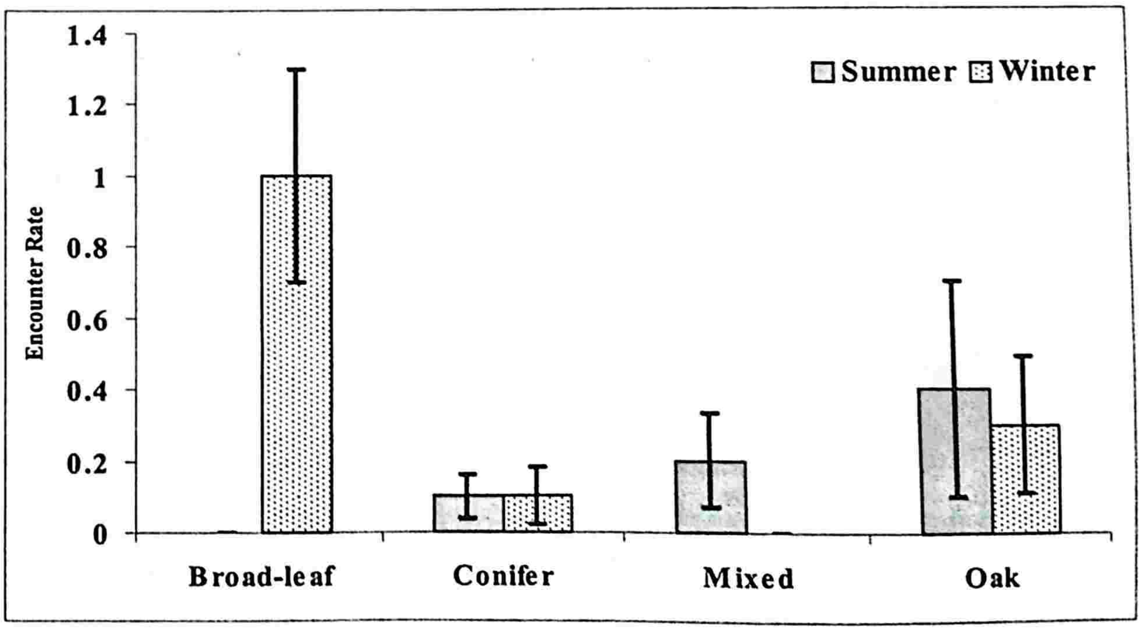
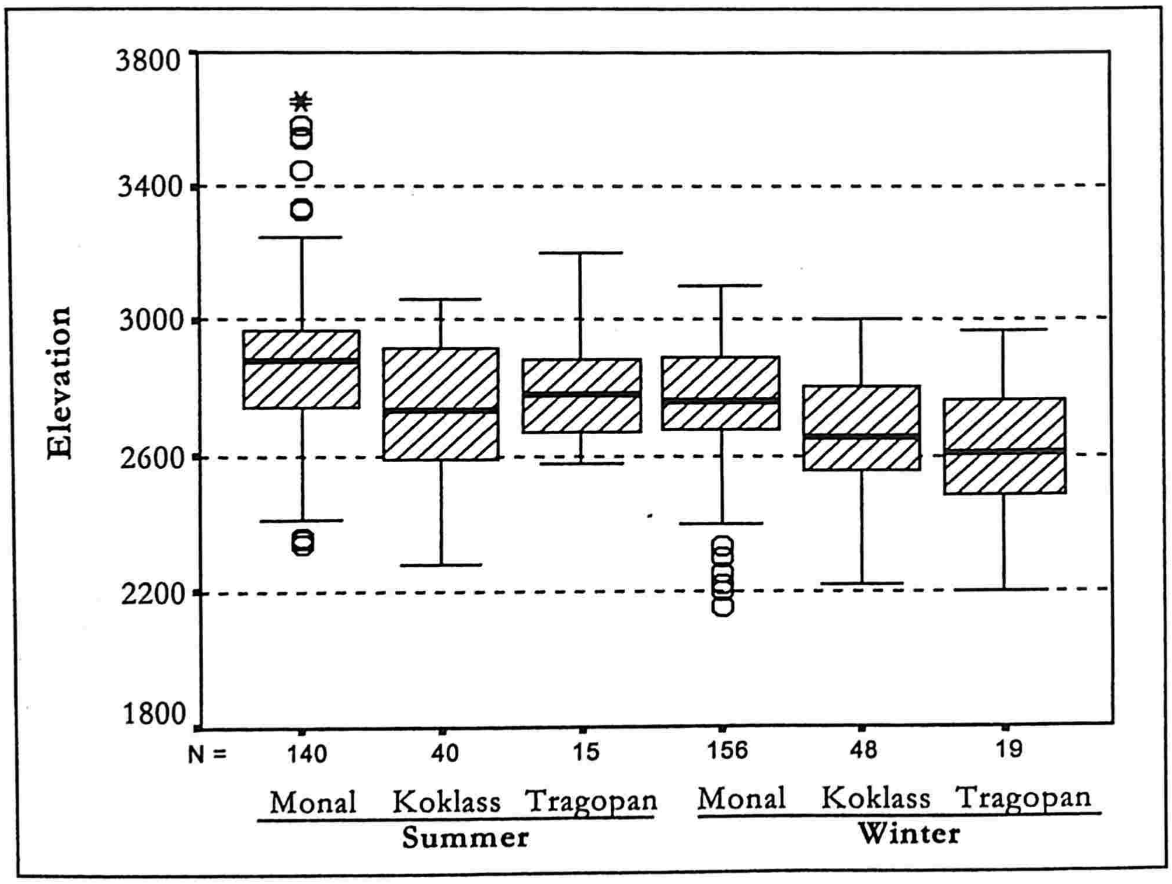


Figure 5.5. Use of vegetation types by western tragopan in summer and winter in the study area (mean ± SE)



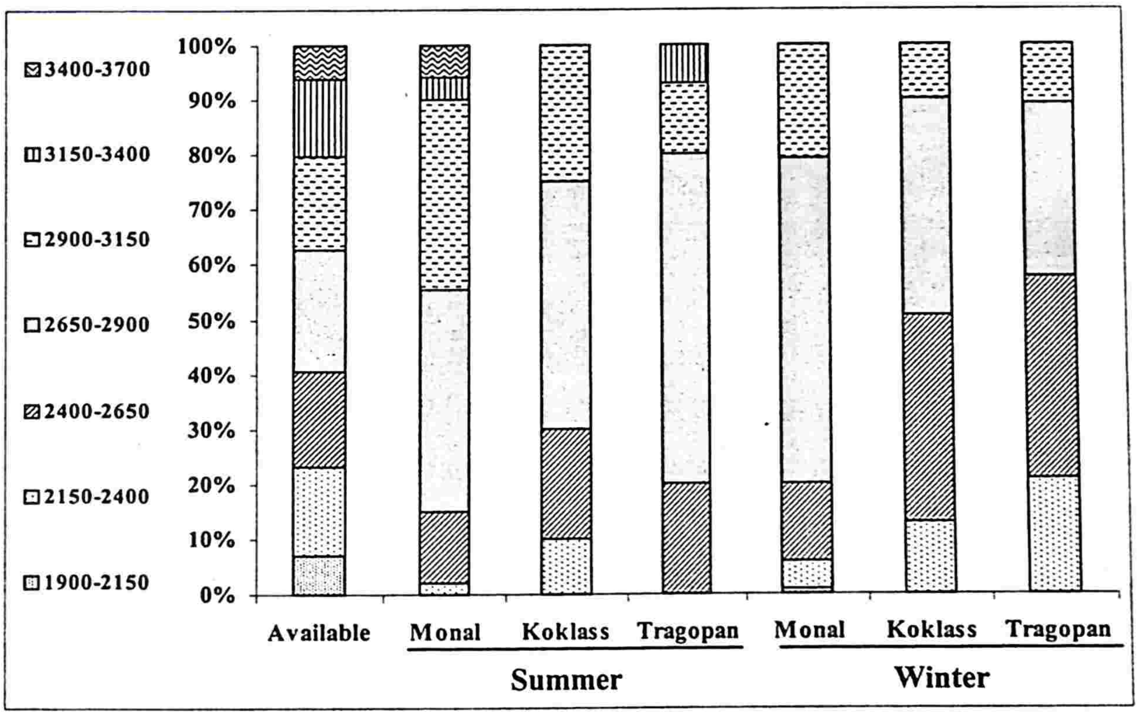
Elevation: All three species were largely concentrated in middle elevation areas (2600-3000m), and the concentration was found shifted to lower elevations in winter, which could be attributed to heavy snow at higher elevations (Fig. 5.6). Himalayan monal appeared to show high fluctuation in altitudinal distribution, and was distributed between 2340 and 3660m (mean 2874 ± 253 SD) in summer. Movement towards lower elevation areas during winter was significant (Mann-Whitney U test, Z = -4.402, $p < 0.001$) and was confined to below 3100m (mean 2775 ± 131 SD), reaching as low as 2150m. Koklass maintained a relatively stable altitudinal distribution, mostly ranging between 2220m and 3060m in both summer (2733 ± 220 SD) and winter (2650 ± 197 SD) (Mann-Whitney U test, Z = -1.874, p = 0.06). Western tragopan appeared to occupy areas that fall within lower and upper limit of Himalayan monal and koklass distributions respectively, and it ranged between 2575 and 3200m (2796 ± 167SD) in summer. Like Himalayan monal, it also responded strongly to snow conditions, and was largely restricted to areas between 2220 and 2970m in winter (2610 ± 216SD). The altitudinal distribution between the seasons

Figure 5.6. Box plot depicting use of elevation by the study species in summer and winter



was statistically significant (Mann-Whitney U test, $Z = -2.708$, $p < 0.05$). Proportional availability of different elevation categories in the study area was almost constant and it was found that Himalayan monal relatively preferred areas within 2650-3150m, while koklass and western tragopan showed relative preference to staying in the 2650-2900m zone (Fig. 5.7). During winter, there was a consistent downward movement to lower elevation categories. Altitudinal overlap between these species, at least in parts of their distribution range, was apparent in summer, and was more so during winter.

Figure 5.7. Availability and use of different elevation classes by the study species in summer and winter



Aspect: There was disproportionate availability of areas under different aspects/hill-direction, significantly less represented by northeast and northwest aspects (Fig. 5.8). There was a marked difference in proportionate use of these aspects by individual species across seasons (Fig. 5.8. & Fig. 5.9). During summer, Himalayan monal used these aspects mostly in proportion to availability, except the northeast and west that were used more than and less than availability respectively. Though koklass used northern and eastern aspects in proportion to available, it showed clear preference to south and southeastern aspects. Western tragopan had strong preference for east, south and southeastern aspects. However, during winter, all these species were seen using south and southeastern aspects much higher than the proportional availability, though Himalayan monal and koklass continue to use eastern aspects little more than the available proportions (Fig. 5.9).

Figure 5.8. Availability and use of aspects by the study species in summer in the study area

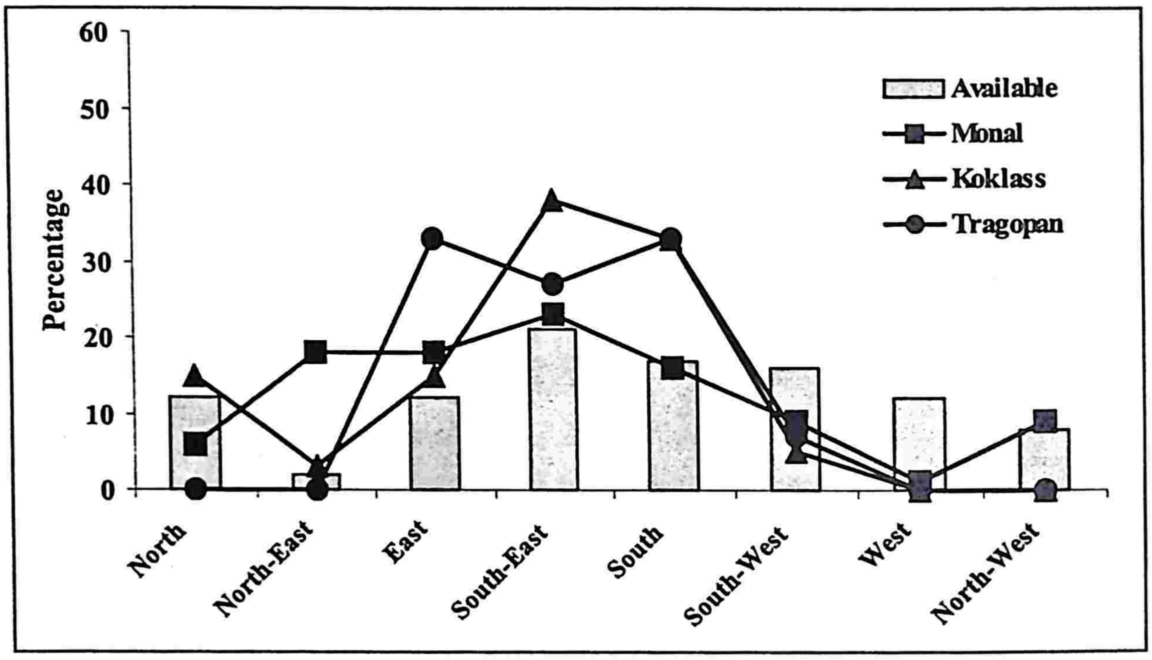
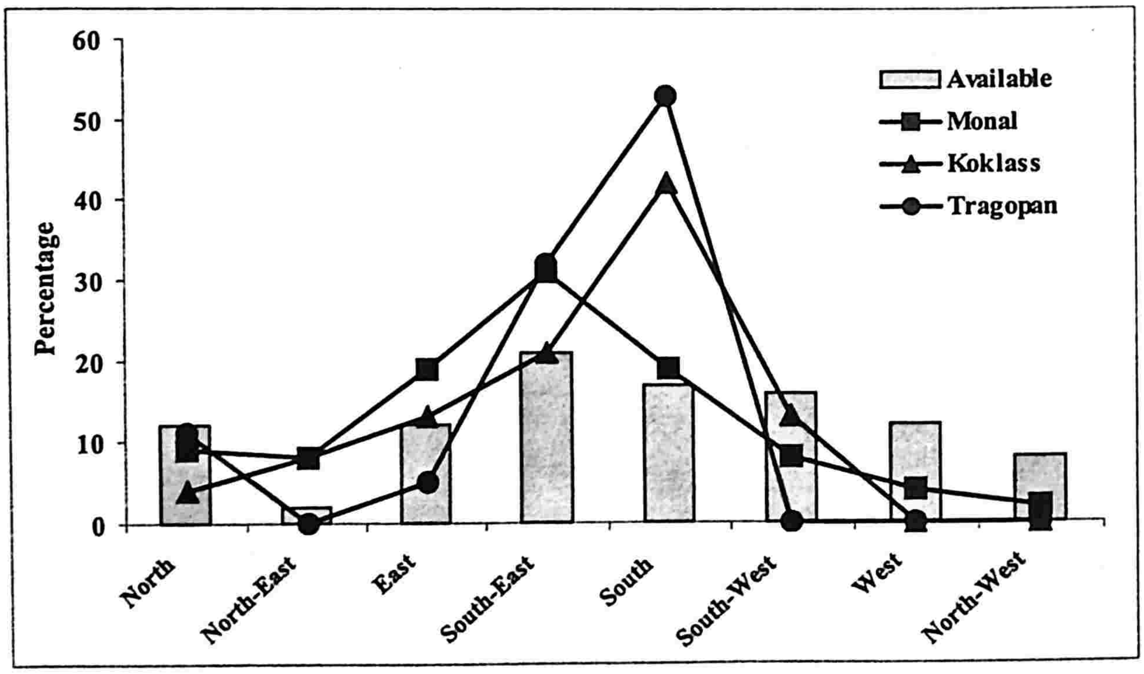


Figure 5.9. Availability and use of aspects by the study species in winter in the study area



Slope: These species used gentle to moderate slopes (25-45°) with slight variation between species, and were found using comparatively steeper slopes during winter (Fig. 5.10). However, these differences were statistically insignificant (Mann-Whitney U test: Himalayan monal $Z = -1.800$, $p = 0.07$; koklass $Z = -0.3190$, $p < 0.75$; western tragopan $Z = -0.3340$, $p < 0.76$). Himalayan monal, though ranged from 10° to 55° slopes, largely used between 25 and 40°, while koklass and western tragopan respectively used 25-45° (range: 5-50°) and 30-40° (range: 10-50°) slopes. In comparison to availability of different slope categories, preference to certain slope categories was interestingly conspicuous among these species (Fig. 5.11). Himalayan monal preferred gentle (20-30°) to moderate slopes (30-40), koklass preferred gentle slopes (20-30) and western tragopan preferred moderate (30-40) slopes.

Figure 5.10. Box plot depicting use of slope by the study species in summer and winter

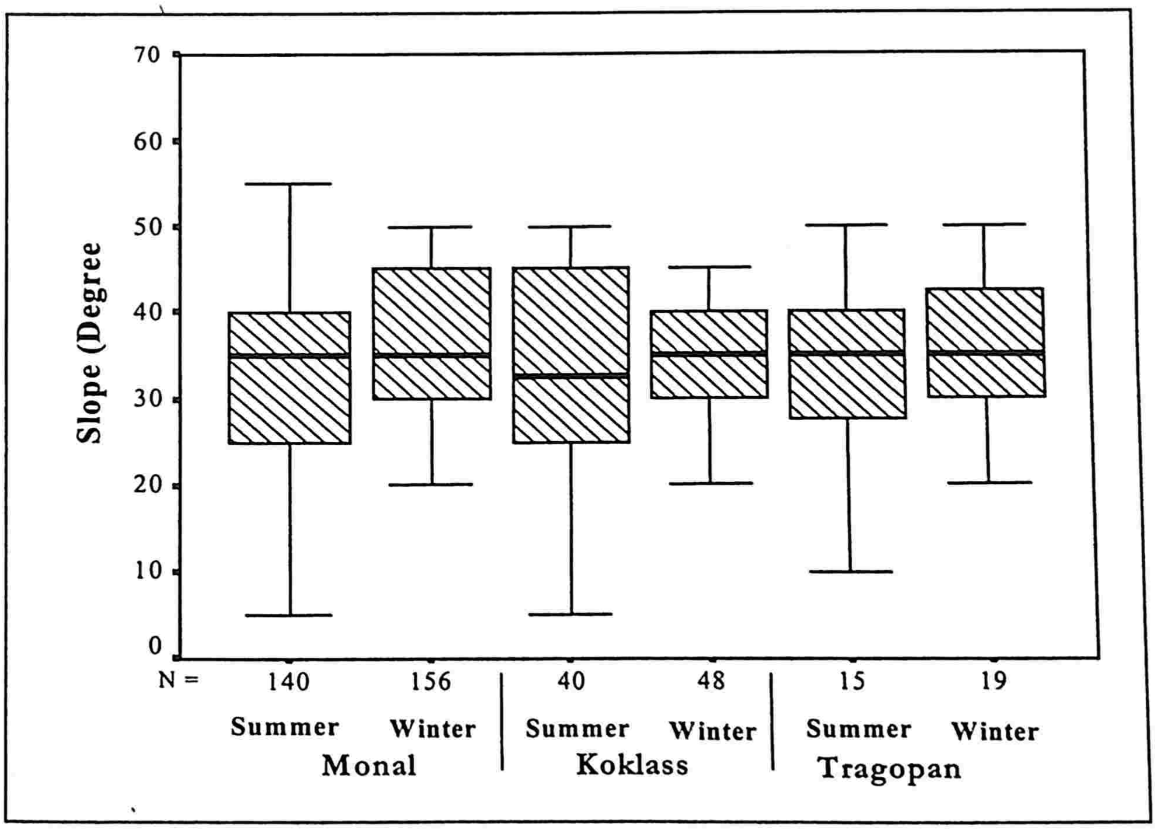
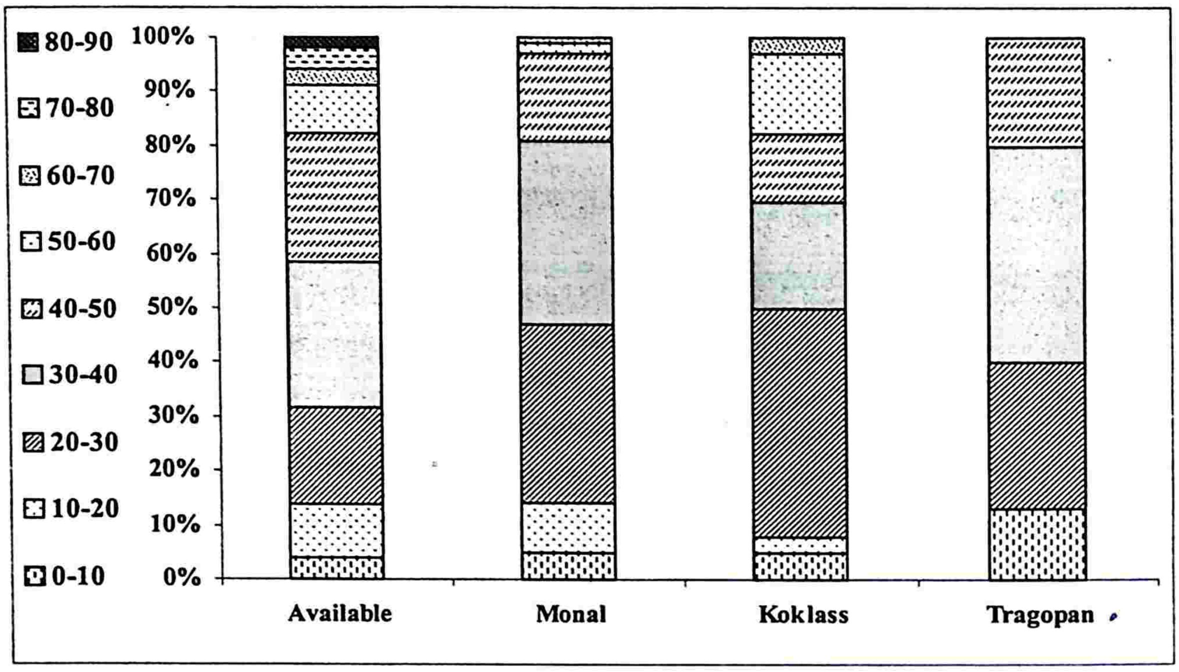


Figure 5.11. Availability and use of slope classes by the study species in summer



5.3.2. Microhabitat use

Microhabitat variables could be quantified for 296 observations (140 in summer and 156 in winter) of Himalayan monal, 88 observations of koklass (40 in summer and 48 in winter) and 34 observations of western tragopan (15 in summer and 19 in winter). Rest of the sighting were either inaccessible for data collection or actual locations of the birds could not be established. Of the 40 variables quantified, only 22 were found relevant and the rests were either strongly auto-correlated or redundant. Use of individual variables varied between seasons, except for canopy cover, litter-cover and litter depth that were used in similar fashion in both the seasons (Table 5.1). The values presented in the table, however, present only the average use of these variables individually, but are difficult to explain any pattern directly based on these values as the variables tend to have combined effect in determining habitat use by the species.

As expected, Classification Tree unraveled certain features to be associated more strongly with these species and composite influence of the habitat variables was distinct within species and between seasons. The Tree identified twelve variables, three physical (elevation, aspect and slope) and nine biological (vegetation type, tree density, canopy cover, shrub species, shrub density, bare ground, litter cover, soil depth & distance to water), to have significant association with the habitat use of these species during summer. Original Tree had 22 terminal nodes, beyond which no splitting was possible, and it was later manually pruned to 12 terminal nodes/clusters on the basis of very few records in such associations or the group was largely represented by a single species. The clustering of habitat variables were hierarchical represented by the largest proportion of any single variable at the terminal node, followed by the less represented ones at the decreasing order. From the second spilt onwards, more than one parallel homogenous group could be formed if the observations had multiple associations with the habitat features. Minimum cut of the model, *i.e.* minimum number of observations/occasions that had consistently similar set of variables/homogenous groups, was decided to be 5 and the overall accuracy or in opposite term, misclassification error rate of the model for summer season was 12%.

Figure 5.12 depicts two clear patterns divided into broadleaf & mixed elements on one-side and conifer & alpine elements on the other, and all these three species used one or more cluster of variables within these broad vegetation types. Himalayan monal used both the vegetation types equally, showing tendency to be generalist in using the microhabitat variables. Use of *Krummholtz* (alpine scrub), alpine meadow and *thaches* (transition campsite of migrant sheep and goats structurally resemble canopy gap) were revealing, which otherwise got masked in the macrohabitat analysis since the encounter rates were pooled to relate only the major vegetation types. In the conifer and alpine associated vegetation, significant proportion of records (82%) was in *Rhododendron*, *Lonicera*, *Rosa*, and *Cotoneaster* dominated shrub composition and mostly within 60m from water source (43 records). In the broad leaf dominated forests, areas with low shrub density dominantly associated with shrub species such as *Thamnoclamus, Indigofera, Prinsepia, Rhododendron* and *Viburnum* were used in great proportions. Wherever these birds used higher shrub density area, soil depth was found to be suited to facilitate digging for food resources. These birds also showed preference towards more open areas or bare ground. Koklass was largely restricted to broadleaf elements and there were two clear habitat use patterns largely determined by shrub species composition and associated variables. In areas with shrub species such as *Cotoneaster, Lonicera, Rhododendron* and *Sorberia*, the ground was either covered with herb/grass species or litter, where as low shrub density and higher bare ground was used within *Thamnoclamus, Indigofera, Prinsepia, Rhododendron* and *Viburnum* shrub dominated areas. Western tragopan also showed relative preference to broad leaf associated habitat features and was largely found in areas dominated by *Thamnoclamus, Rhododendron* and *Viburnum* and in both high (5 records) and low (6 records) densities. Areas with high shrub density invariably had less soil depth, while the low density areas were covered with more of herb, grass or litter cover.

Tree model for winter season identified 14 variables, including the 12 used in summer and additional two of log density and rock cover, to have significant influence in habitat use pattern of the study species. The model with minimum cut of 5, resulted in 27 terminal nodes and with 14% misclassification error rate. It was then pruned down to 10 nodes, following similar approach that was adopted for summer season. Absence of association with broad vegetation types was apparent, and habitat association was strongly based on dominance of certain shrub species (Fig. 5.13). Himalayan monal showed significant relative preference to areas with high tree density and canopy cover dominated by *Thamnoclamus, Rhododendron, Viburnum,* and interestingly these areas were above 2600m (89 records). Twenty-one records were in low tree density areas, but still continued to have higher canopy cover. In lower altitude, higher shrub density was chosen. Koklass also responded in a similar fashion as that of Himalayan monal and used areas with high tree density and canopy cover above 2600m. Use of rock cover was distinct (26 records) and had strong association with shrub species such as *Indigofera, Rosa* and *Sorberia,* which mostly grow in lower elevation and steeper slopes. These shrub species were used by western tragopan as well, but in low density consistently close to water. In areas above 2600m, it was associated with low canopy cover and higher litter-cover.

