IMPACT OF HABITAT DISTURBANCES ON BIRD AND BUTTERFLY COMMUNITIES ALONG THE YUKSAM-DZONGRI TRAIL IN KHANCHENDZONGA BIOSPHERE RESERVE

A thesis submitted to the
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By

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Dedicated to my beloved parents

CERTIFICATE

This is to certify that the thesis entitled "***Impact of habitat disturbances on bird and butterfly communities along the Yuksam-Dzongri trail in Khanchendzonga Biosphere Reserve***" is a bonafied piece of original research work carried out by Mr. Nakul Chettri during the period 1996 to 1999 under our supervision.

Mr. Chettri has fulfilled all the criteria for submitting his thesis. In habits and character he is a fit and proper person for the Ph.D. degree of the University of North Bengal. We forward and recommend the thesis for submission to the University of North Bengal.

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Contents

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Acronyms

A_1	Canopy trees
A_2	Sub-canopy trees
AB	Abundance
AC	Accidental sightings
A/F	Abundance/frequency ratio
ANOVA	Analysis of variance
BA	Basal area
BSD	Bird species richness
BSR	Bird species diversity
BTSD	Butterfly species diversity
BTSR	Butterfly species richness
CA	Carnivores
CC	Closed canopy
DBH	Diameter at breast height
DN	Density
FoVI	Fodder value index
FR	Frugivores
FVI	Fuelwood value index
GF	General feeders
GR	Granivores
GS	Gentle slope
H'	Shannon weiner's index
HMI	Himalayan Mountaineering Institute
IN	Insectivores
IVI	Important value index
KBR	Khanchendzonga Biosphere Reserve
KNP	Khanchendzonga National Park
LF	Lower forest
MS	Medium slope
NE	Nectarivores
OC	Open canopy
OM	Omnivores
PC	Principle component
PCA	Principal component analysis
RS	Resident species
SS	Steep slope
SV	Summer visitor
TSD	Tree species diversity
TSR	Tree species richness
UF	Upper forest
WV	Winter visitor

List of tables and appendices

List of figures and photoplates

Summary

Sikkim is widely acknowledged as India's most significant biodiversity Hot Spot. During the past few decades, there has been a visible symptom of landscape degradation and depletion of forest quality at some locations in Sikkim. Tourism impact, unregulated resources extraction, hunting and poaching, profitable and non-profitable forest products collection became the primary threats to biodiversity in the state. Yuksam-Dzongri trekking trail is an attractive destination for both tourists and naturalists. The natural resources of the area faced tremendous pressure resulting from the rise in population, tourist number and the number of trainees of Himalayan Mountaineering Institute. Studies on such disturbances and their consequent responses by both plant and animals are ever-ignored issues in this area. Even the checklists for flora and fauna were not available and records not maintained properly.

A multi-disciplinary group of experts and research team was involved in monitoring and applied research during Sikkim Biodiversity and Ecotourism Project tenure. Various research thrusts in the project were (i) dynamics of tourism growth and assessment of landscape change, (ii) socio-economic development, tourism growth and environmental degradation, (iii) holistic study of sacred Khecheopalri lake ecosystem, (iv) impact of grazing on plant diversity and productivity in an

alpine pasture, and (v) impact of habitat disturbances on bird and butterfly communities along the trail.

The present study was undertaken to address the fifth issue i.e. impact of habitat disturbances on bird and butterfly communities along the trail. An extensive research work was carried out during the period 1996 to 1999 with two broad hypotheses as (i) intensive firewood and fodder extraction will modify tree species composition, age structure and woody biomass productivity of warm-temperate (lower forest) and cool temperate-subalpine (upper forest) forests and (ii) such changes effect bird and butterfly communities at different forest conditions in terms of species composition, abundance and richness. An attempt was made to examine (a) forest cover types and user groups, (b) species preference for fuelwood, fodder and timber, their quality and consumption, (c) tree species diversity, population structure and regeneration, (d) woody biomass, productivity and extraction in closed (stands with less human disturbances and >40% canopy cover) and open (stands with more human disturbances and <40% canopy cover) canopy. The impact was determined in birds and butterfly by evaluating (e) diversity, species composition, seasonal variation and (f) relationships with the habitats various statistical tests.