Table 5.1. Mean values of microhabitat variables used by the study species in summer and winter

Variables	Monal		Koklass		Tragopan	
	Summer (n = 140)	**Winter** (n = 156)	**Summer** (n = 40)	**Winter** (n = 48)	**Summer** (n = 15)	**Winter** (n = 19)
Water (m)	69.0	38.3	90.7	30.9	36.3	35.3
Tree Density (No./plot)	5.1	4.9	6.2	4.2	4.8	3.3
Canopy Cover (%)	31.9	32.6	35.0	32.1	31.0	26.1
Log Density (No./plot)	1.3	0.7	0.8	0.9	1.7	0.4
Bare Ground (%)	31.0	30.0	29.7	30.1	26.0	31.6
Rock Cover (%)	20.8	13.4	15.5	16.9	16.0	22.4
Snow Cover (%)	2.1	17.6	2.1	10.9	2.7	6.8
Snow Depth (cm)	0.9	6.3	3.5	5.1	1.3	3.3
Shrub Density (No./plot)	3.8	3.3	5.6	3.2	6.2	2.6
Litter Cover (%)	46.9	46.5	54.3	44.7	42.3	43.2
Litter Depth (cm)	3.6	2.6	2.8	2.7	2.7	2.6
Soil Depth (cm)	5.1	3.5	3.9	3.0	3.7	3.4
Herb Density (No./plot)	3.0	1.0	3.8	1.4	2.7	0.9
Grass Density (No./plot)	2.9	2.6	4.2	2.3	1.8	3.5
Invertebrate	1.4	0.5	1.3	0.4	1.5	0.4

5.3.3. Home range of western tragopan

One female western tragopan was caught on 14th May 1999 in a leg-hold noose, radio tagged and released on the same spot. Since there was no possibility of increasing sample size of radio-tagged bird, the results obtained from one female bird are presented descriptively, and no further inference is sought. A total of 72 radiolocations representing 51 for summer and 21 for autumn (just beginning of winter) were obtained. Estimated home range of the female bird was 31.6ha for the entire study period, and it was 20.5ha in summer and 4.7ha in winter. The bird moved to a lower elevation area between Rolla and Dulunga *thach* in the month of October and continued to stay there until the signal was lost in late November 1999. The radio-tagged bird used five broad vegetation types *viz*, mixed conifer forest, mixed conifer and broadleaf forest, broadleaf forest, open forest and grassy blanks (Fig. 5.14). *Abies* pindrow and *Taxus baccata* dominated the conifer forests

Figure 5.12. Classification tree depicting microhabitat features used by the study species during summer season

([a] - Used above 45% canopy cove, [b] - Purely within broadleaf and old growth forest, [c] - <30° slope, [d] - East and Southwest facing slopes, [e] - Higher tree density area >5/plot)

(Th. – Thamnoclamus spathiflorus, So.- Sorberia tomentosa, Co. – Cotoneater affinis, In. – Indigofera heterantha, Lo.- Lonicera, Rh. – Rhododendron arboreum, Pr. – Prinsepia utilis, Ro. – Rosa neivus, Vi. – Viburnum nervosum)

(N – North, S – South, SE – Southeast, E – East, NE- Northeast, NW- Northwest, SW- Southwest)

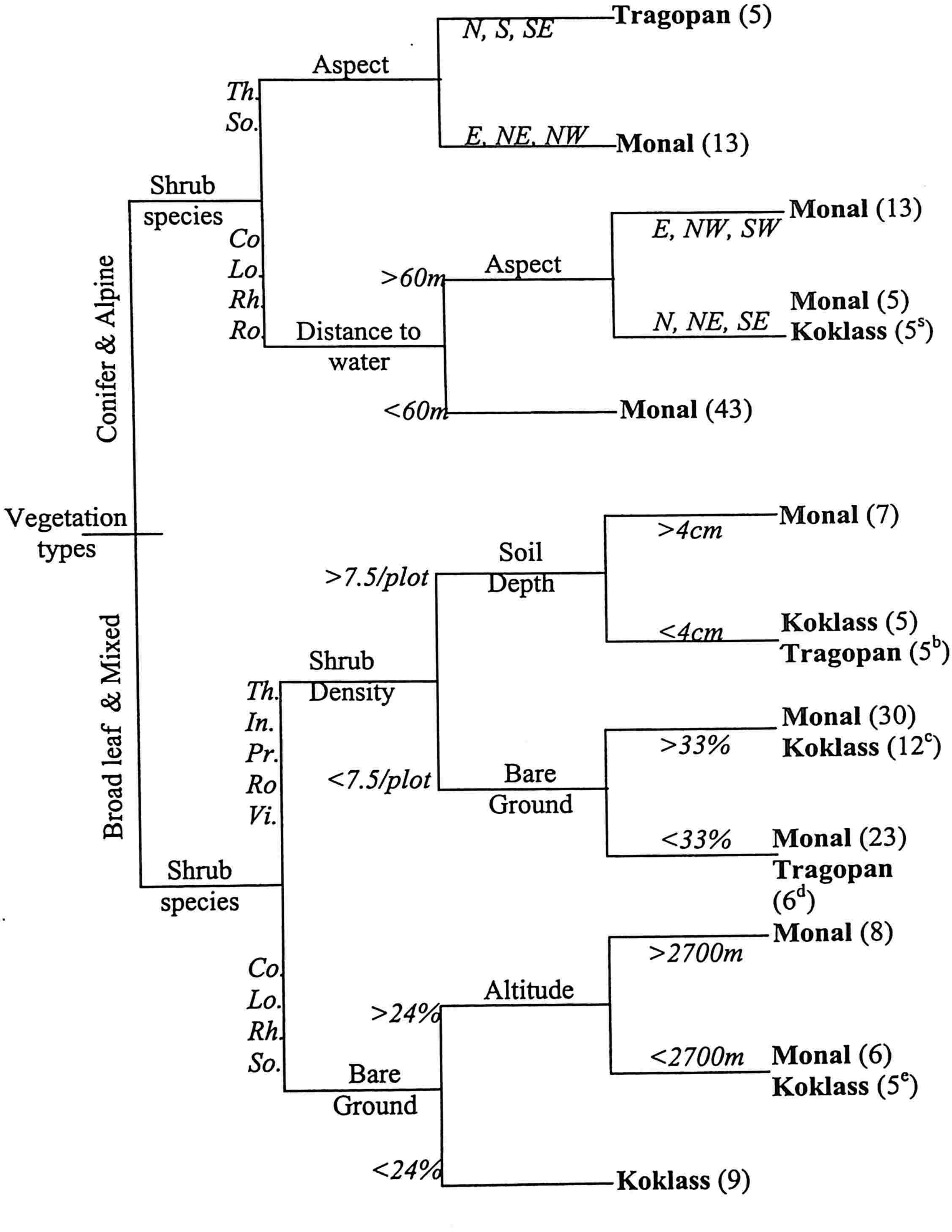
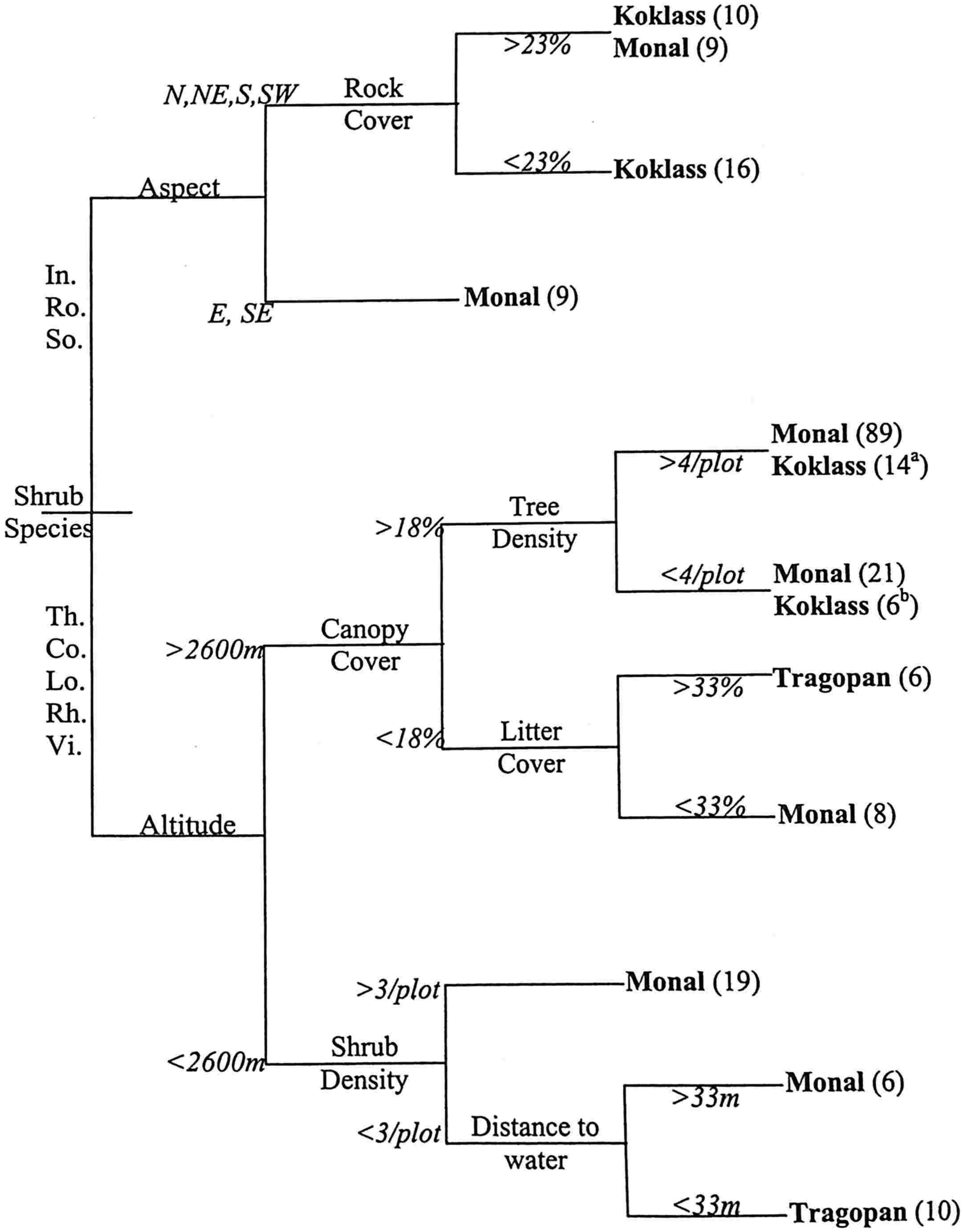


Figure 5.13. Classification tree depicting microhabitat features used by the study species during winter season

([a] -, Used middle elevation shrub species such as Thamnoclamus and Rhododendron in East and South facing slopes, [b] - Used higher soil depth above 3cm)

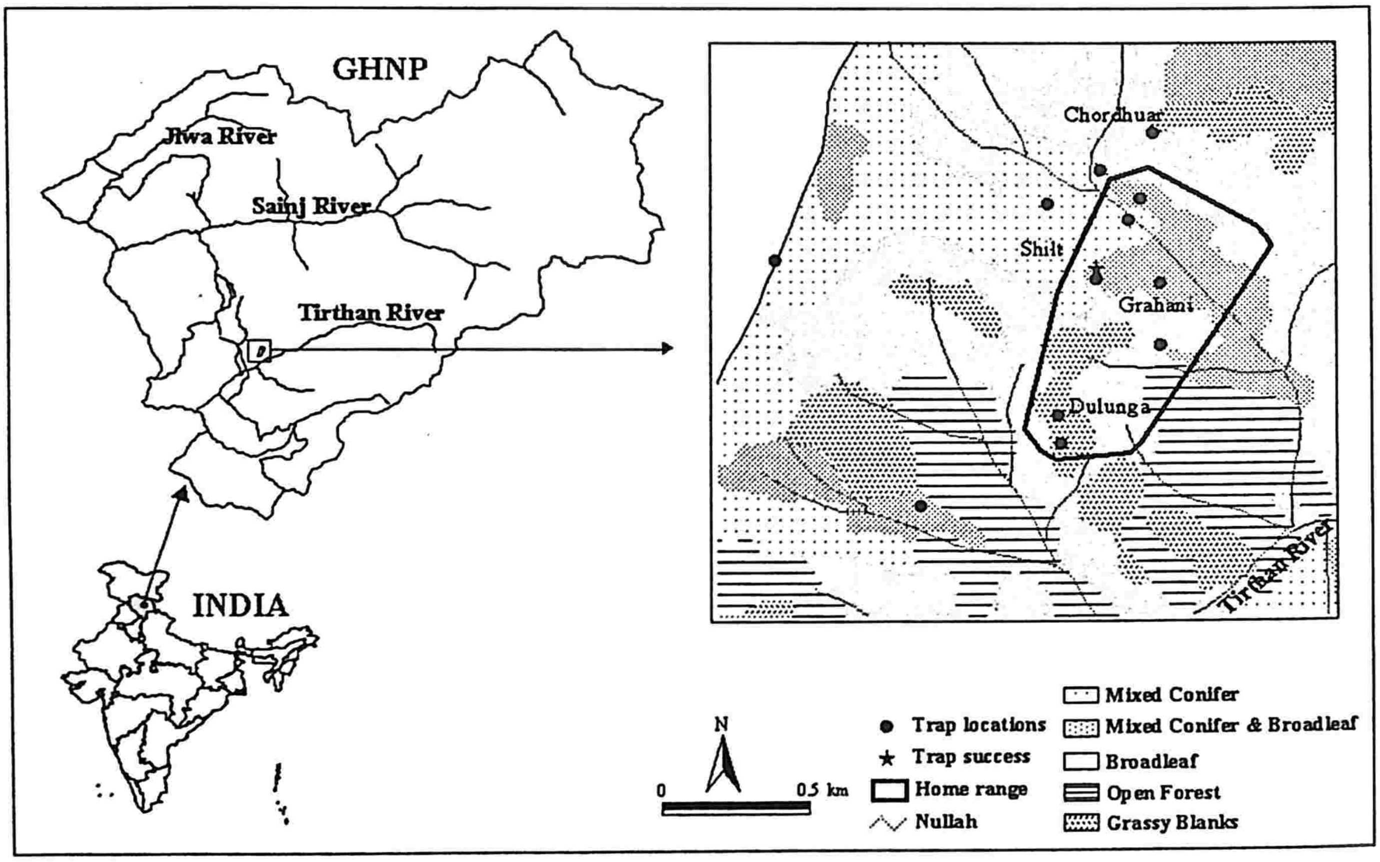
(Th. – Thamnoclamus spathiflorus, So.- Sorberia tomentosa, Co. – Cotoneater affinis, In. – Indigofera hetrantha, Lo. – Lonicera , Rh. – Rhododendron aroboreum, Ro. – Rosa neivus, Vi. – Viburnum nervosum)

(N – North, S – South; SE – Southeast, E – East, NE- Northeast, SW- Southwest)



that were used by the bird. The broadleaf forests in higher altitude were dominated by *Acer caesium* and *Quercus semecarpifolia* and the lower altitude forests by *Juglans regia, Ulmus wallichiana* and *Corylus colurna.* The bird used high tree density (8.4 ± 1.2/plot) and shrub density (8.7 ± 1.5/plot) area, and interestingly, the shrub species in all the nine plots was dominated by *Thamnoclamus spathiflorus.* The canopy cover ranged between 25 and 40%, with mean percentage of 30 ± 1.9 (SE). The elevation of the home range area was between 2440m and 2800m. Specifically, the elevation range 2530 -2620m (n = 31) and 2620-2710m (n = 22) were used to a considerable extent. During autumn, 16 locations (76% of the locations in this season) were distributed in the elevation range 2440-2530m. The bird was found to be frequenting the east, southeast and southern aspects. Majority of the location (57) was in the 10 - 40° slope angle.

Figure 5.14. Home range of and vegetation types use by the radio-tagged bird



5.3.4. Coexistence

On hierarchical scale, these species appeared to live together in the same vegetation types and also, uses of elevation gradients overlapped to a greater extend (Fig. 5.6, Fig. 5.7). Finer probe into habitat use at microscale and the way they used areas of overlap suggested that these birds tend to avoid each other either spatially or chose different set of microhabitat features or both. Himalayan monal, though gave an impression of occupying wider elevation gradients, occupied higher elevation gradients mostly above 2700m. Koklass overlapped with Himalayan monal about 200m in the higher elevation, but majority of them used areas below 2900m. Western tragopan, however, had a significant overlap with these two species, but not quite completely with Himalayan monal, which overlapped only at the upper lower limit of western tragopan's distribution. Relative concentration in certain elevation gradients reflected the vegetation use by these species, for example, higher abundance of koklass in broad leaf forest is seen at lower elevation forests. Within these elevation gradients, spread of aspect use was wider for Himalayan monal, but koklass and western tragopan seemed to prefer south and east facing slopes, and south and southeast facing slopes respectively, thus minimizing habitat overlap to some degree (Fig. 5.8). Also, western tragopan preferred steeper slopes as compared to koklass (Fig. 5.11). During winter, altitudinal overlap was much greater and western tragopan seemingly shared almost the same elevation and aspects with koklass. Though Himalayan monal descended to lower areas, overlapping with the other two species, but large proportions of individuals continued to stay at higher altitudes.

Even after this exclusiveness, habitat overlaps at macroscale still existed and more so during winter season when they were pushed to a narrow limit by snow condition. Classification Tree, however, revealed use of specific habitat features by individual species allowed the species to coexist. Rarely all three species used similar composition of variables and wherever they did, the proportion of individuals using such a composition was too few. In summer months, when there was no climatic compulsion for habitat use, Himalayan monal used both broad leaf and conifer-dominated elements almost equally (Fig. 5.12). Koklass was less represented in this habitat type if compared to the total observations. Western tragopan avoided Himalayan monal by choosing areas with mountain bamboo

(*Thamnoclamus spathiflorus*) in south, southeast and north facing slopes. Himalayan monal, in conifer/alpine forests, were found in association with *Rhododendron arboreum* and *Cotoneaster affinis*, and particularly close to water sources. Broadleaf and mixed forests were used almost equally and abundantly by these species, but were found separated by shrub species, shrub density and ground cover. Himalayan monal appeared to avoid high shrub density, while koklass and western tragopan preferred to use both high and less shrub density areas. When these three species occurred in high shrub density, Himalayan monal preferred high soil depth, and western tragopan was exclusively found in pure broadleaf and old growth forest. In low shrub density area, which was preferred by Himalayan monal, koklass used steeper slopes with more of bare ground and western tragopan avoided koklass and Himalayan monal by utilizing high ground cover and in east and southeast facing slopes respectively. In lower altitude, koklass avoided Himalayan monal by occupying high tree density and vegetative cover. Himalayan monal used more of open area, where as western tragopan was not found in this zone.

Despite forced into a narrow belt of elevation in winter, there was a clear avoidance of each other (Fig. 5.13). Over 70% of Himalayan monal recorded in this season were above 2600m elevation and in areas with high canopy and tree density. Koklass shared these habitat features with Himalayan monal in higher elevations, but was separated either by dense shrub dominated by *Thamnoclamus* and *Rhododendron* or low tree density (Fig. 5.13). Western tragopan, wherever shared habitat with Himalayan monal above 2600m, showed complete avoidance, restricted to low canopy area, but with high litter cover. In areas below 2600m, western tragopan chose to use low shrub density and close to water, whereas Himalayan monal used high shrub density. Koklass showed specific preference to rock cover associated with shrub species such as *Indigofera, Rosa* and *Sorberia.* Western tragopan was not found in such association. However, Himalayan monal shared these habitat features, but was spatially separated by aspects and in areas where both of these species used high rock cover, Himalayan monal was mostly found in cliffs and koklass in forested area. Interestingly, despite strong altitudinal overlap, koklass and western tragopan were never found using similar resources in this season.

5.4. Discussion

Large body size (with high fat deposits and thick feather structure) and other morphological features have presumably enabled the pheasant species to inhabit the high altitudes of the Himalaya. Here in the high altitude, the birds are required to negotiate with low temperature, low atmospheric pressure, and the effect of radiation (Terborgh 1989), besides the limitation for habitat and food caused by extreme climates. The birds living in such conditions have evolved certain physiological and behavioural mechanisms to overcome these impediments (Phillips et al. 1985). As an ecological response to these factors and inter-intra specific competition for resources, the birds tend to choose specific habitat characteristics or avoid each other temporally or both (Cody 1985). Majority of the pheasants favour dense woody or shrub vegetation (Fuller and Garson 2000) and only a handful of species inhabits more open habitats such as agricultural field (Indian peafowl), grassy slopes (cheer pheasant) and alpine meadow (Chinese monal). Preference to dense woody elements by the study species was evident from occupying middle elevation forests, where the tree density is significantly higher as compared to lower temperate zone (Singh 1999). With an exception of some individuals of Himalayan monal that used alpine meadows during summer, these birds were predominantly forest dwellers. However, within the forests, these birds (mostly Himalayan monal) tend to use cliffs and canopy-gap (both natural and man made), but these features become suitable only if interspersed with the forests. At a broad scale, habitat of these species could be characterized as a mosaic of forests, scrub, canopy-gap and cliffs. Association with certain microhabitat features further provides habitat identity to these species individually.

In the temperate region, south facing slopes are vastly dry with relatively much less tree cover (Mani 1974), and north facing slopes are primarily dominated by conifer elements (Singh and Rawat 1999). Wherever the south facing slopes support good forest cover, the pheasants and other wildlife diversity is found to be rich (Dhar 1997). On the contrary, conifer forests that sustain acid rich soil become less suitable for under growth vegetation and other food resources for the pheasants. Gaston and Garson (1992) attribute the rich and abundant pheasant diversity in GHNP to the extensive forest cover in the south facing slopes. These areas also support high organic matter and less soil moisture (Singh and Rawat 1999), making the ground suitable for these ground-dwelling birds. This could perhaps be the reason for relative preference to broad leaf associated vegetation types by the study species. Conifer elements within mixed forests, however, provide valuable roosting sites for all the three species, particularly during winter when most of the broadleaf trees become leafless (Ramesh 1995, *pers. observ.*). Also it provide winter habitat to species like Himalayan monal. For example, in north facing slopes, *kharsu* oak (semi-evergreen) forests is mixed with conifer elements above Basu Reserve Forest, and the Himalayan monal that used these forests showed a shift in winter to lower elevation areas dominated by conifer forests. This was the reason for inflated encounter rate in this forest type during winter (Fig. 5.3).

Himalayan monal, despite being a generalist in using different vegetation types, showed a strong affinity to *kharsu* oak forest regardless of seasons. This affinity is found to be wider across other populations in the western Himalaya (Kumar 1997, Gaston et al. 1983a). Cliffs associated with the *kharsu* oak forests provide suitable escape cover from mammalian predators and snow in winter (Kumar 1997, *pers. observ.*) and also, the vegetative food is continued to be available in the cliff areas even in winter. These together could facilitate preference to this habitat type in both the seasons. Koklass, on the contrary, did not exhibit significant affinity to any particular forest types, though tend to favour broad leaf associated forests (Gaston et al. 1983a, Hussain et al. 2001). However, the forest types alone did not show much influence, rather it was the habitat structure that appears to determine habitat use by the species. Previous works have consistently noted use of conifer-dominated elements and *kharsu* oak forests by western tragopan in both the seasons (Hume and Marshall 1897, Gaston et al. 1983a, Islam and Crawford 1987). In contrast, pure conifer forest was relatively less used (including the radio-collared bird), but at the same time, as recorded by Islam and Crawford (1987) that structural component seems to determine the habitat condition for the species than purely the vegetation types.

As compared to earlier observations on elevation use (Johnsgard 1986, Kumar 1997), the upper limit of the distribution was constantly low, since the tree line (beyond which there is no tree growth) was confined to <3400m. Declining trend in tree line towards western axis in the Himalayan mountain system is said to be a common phenomenon due to the difference in geomorphology, climate and rainfall (Mani 1974). Even the lower limit of Himalayan monal is comparatively low, and koklass and western tragopan was restricted to a narrow limit in the middle elevation forests. Due to proximity to Trans Himalayan zone, the study area is partly under the shadow of trans Himalayan influence and that this area remains cold and dry, and perpetual snowline occupy about 230 km^2. These climatic and phytological influences appear to be responsible for the restricted altitudinal distribution. And in winter, movement to lower elevation area was as low as 2000m in all the species, which is again the lowest record for Himalayan monal and western tragopan. The pheasant populations at lower elevation in winter were observed to be less affected by biotic factors at least during the study period, since the villages located at the bottom of distribution range were very few and that poaching and habitat degradation were relatively less. Though lower elevation forests appear less occupied and give the impression of less suitable in summer season, maintaining a significant portion of the available habitat is crucial for winter survival, and the population as a whole. Currently, relatively better population status of the species in GHNP can partly be attributed to the availability of extensive winter habitat, absence of such habitat in Solang valley has been postulated to be the cause for local extinction of these species (Gaston et al. 1983a). Utility of south and east facing aspects and gentle slopes is common in these species (Johnsgard 1986, Kumar 1997). Because, the south and east facing slopes support rich understorey (Singh 1999) and are comparatively warmer, the pheasants tend to use these slopes for breeding and roosting. Slope as a habitat correlate might be redundant since the slope is auto-correlated with the tree and shrub densities (low tree density in steeper slopes, while shrub species such as *Indigofera* grow in high density in steeper slopes), which proved to be primary habitat determinants. However during winter when the habitat is snow covered making difficult for the species to dig through for food and resting on the ground, use of slightly steeper slopes can potentially serve the purpose.

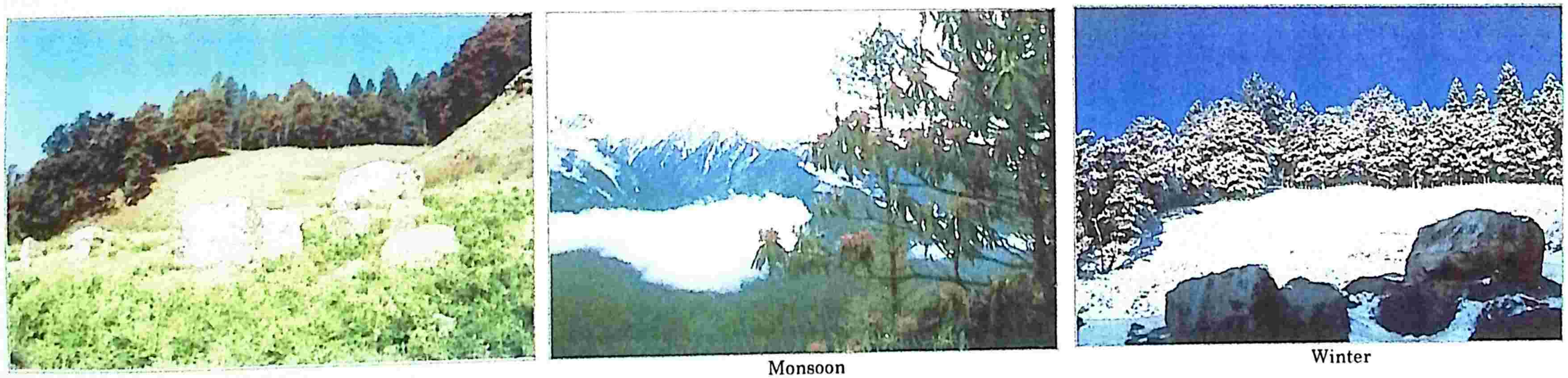
Microhabitat analysis further highlighted habitat structure (both vertical and horizontal axis) to be more correlated with species occurrence. Himalayan monal again proved to be a generalist and utilized wide combinations of microhabitat characteristics. Kumar (1997) found that tree-associated characters (tree density, tree height and higher canopy cover), herb cover, rock cover and litter depth to be highly correlated with Himalayan monal in both winter and summer. On the contrary, it was shrub associated microhabitat characters that showed strong relation with the presence of this species in summer, while in winter, high tree density, canopy cover and litter cover were exploited by the species. Because of the ability to maneuver its survival chance, both by occupying prime habitat that support good vegetative cover and escape terrain, and ability to traverse wide altitudinal area, Himalayan monal appear to be far more successful than other two species. Koklass showed an interesting association with deciduous shrub species such as *Cotoneaster, Lonicera* and *Sorberia* and high herb/grass cover or litter cover in lower altitudes. In the higher altitude where the tree density was higher, these birds tend to use low shrub density primarily *Thamnoclamus* and *Rhododendron.* This could be a strategy to use whatever is available and can provide cover to the species. This observation was not in common with a concurrent study on the species that strongly suggests no role for shrub layer, but ground layer to be responsible for habitat selection (Hussain et al. 2001). During winter, use of high tree density and canopy cover could be a response to snow cover in the relatively open habitats. Selection of rock cover (which is often rock overhangs) could also be to avoid snow cover. Western tragopan was proved to be habitat specialist and its preference to broad leaf and mixed forests particularly in association with ringal bamboo, *Rhododendron* and *Viburnum* has widely been reported (Roberts 1970, Ali and Ripley 1983, King 1981, Gaston et al. 1983a, Islam 1985, Hume and Marshall 1897, Birdlife International 2001). In winter, they tend to use more open habitats, where they risk increased predation pressure from avian predators. The differential habitat use (both habitat and season) exhibited by these three species necessitates management strategy at appropriate space and time. This includes habitat management and protection in lower altitude forests, where these birds tend to congregate in winter.