Yuksam-Dzongri trekking corridor (26 km long) encompasses elevation from 1780 m to 4000 m. The area extends from 27°19′13″ to 27°29′4″ north latitude and 88°9′18″ to 88°15′ east longitude. The trail passes through Sachen, Bakhim and

Tshoka in the southwestern part of Khangchendzonga Biosphere Reserve in Sikkim, India. Temperate conditions prevailed at Yuksam, sub-alpine at Tshoka and alpine at Dzongri. Summer temperatures at these places were mild ranging from 20°C to 24°C at Yuksam, 15°C to 16°C at Tshoka and 11°C to 13°C at Dzongri. Yuksam is a trailhead for this corridor and leads to the Base Camp, Dzongri, Thangsing and Gocha La in West Sikkim. Yuksam has 11 settlements with 274 households comprising of 1573 people. One settlement with nine households is inside the reserve at Tshoka (3000 m) on the trail. Majority of the ethnic people of Yuksam are Subbas, followed by Bhutias, Lepchas, Nepalis and Tibetan Refugees mainly at Tshoka.

Salient findings of the research

1. Land use cover at the warm temperate broadleaf forest covered an area of 1666 ha and cool temperate-sub-alpine forest 1265 ha. The trekking corridor comprised of 986 ha closed canopy forest and 2009 ha open canopy forest.

2. Records on incidental animal sighting by villagers revealed 19 species including three endangered species viz., snow leopard, musk deer and red panda. Commonly sighted animals are Himalayan barking deer, Himalayan black bear, ghoral, clouded leopard and leopard cat.

3. In Yuksam, out of 11 settlements five use the Yuksam-Dzongri corridor forest for firewood, fodder and grazing.

Remaining six settlements are more dependent on other surrounding forests. Tshoka, a settlement inside the biosphere reserve area was totally dependent on trail forest. Apart from these settlements, Himalayan Mountaineering Institute (HMI), travel agencies and their support staff and trans-humans (yak and sheep herders) also depend on corridor forest either for firewood or for fodder.

4. The total demand of fodder was found 1209 Mg yr^{-1} for the entire livestock present in the study area. During 1996-98, a net increase of 63% fodder demand was estimated. Fodder demand for cattle was the highest (41%) followed by sheep (21%) and goat (14%). The demand for dzo, yak, pig and horses were, 13%, 8%, 1% and 2% respectively.

5. Collections of firewood from forests were mainly made during the winter season. Frequency of collection was recorded highest during the month of January and minimum in September. The data from the field revealed that frequency of chopping trees for firewood was the highest for medium sized trees followed by small and large trees.

6. The total demand for the firewood for community as well as other tourism purposes was estimated to be 2433 Mg $year^{-1}$. About 55% of the total demand was met from the trail forests both for community and tourism purposes.

Domestic cooking is the major consumer of fuelwood followed by water heating and other purposes. Consumption ranged from 2264 Mg year^{-1} by community and lowest of 1.02 Mg year^{-1} by pack animal operators. Amount of the firewood consumption among the family was the highest in winter (29±10.1 kg^{-1}day^{-1}family^{-1}) and lowest in summer (18±6.9 kg^{-1}day^{-1}family^{-1}). The mean daily consumption of the wood was found 25.5 kg^{-1}day^{-1}family^{-1} for an average household size of 6.28 individuals with per capita of 3.45 kg at lower elevation and 4.17 kg at higher elevation. Hotels and lodges consumed about 40-50 kg of firewood daily and Himalayan Mountaineering Institute (HMI) course groups used about 240-520 kg per day per group depending on the size of groups.

7. Out of total 273 households, 80% of the households used firewood followed by 14% kerosene, 3% LPG and 4% electricity at Yuksam and 100% firewood at Tshoka. Large number of trees with <10 cm DBH were used as timber for house construction and renovation just in a time interval of 3-5 years. Use of medium sized trees (20-40 cm DBH) and large trees (40-70 cm DBH) were comparatively low and in greater time intervals of 5-7 years and 15-25 years, respectively. Number of lopped branches and chopped trees were high in the open forest condition and low in the closed canopy forest. Other indicators of disturbance like depth of humus, depth of dry leaf litter and depth of clayey

soil were higher in the closed canopy forest showing less interference. Trampling impression and dung numbers were higher in open forest condition where animals were usually stalled overnight.

8. With reference to community preference of firewood species, *Rhododendron* spp. and *Quercus* spp. matched with high wood quality suggesting that their preference of firewood species was compatible with energy/chemical properties of woody species.

9. Firewood collections were mainly made during the winter (November to March) season. Tourism enterprises (travel agencies and the support staff) related collection of the firewood occurred mainly in two-peak tourist seasons during March to May and August to December. Frequency of chopped trees showed a low pressure on 10-20 cm diameter at breast height (DBH) class, medium pressure on 50-60 cm and high pressure on 20-50 cm class trees at the lower forest.

10. Out of 56 tree species recorded from the sampled plots of the lower forest, 52% species were widely used as firewood, 37% fodder and 32% timber. In the upper forest, out of 32 species encountered 53% were used as firewood, 31% fodder and 31% timber.

11. In the lower forest, tree species diversity was found greater in the open canopy forest (H′=5.5) than in the closed

canopy forest (H′=2.04), whereas at the upper forest, it was higher in the closed canopy forest (H′=2.8) compared to that of open canopy forest (H′=2.5).

12. Out of 56 woody tree species, only twenty species were found regenerating at the lower forest accounting 43% of the total at the closed and only 47% at the open canopy forests. At the upper forest out of 32 species, 19 species were found regenerating and accounted 56% of the total species at the closed canopy and 58% at the open canopy forest.

13. The open canopy condition of the lower forest showed markedly reduced IVI values and basal area of the species of high firewood preference compared to the closed canopy forest. At the upper forest also, the IVI and basal area values of used species were similar.

14. Densities of trees reduced from 435 trees ha^{-1} in the closed canopy condition to 206 trees ha^{-1} in the open canopy at the lower forest. Likewise, at upper forest, it reduced from 319 trees ha^{-1} in the closed canopy forest to 222 trees ha^{-1} in the open canopy forest.

15. The basal area of the trees reduced from 59 m^2ha^{-1} in the closed canopy forest to 23 m^2ha^{-1} in the open canopy forest at the lower forest and from 50 m^2ha^{-1} in the closed canopy forest to 40 m^2ha^{-1} in the open canopy forest at the upper forest.

16. The standing woody biomass were 704 Mg ha^{-1} and 399 Mg ha^{-1} in the closed canopy and open canopy forest respectively at the lower forest, and 382 Mg ha^{-1} and 306 Mg ha^{-1} in the closed and open canopy forests at the upper forest. Standing woody biomass of *Quercus lamellosa* shared 37-40% and net primary productivity (NPP) of the stands 18-28% in both the closed canopy and open canopy conditions of the lower forest.

17. Annual extraction of nearly 50% of the net primary productivity (NPP) was recorded from both the closed canopy and open canopy conditions at the lower forest whereas at upper forest, about 46% of NPP removal was recorded from the open canopy forest and 21% from the closed canopy forest. Extraction of *Q. lamellosa* was the highest in the close canopy and open canopy forests followed by *B. sikkimensis, A. laevigatum* and *Quercus* sp.

18. Sikkim Biodiversity and Ecotourism Project conducted various capacity-building training and conservation awareness programs and promoted eco-friendly tourism in the study area during 1996-1999. Development and compliance of code of conduct for conservation by travel agencies and by visitors as well as by the community was an initial step towards reduction of firewood collection from the corridor. Provision of kerosene and liquified petroleum gas (LPG) from policy level decision made

convincing impacts by the reduction of fuelwood use both by travel agents and communities.

19. An increase of LPG use from 1% to 3% among the community and from 8% to 14% among the tourism related stakeholders was recorded during the period from 1996 to 1998. Similarly, stove and kerosene use increased from 5% to 14% among the communities and from 14% to 18% among the tourism-related stakeholders. There was a substantial reduction of firewood use from 93% in 1996 to 80% in 1998 among the communities and from 73% in 1996 to 49% in 1998 among the tourism enterprises.