"Two species of animal can coexist in the same area only if they differ in ecology. Such ecological isolation brought about through competitive exclusion is of basic importance in the origin of new species, adaptive radiation, species diversity and the composition of fauna" quotes Lack (1971) in his popular book on ecological isolation in birds. The strategy to coexist is to partition resources in such a way that each species is limited by different factors (MacArthur 1958). The fact that the study species share the same phylogenetic clan and environment, and have similar morphological adaptations explain their genetic and ecological make up to choose similar resources. But the magnitude of preference to certain resources determines the nature of competition, and in this case, these species appear to show spatial and temporal avoidance from each other in selecting resources. If viewed at a hierarchical scale, the distance to resource overlap was constantly increasing among the species, and in areas of overlap, there was a temporal adjustment. There wasn't a single occasion when these three species were seen together and when they did occur in proximity, they maintained a particular distance from each other. Use of different elevation gradients set right major resource partitioning between the species. The distribution pattern was clear that Himalayan monal could be linked with higher elevation broad leaf and conifer elements, koklass with middle and lower elevation broad leaf elements and western tragopan in middle elevation broad leaf and conifer elements. Also dissimilar microhabitat use enables the species to coexist. However, the effect of exclusiveness on the species survival chance in terms of habitat quality and predation risk still remains unanswered. Only then, one can understand the benefit or loss of sympatric life, and it can perhaps explain ecological reason for the naturally low population size in the western tragopan. A study dealing with food habits of these birds would elucidate a complete picture of coexistence in these birds.

Temperate forest

Subalpine Oak forest

Alpine scrub and meadow



Spring

Monsoon

Winter

Plate 2. Landscape components in GHNP

CHAPTER 6.

SPATIAL DISTRIBUTION

6.1. Introduction

Distribution of any life form, both spatial and temporal, is largely governed by food abundance (Newton 1980, Hill and Robertson 1988, Gill 1996, Franco et al. 2000) and favourable climatic condition (Darlington 1957; Ford 1982; Woodward 1987; Walker 1990). The burgeoning human population and associated land use changes have a played decisive role in affecting the distribution of several species (O'Connor and Shrubb 1986, Gill et al. 1996, Vitousek et al. 1997, Liu et al. 1999, Osborne et al. 2001). Availability of food resources, climatic conditions and biotic disturbances are highly variable in space and time. As a result, species distribution is generally aggregated in patches, thus exhibiting relative preference to such areas. Therefore, documentation of such patterns becomes a necessity in any basic research on the species and more significantly, it has conservation implication. The information generated through intensive field research on one or more species not only provide useful insight of their ecology, but also helps in generating spatial distribution maps, which could be used to address conservation issues both at the local and landscape levels.

Preparation of distribution maps can range from a simple one, by connecting outer most points of location data to application of advanced mathematical functions such as prescriptive or probabilistic models (Bonham-Carter 1994, Lenton et al. 2000). The use of sophisticated technologies, particularly Remote Sensing and GIS, has opened up a new paradigm in mapping spatial pattern of species distribution and wildlife habitats (Worah et al. 1989, Buckland and Elston 1993, Mladenoff et al. 1995, Nagendra and Gadgil 1999, Gough and Rushton 2000). This is primarily because these tools are cost effective for the vast areas of landscape and also help in establishing linkages between diverse potential correlates that affect the presence of species and consequently, enables modeling species distribution. The studies conducted so far in India have focused primarily on image processing and visual interpretation of satellite data for vegetation characterization (e.g. Negi 1980, Porwal and Pant 1989, Pant and Roy 1992, Singh 1999, Sen 2000, Uniyal 2001), detecting changes in land cover or land use (Lal et al. 1991, Pant and Kharakwal 1995, Das et al. 1996, Ghosh et al. 1996, Awasthi 2001) and preparation of wildlife habitat maps (Dutt et al. 1986, Worah et al. 1989, Porwal and Roy 1991, Roy et al. 1995, Porwal et al. 1996, Kushwaha 1997, Behera et al. 2000, Naithani 2000, Alfred et al. 2001).

Attempts to map species distribution would have to consider identification of appropriate surrogates (such as habitat features, food, climatic zones and various biotic factors). Though identification of 'appropriate surrogates' may be a relatively simple task, but it is often impossible to correctly measure all the factors involved. Also, some factors exert only a limited influence on the species and effects of several factors are unknown (Gough and Rushton 2000). It is also redundant to quantify each one of them, when there is scope to detect fewer surrogates that can potentially explain the species occurrence. Therefore, it becomes important to develop a model (a simplified representation of the relationship between species and, biotic and abiotic factors) using minimum possible variables that account for maximum influence on the species occurrence. The other important aspect or usefulness of the model is that it allows for extrapolation in both space and time (Starfield and Bleloch 1986).

Gough and Rushton (2000) discuss the distribution models under two broad categories, *viz.*, associative approach and process-based approach, considering the underlying philosophy involved in the models. Associative approach attempts to identify association and extent of relationship between dependent variables (in this case, presence of individuals) and environmental features (or explanatory variables). Once the relationship has been established, the species distribution can be predicted and extrapolated for a large area. Whereas, process-based approach considers one more dimension to the explanatory variables and necessitate incorporation of information on life history processes such as natality, mortality, dispersal and, other inter and intra-specific behavioural responses. Literature available on modeling species distribution in GIS reveals an increasing trend in such studies since 1990s, but largely on the associative category (e.g. Walker 1990, Buckland and Elston 1993, Carroll et al. 1999, Manel et al. 1999, Collingham et al. 2000, Franco et al. 2000, Lenton et al. 2000, Odom et al. 2001, Osborne et al. 2001). Difficulties in acquiring data on population responses compounded by lack of thorough knowledge on species biology and behaviour have perhaps resulted in a limited number of process-based models (Kareiva and Wennergren 1995, Wennergren et al. 1995, Lima and Zollner 1996, Allen et al. 2001). Nonetheless, the models based on associative approach can effectively depict and predict current pattern of distribution at varying scales and are no means inferior in planning and executing conservation actions.

Several studies have considered habitat features as potential surrogates to model and map faunal distribution (Smith and Connors 1984, Augustin et al. 1996, Beard et al. 1999, Carroll et al. 1999, Franco et al. 2000, Lenton et al. 2000, Osborne et al. 2001, Pearce et al. 2001). Prior knowledge on relationships between habitat features and presence/absence of animals would play a guiding role in mapping distribution. Rule-based models (an associative approach category) make effective use of such knowledge and determine the species distribution at least on a coarse scale by delineating area used/preferred by the species. When dealing with a large number of predictor variables, which is often the case, several multivariate statistics are helpful in removing redundancy that occur due to correlation within variables. Statistical methods such as regression and discriminant function analysis have the ability to deal with such data sets and enable construction of mathematical functions for predicting spatial distributions. However, the logistic regression technique has been more popular in GIS based spatial analysis as it works on the basis of binomial distribution theory. Hence, it can effectively deal with presence/absence data (dichotomous response variable) to map and predict distribution (Trexler and Travis 1993, Menard 1995, Manel et al. 1999, de Vasconcelos et al. 2001). The distribution predicted by these models is, however, not necessarily without bias as the probability of distribution in a given unit tends to be dependent upon the values at neighbouring units within a particular zone of influence (Legendre and Fortin 1989). The effect of neighbours in a spatial sense is generally referred to spatial autocorrelation and, it is important to investigate and incorporate such information while developing distribution models (Legendre 1993, Augustin et al. 1996, Gough and Rushton 2000).

Pheasants are generally known to have a strong association with physical habitat features and many are habitat specific (Fuller and Garson 2000). Natural history observations and recent ecological studies on the pheasants have further presented enough evidence for existence of strong relationships between the pheasant distribution and the inter-related physical environment such as vegetation, elevation, aspect, slope and other local ecological factors (Severinghaus 1979, Johnsgard 1986, Gaston et al. 1983a, Islam and Crawford 1987, Sathyakumar et al. 1993, Kumar 1997). This has a wider implication in macro-ecology and conservation biology if attempts are made using GIS. It is noteworthy that several Himalayan pheasants including the study species were abundant and widely distributed in the past (Humes and Marshal 1879), but presently, many of them are restricted to either narrow and/or discontinuous ranges (Fuller and Garson 2000). There can be several natural and human induced factors that have contributed to such status, but it is logical to assume that the species having a patchy distribution is often at the risk of local extinction, given the continued threat posed by human related activities and also due to natural catastrophes. On the other hand, the distribution patterns of pheasants within their biogeographical range have been poorly understood. Gaston (1982) attempted to map distribution of Himalayan pheasants on a macro scale based on locality records obtained by several pheasant biologists and organizations. This attempt had its inherent problem due to lack of information from several areas and it was mere reflection of areas visited by these biologists. Using remotely sensed data and other broad scale physical features, attempts were made to map potential habitats of western tragopan in Tons catchment of western Himalaya (Prasad 1993) and in GHNP (Naithani 2000). The maps that were obtained on the basis of overlay procedure in GIS depict only the maximum habitat available to the species in the study sites and also, data quality mostly based on secondary sources is not suited for wider extrapolation.

Prior to the present study, three major surveys had been carried out in GHNP to establish distribution of the study species as part of the Himachal Wildlife Project (Gaston and Garson 1992). Due to logistic constraints and limitation of time, the survey teams were able to cover only areas close to major trails and hence, the information collected on pheasant distribution was biased towards these areas. Moreover, the nature of the surveys with inadequate sampling efforts did not permit extrapolation of their observation to the rest of the areas. In a nutshell, even after these surveys, information on pheasant distribution in GHNP still remained inadequate. The present study is an attempt to fill this gap based on intensive field research combined with GIS and captures a comprehensive picture on spatial distribution of the three study species in GHNP. Within the broad spectrum of the study, the focus was on the following questions relevant for elucidating current status of these species and for providing a basis for future research and management.

1. How much of the area in GHNP has potential to support the study species?
2. What is the chance or the probability that the species is likely to be present within the potential habitats and in GHNP as a whole?

6.2. Methods

6.2.1. Field Data

Primary field data on direct (sightings) and indirect (calls, track and faeces) evidences of species occurrence were gathered based on systematic trail walks and opportunistic searches carried out in the intensive study site (chapter 3 and 4). Sampling efforts were standardized, so as to equally cover all habitat types within the study site. Extensive surveys and opportunistic searches carried out in other parts of GHNP also provided field data on presence/absence of the species. Efforts were also made to gather secondary data through interviews with the three researchers working on other wildlife in GHNP during the same period and local people who visited the area frequently, and from published and unpublished literatures (Gaston et al. 1981, Gaston and Garson 1992, Himachal Pradesh Forest Dept., National Park records, etc.). All these records (both primary and secondary) were plotted on 1:50,000 scale topographic maps published by Survey of India. A perusal of the above efforts on a map revealed that excepting for parts of Jiwa valley, rest of the forested areas had adequately been covered during the entire stay in Great Himalayan National Park (Fig. 3.1).

6.2.2. Digitization and acquiring spatial data

Records (both direct and indirect) of the pheasants were converted into digital data in GIS using Arc/info software, and were stored on the base map previously prepared for the intensive study area and GHNP. The entire map was divided into 100 × 100m grids and the records were plotted as presence and absence information regardless of the number of records available for each of the individual grids. Identity was assigned to each grid as 1, if the bird was recorded to be present and 0 otherwise. Spatial data on bio-physical characters concurrently generated for GHNP (Mathur and Naithani 1999, Singh 1999) was utilized for preparing required spatial layer on physical and habitat features relevant for the species. Important macro-habitat characteristics and variables considered for the analysis were landcover, altitude, aspect, slope, water source and Normalized Differential Vegetation Index (NDVI). Mapping of vegetation types was done based on remotely sensed data of IRS-1B LISS II sensor for the month of September/October. Geocoded False Color Composite (FCC) on 1:50,000 scale for the entire study area was procured, and the bands used were infrared, red and green. Based on the standard analytical and ground truthing procedures, 11 forest and 11 non-forest classes of landcover categories were delineated and mapped (Singh 1999). These land cover classes and the interpretation key used during the visual interpretation are presented in Table 6.1.

Table 6.1. Land cover classes and the interpretation key used for the visual interpretation of satellite imageries (source: Singh 1999)

S. No.	Class (Mapping)	Tone	Texture	Physiography	Altitude (m)	Forest Type/physical character	Characteristic species
1	Conifer Forest	Bright Red	Medium to coarse	Moderate to steep slopes	600-1700	Subtropical chir pine forest	*Pinus roxburghii*
2	Broadleaf Forest	Bright red to deep red	Medium to coarse	Gentle to medium slopes (bouldery land)	1500-3300	Himalayan moist temperate (and)	*Quercus floribunda, Aesculus indica, Betula alnoides, Prunus* sp.
						Kharsu Oak forest	*Quercus semecarpifolia*
3	Broadleaf mixed with conifer	Various shades of red to brownish red	Medium to coarse	Gentle to medium slopes, spurs with good soil	1500-3000	Himalayan moist temperate forest	*Acer sp., Quercus semecarpifolia, Betula utilis, Abies pindrow, Taxux, Prunus cornuta*
4	Temperate Mixed Conifer	Brownish red to dark brown	Medium to coarse	Moderate to steep slopes	1500-3000	Western mixed conifer (and)	*Pinus wallichiana, Picea smithiana, Abies Pindrow*
						Moist deodar forest	*Cedrus deodara*
5	Conifer Mixed with broadleaf	Brownish red to bright red	Medium to very coarse	Gentle to medium slopes on good soils	1500-3300	Himalayan moist temperate forest	*Pinus wallichiana, Abies Pindrow, Cedrus deodara, Quercus floribunda, Aesculus indica,*
6	Secondary Scrub	Light Pink - shades of brown	Medium to coarse	Medium to higher slopes,	1500-3300	Temperate secondary Scrub	*Berberis chitria, Indigofera, Rosa*
7	Alpine Scrub	Pinkish red / cyan yellowish	Medium to coarse	Gentle to moderate slopes (moist)	3000-3600	Moist alpine scrub	Betula utilis-Rhododendron
8	Slope Grasses	Whitish yellow to light pink	Medium to coarse	Steep Slopes	1500-2500		*Poa sp* and mixture of other of grasses
9	Grassland	Whitish yellow to light pink	Smooth to smooth	Gentle to moderate slopes	1500-3600	Temperate, subalpine and alpine grasslands	*Poa sp., Agrostis sp., Primula sp., Gentiana sp., Aster sp., Brassicaceae*
10	Riverine	Light to brownish red	Medium to coarse	River beds and on sides slopes	1500-2500	Himalayan moist and dry temperate forest	*Alnus nitidia, Hippophae salicifolia Myricaria germanica*

11	Plantation	Redish brown	Fine to medium	Medium to higher slopes	1500-3300	Temperate zone plantation	*Pinus wallichiana*, with Abies, Acer sp.
12	Agriculture /Settlement /Orchards	Light pink to dark cyan to yellowish red	Medium to coarse	Very Gentle to Medium slopes	1300-2500	Temperate Zone (Moist)	Wheat, Potato, *Eleusine coracons* Apple, Peach etc.
13	Exposed rocks with slope grasses	Yellowish white to dark cyan	Medium to coarse	Steep to moderate slopes	1500-2500	Temperate zones	Various species of grasses with cliffs, rocks exposed
14	Escarpment	Dark cyan to dirty blackish	Medium to coarse	Very steep slopes	1500-2500	Temperate zone	Scattered grasses
15	Alpine Exposed rocks with slope grasses	Yellowish white to dark cyan	Medium to coarse	Steep slopes	2500-3600	Alpine zone	Various species of grasses, Asters and Primulas
16	Land-slides	Cyan to bluish cyan	Smooth to medium	Steep to moderate slopes	1500-3600	Throughout	Exposed sand and boulders
17	Moronic beds	Grey to dirty brown	Medium to coarse	Middle or margin of moraines	Above 3600	After and within moraine	Small pebbles
18	Glaciers	White	Fine	Upper most reaches	Above 3600	Above moraines	Glacier
19	Moraine	Grey to dirty grey and white	Medium to coarse	Medium to higher slopes in upper reaches	Above 3600	Below snow line in valleys	Moraine
20	Permanent Snow	White to dirty white	Smooth to fine	Gentle to medium slopes of N and NW aspect	Mostly above 3000	Above snow line	Permanent snow
21	Lakes	Dark blue to black	Smooth to fine	Pene plain	2000-4000	Higher reaches	Water bodies
22	Rivers	Dark blue to black	Medium	Valley bottom	1500-3600	Throughout	Water channel and sand

Digital data on contour and drainage were used to create Digital Elevation Model (DEM) on the basis of interpolation. This elevation model was developed at 100 × 100m spatial resolution and provided surrogate for altitude. Similarly, information on aspect and slope angle was derived from DEM. Drainage information was used as a surrogate for water source for the pheasants, and Euclidean distance was calculated for each grid from the nearest water sources. Digital data of IRS 1D LISS III, which had finer resolution of 23.5-pixel size, was used to estimate NDVI value for each grid. The NDVI indicates the proportion of photosynthetically absorbed radiation by chlorophyll and spongy mesophyll leaf structure, and is calculated based on measured intensities reflected in spectral bands using the formula; NDVI = Near Infra Red - Red / Near Infra Red + Red. The index value, which ranges from -1 for low green vegetation to 1 for higher green vegetation, can potentially give an idea on both tree and ground cover. The entire analysis was done for non-winter months, considering that the habitats used by these birds in these months are of their natural choice and are not constrained by any extraneous influence, which is the case in winter. Moreover, winter distributions of the pheasants are determined by various factors, which could not be adequately documented, and therefore, attempt was not made to model winter distribution of these species.

6.2.3. Rule based model

The elevation range, vegetation types, and slope categories where the pheasants are known to occur were delineated from the existing spatial layers to construct rule-based model. The rule based model works on the basis of Boolean logic, which relies on well-established available knowledge and prescribes the area to be either suitable (1) or unsuitable (0) without any other middle level (Lenton et al. 2000). The existing information available in the literature (Johnsgard 1986, Islam 1985, Kumar 1997) combined with personal field records was utilized to identify suitable broad habitat characteristics. The variables and criteria incorporated in the model depicted the elevation range, vegetation types and slope categories that potentially hold the species during non-winter season in GHNP (Table 6.2). Unique numbers were assigned to each category in all the variables and initials maps of potential areas and otherwise for each variable were prepared. Overlay analysis was then, performed in Arc/info software to obtain final map depicting potential area of distribution of these pheasants.

Table 6.2. The range and type of macro-habitat variables incorporated in the rule based model to determine potential area of distribution for the study species

Species	Elevation range (m)	Vegetation type	Slope (°)
Himalayan monal	2400 – 3600	Mixed conifer forest, conifer dominated mixed forest, broadleaf dominated mixed forest, broadleaf forest, grassy slopes and alpine scrub	0 – 60
Koklass	2300 – 3400	Mixed conifer forest, conifer dominated mixed forest, broadleaf dominated mixed forest, broadleaf forest and secondary scrub	0 – 40
Western tragopan	2500 – 3400	Mixed conifer forest, conifer dominated mixed forest, broadleaf dominated mixed forest and broadleaf forest	0 – 40

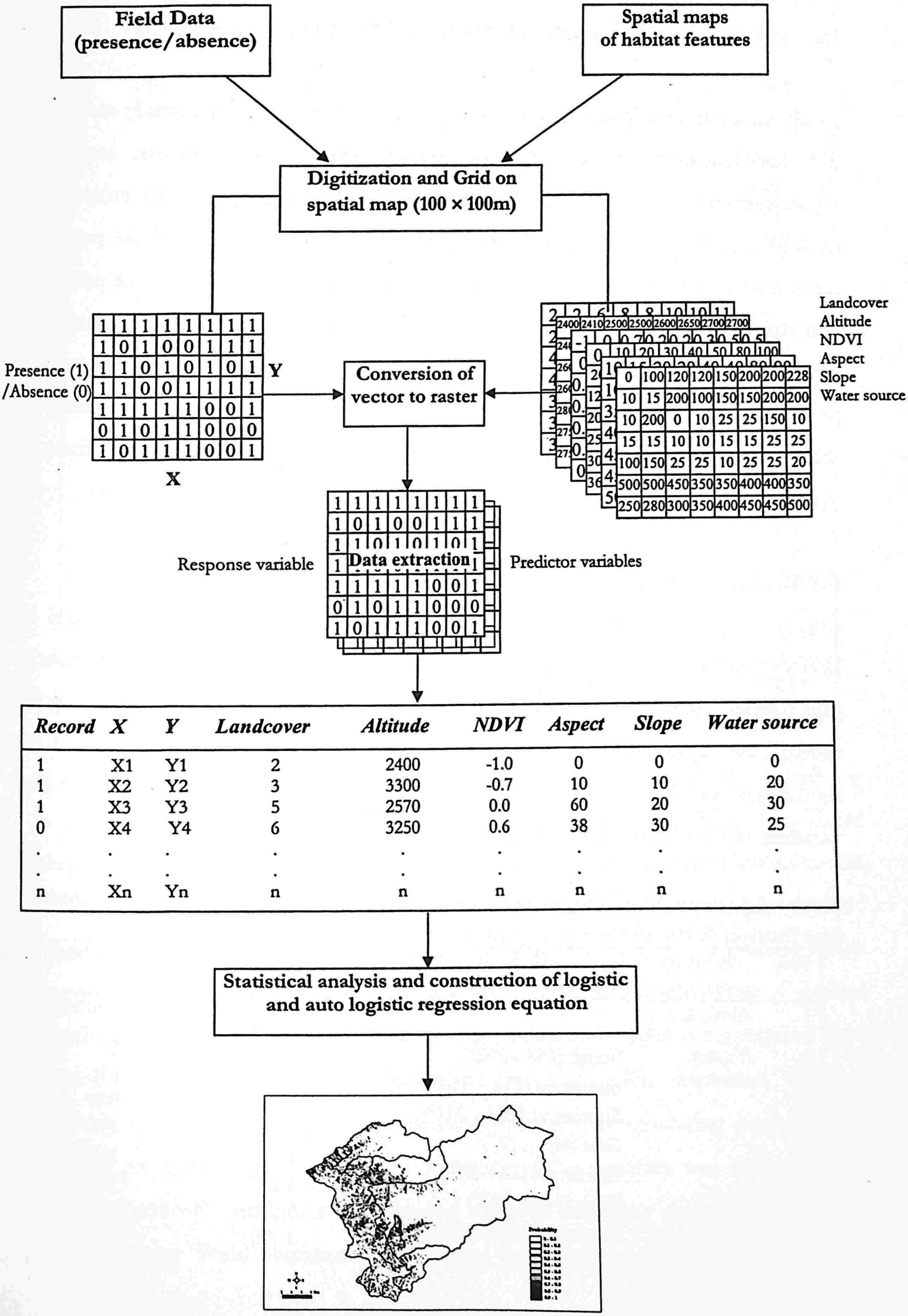
6.2.4. Probabilistic model

The primary objective of this model was to prepare a probability surface of distribution for the study species in the study area. As the model was attempted on grid based raster information, the thematic maps in vector format such as land cover features, distance to water source and presence/absence data were converted to raster format, and it was ensured that these variables were in the same resolution, i.e. 100 × 100m. The thematic maps of land cover and other physical features (explanatory variables) were stacked as one unit, and information on these variables corresponding to each grid of presence/absence map (response variable) was extracted in GIS. The data were taken to SPSS/PC software for further analysis and construction of equation to generate probability distribution maps for the pheasants (Figure 6.1).

6.2.4.1. Exploratory analysis

Though there were straightforward options for model building and preparation of distribution map in Arc/info environment itself, SPSS/PC software was preferred in order to have better control over the data. It allowed proper understanding on the relationship between explanatory and response variables individually and in

Figure 6.1. Flow chart depicting the process followed to build model and preparation of distribution map for the study species



1	1	1	1	1	1	1	1
1	0	1	0	0	1	1	1
1	1	0	1	0	1	0	1
1	1	0	0	1	1	1	1
1	1	1	1	1	0	0	1
0	1	0	1	1	0	0	0
1	0	1	1	1	0	0	1

0	100	120	120	150	200	200	228
10	15	200	100	150	150	200	200
10	200	0	10	25	25	150	10
15	15	10	10	15	15	25	25
100	150	25	25	10	25	25	20
500	500	450	350	350	400	400	350
250	280	300	350	400	450	450	500

Record	*X*	*Y*	*Landcover*	*Altitude*	*NDVI*	*Aspect*	*Slope*	*Water source*
1	X1	Y1	2	2400	-1.0	0	0	0
1	X2	Y2	3	3300	-0.7	10	10	20
1	X3	Y3	5	2570	0.0	60	20	30
0	X4	Y4	6	3250	0.6	38	30	25
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
n	Xn	Yn	n	n	n	n	n	n

complexity. For the model, data on occurrence of the pheasants was included only from the intensive study area due to greater reliability and accuracy.

In all, the number of grids assigned as 1 (presence) in the intensive study area were 226 for Himalayan monal, 109 for koklass and 68 for western tragopan. Approximately double of this number were randomly selected from the entire area, excluding those plots which were marked as presence, either based on personal records and/or secondary sources. Each explanatory variable extracted for presence and absence grids were plotted using Box & Whiskers plot to understand similarity between 1 and 0 grids. Mann-Whitney U and Pearson's Chi-square tests were performed respectively for discrete variables (altitude, NDVI, slope and distance to water source) and categorical variables (land cover and aspect) to see if there is significant differences exist between 1 and 0 grids representing these variables.

6.2.4.2. Logistic regression

Logistic regression was preferred due to dichotomous response variable and its ability to handle categorical explanatory variables. Of the entire field data set now in grid format, 80% of the plots (called training data set) were randomly selected for model building and the remaining 20% data were stored for later validation of the model. The variables were coded, and dummy variables were created for categorical variables that had more than one category (Table 6.3).

Table 6.3. Variables considered for logistic regression function to predict distribution of the pheasants (1 – presence and 0 – absence/random)

No.	Primary variable	Dummy variable	Measurement unit	Code
1.	Altitude		Meter (0 – 6248)	Altitude
2.	Aspect	South (158 - 202°)	1 / 0	S
		Southeast (113 – 157°)	1 / 0	SE
		Southwest (203 - 247°)	1 / 0	SW
		East (68 - 112°)	1 / 0	E
		Northeast (23 – 67°)	1 / 0	NE
		West (248 - 292°)	1 / 0	W
		Northwest (293 - 337°)	1 / 0	NW
		North (0 - 22°, 338 – 360°)	1 / 0	N

3.	Slope		Degree (0 – 90°)	Slope
4.	NDVI		Index (-1 to +1)	NDVI
5.	Distance to water source		Meter (0 – 500)	DWS
6.	Land cover	Conifer forest (Chir pine stand)	1 / 0	Veg1
		Mixed conifer forest	1 / 0	Veg2
		Conifer dominated mixed forest	1 / 0	Veg3
		Broadleaf dominated mixed forest	1 / 0	Veg4
		Broadleaf forest	1 / 0	Veg5
		Riverine forest	1 / 0	Veg6
		Secondary scrub	1 / 0	Veg8
		Slope grasses	1 / 0	Veg9
		Alpine scrub	1 / 0	Veg10
		Grasslands	1 / 0	Veg11
		Plantations	1 / 0	Veg26
		Habitation/agricultural land	1 / 0	Veg21
		Exposed rocks with slope grasses	1 / 0	Veg12
		Escarpment	1 / 0	Veg13
		Alpine exposed rocks with slope	1 / 0	Veg14
		grasses	1 / 0	Veg15
		Landslides	1 / 0	Veg17
		Lakes	1 / 0	Veg18
		Rivers	1 / 0	Veg19
		Permanent snow	1 / 0	Veg22
		Glacier	1 / 0	Veg25
		Moraine	1 / 0	Veg30
		Moraine islands		

Variables were ranked on the basis of exploratory analysis and also based on biological influence on the species occurrence. Forward stepwise and Enter elimination processes were applied to identify and remove redundant variables and those variables that did not contribute significantly in segregating presence of pheasants from random plots. Enter method was more useful as it enables better control over explanatory variables and consequently, allows inclusion of desired variables that have biological significance, but could have been compromised over better model fit by different elimination processes. The explained variation collectively contributed by the explanatory variables in separating presence and random plots, and overall prediction efficiency of the variables was assessed based on Nagelkerke-R^2. Influence of individual variables including dummy variables was assessed using Wald statistics. Hosmer and Lemeshow goodness-of-fit test (chi-square test) and concordance analysis (classification tables) were done to understand the fit of the model (Hosmer and Lemeshow 1989). Sensitivity (percentage true positive or presence correctly predicted) and specificity (percentage true negative or absence correctly predicted) were calculated for each cut-off point (0.1 to 0.9) and best cut-off point was chosen on the basis of optimum sensitivity and specificity. The cut-off level would allow categorization of the probability values to represent either 0 if it is below the cut-off point or 1 if it is above the cut-off point. Logistic regression was done using the selected variables and at an appropriate cut-off level and the probability of occurrence was estimated for each of the three pheasant species using the following formula.

Probability of event (or presence) = $1 / (1 - EXP^{-z})$

where $Z = \alpha + (\beta_1 \times X_1) + (\beta_2 \times X_2) + (\beta_3 \times X_3) + \ldots\ldots..(\beta_k \times X_k)$, α = constant, β = coefficients and X = predictor variable.

Once the model was developed on a training data set, it was applied on the remaining 20% of data set (the validation data set) to test for accuracy and develop the equation given above. The equation was then taken to GIS and probability of occurrence of pheasants was predicted for the entire GHNP. Distribution map of probability surface was generated using Arcinfo and Arcview software.

6.2.4.3. Autologistic model

The model developed above based on logistic regression function had limitation due to non-inclusion of information on spatial autocorrelation both within the covariates and probability of occurrence. The general tendency in the Himalayan ecosystem is that there is a decrease of 1° C temperature after every 100m increase in elevation till ca. 4000m. This phenomenon has strong influence on the structure and composition of vegetation and greatly contributes to spatial heterogeneity. Though the effect of spatial autocorrelation in the explanatory variables could be accounted to some extent by the temperature effect in the study area, the probability of the pheasant predicted to be in one grid does depend upon neighbouring grids, and this had to be addressed in the model. An improved version of logistic regression referred as autologistic model suggested by Augustin et al. (1996) was adopted to include the effect of spatial autocorrelation in the model.

Autologistic model includes one more variable derived from the predicted probability of occurrence obtained using ordinary logistic regression. The new variable defined as autocovariate was calculated using the formula given in Augustin et al. (1996) as follows:

$$\text{Autocovariate} = \frac{\sum_{j=1}^{k_i} w_{ij} p_j}{\sum_{j=1}^{k_i} w_{ij}}$$

p_{j1}	p_{j2}	p_{j3}
p_{j4}	P_i	p_{j5}
p_{j6}	p_{j7}	p_{j8}

(A)

The equation computes a spatial autocorrelation value (or autocovarite) for a given grid (Pi) based on weighted-average of the probability values predicted by logistic regression model. The new value to Pi is derived from a set of neighbouring grids (k_i), which in this case was limited to eight nearest neibhours (A) and the distance between the neibhours and Pi determined the weights assigned to the grids j. This sort of weighting is required, as the effect of neibhourhood is distance dependent; higher values in the nearest neibhours are likely to have greater influence than the farthest ones. The weight to grid j was calculated based on $1/h_{ij}$ or w_{ij}, where h_{ij} is the Euclidean distance between grid i and j. This procedure was carried out for all the grids individually and new values of autocovarites were computed for all the grids within the study area. The above analysis was performed in Arc/info using moving window operation, which resulted in a new map of autocovariate. The entire procedure was repeated on the new map and was continued iteratively until adequate convergence. The convergence was established on the basis of variance associated with the map of autocovariates. The variances were plotted on a graph against each iteration and the iteration was stopped when the variance reached an asymptote. The latest map of autocovariate was then stacked along with the layers of selected explanatory variables in final logistic regression model. The extraction of data from GIS and further statistical procedures were similar as that of logistic regression analysis, except that no elimination process was applied. The autologistic equation developed, as below, was then taken to Arc/info and the final map of probability of distribution was predicted for the study species.

Probability of event (or presence) = $1 / (1 - EXP^{-z})$

where $Z = \alpha + (\beta_1 \times X_1) + (\beta_2 \times X_2) + (\beta_3 \times X_3) + \ldots\ldots.. + (\beta \times \text{autocovariate})$

α **= constant,** β **= coefficients and** X **= predictor variable.**

The cut-off level that was determined in the logistic regression model was used to generate maps of presence/absence for the pheasants. Final maps of both probability distribution and presence/absence were done in Arcview software. Original records of presence obtained from intensive study, surveys and secondary sources were overlaid on the final maps to ascertain predictive ability of the maps in field condition.

6.3. Results

6.3.1. Rule based model

Rule based model delineated the potential area of distribution for Himalayan monal (Fig. 6.2), koklass (Fig. 6.3) and western tragopan (Fig. 6.4) at a very coarse level. The areas predicted, however, indicate that the study species will be restricted within the predicted area or in other words, it can be viewed as the upper limit of habitat availability for these species in GHNP. The spatial arrangement of the potential habitat illustrates noncontiguous distribution and this has further been isolated by location of high concentration of human population and associated agriculture/horticulture activities.

Figure 6.2. Potential area of distribution predicted for Himalayan monal in GHNP using rule based model

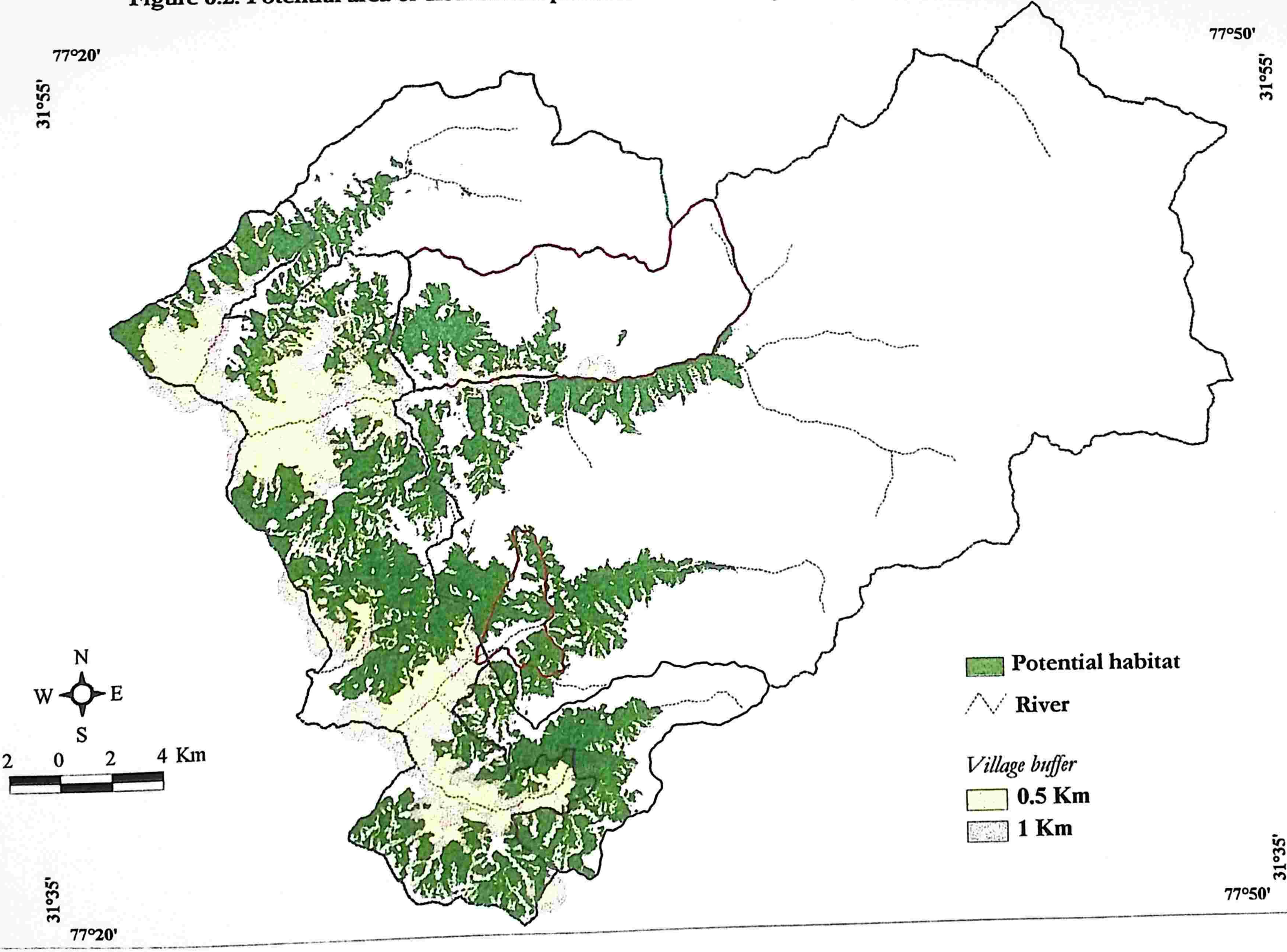


Figure 6.3. **Potential area of distribution predicted for koklass in GHNP using rule based model**

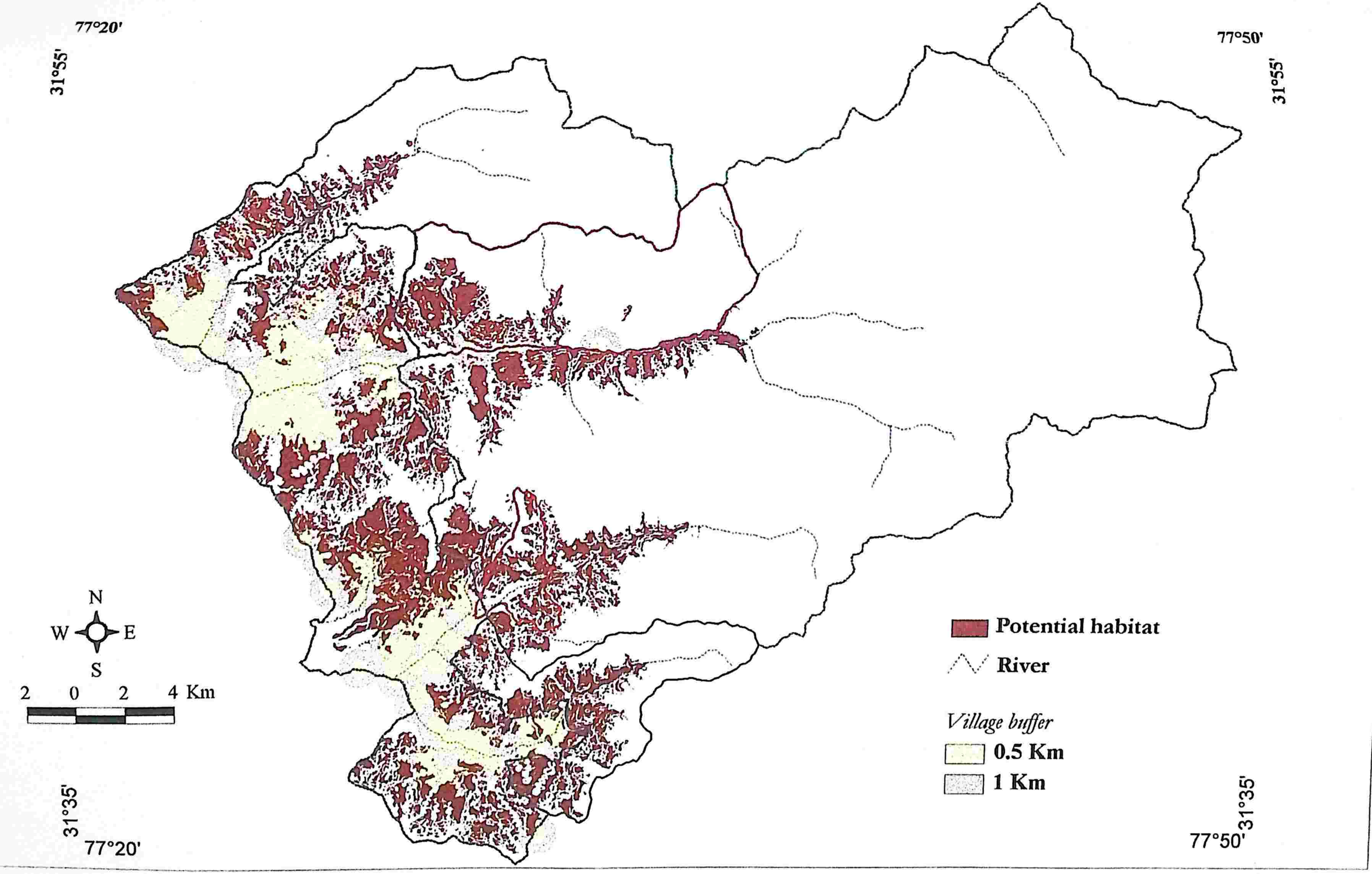
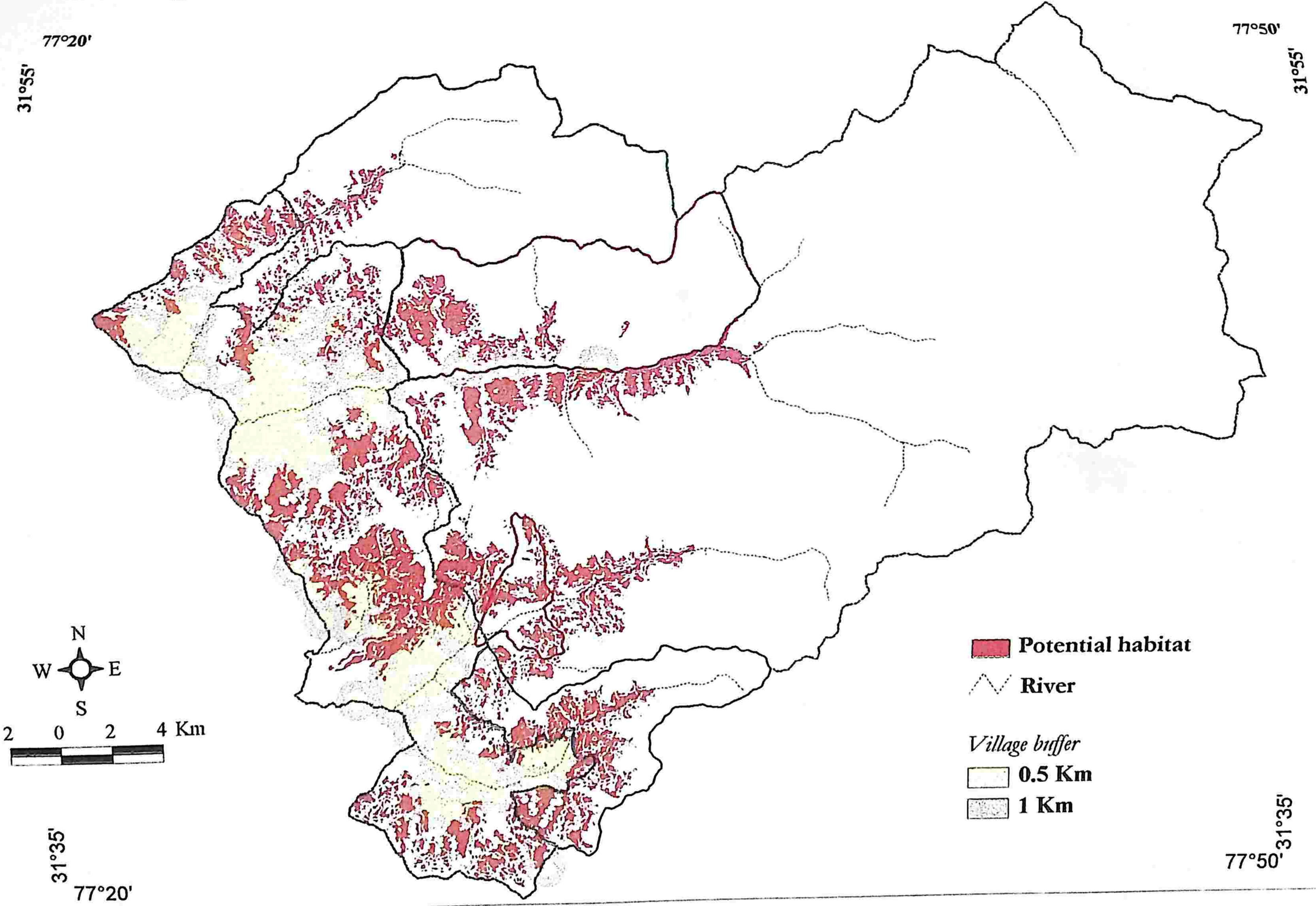


Figure 6.4. Potential area of distribution predicted for western tragopan in GHNP using rule based model



Estimated area of potential distribution area in entire GHNP for Himalayan monal, koklass and western tragopan was 255 km², 140 km², and 118 km² respectively, of which about 50% lie in ecozone and areas under effective protection in GHNP is considerably less (Table 6.4). Tirthan valley was found to be supporting greater proportion of potential habitats of these pheasants.

Table 6.4. Estimated area of potential distribution of the pheasants in the study area (values in km², and the parentheses are the proportions)

Species	GHNP	Tirthan WS	Sainj WS	Ecozone	Total
Himalayan monal	92.5 (12.3)	30.3 (49.7)	22.0 (24.4)	110.1 (41.4)	255.0 (21.8)
Koklass	41.9 (5.6)	14.7 (24.1)	10.6 (11.8)	73.1 (27.5)	140.3 (12.0)
Western tragopan	36.6 (4.9)	14.3 (23.4)	8.6 (9.6)	58.0 (21.8)	117.6 (10.0)

6.3.2. Logistic regression

Exploratory analysis revealed a clear pattern in 'presence' grids for each of explanatory variables involved in the model building. It was found that Himalayan monal was using areas of middle altitude, gentle slopes, and relatively higher canopy cover (indicated by high NDVI values) and close to water sources (Fig. 6.5). A similar pattern also emerged for koklass (Fig. 6.6) and western tragopan (Fig. 6.7), with marginal differences in upper or lower limit of records. In comparison with random/absence grids, the observed pattern was significantly different in the case of altitude, NDVI, land cover and aspect (Table 6.5.). The trend was again similar for all the three species.

Forward stepwise method eliminated slope, DWS and eight dummy variables (of land cover) from the model and had a better model fit and prediction level for Himalayan monal. Enter method where different combination of the explanatory variables, including the above eliminated ones, were used to develop a better model fit also produced similar result as that of forward stepwise method. The -2 Log Likelihood value and R^2 were 335.6 and 0.63 respectively, indicating improvement of model fit with inclusion of the above variables and a combined effect of the variables in predicting probability of occurrence.

Figure 6.5. Box plots depicting observed pattern in random (or absence) and presence grids across different variables for Himalayan monal

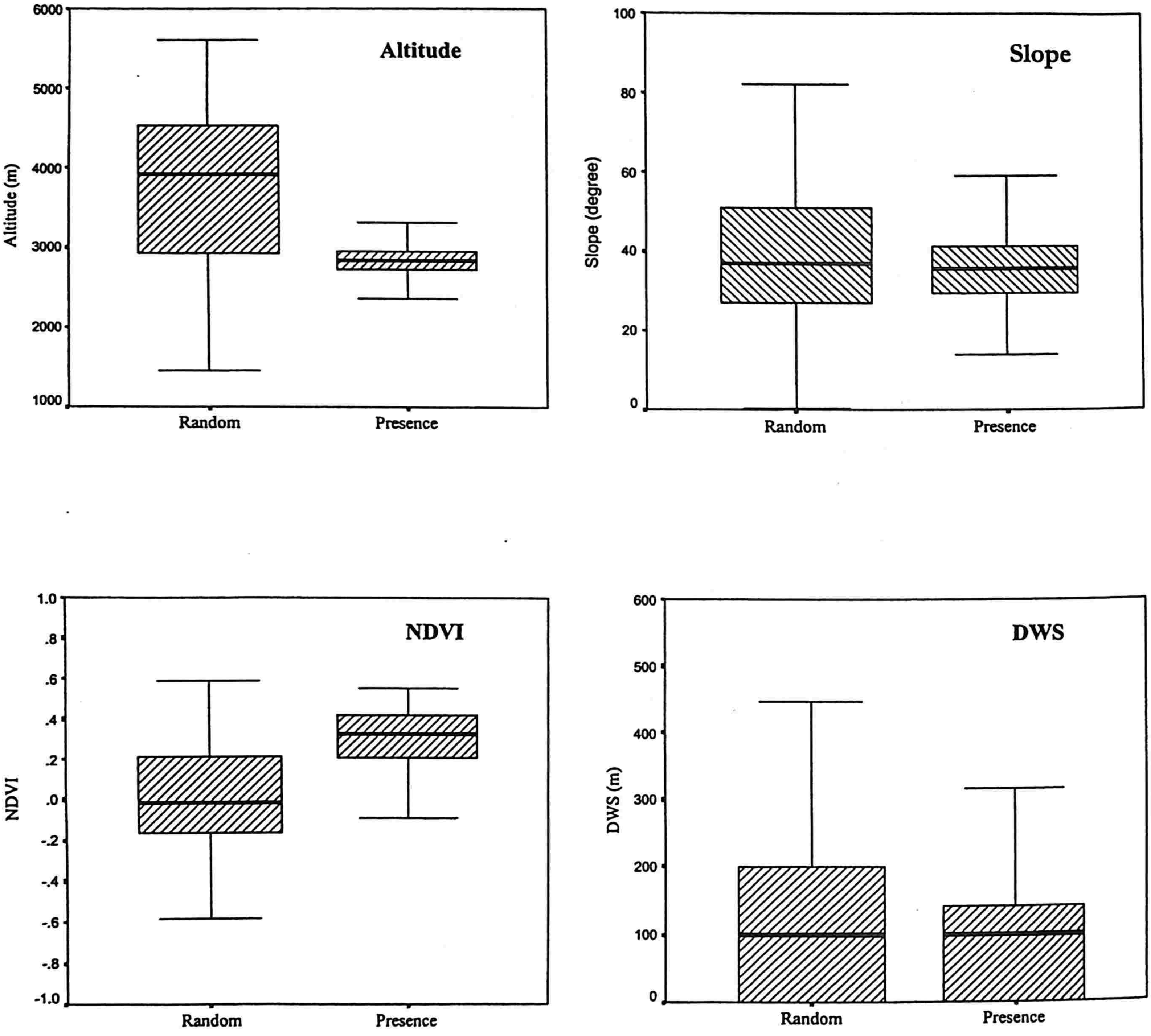


Figure 6.6. Box plots depicting observed pattern in random/absence grids and presence grids across different variables for koklass

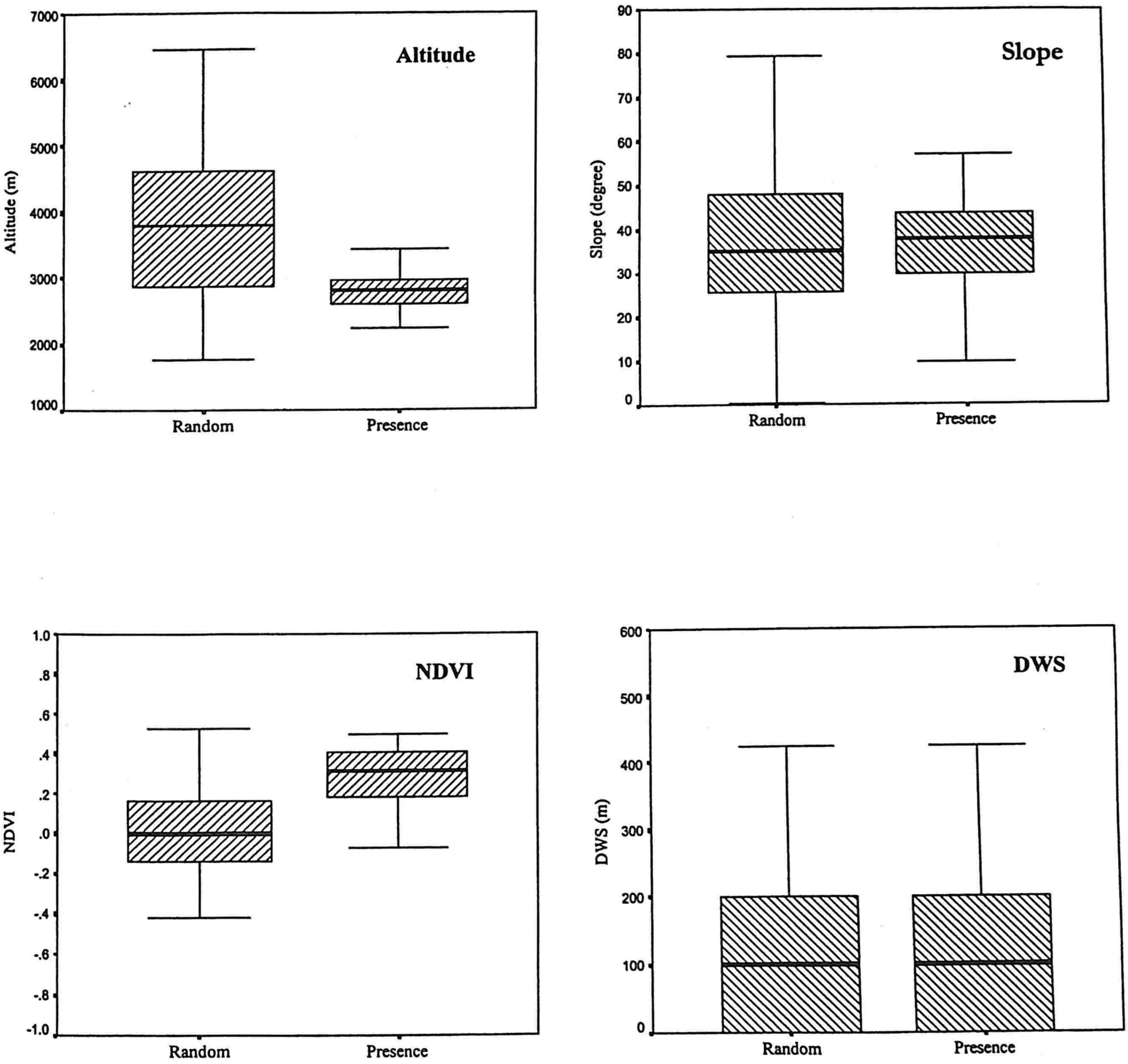


Figure 6.7. Box plots depicting observed pattern in random/absence grids and presence grids across different variables for western tragopan