20. Over the two year period, 7149 bird (individuals) representing 143 species were detected. Of these 143 recorded species, 40% (57) were common among the four stands. About 22% species differed significantly between the two-forest types (lower and upper forest) and only about 15% species significantly differed between the habitat conditions (closed canopy and open canopy forest). Out of 143 species, 10% were restricted to the closed canopy condition in contrast to 16% in open canopy conditions of the lower forest. In the upper forest, only 3% of the total species were observed as exclusively present in the closed canopy and 6% at the open canopy forests.

21. Bird species richness (BSR) and diversity (BSD), and tree species richness (TSR) and diversity (TSD) showed strong

negative and linear trend with increasing elevation. The relationships for bird species and its diversity had stronger trend with increasing elevation than tree species and its diversity.

22. Both the BSR and BSD showed positive and linear relationship with the TSR and TSD. But the relationships were not consistent at different habitat conditions, seasons and forest areas. Both the canopy conditions and the forests showed strong seasonal variation in bird species diversity.

23. Five principal components (PCs) from Principal Component Analysis (PCA) were extracted to represent vegetation parameters which together accounted 83.1% of the total variance. The PC1 represented habitat with closed canopy, higher woody biomass and high basal area. The PC2 represented habitat with higher number of lopped branches and chopped trees with lower litter and humus depths, and higher trampling suggesting high disturbances. The PC3 represented diverse stand with higher herb as well as shrub richness and complex vertical stratification.

24. BSR and BSD were significantly and positively correlated with PC3, which represented the tiered heterogeneity with diverse habitat. Bird density showed significant positive relationships with PC2 and PC3, which suggested that the

disturbed areas and habitat with vertical heterogeneity have higher bird density.

25. Species composition (number of species/guild) showed significant difference between the two forest types, seasons and guilds. This suggests that there was a variation in species composition at the two forests types, seasons and among the feeding guilds.

26. Among the migratory groups, incidental species significantly differed between the habitat conditions and seasons. Resident species composition was significantly influenced by season. There was a significant variation in summer visitors between the seasons as well as at different habitat conditions. Summer visitors showed weak but significant difference between the two forests, habitat conditions and seasons. Among the feeding guilds, insectivores significantly differed between the two forests as well as between seasons. Apart from insectivores, forest types, plots and seasons also significantly influenced the omnivores. Among the migratory groups, only winter visitors were found to have significant relation with PC2. Insectivores were positively related with PC1, omnivores with PC2 and PC3. Nectarivores were positively related with PC2 and carnivores were positively correlated with PC3.

27. A total number of 49 butterfly species were observed and recorded within an altitudinal range of 1700 to 3700 m amsl. The most common species were moore's bushbrown, plain tiger, common tiger and common crow. Lesser-sighted species were common bluebottle, yellow sailor, hill gegebel and spectacle swardtail.

28. Butterfly species diversity, its richness and the evenness were all significantly differed between the forest types (Mann Whitney test U=2489.5, P<0.000, U=2070.5, P<0.009, U=2175.5, P<0.001) respectively. On the other hand, the difference in butterfly species between the open and closed canopy conditions was significant (U=1799.5, P<0.21).

29. Mean number of species of butterflies differed significantly between the forest types and habitat condition (ANOVA: $F_{1,106}$= 7.4, P<0.007 and $F_{1,106}$= 5.9, P<0.01) respectively. Significant interaction between the forest types and seasons ($F_{1,106}$= 9.2, P<0.003) indicates that the forest types and seasons influenced the variation in number of species among the forests with the change of the season.

30. Both butterfly species diversity (Y=9.58-1.2lnx, R^2=0.59, P<0.001) and its richness (Y=9.08-1.1lnx, R^2=0.30, P<0.01) were significantly and negatively correlated with the rise in elevation.

31. The regression drawn on the diversity indices showed significant relationship between the tree species diversity

and butterfly species diversity ($Y=-0.42+0.46x$, $R^2=0.53$, $P<0.001$) but the relationship among the species richness of these two groups were not significant ($Y=0.64+0.12x$, $R^2=0.12$, $P<0.15$).