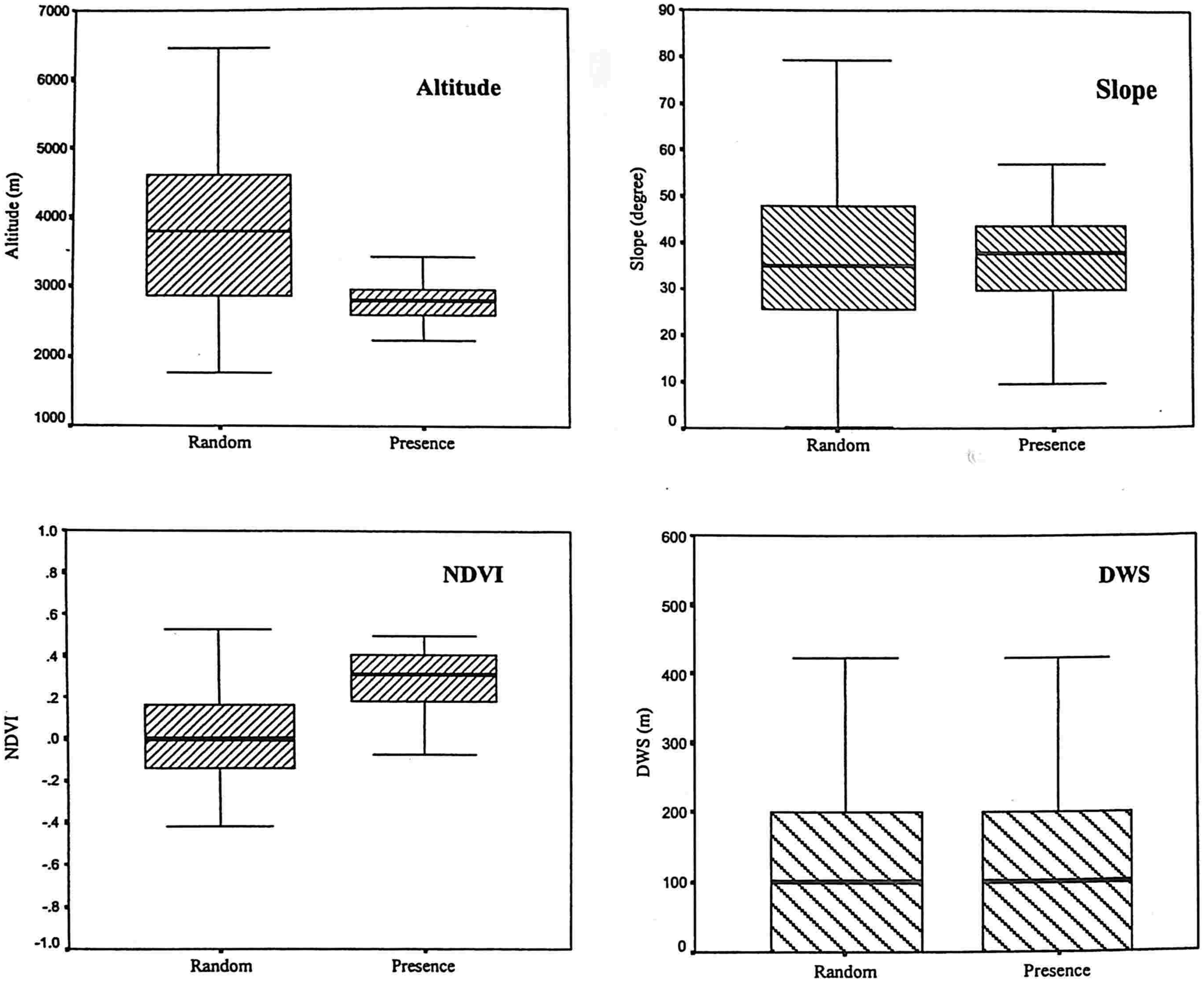


Table 6.5. Univariate analysis of the variables between random plots and presence plots for the pheasants

Variable	**Statistical test**	**Significance level (p value)**		
		Himalayan monal	**Koklass**	**Western tragopan**
Altitude	Mann-Whitney U	**0.000**	**0.000**	**0.000**
Slope	Mann-Whitney U	0.172	0.851	0.078
NDVI	Mann-Whitney U	**0.000**	**0.000**	**0.000**
DWS	Mann-Whitney U	0.074	0.903	0.728
Land cover	Pearson Chi-Square	**0.000**	**0.000**	**0.000**
Aspect	Pearson Chi-Square	**0.000**	**0.000**	**0.000**

Hosmer and Lemeshow goodness-of-fit test indicated that the obtained model did not differ significantly from null model or expected fit (χ^2 = 0.8788, p = 0.99). Overall correct prediction rate of the model was 83.6%. Prediction rate for true positives (presence - 1) was 75.9% and it was 87.3% for true negatives (not present - 0). The best cut-off level that optimized sensitivity and specificity was at 0.5 (Figure 6.8). Final analysis at this cut-off point had two discrete variables (**altitude** and **NDVI**) and two categorical variables (**land cover** with 14 dummy variables and **aspect** with 8 dummy variables) in the equation (Table 6.6). These variables, however, showed multicollinearity as indicated by larger significant values, and this together with large number of categorical dummy variables (which tend to inflate standard error) made Wald statistics insignificant in the analysis.

The elimination processes (forward stepwise and enter) applied for koklass and western tragopan also retained four variables similar to Himalayan monal, i.e. altitude, NDVI, land cover and slope. The same set of dummy variables also included in the equation, except that dummy variable 'north' was rejected in the case of western tragopan due to lack of records. Estimated -2 Log Likelihood and R^2 in the model obtained for koklass and western tragopan were 165.22 and 0.63, and 68.39 and 0.78 respectively. Hosmer and Lemeshow goodness-of-fit test revealed better model fit for both koklass (χ^2 = 1.7450, $p < 0.99$) and western tragopan (χ^2 = 7.7788, $p < 0.46$). Overall correct classification rate of the model for koklass was 81.97%, while predicted positives and negatives were 70.59% and 88.05% respectively. The model predicted 86.5% of true positives 91.1% true negatives correctly for western tragopan, and overall rate of correct classification was 82.0%. The best cut-off point optimizing sensitivity and specificity was found to be at 0.5 for both the species (Fig. 6.9 and Fig.6.10). The coefficient values that were incorporated in the final logistic regression equations for these two species have been presented in Table 6.6.

Figure 6.8. Concordance analysis depicting sensitivity and specificity in different cut-off of values (for Himalayan monal)

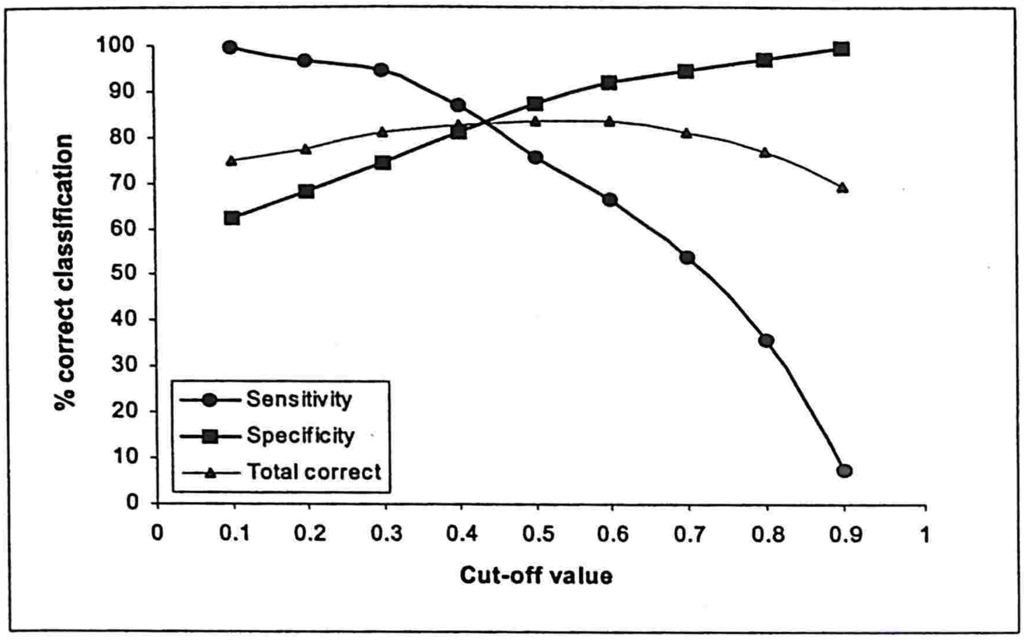


Figure 6.9. Concordance analysis depicting sensitivity and specificity in different cut-off of values (for koklass)

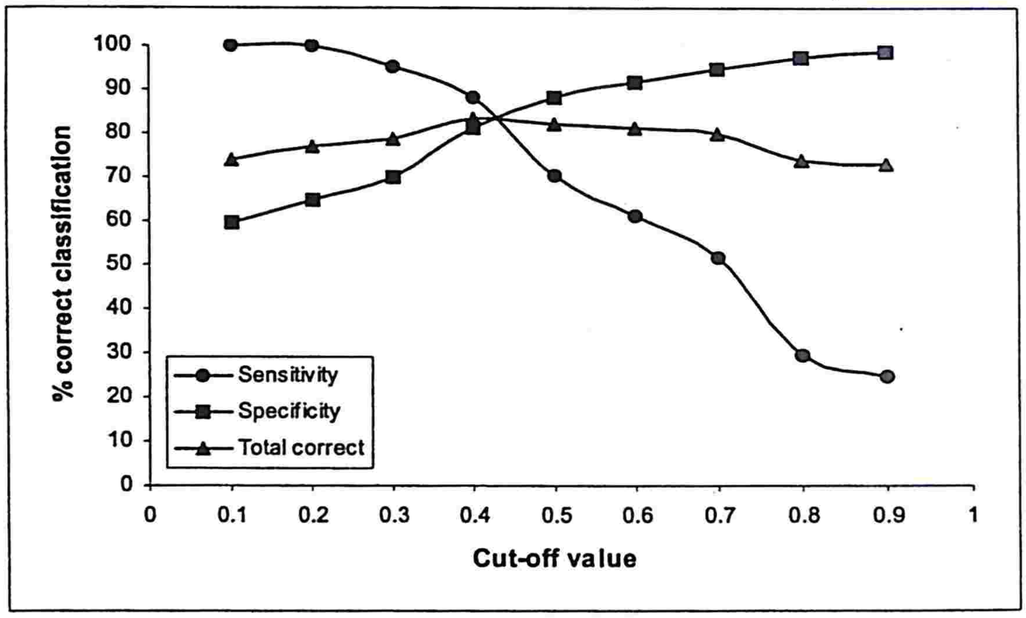


Figure 6.10. Concordance analysis depicting sensitivity and specificity in different cut-off of values (for western tragopan)

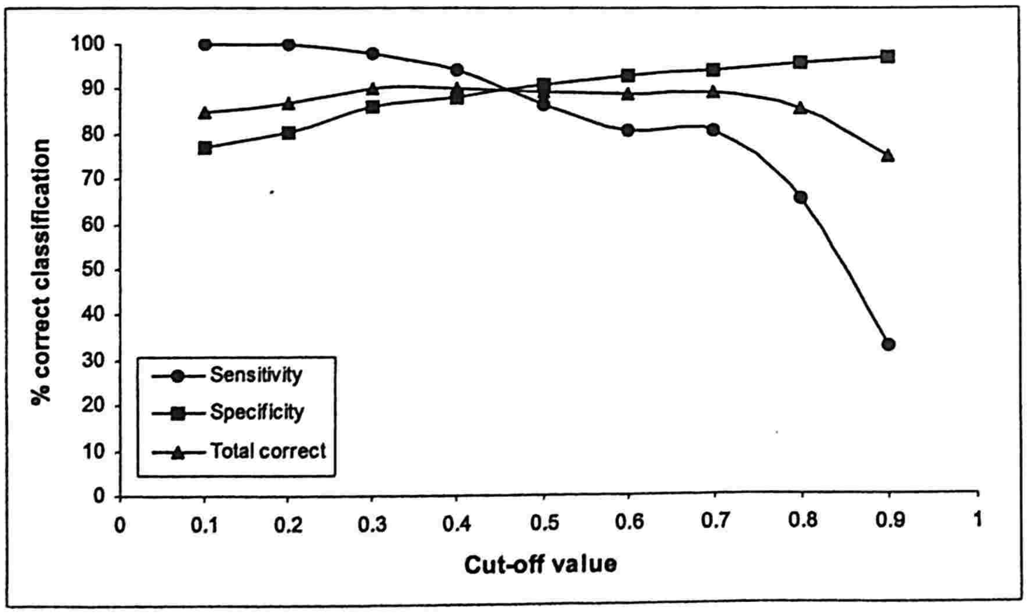


Table 6.6. Variables and coefficient values used in logistic regression model

Variables	Himalayan monal		Koklass		Western tragopan	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Constant	0.2200	0.99	2.2977	0.98	-5.5663	0.97
Altitude	-0.00004	0.92	-0.0012	0.02	-0.0010	0.35
NDVI	0.8400	0.36	0.1375	0.92	5.1758	0.08
Veg2	0.9874	0.88	8.8105	0.95	8.7953	0.96
Veg3	8.6148	0.89	8.7112	0.95	7.3362	0.97
Veg4	10.7001	0.87	8.3437	0.95	5.5488	0.97
Veg5	10.0984	0.88	9.1172	0.94	8.5786	0.96
Veg8	9.2732	0.89	8.8491	0.95	-2.1049	0.99
Veg9	8.0780	0.90	5.6596	0.97	-5.6412	0.98
Veg10	-0.2889	0.99	-1.5494	0.99	-1.4178	0.99
Veg11	-0.5675	0.99	-4.4202	0.98	-1.6418	0.99
Veg12	10.3043	0.87	9.2541	0.94	10.1883	0.95
Veg13	9.8530	0.88	9.5875	0.94	9.3118	0.96
Veg14	**-0.0616**	1.00	-1.1659	0.99	0.3425	0.99
Veg19	**-0.0929**	0.99	-4.8068	0.97	0.9220	0.99
Veg21	-1.0469	0.99	-3.5419	0.99	-4.1635	0.98
Veg22	-0.2423	0.99	0.1393	1.00	-0.3359	0.99
South	-10.1665	0.95	-7.1556	0.83	-0.3760	0.79
Southeast	-9.1697	0.96	-7.0118	0.83	0.2718	0.85
Southwest	-10.1674	0.95	-7.6796	0.81	-1.5117	0.29
East	-8.4739	0.96	-4.7345	0.88	0.6332	0.62
Northeast	-10.4046	0.95	-7.9572	0.81	-1.1916	0.37
West	-11.3041	0.95	-8.0773	0.80	-2.0204	0.14
Northwest	-11.5643	0.94	-8.3582	0.80	-9.6154	0.88
North	-10.6413	0.95	-8.0102	0.81	-	-

The equations developed for all the three species responded well in the validation data set. Comparison of classification rate for predicted positives and negatives indicated consistently higher rating in the validation data set (Table 6.7 A, B & C). These equations once applied on spatial maps of explanatory variables produced probability distribution for the entire area of GHNP for Himalayan monal (Fig.

6.11), koklass (Fig. 6.12) and western tragopan (Fig. 6.13). Except that each pixel had associated with individual probability values, the general pattern appeared to corroborate with the maps prepared based on rule-based model.

Table 6.7. Classification tables presenting the rate of true positives (TP), true negatives (TN) and corresponding predicted positives (PP) and predicted negatives (PN) in logistic regression model

A. Himalayan monal

Training data set (80%)

	TP	TN
PP	129	44
PN	41	303
% Correct	75.9%	87.3%

* *Total correct – 83.6%*

Validation data set (20%)

	TP	TN
PP	32	10
PN	6	87
% Correct	84.2%	89.7%

* *Total correct – 88.2%*

B. Koklass

	TP	TN
PP	60	19
PN	25	140
% Correct	70.6%	88.1%

* *Total correct – 82.0%*

	TP	TN
PP	21	4
PN	3	35
% Correct	87.5%	89.7%

* *Total correct – 88.9%*

C. Western tragopan

	TP	TN
PP	45	9
PN	7	92
% Correct	86.5%	91.1%

* *Total correct – 89.5%*

	TP	TN
PP	15	39
PN	1	0
% Correct	93.8%	100%

* *Total correct – 98.2%*

6.3.3. Autologistic model

Number of iterations to reach an asymptote of variance was 10 for all three species. Autocovariate estimated at this iteration and along with other explanatory variables improved the model fit and prediction efficiency at cut-off point 0.5. In comparison with ordinary logistic regression model, autologistic model showed consistent decrease and increase respectively in -2 Log Likelihood values and R^2 for Himalayan monal (266.3 and 0.80), koklass (127.6 and 0.79) and western tragopan (39.2 and 0.91). Chi-square value estimated based on Hosmer-Lomeshow goodness-of-fit test also revealed better model fit with autologistic data. The rate of predicted positives and negatives were also considerably high in this model (Table 6.8). Interestingly, incorporation of another variable i.e. autocovariate in the model appeared to have

Figure 6.11. Probability of occurrence predicted for Himalayan monal based on logistic regression model

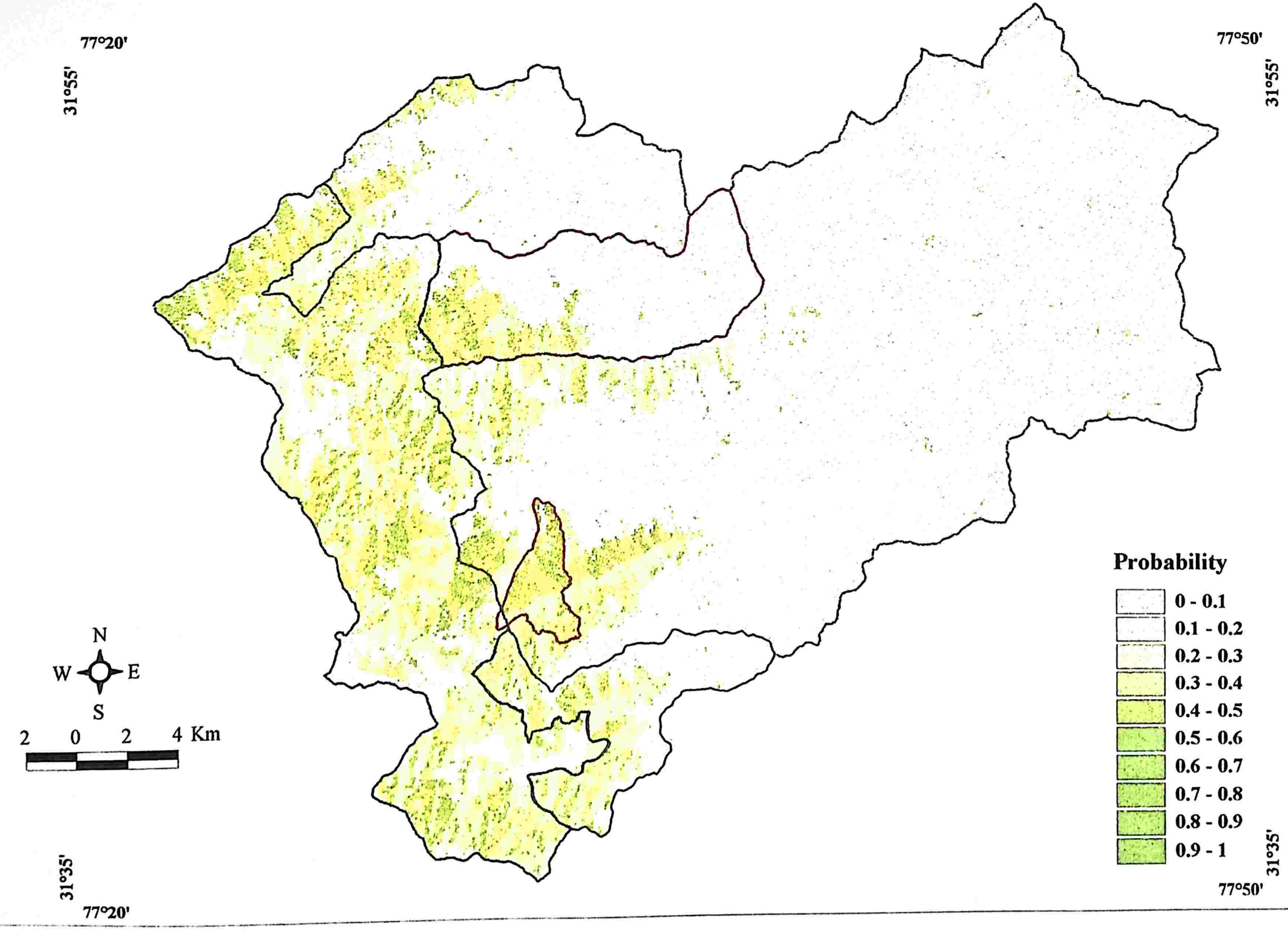


Figure 6.12. Probability of occurrence predicted for koklass based on logistic regression model

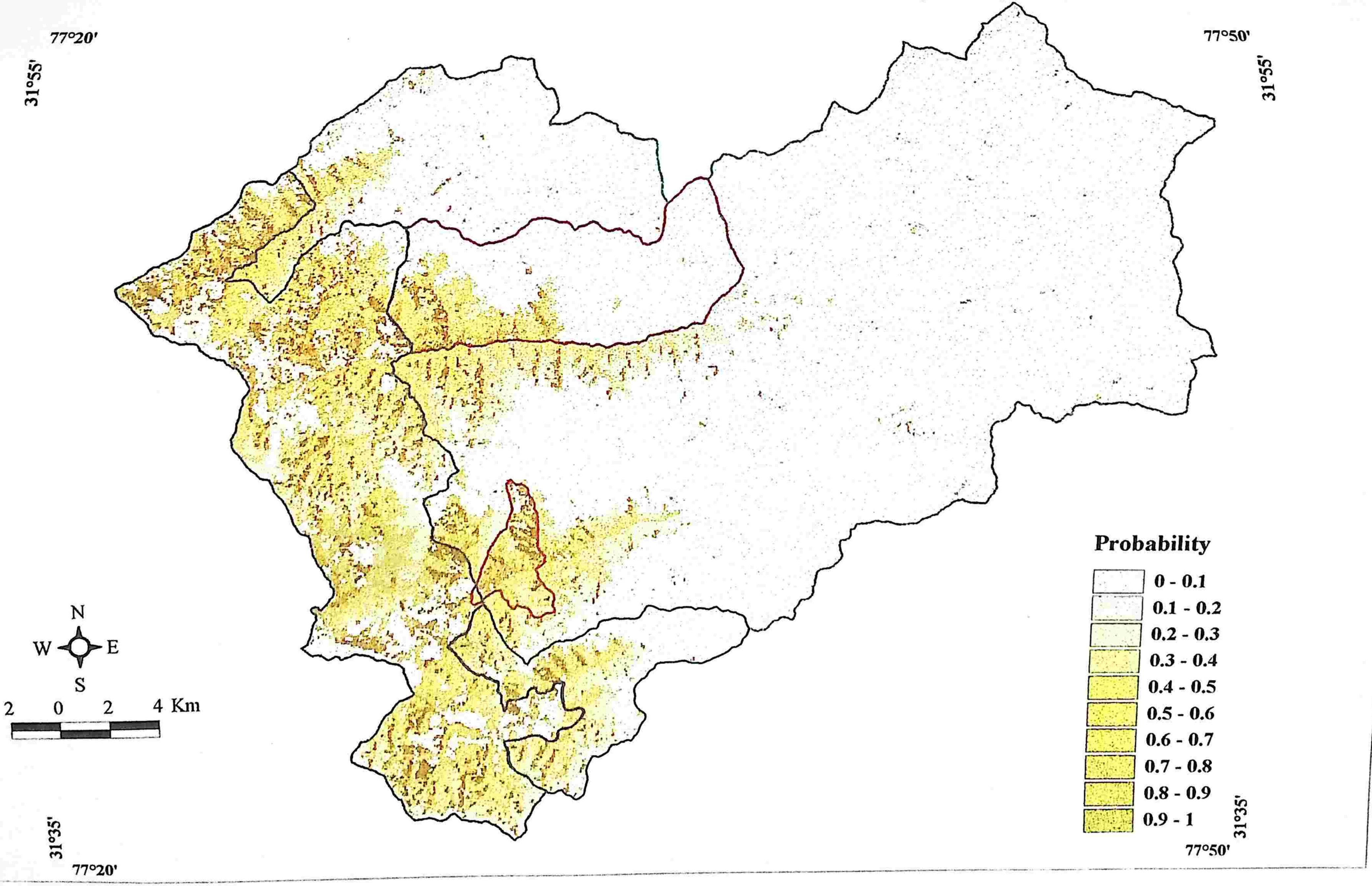
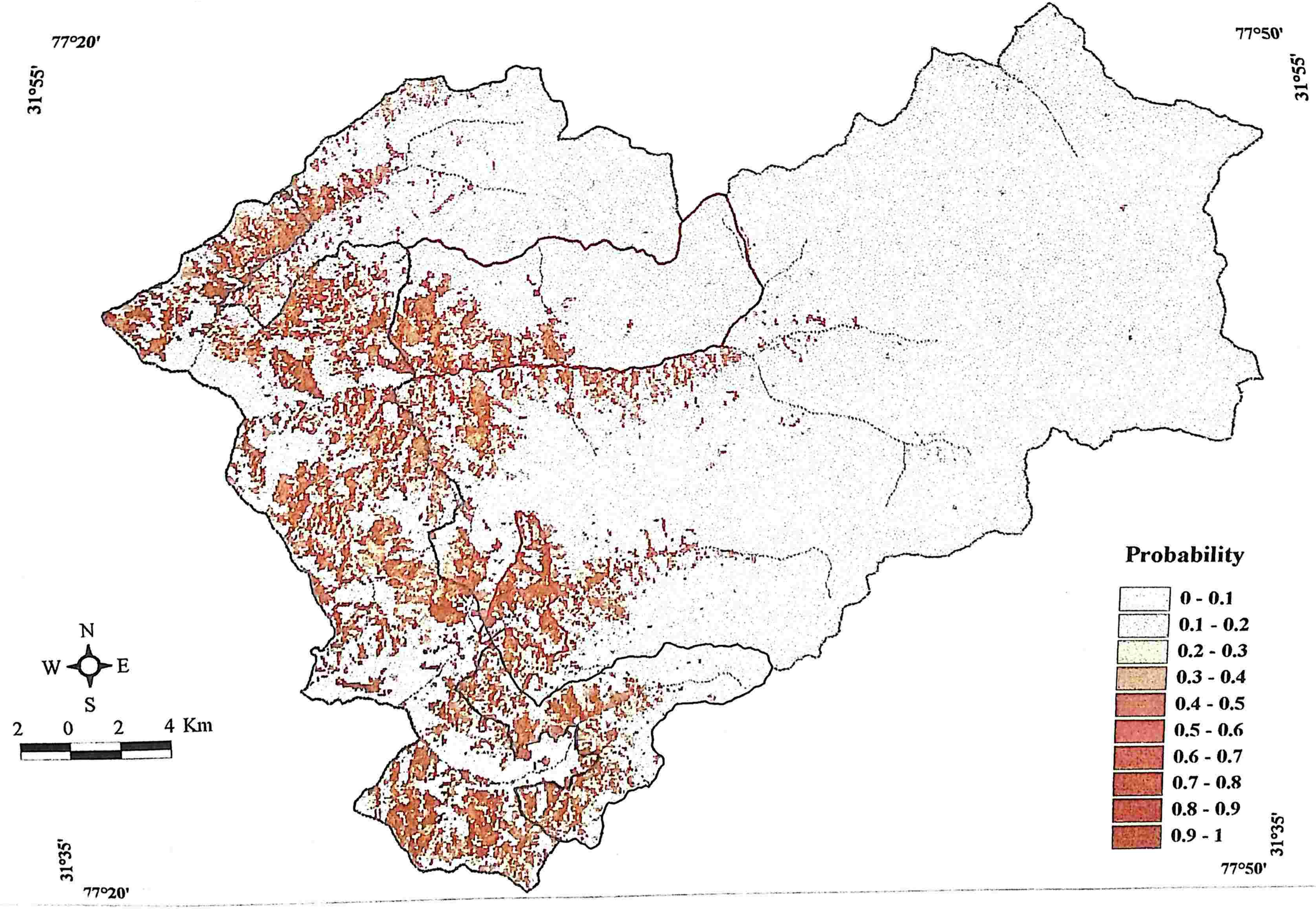


Figure 6.13. Probability of occurrence predicted for western tragopan based on logistic regression model



altered the overall contribution of the explanatory variables in the model. In the case of Himalayan monal, autocovariate (p < 0.000), NDVI (p < 0.06) and aspects particularly southeast (p < 0.07) were found to have greater contribution in predicting monal distribution. Almost similar results were obtained for koklass and western tragopan, with significant contribution from autocovariate (Table 6.9). The final equations obtained for the study species contained the same set of variables used in ordinary logistic model and newly generated autocovariate (Table 6.9). The equation on GIS resulted in final map of probability surface on the distribution of these species in GHNP (Figs. 6.14 - 16). Using the cut-off point 0.5, the probability surface was converted into presence (less than 0.5)/absence (above 0.5) to generate final maps of presence/absence for Himalayan monal (Fig. 6.17), koklass (Fig. 6.19) and western tragopan (Fig. 6.20). The final maps of presence/absence indicated a clustered distribution confined to three major isolated areas in GHNP. Original records of presence overlaid on these maps reflected almost similar distribution pattern, particularly in the park area including the intensive study area, based on which the model was developed. Some of the areas in the ecozone have been predicted as occurrence areas for the three species, whereas the field condition at the time of surveys revealed very low probability for these birds to be found there.

Table 6.8. Classification table presenting the rate of true positives (TP), true negatives (TN) and corresponding predicted positives (PP) and predicted negatives (PN) in autologistic model

A. Himalayan monal

	TP	TN
PP	200	35
PN	24	395
% Correct	89.3%	91.9%

* *Total correct – 91.0%*

B. Koklass

	TP	TN
PP	80	16
PN	15	204
% Correct	84.2%	92.7%

* *Total correct – 90.2%*

C. Western tragopan

	TP	TN
PP	67	3
PN	1	137
% Correct	98.5%	97.9%

**Total correct – 98.1%*

Table 6.9. Variables and coefficient values used in autologistic model

S. No.	Variables	Himalayan monal		Koklass		Western tragopan	
		Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
1.	Constant	-6.9298	0.93	-31.7192	0.66	-11.4106	0.94
2.	Altitude	-0.0002	0.70	0.0040	0.00	-0.0008	0.36
3.	NDVI	-2.0900	0.06	-3.3592	0.04	-1.7180	0.40
4.	Autocor	19.7836	0.00	22.3011	0.00	11.5799	0.00
5.	Veg2	3.8446	0.96	7.5460	0.92	8.4577	0.95
6.	Veg3	1.9012	0.98	6.8047	0.93	6.7343	0.96
7.	Veg4	2.9948	0.97	8.5406	0.91	8.9897	0.95
8.	Veg5	3.4867	0.96	6.1801	0.93	8.4715	0.95
9.	Veg8	2.8417	0.97	6.9083	0.92	-2.6087	0.99
10.	Veg9	3.7749	0.96	6.6335	0.93	-0.8997	0.99
11.	Veg10	-0.8953	0.99	-1.1716	0.99	0.5007	0.99
12.	Veg11	-4.0058	0.96	-0.6028	0.99	-0.0403	1.00
13.	Veg12	2.9144	0.97	7.6004	0.92	7.9529	0.96
14.	Veg13	2.8709	0.97	5.0353	0.95	9.8346	0.95
15.	Veg14	-0.4081	0.99	-0.6378	0.99	2.5185	0.99
16.	Veg19	0.6966	0.99	-3.0694	0.97	2.5300	0.99
17.	Veg21	-4.7457	0.96	4.8028	0.98	-0.4287	0.99
18.	Veg22	1.2878	0.99	-1.8101	0.99	3.0310	0.99
19.	South	-5.7435	0.11	1.8383	0.16	-0.6401	0.56
20.	Southeast	-6.4764	0.08	1.9111	0.18	-0.3191	0.77
21.	Southwest	-5.0383	0.17	2.5191	0.08	0.4593	0.68
22.	East	-5.6527	0.12	1.7847	0.21	-0.1380	0.90
23.	Northeast	-5.4081	0.14	2.7804	0.04	-0.0660	0.96
24.	West	-4.5056	0.22	2.8334	0.05	2.0159	0.09
25.	Northwest	-4.5427	0.21	2.4917	0.07	-8.9297	0.89
26	North	-4.9459	3.6087	2.1078	0.12	-	-

Figure 6.14. Probability of occurrence predicted for Himalayan monal based on autologistic regression model

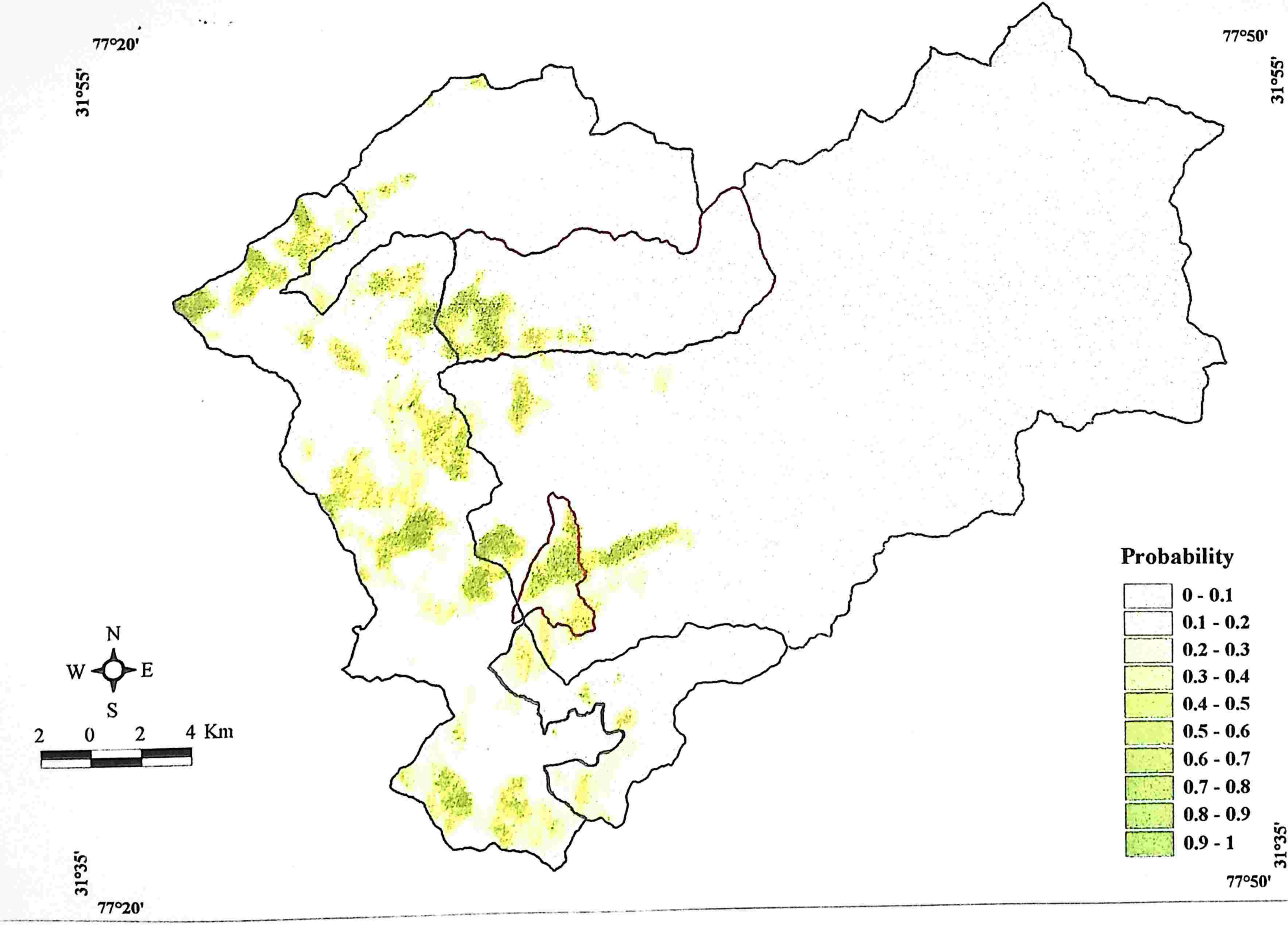


Figure 6.15. Probability of occurrence predicted for koklass based on autologistic regression model

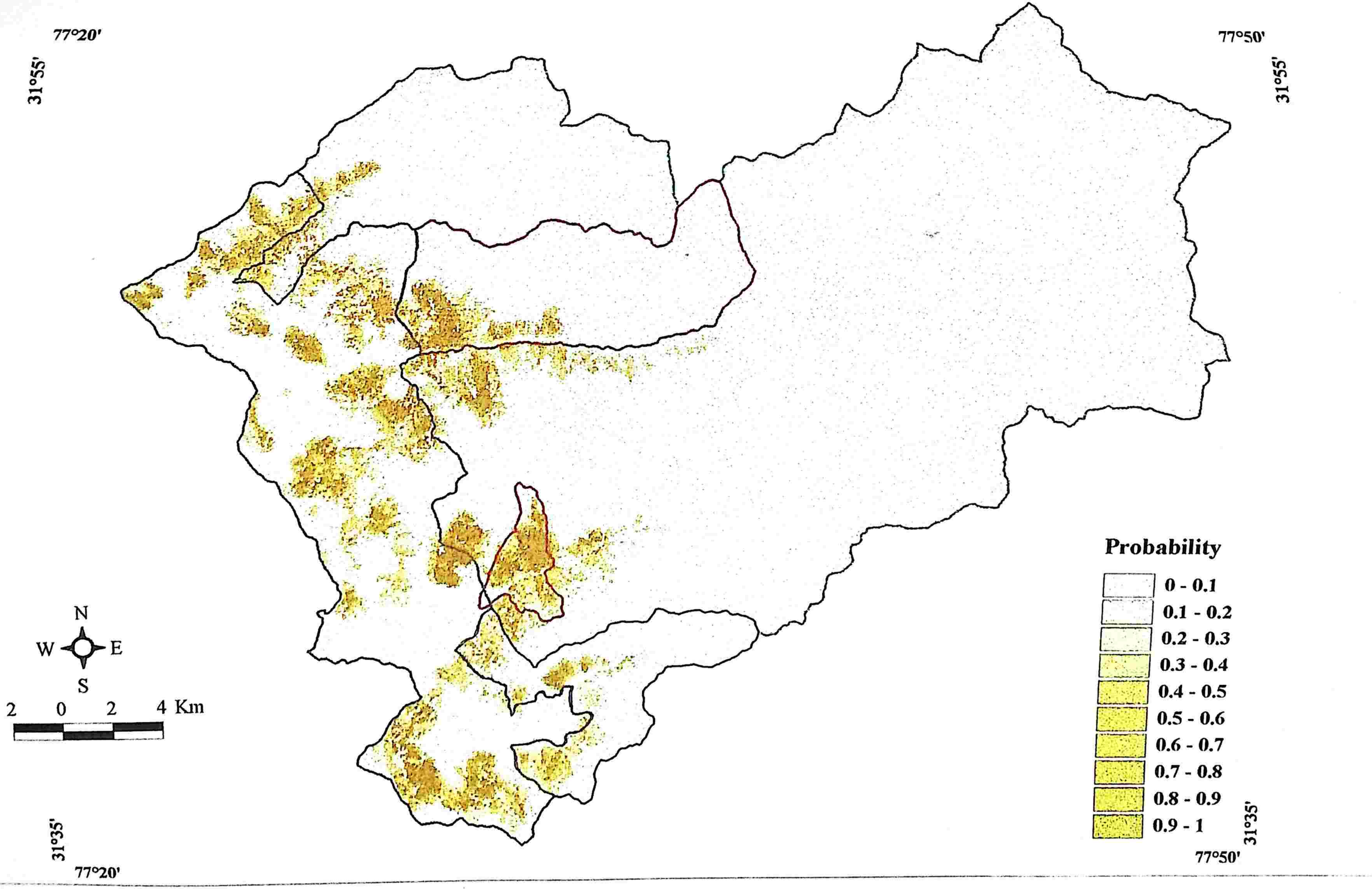
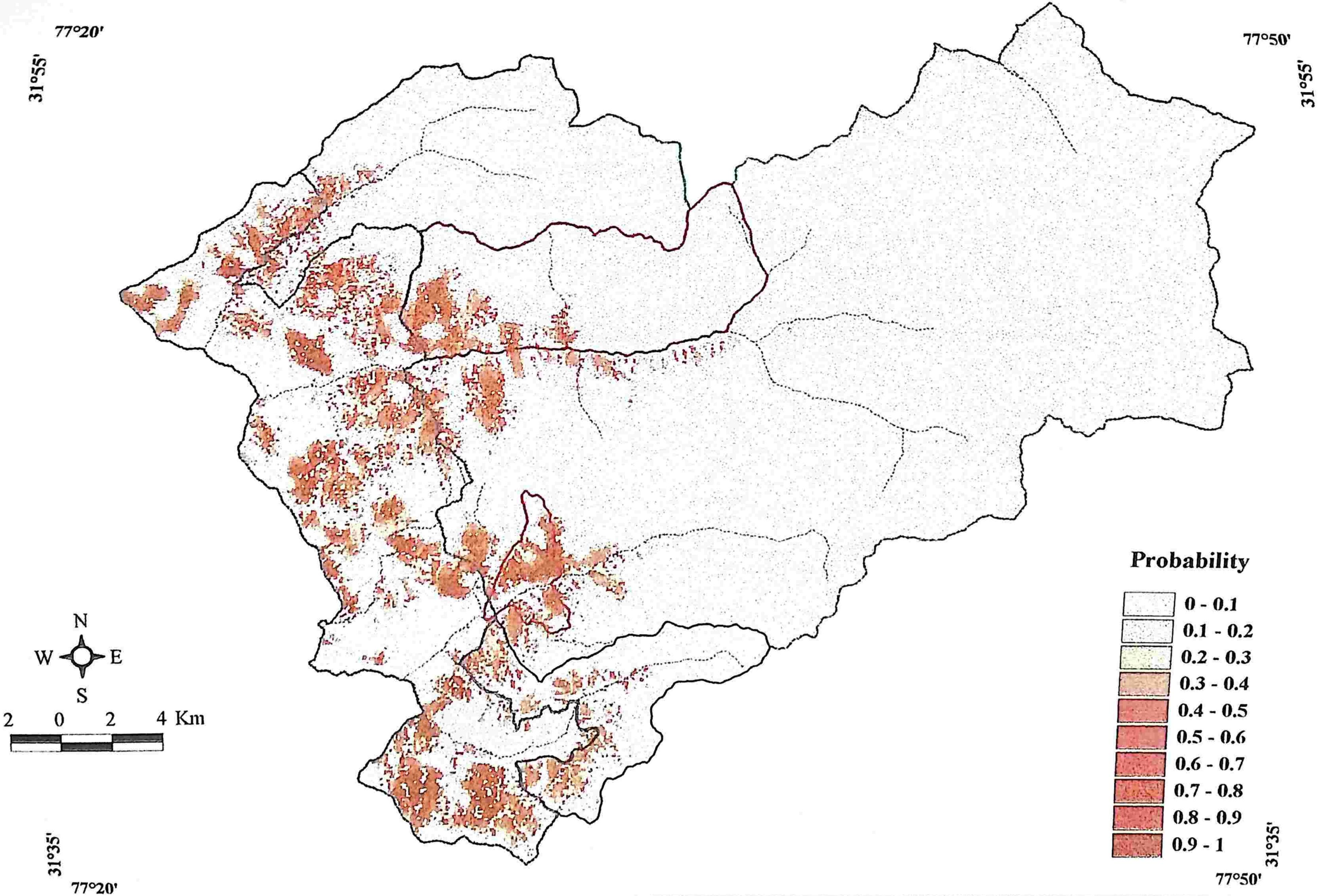


Figure 6.16. Probability of occurrence predicted for western tragopan based on autologistic regression model



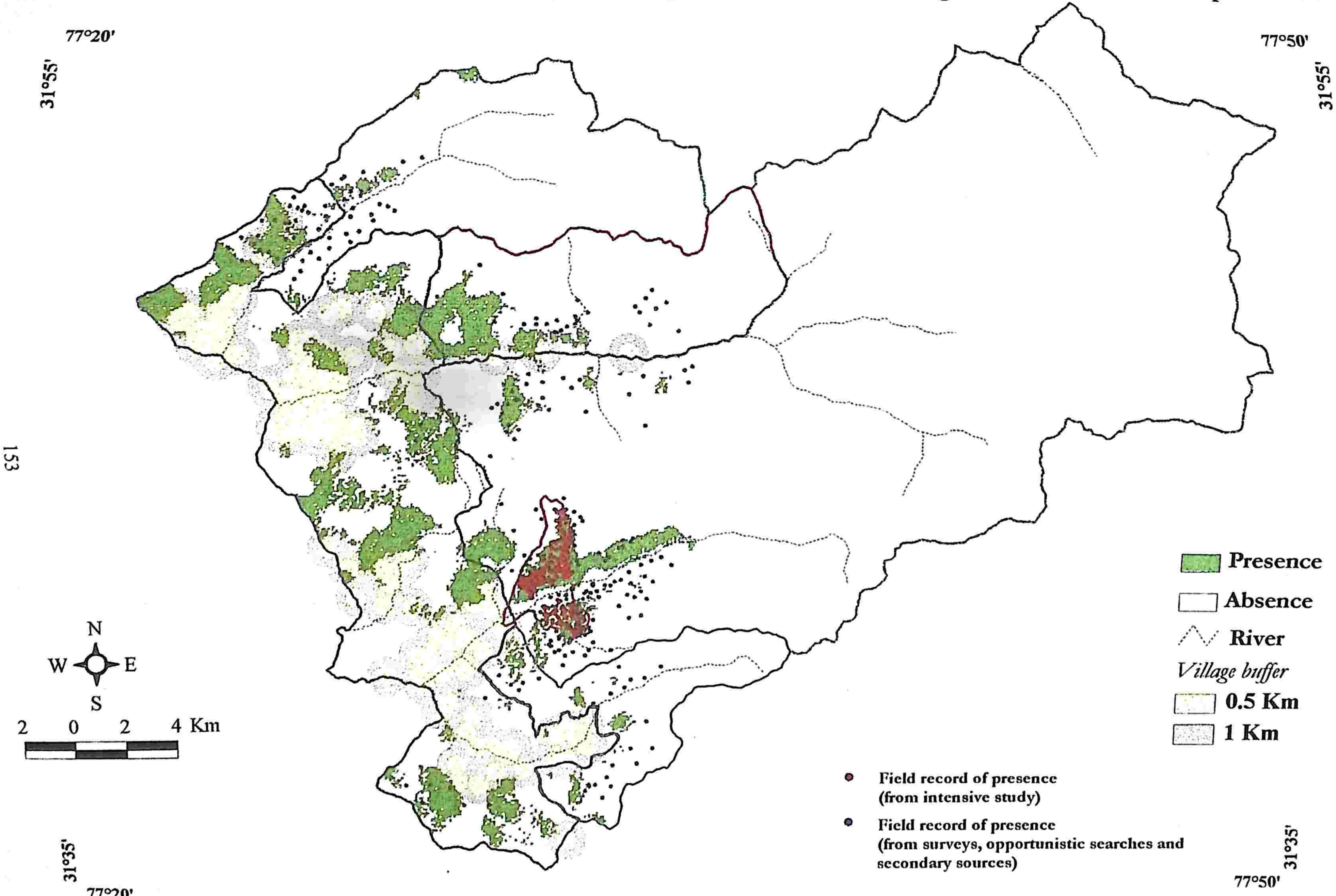


Figure 6.17. **Presence/absence of Himalayan monal predicted based on autologistic model at the cut-off point of 0.5**

Figure 6.18. **Presence/absence of koklass predicted based on autologistic model at the cut-off point of 0.5**

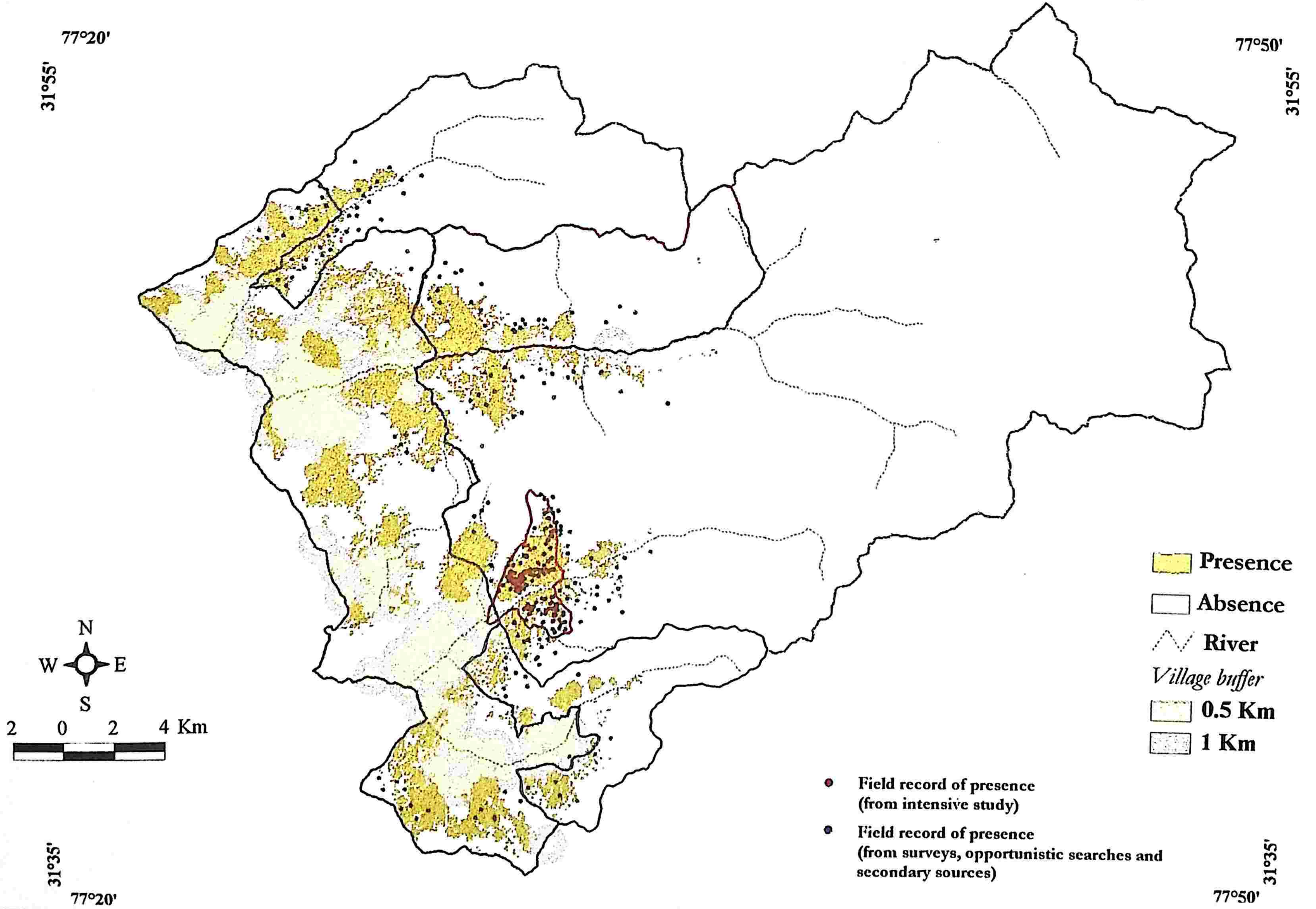
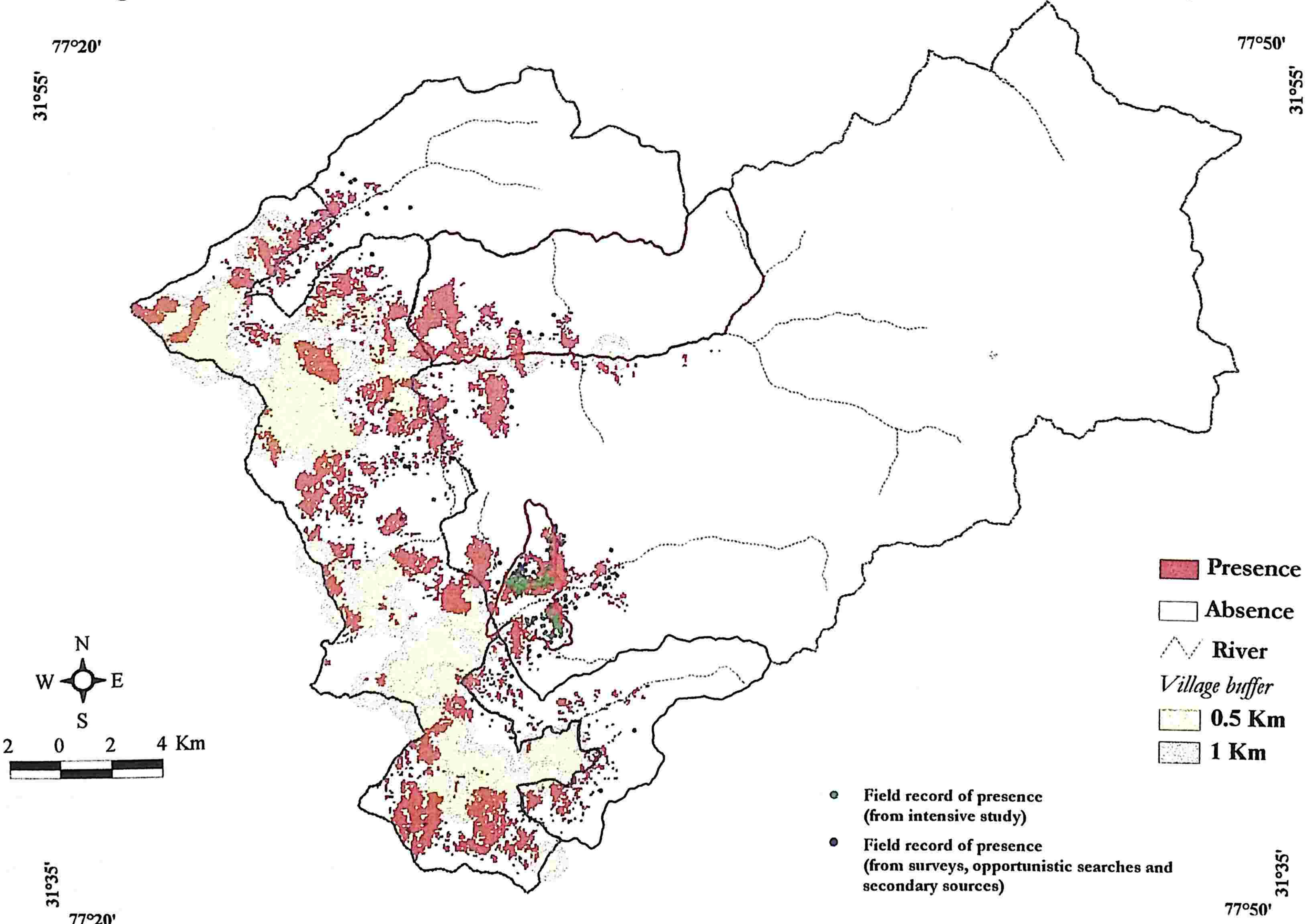


Figure 6.19. **Presence/absence of western tragopan predicted based on autologistic model at the cut-off point of 0.5**



6.4. Discussion

Spatially explicit maps are considered to have persuasive effect and more advantageous than numbers when dealing with wildlife management, research and advocacy (Buckland and Elston 1993, Cardillo et al. 1999, Boone and Krohn 2000). Conventionally, distribution maps were prepared by plotting actual records of presence on a spatial map and polygons were drawn connecting these points to depict distribution of the species concerned. Besides being less informative, such attempts invoke enormous deal of efforts, both time and manpower. In addition, logistic constraint posed by terrain conditions, particularly in the Himalaya, entails an alternative approach so as to enable prediction or extrapolation based on sample of observations or records (Augustin et al. 1996, Williams et al. 1997, Manel et al. 1999). Rapid progress in computer based mapping technology and development of highly equipped software that can handle large and complicated data, have been of immense help and have provided the required thrust in mapping wildlife distribution and habitats. In particular, use of GIS in wildlife studies has seen a major leap in last 15 years from a rare to widely used analytical tool, largely due to increasing realization on its potential and accessibility.