32. Pearson product moment correlation on 3PCs extracted from the vegetation data showed significant correlation of butterfly diversity only with PC3. The correlation with the other components was insignificant.

33. The overall trend in diversity indices in butterflies, birds and the trees were remarkably similar across the elevation and habitat types. All the three groups (trees, birds and butterflies) were generally higher at the open canopy forest and showed a strong correlation among the groups.

Conclusion

Forest based resources are the integral part of livelihood for the people of Yuksam and Tshoka. Population growth and rapid increase in tourism sector have caused threat to the forest resources and biodiversity of the area. Substantial closed canopy areas have been opened as a result of firewood, fodder and timber extraction. Tourism related pressure on the forest has been more distinctly visible at Tshoka, the first camping site on the trail. Removal of selective canopy species for firewood and timber has changed the forest structure. Regeneration of canopy species has been relatively lowered at the open canopy conditions where the human pressures are maximum.

Bird diversity reflect tree diversity and feeding guilds appeared as predictor for habitat quality. Maintenance of habitat heterogeneity is important for conservation of biological diversity in the area. Therefore, maintenance of vegetation rich habitats with structural complexity is recommended for conservation of bird. Analysis on community structure of butterfly and their association/relationship with the habitat revealed that they are more sensitive to the human disturbances. There is strong correlation among the tree, bird and butterfly diversity indices. This finding has asserted indicator properties of birds and butterflies in biodiversity assessment.

If managers wish to regulate pattern of harvest on natural resources based on disturbance regime, then strategies to compensate for these initial differences must be developed first for conservation. Management of this trekking corridor forests should be oriented in such a way that only the canopy species regeneration is encouraged. Compliance to the code of conduct for conservation by tourists, enterprises and communities especially on the use of alternative to firewood would enhance the forest condition making the destination more attractive and valuable in terms of biodiversity.

CHAPTER I

Chapter I

Introduction

An age-old pursuit of many biologists has been on relating the distribution and abundance of organisms in their natural environment. Knowledge of external environmental factors, their influence on the organisms and interactions help in explaining the distribution patterns of life forms in natural ecosystems. In the field of biodiversity conservation anthropogenic factors are considered important driving forces that lead to biodiversity loss; yet till date there are only a few empirical assessments on how human actions affect biodiversity qualitatively and quantitatively. The proximate causes of biodiversity loss are attributed to be of biological origin while the ultimate causes are social, economical and political (Machlis & Forester 1996). Qualitative statistical analysis of the interrelationships of plants, animals and their environment has been an area of active pursuit in biodiversity assessment studies undertaken in the recent years. Moreover, as the biodiversity is reeling under tremendous pressure in most of the regions of the world; determination of key relationships between plant and animal populations in an ecosystem have become an area of extensive research in the field of conservation biology. It is assumed that, if the factors determining the distribution of animals are known, then specific predictions can be made concerning the response of animals to some disturbances. Thus, certain animals can respond and indicate the nature and quantum of environmental changes either individually or as a community.

1.1 Background

The precise meaning of community in ecology is one of the most debated concepts (Wiens 1989, Peter 1991). Several theoretical and practical difficulties plague community ecology. Properties of multispecies system, which exist in a constant state of flux, both in time and space, are difficult to investigate and decipher. Even, if it can be done, easily measurable attributes such as relative abundance estimate from samples are of questionable significance (Wiens 1989). Further, trying to make sense by correlation analysis of various communities, resource and habitat parameters provide no sure guide to underlying causes for observed community pattern (Gilbert 1984). Despite these obvious problems, community ecology has grown and flourished with tremendous applications, particularly with respect to conservation.