As described in the chapter 2, GHNP supports a large area of inhospitable topography with steep slopes and rugged terrain, thus limiting easy access to humans. With this limitation and availability of extensive spatial database documented by the project in collaboration with Indian Institute of Remote Sensing, Dehradun, the modeling approach was chosen to prepare distribution maps for Himalayan monal, koklass and western tragopan. The entire attempt was done on three stepwise schemes in GIS and primarily following associative model approach. 1) Rule based model provided a platform to identify the maximum possible area where the species are expected to be found in GHNP. 2) Logistic regression technique enabled to create a surface map of probability of occurrence using the potential covariates that were recognized to be influencing the distribution of the pheasants. 3) The model was further improved by incorporating information on spatial autocorrelation and final maps of probability distribution and presence/absence maps were obtained.

6.4.1. Rule based model

The results obtained using rule-based model does not necessarily reflect the true distribution of the study species. It only delineates the areas that have potential to be occupied by the pheasant species, based on broad-scale habitat variables. Himalayan monal, koklass and western tragopan are known to occur in a limited elevation range and exhibit strong association with temperate forests in the Himalaya during summer (Johnsgard 1986; Gaston and Garson 1992; Kumar 1997). It is possible to identify these features in a spatial map and, depending on the quality and scale of the data, the results can provide simple and less informative maps to habitat suitability index maps. Since the parameters incorporated in the rule model did not account for local variation or relative preference by the species within different habitat categories, extrapolation of the predicted binary response, i.e. occupied or unoccupied, to a large area is likely to be misleading. The inter-related biotic and abiotic factors and behaviour of the species are variable across space and time, and without considering these phenomena, generalization of observed pattern to a large area do not necessarily portray the reality. Nonetheless, it is logical to assume that the maps obtained by this model have the ability to depict **the maximum area** available to these species in GHNP, and general distribution pattern of the pheasants potentially revolves around this area.

The model revealed that the potential habitats available to these species are non-contiguous and a considerable proportion falls outside the Protected Area. About 50% of the predicted potential habitats lie in ecozone, dominated by human settlements. Opportunistic surveys carried out in parts of potential area in this zone indicated that these areas either do not support the pheasant populations or face severe pressure wherever they occur. Expansions of agriculture lands and consequent decrease in forested areas over decades (Mathur and Naithani 1999) seem to have affected the habitat and population of these species in the ecozone. Particularly during winter when they are forced to move to lower altitude by severe snow, they find themselves close to human habitation and often get poached

(Baviskar 1999). As seen in the predicted maps, potential habitat of these pheasants have been fragmented by the villages and the pheasants appear to be confined to three watershed areas, i.e., Tirthan, Sainj and Jiwa. Within GHNP, despite having dense forest and high tree canopy, parts of Sainj valley (specifically, lower part of Homkhani forests) hardly support the pheasant population, perhaps due to biotic disturbance from close-by villages. In such a situation, the potential habitats that are under effective protection are restricted only to a small proportion of Tirthan and Jiwa valleys. Moreover, an area of 10.6 km^2 of potential habitat had been excluded from Jiwa valley during final notification of GHNP for the upcoming Parvati Hydro electric project. This is not only likely to have a serious impact in the excluded area, but also in other parts of Jiwa valley once the project begins to take full shape. Considering these facts, it is apparent that park areas in Tirthan valley and parts of Sainj valley, are the only areas potentially left for survival of these pheasants. These areas are also not large and are about 90 km^2 for Himalayan monal, 40km^2 for koklass and 35 km^2 for western tragopan. It is essential to note that western tragopan is a low density and habitat specific species, closely associated with shrubby undergrowth, particularly bamboo species (*Thamnocalamus spathiflorus*), which is found in patchy distribution (Singh and Rawat 1999). Further improvement in the model incorporating such finer scale information is likely to project much lower potential area for this species. The resultant habitat maps of western tragopan prepared by Prasad (1993) and, Mathur and Naithani (1999) are also likely to reveal reduced habitat availability for the species if above issues are incorporated in the model.

6.4.2. Probabilistic model

It is often impossible to state in absolute terms about the presence of free ranging animals, because of complex nature of the ecosystem where it lives in, and variability influenced by inter and intra-specific interactions. The approach that seeks to generate probability of presence or an estimate of the likelihood of encountering the animal in a given landscape would be very useful and realistic for decision-making (Gough and Rushton 2000). Distribution maps obtained for Himalayan monal, koklass and western tragopan in this study represent probability values (0 to 1) in 1 ha plots (100 x 100 grid cells), indicating the chance of encountering the particular species in the plots during non-winter season. The entire approach was based on the premise that the species distribution is related to vegetation and topographic features. It was revealed from both univariate and multivariate statistical tests that of the six variables chosen for model development, variables such as altitude, land cover classes, NDVI and aspect categories were sufficient enough to predict the distribution of the species. Availability of large number of drainage in higher reaches close to perpetual snow line area (absence plots) and the possible autocorrelation between slope and vegetation types perhaps contributed to insignificant influence on the overall prediction by DWS and slope respectively. It was also possible that the drainage data did not form an appropriate surrogate for water availability, as the spatial layer on drainage represent mostly of large streams and do not necessarily depict water availability for the species during this period.

Spatial mapping of probability of occurrence using logistic regression method has been found to be effective in predicting occurrence of several species of mammals (Buckland and Elston 1993, Augustin et al. 1996, Carroll et al. 1999, Odom et al. 2001), birds (Beard et al. 1999, Manel et al. 1999, Franco et al. 2000, Osborne et al. 2001) and also for predicting natural events such as fire ignition probability and weed growth (Collingham et al. 2000, Gunter et al. 2000, de Vasconcelos et al. 2001). In the present study, logistic regression technique provided a basis for constructing probabilistic model and enabled to remove redundant variables from the equation. Besides DWS and slope, eight dummy variables (mostly non-forest classes) were found to be insignificant in model building and were removed from final equation for all the three species. In the case of western tragopan, one dummy variable in aspect category, i.e. north, was also found to be redundant due to absence of records in this category. These variables collectively accounted for 63%, 63% and 78% of explained-variation respectively for Himalayan monal (R^2 = 0.63), koklass (R^2 = 0.63) and western tragopan (R^2 = 0.78). Though the relationship of altitude with the pheasant occurrence was nonlinear, estimated coefficient indicated negative relationship, perhaps due to greater representation of higher altitude areas in the absence/random plots. Shrub/canopy cover indicated by NDVI and other landcover classes particularly CDM, BDM, BL, SLG, ALSC and EXR were found to be positively correlated with the occurrence of Himalayan monal and koklass. In the case of western tragopan, only NDVI and broadleaf dominated vegetation categories appeared to have a positive relationship with the species occurrence. Although above explanation indicate the role of individual variables in the equation, it could not be substantiated due to observed multicollinearity in the explanatory variables, as indicated by large p-values. Multicollinearity is known to exist when explanatory variables are highly correlated with each other and is an intractable problem in all regression analysis as it undermines statistical significance of individual explanatory variables (Allen 1997). However, since the objective was to come up with an overall prediction of species distribution regardless of which variable is contributing in relative magnitude, multicollinearity was not a problem. Moreover, it was found that these variables together predicted the distribution well and removal of any of the covariates from the model resulted in reduction of prediction rates.

There have been several attempts to map spatial distribution based on statistical relationship between distribution data and vegetation or habitat data. However, only recently effects of spatial autocorrelation are being incorporated in spatial modeling of wildlife-habitat associations (Augustin et al. 1996, Osborne et al. 2001). Beard et al. (1999) observed that information on influence of neighbours could alone provide better model prediction. In the present case, incorporation of autocovariate in the logistic regression model considerably increased explained variation of predictor variables (indicated by improved R^2 values) and prediction efficiency of presence plots. The prediction efficiency increased from about 76%, 71% and 87% respectively for Himalayan monal, koklass and western tragopan in logistic model to 89%, 84% and 98% in autologistic model. The maps obtained for these species based on autologistic equation resembled the field condition to a large extent at least in the park area and Sainj Wildlife Sanctuary. Due to insufficient field observation in the ecozone and Tirthan Wildlife Sanctuary, it was not possible to conclude on the prediction efficiency in these areas. However, the model seems to have predicted distribution in certain areas where these species were not found to occur, particularly in the ecozone. It was possible that the model was slightly biased due to low representation of random plots from lower altitude areas, particularly from ecozone (Fig. 6.7, Fig. 6.8 and Fig. 6.9), or perhaps the pheasants have been wiped out from these areas. Though the logistic regression and autologistic models respectively accounted for 87% and 98% of prediction rate for western tragopan, the field condition did not completely corroborate the result, specifically in ecozone. It is likely that the model was constructed based on a low sample size and did not have adequate representation from ecozone areas. There is a potential that the model can be improved by incorporating microhabitat information such as shrub density and response of these species to local climatic condition. It is important to note that majority of the predicted area in Jiwa valley falls in ecozone including the 10.6 km^2 that was excluded from the park area during final notification of the park. This invokes serious concern as the upcoming project has all potential to wipe out the pheasant population from Jiwa valley, which is otherwise considered to be one of the better wildlife areas.

To summarize, the spatial model developed in this study performed well in predicting distribution of Himalayan monal, koklass and western tragopan within well-protected area (as indicated by field records plotted over the predicted area). Independent surveys in rest of the areas would validate the observed pattern of the predictive model. From management point of view, the resultant maps (both potential habitat and distribution) can form useful baseline to undertake future monitoring and would enable efficient management approach for these species.

REFERENCES

Ahmed A. and Musavi H.M. 1997. **Sex-ratio: A problem in the management of Kalij pheasant.** Pp 82, In: (Abstract), The International Symposium on Galliformes 1997, Melaka, Peninsular Malaysia.

Alfred J.R.B., Kankane P.L., Arun Kumar, Roy P.S., Singh S. and Verma M. 2001. **Habitat suitability analysis of Chinkara, *Gazella bennetti* in Rajasthan – A Remote Sensing and GIS approach.** Records of Zoological Survey of India, Occasional Paper No. 189: 1 – 73.

Ali S. 1981. **The Himalaya in Indian Ornithology.** Pp 16-31, In: Lall J.S. and Moddie A.D. (*eds*) 1981. The Himalaya- aspects of change. Oxford University, India International Centre, New Delhi.

Ali S. and Ripley S.D. 1983. **The compact Handbook of the birds of Indian and Pakistan.** Oxford University Press, Bombay, India.

Allen C.R., Pearlstine L.G. and Kitchens W.M. 2001. **Modeling viable mammal populations in gap analyses.** Biological Conservation 99: 135 – 144.

Allen M.P. 1997. **Understanding regression analysis.** Plenum Press, New York.

Anderson A. 1886. **Report on the demarcation and settlement of the Kullu forest.** Government Press, Lahore.

Anderson B.W. and Ohmart R.D. 1981. **Comparisons of avian census results using variable distance transect and variable circular plot techniques.** Studies in Avian Biology No. 6: 186-192.

Anon 1972. **Indian Wildlife (Protection) Act, 1972.** Ministry of Environment and Forest, Govt. of India, New Delhi. Natraj Publishers, Dehradun. Pp 86.

Anon 1992. **Putting biodiversity on the map: priority areas for global conservation.** International Council for Bird Preservation, Cambridge, U.K.

Augustin N.H., Mugglestone M.A. and Buckland S.T. 1996. **An autologistic model for the spatial distribution of wildlife.** Journal of Applied Ecology 33: 339 – 347.

Awasthi A. 2001. **Ecological impact of anthropogenic pressures on high altitude forest along Bhagirathi catchment, Garhwal Himalaya.** Ph.D. thesis submitted to Deemed University, Forest Research Institute, Dehradun, India.

Balen S.V. and Holmes D.A. 1993. **Status and conservation of pheasants in the Greater and Lesser Sundas, Indonesia.** Pp 40-49, In: Jenkins, D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Baral H.S., Gurung P., Kaul R. and Ramesh K. 2001. **Santel Galliformes survey 2001.** Report submitted to World Pheasant Association, King Mehendra Trust for Nature Conservation, Nepal and Bird Conservation Nepal.

Baviskar A. 1999. **Intensive micro-study to assess socio-economic conditions of people using the Great Himalayan National Park.** Final Report of Forestry Research Education and Extension Project – Great Himalayan National Park, Wildlife Institute of India, Dehradun.

Beard K.H., Hengartner N. and Skelly D.K. 1999. **Effectiveness of predicting breeding bird distributions using probabilistic models.** Conservation Biology 13(5): 1108 – 1116.

Begon M. 1979. **Investigating animal abundance: capture-recapture for biologists.** Edward Arnold (Publishers) Limited. Pp 97.

Behera M.D., Srivastava S., Kushawha S.P.S. and Roy P.S. 2000. **Stratification and mapping of *Texus baccata* L. bearing forests in Talle valley using remote sensing and GIS.** Current Science 78(8): 1008 – 1013.

Bhatnagar Y.V. 1997. **Ranging and habitat utilization by the Himalayan ibex (*Capra ibex sibirica*) in Pin Valley National Park.** Ph.D. thesis. Saurashtra University, Rajkot, India. Pp 114.

Bibby C.J., Burgess N.D. and Hill D.A. 1992. **Bird census techniques.** Academic Press Limited, London. Pp 267.

Birdlife International 2001. **Threatened birds of Asia: the Birdlife International Red Data Book.** Cambridge, U.K.: Birdlife International.

Block W.M. and Brennan L.A. 1993. **The Habitat Concept in Ornithology: theory and applications.** In: Power D.M. (*ed*) 1993. Current Ornithology Vol. 11. Plenum Press, New York.

Blower J.G., Cook L.M. and Bishop J.A. 1981. **Estimating the size of animal populations.** George Allen & Unwin Limited, London. Pp 128.

*Bonham-Carter G.F. 1994. **Geographical Information System for geoscientists.** Pergamon Press, Oxford.

Boone R.B. and Krohn W.B. 2000. **Predicting broad-scale occurrence of vertebrates in patchy landscapes.** Landscape Ecology 15: 63 – 74.

Brown J. H. 1984. **On the relationship between abundance and distribution of species.** American Naturalist 124: 255 – 279.

Bub H. 1991. **Bird trapping and bird banding.** Cornell University Press, New York.

Bull E.L. 1981. **Indirect estimate of abundance of birds.** Pp 76 – 80, In: Ralph C.J. and Scott J.M. (*eds*). Estimating the number of terrestrial birds. Studies in Avian Biology 6. Cooper Ornithological Society, Las Cruces.

Buckland S.T. and Elston D.A. 1993. **Empirical models for the spatial distribution of wildlife.** Journal of Applied Ecology 30: 478 – 495.

Buckland S.T., Anderson D.R., Burnham K.P. and Laake J.L. 1993. **Distance sampling – estimating abundance of biological populations.** Chapman & Hall, London.

Bump G. 1941. **The introduction and transplantation of gamebirds and mammals into the state of New York.** Transactions of the North American Wildlife Conference 5: 409-420.

Burnham K.P., Anderson D.R. and Laake J.L. 1980. **Estimation of density from line transects sampling of biological population.** Wildlife Monograph No. 72.

Burnham K.P., Anderson D.R. and Laake J.L. 1981. **Line transect estimation of bird population density using a Fourier series.** Pp 466 – 482, In: Ralph C.J. and Scott J.M. (*eds*). Estimating the number of terrestrial birds. Studies in Avian Biology 6. Cooper Ornithological Society, Las Cruces.

Cardillo M., Macdonald D.W. and Rushton S.P. 1999. **Predicting mammal species richness and distribution: testing the effectiveness of satellite-derived landcover data.** Landscape Ecology 14: 423 – 435.

Carroll C., Zielinski W.J. and Noss R.F. 1999. **Using presence-absence data to build and test spatial habitat models for the Fisher in the Klamath region, U.S.A.** Conservation Biology 13(6): 1344 – 1359.

Caughley G. 1977. **Analysis of vertebrate populations.** John Wiley & Sons, New York. Pp 234.

Caughley G. 1994. **Directions in conservation biology.** Journal of Animal Ecology 63: 215 – 244.

Champion H.G. and Seth S.K. 1968. **A revised survey of forest types of India.** Manager of Publications, Government of India.

Chaudhry A.A. 1993. **Distribution and status of Pheasants in Pakistan.** Pp 7 – 14, In: Jenkins, D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Cody M.L. 1985. **An introduction to habitat selection in birds.** In: Cody M.L. (*ed*) 1985. Habitat selection in birds. Academic Press, Florida.

Collar N.J. and Andrew P. 1988. **Birds to Watch: The ICBP world checklist of threatened birds.** Technical Publication No.8. International Council for Bird Preservation, Cambridge, U.K.

Collingham Y.C., Wadsworth R.A., Huntley B. and Hulme P.E. 2000. **Predicting the spatial distribution of non-indigenous riparian weeds: issues of spatial scale and extent.** Journal of Applied Ecology 37:13 – 27.

Conroy M.J. and Carroll J.P. 2000. **Estimating abundance of Galliformes: tools and application.** Pp 204 – 215, In: Woodburn et al. (*eds*) 2000. Galliformes 2000: Proceedings of the 2nd International Galliformes Symposium, Kathmandu and Royal Chitwan National Park, Nepal, 24th September to 1st October 2000.

Cu N and Eames J.C. 1993. **The distribution and status of pheasants in Vietnam.** Pp 20 – 27, In: Jenkins, D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association Reading, U.K.

Darlington P. J. 1957. **Zoogeography: the geographical distribution of animals.** John Wiley and Sons, New York.

Das K.K., Ravan S.A., Negi S.K., Jain A. and Roy P.S. 1996. **Forest cover monitoring using remote sensing and GIS – a case study in Dhaulkhand range of Rajaji National Park, Uttar Pradesh.** Journal of Indian Society of Remote Sensing 24(1): 33 – 42.

Dawson D.K. 1981. **Sampling in rugged terrain.** Pp 311 – 315, In: Ralph C.J. and Scott J.M. (*eds*). Estimating the number of terrestrial birds. Studies in Avian Biology 6. Cooper Ornithological Society, Las Cruces.

De'ath G. and Fabricius K.E. 2000. **Classification and Regression Trees: a powerful yet simple technique for ecological data analysis.** Ecology 81(11): 3178 – 3192.

del Vasconcelos M.J.P., Silva S., Tome M., Alvim M. and Pereira J.M.C. 2001. **Spatial prediction of fire ignition probabilities: comparing logistic regression and neural networks.** Photogrammetric Engineering and Remote Sensing 67(1): 73 – 81.

Delacour J. 1977. **The Pheasants of the World.** Spur Publications and the World Pheasant Association. Pp 395.

DeMaso S.J., Guthery F.S., Spears G.S. and Rice S.M. 1992. **Morning covey calls as an index of northern bobwhite density.** Wildlife Society Bulletin 20:94 – 101.

Devan M.L. 1988. **State of Himalayas - Ecology, Environment, Geography, Resource and Publications: A call for Action.** Pp 183, In: Chadha, S.K. *(ed)* 1988. Himalayas: ecology and environment, Mittal Publications, Delhi, India.

Dhar U. 1997. **Himalayan biodiversity - action plan.** G.B. Pant Institute of Himalayan Environment and Development, Himavikas Publication No.10. Gyanodaya Prakashan, Naintital. Pp 136.

Duke G. 1989. **Western tragopan surveys in Pakistan 1988.** Unpublished report to International Council for Bird Preservation, Cambridge.

Duke G. 1990. **Using call counts to compare western tragopan populations in Pakistan's Himalaya.** Pp 116 – 122, In: Hill, D.A., Garson, P.J. and Jenkins, D. *(eds)* 1990. Pheasants in Asia 1989. World Pheasant Association, Readings, U.K.

*Dutt C.B.S., Kotwal P.C. and Shedha M.D. 1986. **Forest cover type mapping of Kanha National Park using remote sensing technique.** Proceeding of seminar-cum workshop on wildlife habitat evaluation using remote sensing technique, Dehradun. Pp75 – 82.

Dutta S.K. 1999. **Assessment of herpetofauna: Diversity, distribution, ecological requirements and responses to human activities in GHNP and WLSs.** Final Report: Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Emlen J.T. 1956. **A method for describing and comparing avian habitats.** Ibis 98 (4): 565-575.

Emlen J.T. 1971. **Population densities of birds derived from transect counts.** Auk 88: 323 – 342.

Farnsworth G.L., Pollock K.H., Nichols J.D., Simons T.R., Hines J.E. and Sauer J.R. 2002. **A removal model for estimating detection probabilities from point-count surveys.** Auk 119(2): 414 – 425.

Ford M. J. 1982. **The changing climate: responses of the natural fauna and flora.** George Allen and Unwin, London.

Franco A. M. A., Brito J. C. and Almeida J. 2000. **Modelling habitat selection of Common Cranes *Grus grus* wintering in Portugal using multiple logistic regression.** Ibis 142: 351 – 358.

Franzreb K.E. 1981. **The determination of avian densities using the variable-strip and fixed-width transect surveying methods.** Pp 139-145, In: Ralph C.J. and Scott J.M. (*eds*) 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology No. 6. Cooper Ornithological Society, Las Cruces.

Fuller R. A. and Garson P. J. (*eds*) 2000. **Pheasants: status survey and conservation action plan 2000-2004.** WPA/Birdlife/SSC Pheasant Specialist Group. IUCN, Gland. Switzerland and Cambridge, U.K. and the World Pheasant Association, Reading, U.K.

Garson P.J. 1983. **The cheer pheasant *Catreus wallichi* in Himachal Pradesh, Western Himalaya: An update.** Journal of World Pheasant Association 8: 29-39.

Gaston A.J. 1980. **Census techniques for Himalayan pheasants including notes on individual species.** Journal of the World Pheasant Association 5: 40-53.

Gaston A.J. 1982. **Maps of recent pheasant observations in the Himalayas.** Pp 65 – 77, In: Savage C.D.W. and Ridley M.W. (*eds*) 1982. Pheasants in Asia 1982. World Pheasant Association, Reading, U.K.

Gaston A.J. and Garson P.J. 1992. **A re-appraisal of the Great Himalayan National Park.** Unpublished Report to International Trust for Nature Conservation, U.K.

Gaston A.J. and Singh J. 1980. **The status of cheer pheasant *Catreus wallichii* in the Chail Wildlife Sanctuary, Himachal Pradesh.** Journal of the World Pheasant Association 5: 68 – 73.

Gaston A.J., Garson P.J. and Hunter M.L. Jr. 1981. **The Wildlife of Himachal Pradesh, Western Himalaya.** University of Maine school of Forest Resources Technical Notes No. 82.

Gaston A.J., Garson P.J. and Hunter M.L.Jr. 1983a. **The status and conservation of forest wildlife in Himachal Pradesh, Western Himalayas.** Biological Conservation 27: 291 - 314.

Gaston A.J., Garson P.J. and Pandey S. 1993. **Birds recorded in the Great Himalayan National Park, Himachal Pradesh, India.** Forktail 9: 45-57.

Gaston A.J., Islam K., and Crawford J.A. 1983b. **The current status of western tragopan.** Journal of the World Pheasant Association 8: 68 – 73.

Gaston A.J., Lelliott A.D. and Ridley M.W. 1982. **Display flights of the male monal pheasant, *Lophophorus impejanus*.** Journal of World Pheasant Association 7: 90-91.

Ghose D., Kaul R. and Saha G.K. 2000. **Distribution and habitat use of Blyth's tragopan in Mizoram, India.** Pp 103 – 107, In: Woodburn M., McGowan P., Carroll J., Musavi A. and Zheng-wang Z. *(eds)* 2000. Galliformes 2000: Proceedings of the 2nd International Galliformes Symposium, Kathmandu and Royal Chitwan National Park, Nepal, 24th September to 1st October 2000.

Ghosh S., Sen K.K., Rana U., Rao K.S. and Saxena K.G. 1996. **Application of GIS for land-use/landcover change analysis in a mountainous terrain.** Journal of Indian Society of Remote Sensing 24(3): 193 – 202.

Gill J. A. 1996. **Habitat choice in pink-footed geese: quantifying the constraints determining winter site use.** Journal of Applied Ecology 33: 884 – 892.

Gill J. A., Sutherland W. J. and Watkinson A. R. 1996. **A method to quantify the effect of human disturbance on animal populations.** Journal of Applied Ecology 33: 786 – 792.

Gotch A.F. 1981. **Birds – their Latin names explained.** Blanford Press, Dorset.

Gough M. C. and Rushton S. P. 2000. **The application of GIS-based modelling to mustelid landscape ecology.** Mammal Review 30 (3 & 4): 197 – 216.

Green M.J.B. 1986. **The birds of the Kedarnath Sanctuary, Chamoli district, Uttar Pradesh: status and distribution.** Journal of Bombay Natural History Society 83: 603 – 617.

Grimmett R., Inskipp C. and Inskipp T. 1998. **Birds of the Indian Subcontinent.** Oxford University Press, Delhi. Pp 888.

Guang-mei Z. and Zheng-wang Z. 1993. **The distribution and status of pheasants in China.** Pp 15 – 19, In: Jenkins D. *(ed)* 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Gunter J.T., Hodges D.G., Swalm C.M. and Regens J.L. 2000. **Predicting the urbanization of pine and mixed forest in Saint Tammany Parish, Louisiana.** Photogrammetric Engineering and Remote Sensing 66(12): 1469 – 1476.

Guthery F.S. 1988. **Line transect sampling of bobwhite density on range land: evaluation and recommendations.** Wildlife Society Bulletin 16: 193 – 203.

Hill D. and Robertson P. 1988. **The Pheasants: ecology, management and conservation.** BSP Professional Books, Oxford, U.K. Pp 281.

Hosmer D.W. Jr. and Lemeshow S. 1989. **Applied logistic regression.** John Willey & Sons, New York.

Howman K.C.R. 1976. **Census counts of koklass in Pakistan.** American Pheasant and Waterfowl Soc. Mag. 77(8): 2- 10.

Hume A.O. and Marshall C.H.T. 1879. **The game birds of India, Pakistan, Bangladesh, Burma and Srilanka (*including Nepal, Bhutan and Tibet*).** Vol. 1. Reprinted in 1995 by Bhavana Books and Prints, New Delhi.

Hussain M.S., Khan J.A. and Kaul R. 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.

Iqbal S.M. 1993. **Patterns of habitat use by white-crested kalij at two sites in the Indian Himalayas in 1988-89.** Pp 15, In: (Abstract) Jenkins D. *(ed)* 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Islam K. 1982. **Status and distribution of the western tragopan in Northeastern Pakistan.** Pp 44 – 5, In: Savage C.D.W. and Ridley M.W. *(e*ds). Pheasants in Asia 19*82*, World Pheasant Association, Reading, *U*.K.

*Islam K. 1985. **Habitat use by western tragopan in northeastern Pakistan.** MS thesis. Oregon State University, Corvallis, Oregon.

Islam K. and Crawford J.A. 1987. **Habitat use by western tragopa*n Tragopan melanocephal*us (Gray) in northeastern Pakistan.** Biological Conservation 40: 101 – 115.

Islam K. and Crawford J.A. 1993. **Sex ratio in western tragopan and its implication for population estimation.** Pp 131-133, In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

James F.C. and Shugart H.H.Jr. 1970. **A quantitative method of habitat description.** Audubon Field Notes 24(6): 727-736.