Habitat destruction is considered the most widespread anthropogenic cause of biodiversity loss (Brown 1985, Wilson 1988, Hannah *et al.*1995). It may differentially increase vulnerabilities as some species show poorer level of adaptation to habitat alteration

(Lovejoy 1986, Vermeij 1986). Therefore, extinction selectivity suggests that certain habitats and species are more at risk (Teborgh & Winter 1980, Slobodkin 1986). Particular attention has been paid to high biodiversity areas and accelerated rate of deforestation (Myers 1988). A decline in biodiversity has been associated with specific land-use changes, such as urbanisation (Leidly & Fiedler 1985), colonisation adjacent to protected areas (Neuman & Machlis 1989), and the fragmentation of forest as a result of resource extraction (Harris 1984, Hanson *et al.* 1990). The comparative studies are rare, and predictive ability is especially meagre. Hence there is a need to better understand relationship between human actions, habitat alterations and biodiversity loss (Machlis & Forester 1994).

1.2. Rationale for selecting the site

Sikkim is a small Indian state and belongs to one of two 'Biodiversity Hotspots' of India (Myers 1990). The Eastern Himalaya (Khanchendzonga area) supports a wide diversity of birds due to complex physiography and bioclimatic zonation (Ives & Messerli 1989) and its location at convergence of the Paleoartic and Oriental Zoogeographic Realms (Inskipp 1989). The area was identified by Birdlife International as a priority I endemic bird area since it supports 25 restricted range bird species, of which 21 are confined to the region (Bibbly 1992). In recent years, Carpenter

(1996) studied the altitudinal distribution of 251 bird species reporting 49% as frequent, 24% as long distant migrants and 27% as common in the Nepal part of Khanchendzonga region. Among the 8 species of birds, which were considered to be at risk in this area and listed as rare, vulnerable or endangered in the region, four species viz. satyra tragopan, Nepal cutia, short billed minivet and little pied flycatcher were recorded in present study from the temperate forest beyond the zone of agriculture activities (unpublished observation).

Yuksam and Yuksam-Dzongri trekking corridor is an important destination for nature tourists in Sikkim. Though, this trekking route is extremely important part of the tourism zone and needs to remain a pristine state to continue to attract the tourists; it faces impact of tourism pressure. Over the years this impact has made certain visible changes in the landscape and the ecology. Inspite of being tourism zone of Khanchendzonga Biosphere Reserve, Yuksam-Dzongri trekking corridor faces tremendous pressure on its natural resources, which brought out some visible changes during the last decade. Resources utilization in terms of firewood, fodder, timber, non-timber forest products (NTFPs) and open grazing are age-old practices for the people living here. The rise in tourist number, increase in resource use by the local population and use of the area for adventure and climbing courses by the Himalayan Mountaineering Institute, the pressure on natural resources has increased manifold. Study on the intensity of habitat disturbances and consequent impact on flora and fauna are the issues that have not attracted the desired level of attention from the concerned conservation organisations. The information gap is so wide that even checklist of flora and fauna are not available; and records are not maintained properly. Information to the tourists about the biodiversity of the trekking route and the area is completely lacking. Broadly speaking, the present work is an attempt to focus on such issues and also on the consequences of resource extraction on forest quality and wildlife inhabiting the forests. In addition to this, an attempt has been made to compile comprehensive checklists of avifauna and butterflies and woody tree species along the corridor.

1.3. Sikkim Biodiversity and Ecotourism Project

The Sikkim Biodiversity and Ecotourism Project was a collaborative initiative designed to initiate conservation activities for protection of the biological diversity of tourism promotion zones. The core activities of the project encompassed participatory approaches that link tourism related diverse enterprises and traditional cultural practices with conservation action. Working with communities, the private sector and government, the project built upon their skills, interests and knowledge, to enhance: (i) community and private sector conservation practices and ethics; (ii) economic returns from ecotourism services and enterprises; and (iii) contribution to policies that meet ecotourism and conservation goals. The Project was a joint effort of The Mountain Institute and G.B. Pant Institute of Himalayan Environment and Development. Project collaborators include the Travel Agents Association of Sikkim (TAAS), The Green Circle (a Sikkimese NGO), Khanchendzonga Conservation Committee (a Yuksam based rural Sikkimese NGO) and local communities at the sites.