Jandrotia J.S., Katoch S.S., Kaul R. and Seth K. 2000. **Surveys of pheasants in Chamba Districts of Himachal Pradesh, India.** Pp 75 – 78, In: Woodburn et al. (eds) 2000. Galliformes 2000: Proceedings of the 2nd International Galliformes Symposium, Kathmandu and Royal Chitwan National Park, Nepal, 24th September to 1st October 2000.

Jandrotia J.S., Sharma V. and Katoch S.S. 1995. **A pheasant survey in the Ravi catchment of Chamba District, Himachal Pradesh, India.** Annual Review of the World Pheasant Association 1994 – 1995: 67 – 74.

Jandrotia J. S. 1999. **Pheasant surveys in Chamba valley, Himachal Pradesh.** (Abstract) Regional Workshop on research techniques and management of Pheasant. Sai Ropa, Great Himalayan National Park.

Johnsgard P.A. 1973. **Grouse and quails of North America.** University of Nebraska Press, Lincoln.

Johnsgard P.A. 1986. **The Pheasants of the World.** Oxford University Press, New York. Pp 300.

Johnson D.H. 1980. **The comparison of usage and availability measurements for evaluating resource preference.** Ecology 61: 65-71.

Julka J. M. 1999. **Biodiversity assessment of annelida and mollusca in the Great Himalayan National Park.** Final Report: Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Kareiva P. and Wennergren U. 1995. **Connecting landscape patterns to ecosystem and population processes.** Nature 373: 299 - 302.

*Kaul R. 1989. **Ecology of the Cheer pheasant *Catreus wallichii* in Kumaon Himalaya.** Unpublished Ph.D. thesis. University of Kashmir, Srinagar

Kaul R. and Ahmed A. 1993. **Pheasant surveys in Arunachal Pradesh, India, in February - March 1991.** Pp 50 – 54, In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Kaul R. and Garson P.J. 1993. **Present distribution and status of pheasants in India.** Pp 157, In: Jenkins D. (ed) 1993. Pheasants in Asia 1992. World Pheasant Association Reading, Reading, U.K.

Khaling S. 1997. **Satyr tragopan in the Singhalila Natinal Park, Dargeeling, India.** Tragopan: Newsletter of the WPA/SSC/Pheasant Specialist Group 6: 13-14.

Khaling S. 1999. **Certain aspects of ecology and behaviour of the satyr tragopan *Tragopan satyra* in Singhalila National Park, Darjeeling, India.** Unpublished Ph.D. thesis, North Bengal University.

Khaling S., Kaul R. and Saha G.K. 1999. **Surveys of the satyr tragopan *Tragopan satyra* in the Singhalila National Park, Darjeeling, India using spring call counts.** Bird Conservation International 9: 361 – 371.

Khan S.B., Javed S., Kaul R. and McGowan P. 2000. **Measuring the population status of the western tragopan *Tragopan melanocephalus* using two methods in the forests of Himachal Pradesh, India.** Pp 224 – 231, In: Woodburn et al. (*eds*) 2000. Galliformes 2000: Proceedings of the 2nd International Galliformes Symposium, Kathmandu and Royal Chitwan National Park, Nepal, 24th September to 1st October 2000.

Khan W.M. and Shah I.H. 1982. **Population dynamics of the koklass pheasant (*Pucrasia macrolopha*) in Malkandi forests, Pakistan.** Pp 40-43, In: Savage C.D.W. and Ridley M.W. (*eds*). Pheasants in Asia 1982, World Pheasant Association, Reading, U.K.

Kimball J.W. 1949. **The crowing count pheasant census.** Journal of Wildlife Management 13: 101 – 120.

Kimball R.T., Braun E.L., Zwartjes P.W., Crowe T.M. and Ligon J.D. 1999. **A molecular phylogeny of the pheasants and partridges suggests that these lineages are not monophyletic** Molecular phylogenetics and evolution Vol. 11 (1): 38-54.

King W.B. 1981. **Endangered birds of the world – the ICBP bird red data book.** Smithsonian Institution Press, Washington DC.

Knick S.T. and Rotenberry J.T. 1999. **Spatial distribution of breeding passerine bird habitats in a shrubsteppe region of southeastern Idaho.** Studies in Avian Biology No.9: 104-111.

Kumar R.S. 1997. **Winter habitat use by Himalayan monal pheasant in Kedarnath Wildlife Sanctuary, Western Himalaya.** M.Sc. thesis, Saurashtra University, Rajkot, India.

Kumar R.S. and Singh P. 1999. **Discovery of a new monal from Arunachal Pradesh.** Oriental Bird Club Bulletin 30: 35-37.

Kumar R.S. and Singh P. 2000. **Survey for pheasants with reference to the distribution of the genus *Lophophorus* in Arunachal Pradesh, India.** Unpublished Report: Wildlife Institute of India. Pp 31.

Kushawa S.P.S. 1997. **Landmass dynamics and Rhino habitat suitability analysis in Kaziranga National Park, Assam.** Project Report, Indian Institute of Remote Sensing, Dehradun.

Lack D. 1971. **Ecological Isolation in Birds.** Harvard University Press, Cambridge.

Lal J.B., Gulati A.K. and Bist M.S. 1991. **Satellite mapping of alpine pastures in the Himalaya.** International Journal of Remote Sensing 12(3): 438 – 443.

Lamba B.S., Narang M.L., Tyagi A.K., Tak P.C. Kumar G. and Bacha M.S. 1982. **Pheasant census survey of Kashmir valley – a report.** Pp 52-54, In: Savage C.D.W. and Ridley M.W. (*eds*). Pheasants in Asia 1982, World Pheasant Association, Reading, U.K.

Lancia R.A., Nichols J.D. and Pollock K.H. 1994. **Estimating the numbers of animals in wildlife populations.** Pp 215 – 253, In: Bookout T.A. (*ed*).

Research and management techniques for wildlife and habitat. The Wildlife Society, Bethesda, USA.

Legendre P. 1993. **Spatial autocorrelation: trouble or new paradigm?** Ecology 74(6): 1659 – 1673.

Legendre P. and Fortin M. 1989. **Spatial pattern and ecological analysis.** Vegetatio 80: 107 – 138.

Lelliott A.D. 1981. **Studies of Himalayan pheasants in Nepal with reference to their conservation.** M.Sc. thesis, University of Durham.

Lenton S.M., Fa J.E. and Val J.P.D. 2000. **A simple non-parametric GIS model for predicting species distribution: endemic birds in Bioko Island, West Africa.** Biodiversity and Conservation 9: 869 – 885.

Lima S.L. and Zollner P.A. 1996. **Towards a behavioural ecology of ecological landcapes.** Trends in Ecology and Evolution 82: 161 - 174.

Liu J., Ouyang Z., Taylor W. W., Groop R., Tan Y. and Zhang H. 1999. **A framework for evaluating the effect of human factors on wildlife habitat: the case of Giant Pandas.** Conservation Biology 13 (6): 1360 – 1370.

Lowe P.R. 1933. **The differential characters in the tarso-metatarsi of Gallus and Phasianus as they bear on the problem of the introduction of the pheasant in Europe and the British Isles.** Ibis 3: 332-343.

MacArthur R.H. 1958. **Population ecology of some warblers of northeastern coniferous forests.** Ecology 39: 599 – 619.

MaCkinon J., Mackinon K., Child G. and J. Thorsell 1986. **Managing Protected Areas in the Tropics.** IUCN, Gland, Switzerland.

Manel S., Dias J.M., Buckton S.T. and Ormerod S.J. 1999. **Alternative methods for predicting species distribution: an illustration with Himalayan river birds.** Journal of Applied Ecology 36: 734 – 747.

Mani M.S. 1974. **Ecology and Biogeography in India.** XXI Biogeography of Himalaya. Junk Publishers, the Hague.

Manuwal D.A. and Carey A.B. 1991. **Methods for measuring populations of small, diurnal forest birds.** In. Carey, A.B. and Ruggiero, L.F. (*eds*). Wildlife-habitat relationships: sampling procedures for Pacific Northwest vertebrates. General Technical Report PNW-GTR 278.

Mathur V.B. and Naithani S. 1999. **Development of a spatial database of the Great Himalayan National Park Conservation Area in GIS domain.** Final

Report, Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Mayr E. and Amadon D. 1951. **A classification of recent birds.** Am. Mus. Novit. 1496: 1 –42.

McGowan P.J.K. 1990. **Calling as a means to survey the Malaysian Peacock Pheasant: a preliminary assessment.** Pp 110 – 115, In: Hill D.A., Garson P.J. and Jenkins D. (*eds*) 1990. Pheasants in Asia 1989. World Pheasant Association, Readings, U.K.

*McGowan P.J.K. 1992. **Social organization in the Malaysian Peacock Pheasant.** Unpublished Ph.D. thesis, Open University, U.K. 576.

McGowan P.J.K. 1994. **Family: Phasianidae (pheasant and partridges).** Pp 434 – 552, In: Del Hoyo J., Elliot A. and Sargatal J. (*eds*) 1994. Handbook of the birds of the world. Volume. 2. New World Vultures to Guineafowl. Lynx Edicions, Barcelona.

McGowan P.J.K. and Garson P.J. 1995. **Status survey and conservation action plan 1995-1999. Pheasants.** IUCN and World Pheasant Association, Switzarlandand U.K. Pp 116.

McGowan P.J.K. and M. Gillman 1997. **Assessment of the conservation status of partridges and pheasants in South East Asia.** Biodiversity and Conservation 6: 1321-1337. Pp 116.

McKelvie C.L. 1985. **A future for Game.** George Allen and Unwin Publishers Ltd., London WC1A 1LU, UK.

Mehta A., Mehta R., Palhan S., Sankaran V., Singh S., Uppal V. and Vania F. 1993. **Biodiversity through ecodevelopment: A preliminary indicative plan for Great Himalayan National Park, Himachal Pradesh and Kalakad Mundanthurai Tiger Reserve, Tamil Nadu.** Indian Institute of Public Administration, New Delhi, India.

Menard S. 1995. **Applied logistic regression analysis.** Sage University paper series on quantitative applications in the social sciences, 07 – 106. Thousand Oaks, CA, Sage.

Mirza Z.B., Aleen A. and Asghar M. 1978. **Pheasant surveys in Pakistan.** J. Bombay Nat. Hist. Soc. 74 : 292-296.

Mishra C., 1993. **Habitat use by goral in Majhatal Arsang Wildlife Sanctuary, Himachal Pradesh.** M.Sc. thesis, Saurashtra University, Rajkot, India. Pp 54.

Mladdenoff D.J., Sickley T.A., Haight R.G. and Wydeven A.P. 1995. **A regional landscape analysis and prediction of favourable gray wolf habitat in the Northern Great Lakes region.** Conservation Biology 9: 279 – 294.

Morrison M.L., Marcot B.G. and Mannan R.W. 1992. **Wildlife habitat relationships; concept and application.** University of Wisconsin press, Madison.

Moynihan M. 1995. **Social structures and behavior patterns of captive and feral Reeves's pheasants *Syrmaticus reevesi* in France.** Alauda 63: 213-228.

Muller-Dembois D. and Ellenberg H. 1974. **Aims and methods of vegetation ecology.** John Wiley & sons, Wiley International Edition. Pp 547.

Nagendra H. and Gadgil M. 1999. **Satellite imagery as a tool for monitoring species diversity: an assessment.** Journal of Applied Ecology 36: 388 – 397.

Naithani S. 2000. **Habitat characterization in Great Himalayan National Park (GHNP), Himachal Pradesh using remote sensing and geographical information system (GIS) technologies with emphasis on geobotanical apsctes.** Ph.D. thesis, H.N.B. Garhwal University, Srinagar, India.

Nangia S., Kumar P. and Rathore B.M.S. 1999. **Social context and socio-economic conditions of people using GHNP and WLS.** Final Report, Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Narang M.L. 1993. **Searches for western tragopan in Himachal Pradesh, India, in 1987-89.** Pp 55 – 57, In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Nawaz R. 1999.**Pheasant surveys in Pakistan and filming the western tragopan.** Annual Review of the World Pheasant Association 1998-1999. Pp 38 – 41.

Nawaz R., Garson P.J. and Malik M. 2000. **Monitoring pheasant populations in montane forests: some lessons learnt from the Pakistan Galliformes Project.** Pp 196 – 203, In: Woodburn et al. (*eds*) 2000. Galliformes 2000: Proceedings of the 2nd International Galliformes Symposium, Kathmandu and Royal Chitwan National Park, Nepal, 24th September to 1st October 2000.

Negi A.S. 1996. **Assessment of issues related to soil erosion, landslides and to provide technical support to park management.** Final Report, Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun. Pp 101.

Negi G.S. 1980. **Visual interpretation of Landsat imagery of Alaknanda catchment.** Indian Journal of Forestry 3(1): 43 – 46.

Newton I. 1980. **The role of food in limiting bird numbers.** Ardea 69: 11 – 30.

Newton I. 1998. **Population limitation in birds.** Academy Press, San Diego, USA. Pp 597.

O'Connor R. J. and Shrubb M. 1986. **Farming and birds.** Cambridge University Press, Cambridge, U. K.

Odum E. P. 1975. **Ecology.** Oxford & IBH Publishing Co. New Delhi. Pp 244.

Odom R.H., Ford W.M., Edwards J.W., Stihler C.W. and Menzel J.M. 2001. **Developing a habitat model for the endangered Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) in the Allegheny Mountains of West Virginia.** Biological Conservation 99: 245 – 252.

Oelke H. 1981. **Limitations of estimating bird populations because of vegetation structure and composition.** Pp 316 – 321, In: Ralph C.J. and Scott J.M (*eds*). Estimating numbers of terrestrial birds. Studies in Avian Biology No.6. Cooper Ornithological Society, Las Cruces.

O'Mehra T.E. 1981. **A field test of two density estimates for transect data.** Pp 193-196, In: Ralph C.J. and Scott J.M (*eds*). Estimating numbers of terrestrial birds. Studies in Avian Biology No.6. Cooper Ornithological Society, Las Cruces.

Orians G. 1971. **Ecological aspects of behaviour.** Pp 586, In: Farner, D. S. and Kingh J. R. (*eds*) 1971. Avian biology Vol.1. Academic press. New York, London.

Osborne P. E., Alonso J. C. and Bryant R. G. 2001. **Modelling landscape-scale habitat use using GIS and remote sensing: as case study of great bustards.** Journal of Applied Ecology 38: 458 – 471.

Pandey S. 1993. **Pheasant surveys and conservation of protected areas in the upper Beas valley, Himachal Pradesh, India.** Pp 58 – 61, In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Pandey S. 1994. **A preliminary estimate of number of western tragopan in Daranghati Sanctuary, Himachal Pradesh.** Ann. Rev. WPA 1993/1994: 49-56.

Pant D.N. and Kharkwal S.C. 1995. **Monitoring land use changes and its impact on environment of central Himalaya using satellite remote sensing.** Journal of Hill Research, Sikkim Science Soceity 8(1): 1 – 8.

Pant D.N. and Roy P.S. 1992. **Mapping tropical dry deciduous forest and landuse in the part of Vindhyan range using satellite remote sensing.** Journal of Indian Society of Remote Sensing 20(1): 9 - 20.

Pearce J.L., Cherry K., Drielsma M., Ferrier S. and Whish G. 2001. **Incorporating expert opinion and fine-scale vegetation mapping into statistical models of faunal distribution.** Journal of Applied Ecology 38: 412 – 424.

Peters J.L. 1934. **Checklist of birds of the World.** Volume 2. Harvard University Press, Cambridge, M.A.

Pettingill O.S. Jr. 1970. **Ornithology in laboratory and field.** IV edition. Burgess Publishing Company, Minneapolis, Minn. Pp 413-425.

Phillips J. G., Butler P.J. and Sharp P.J. 1985. **Physiological strategies in avian biology – tertiary level biology.** Blackie and Son Limited, New York.

Pokorny F. and Pikula J. 1987. **Artificial breeding, rearing and release of Reeve pheasant (*Syrmaticus reevesi* Gray 1929) in Czechoslovakia.** Journal of the World Pheasant Association 12: 75-80.

Porwal M.C. and Pant D.N. 1989. **Forest cover type and landuse mapping using Landsat Thematic mapper False Colour Composite; a case study for Chakrata in Western Himalaya.** Journal of India Society of Remote Sensing 17(1): 33 – 40.

Porwal M.C. and Roy P.S. 1991. **Wildlife habitat analysis in Kanha National Park using remote sensing technique.** Paper presented in the National Symposium on remote sensing of environment, ISRS, Madras, India.

Porwal M.C., Roy P.S. and Chellamuthu V. 1996. **Wildlife habitat analysis for Sambar (*Cervus unicolor*) in Kanha National Park using Remote Sensing.** International Journal of Remote Sensing 17(4): 2683-2697.

Prasad S. N. 1993. **A survey of the potential western tragopan habitat in the Tons Catchment of Uttar Pradesh, from an Aerospace: Remote Sensing perspective.** Final Report submitted to Salim Ali Centre for Ornithology and Natural History (SACON), Coimbatore, India.

Ralph C.J. and Scott J.M. (*eds*) 1981. **Estimating numbers of terrestrial birds.** Studies in Avian Biology 6. Cooper Ornithological Society, Las Cruces.

Ramesh K. 1995. **Western tragopan, *Tragopan melanocephalus* roosting on deodar tree, *Cedrus deodara*.** WPA-India News 2(3): 6-7.

Ramesh K. and Sathyakumar S. 1997. **Conservation status, distribution and relative abundance of mammals with special reference to ungulates in Great Himalayan National Park, Western Himalaya.** Interim Report: Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Ramesh K., Sathyakumar S. and Rawat G.S. 1998 (*In press)*. **Recent trends in the pheasant populations of Great Himalayan National Park, India: Conservation implications.** Proceedings of the National Symposium on Wildlife research, conservation and management, Wildlife Institute of India, Dehradun.

Ramesh K., Sathyakumar S. and Rawat G.S. 1999. **Ecology and conservation status of pheasants of the Great Himalayan National Park, Western Himalaya.** Final Report. Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Rangen S. A, Hobson K.A. and Clark R.G. 2000. **A comparison of density and reproductive indices of song birds in young and old boreal forest.** Wildlife Society Bulletin 20 (1): 110 – 118.

Redmond R.L., Bicak T.K. and Jenni D.A. 1981. **An evaluation of breeding season census techniques for long-billed curlews (*Numenius americanus*).** Pp 197-201, In: Ralph C.J. and Scott J.M. (*eds*). Estimating numbers of terrestrial birds. Studies in Avian Biology No.6. Cooper Ornithological Society, Las Cruces.

Ritchie M.E. and Olff H. 1999. **Spatial scaling laws yield a synthetic theory of biodiversity.** Nature Vol. 500: 557 – 560.

Roberts T.J. 1970. **A note on the pheasants of west Pakistan.** Pakistan Journal of Forestry 20: 319 – 326.

Rodgers W. A. and Pawar H.S. 1988. **Planning wildlife protected area network in India, Volume 1 & 2.** A report prepared for the Department of Environment, Forest and Wildlife, Govt. of India. Wildife Institute of India, Dehradun.

Roy P.S., Ravan S.A., Rajadhya N., Dass K.K., Abhineet J. and Singh S. 1995. **Habitat suitability analysis of *Nemorhaedus goral* – Remote Sensing and Geographical Information System approach.** Current Science 69(8): 685-691.

Sathyakumar S. 1994. **Habitat ecology of major ungulates in Kedarnath Wildlife Sanctuary, Western Himalaya.** Ph.D. thesis, Saurashtra University, Rajkot, India. Pp 244.

Sathyakumar S., Prasad S.N., Rawat G.S. and Johnsingh A.J.T. 1993. **Ecology of Kalij and Monal Pheasant in Kedarnath Wildlife Sanctuary, Western Himalaya.** Pp 83 – 90, In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Seber G.A.F. 1982. **The estimation of animal abundance and related parameters.** Charles Griffin & Company Ltd, London. Pp 654.

Sen N. 2000. **Mapping the biognomy of India – the plants.** Current Science 79(8): 1046 – 1048.

Severinghaus S.R. 1979. **Observations on the ecology and behavior of the Koklass pheasant in Pakistan.** Journal of the World pheasant Association 4: 52-71.

Shabab D. 1996. **Kullu: Himalayan abode of the Divine.** Indus press, New Delhi.

Shah I.H. 1993. **Status, distribution and habitat of koklass in Galis Tract and Kagham Valley, Hazra Division NWFP, Pakistan in 1975-1991.** Pp 155, In: Abstract Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K

Sharma V. and Pandey S. 1989. **Pheasant surveys in Shimla Hills of Himachal Pradesh, India.** Journal of the World Pheasant Association 14: 64-78.

Sharma V. 1993. **Ecological status of pheasants in Himachal Pradesh.** Pp 158, In: Abstract Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Shrestha T.K. 1993. **Impact of habitat fragmentation and deforestation on rare pheasants of Nepal.** Pp 157, In: Abstract Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Sibley C.G. and Ahlquist J.E. 1990. **Phylogeny and classification of birds: a study in molecular evolution.** Yale University Press, New Haven, CT.

Sibley C.G. and Monroe B.L. Jr. 1990. **Distribution and taxonomy of birds of the world.** Yale University Press, New Haven, London.

Singh S. 1999. **Assessment of floral and habitat diversity, and collection of baseline data to monitor vegetation of Great Himalayan National Park Conservation Area.** Final Report of Forestry Research Education and Extension Project – Great Himalayan National Park, Wildlife Institute of India, Dehradun.

Singh S. K. 1997. ***Gucchii*: the edible mushroom of the Himalayan wilds.** Himalayan Paryavaran 5: 75-77.

Singh S.K. 1999. **A study on the plant community composition and species diversity in Great Himalayan National Park, Western Himalaya.** Unpublished Ph.D. thesis, Kumaun University, Nainital, India.

Singh S. K. and Rawat G. S. 1999. **Floral diversity and vegetation structure in Great Himalayan National Park, Western Himalaya.** Final Report: Forestry Research Education and Extension Project – Great Himalayan National Park, Wildlife Institute of India, Dehradun.

Smith K.G. and Connors P.G. 1984. **Building predictive models of species occurrence from total-count transect data and habitat measurements.** Pp 45 – 50, In: Verner J., Morrison M.L. and Ralph C.J, (*eds*) 1984. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. The University of Wisconsin Press.

*Starfield A.M. and Bleloch L. 1986. **Building models for conservation and wildlife management** (2nd edn). Burgess International, Edina, Minnesota.

Sutherland W.J. (*ed*) 1996. **Ecological census techniques: A handbook.** Cambridge University Press. Pp 336.

Terborgh J. 1989. **Where have all the birds gone?** Princeton University Press, New Jersey.

Trexler J.C. and Travis J. 1993. **Nontraditional regression analysis.** Ecology 74(6): 1629 – 1637.

Uniyal S.K. 2001. **A study on the structure and composition of forests along an altitudinal gradient in upper Bhagirathi catchment, Garhwal Himalaya.** Ph.D. thesis, submitted to Deemed University, Forest Research Institute, Dehradun, India.

Uniyal V.P. and Mathur P.K. 1999. **A study on the species diversity among selected insect groups.** Final Report. Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Upreti D.K. 1999. **Lichen flora of Great Himalayan National Park.** Final Report: Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

*Verheyen, R. 1956. **Contribution de l'anatomie et a la systematique des Galliformes.** Bull. Inst. R. Sci. Nat. Belg. 32 (42): 1-24.

Verner J. 1985. **Assessment of counting techniques.** Pp 247 – 302, In: Johnson R.F. (*ed*) 1985. Current Ornithology Vol. 2: 247 – 302.

Verner J. and Milne K.A. 1990. **Analyst and observer variability in density estimates from spot mapping.** The Condor 92: 313 – 325.

Verner J. and Ritter L.V. 1988. **A comparison of transects and spot mapping in oak-pine woodlands of California.** The Condor 90: 401 – 419.

Vinod T.R. 1999. **Ecology and conservation of ungulates in Great Himalayan National Park, Western Himalaya.** Ph.D. thesis, Saurashtra University, Rajkot. Pp 260.

Vinod T.R. and Sathyakumar S. 1999. **Ecology and conservation of mountain ungulates in Great Himalayan National Park, Western Himalaya.** Final Report. Forestry Research Education and Extension Project - Great Himalayan National Park. Wildlife Institute of India, Dehradun.

Vitousek P. M., Mooney H. A., Lubchenco J. and Melillo J. M. 1997. **Human domination of earth's ecosystems.** Science 277: 494 – 499.

Walker P.A. 1990. **Modelling wildlife distributions using a geographical information system: kangaroos in relation to climate.** Journal of Biogeography 17: 279 – 289.

Wellendorf S.D., Palmer W.E. and Bromley P.T. 2000. **Effect of call stimulation on rates of covey calling by northern bobwhite quail in North Carolina, USA.** Pp 191 – 195, In: Woodburn et al. (*eds*) 2000. Galliformes 2000: Proceedings of the 2nd International Galliformes Symposium, Kathmandu and Royal Chitwan National Park, Nepal, 24th September to 1st October 2000.

Wennergren U., Ruckleshaus M. and Kareiva P. 1995. **The promise and limitations of spatial models in conservation biology.** Oikos 74: 349 - 356.

Wetmore A. 1960. **A classification of the birds of the world.** Smithson. Misc. Collect. 139 (11): 1-37.

Whale R. 1996. **Winter survey of Western tragopan in Pallas Valley, Pakistan.** WPA News No. 51. World Pheasant Association, England. Pp 2-6.

Wiens J.A. and Rotenberry J.T. 1981. **Censusing and the evaluation of avian habitat occupancy.** Pp 522-532, In: Ralph C.J. and Scott J.M. (*eds*) 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology No.6. Cooper Ornithological Society, Las Cruces.

Williams P., Humphries C., Vanewright D. and Gaston K. 1997. **Descriptive and predictive approaches to biodiversity measurement.** Trends in Ecology and Evolution 12: 444 – 445.

Williamson K. and Homes R.C. 1964. **Methods and preliminary results of the Common Birds Census, 1962-63.** Bird Study 11: 240-256.

Woodburn M 1993. **Monitoring pheasant populations.** Pp 122 – 127, In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Woodward F. I. 1987. **Climate and plant distribution.** Cambridge University Press, Cambridge, U.K.

Worah S., Bharucha E.K. and Rodgers W.A. 1989. **The use of Geographic Information Systems in identifying potential wildlife habitat.** Journal of Bombay Natural History Society 86(2): 125 – 128.

Yahya H.S.A. 1993a. **Habitat preference in monal pheasants.** Pp 146-147, In: Jenkins, D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Yahya H.S.A. 1993b. **Adaptive significance of vocalization in the koklass pheasant.** Pp 155, Abstract In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Yatim S.H. 1993. **The status and distribution of Pheasants in Peninsular Malaysia.** Pp 28 – 39, In: Jenkins D. (*ed*) 1993. Pheasants in Asia 1992. World Pheasant Association, Reading, U.K.

Yin T. 1970. **Record of the Himalayan monal (*Lophophorus impejanus*) in Burma. Journal of Bombay Natural History Society.** Volume 67 (2): 328.

Yonzon P.B. 1982. **Nepal-Himalaya pheasant surveys at Pipar, Machhpuchare.** Pp 55 – 57, In: Savage C.D.W. and Ridley M.W. (*eds*) 1982. Pheasants in Asia 1982, World Pheasant Association, Reading, U.K.

Young L., Garson P.J. and Kaul R. 1987. **Calling behaviour and social organization in the cheer pheasant: implication for survey technique.** Journal of the World Pheasant Association 12: 30 – 43.

Young L., Zheng G.M. and Zhang Z.W. 1991. **Winter movement and habitat use by cabot,s tragopans *Tragopan caboti* in Southeastern China.** Ibis 133: 121 – 126.

Zheng-Wang Z. 1995. **Brown-eared pheasant project report.** WPA News 49: 14 – 16.

* - *Not seen in original*