The activities of the project included the following three broad groups:

1. Increasing community and private sector biodiversity conservation initiatives.

- Community ecotourism plans covering site-enhancement, trail and site maintenance, natural resource management and monitoring, and conservation education.
- Supporting fuelwood reduction measures by trek operators and local lodges.
- Supporting local NGOs working in ecotourism and conservation.

2. *Increasing economic returns from community-based and Travel Agents' ecotourism.*

- Training in ecotourism services, e.g., for guides, lodge-owners, cooks, porters;
- Supporting new community ecotourism enterprises-vegetables growing, indigenous foods, fuelwood-saving equipment hire for treks, short guide treks;
- Developing marketing strategies for community-based ecotourism and Travel Agents' ecotourism activities; and
- Conducting market research and developing new ecotourism products, e.g., off-season activities, eco-lodge designs.

3. *Improving and contributing to policy-making on conservation and ecotourism.*

- Scientific and participatory monitoring of project activities and impacts;
- Applied research on conservation and ecotourism;
- Sharing of research and monitoring findings among policy-makers, communities and the private sector; and

- Promoting public-private sector dialogue through workshops, exchanges and policy review.

The multi-disciplinary group of experts and research team was involved in monitoring and applied research. Various thrust areas identified for research input in the project were (i) dynamics of tourism growth and assessment of landscape change; (ii) socio-economic development, tourism growth and environmental degradation; (iii) holistic study of sacred Khecheopalri lake ecosystem; (iv) impact of grazing on plant diversity and productivity in an alpine pasture; and (v) impact of habitat disturbances on bird and butterfly communities along the trail. The present work specifically deals only on the effect of habitat disturbances on bird and butterfly communities.

1.4. Rationale for choosing birds and butterflies

Butterfly, as a taxon for community investigation has been largely neglected *vis-à-vis* birds. Butterflies have played a little role in the development of general theories on community organisation. This is surprising, as they are unique by suited for such works, being observable and identifiable with much more suited for manipulative laboratory studies that could supplement/verify conclusions drawn for field investigations. Precisely, because of complex linkages with environment and their pivotal position in trophic level, bird and butterfly offer opportunity to explore many ecological questions with a single system. Typical host specific requirement of butterflies and well-designated guild structure of birds, provide best indication of habitat quality (Gilbert 1984, Javed 1996). Thus, they became the ideal organism to investigate the impact of habitat disturbances and many species may thus serve as bio-indicators (Wong 1985, Kremen 1992,1994, Debinski & Brussard 1994).

Historically, Clement (1920) detailed the root of the concept with potential use of animals as tool for forest quality assessment and became ingrained in the scientific literature. Plants have been the most widely used predictors of physical conditions and specific site factors but their application has been primarily confined to plant ecology. Many taxa of animals were used for this purpose in assessment of habitat quality. In the noted literatures, plant (Cronk 1988), butterflies (Brown 1991, Kremen, 1992,1994, Debinski & Brussard 1994), tiger beetle (Pearson & Cassola 1992, Rodriguez *et al.*1998), birds (ICBP 1992, Debinski & Brussard 1994, Kremen 1994) and mammals (Mittermeier 1988) were extensively used as indicator for assessment of biological diversity. Even Odum, noted in his *Fundamentals of Ecology* (1971 p 138) "...the ecologist constantly employs organisms as indicators in exploring new situations or evaluating large areas." Being ecologically diverse and sensitive to various kinds of perturbation, bird community acts as a better predictor of the quality and health of the habitat than single species (Javed 1996). Bird and butterfly communities are particularly suitable for studying the process of ecosystem recovery, conservation to vegetation succession and dynamics of their changes. These two taxa are emerging as a biodiversity assessment tool in conservation (Debinski and Brussard 1994, Kremen 1994). Moreover, recent literatures accept the indicator concept as doctrine (Block 1989).

Conservation prioritisation of areas often relies on comparison of the relative or absolute number of species (species richness - e.g. Myers 1990). However, this information is not often readily available. Even for small well-studied groups as birds and butterflies, data are often sparse, especially for region with high species richness. Therefore, demands for methods which enable the species richness of the area to be predicted, and several surrogates have been proposed to achieve this (Beccaloni & Gaston 1994). Most studies have attempted to use indicator to identify areas of overall high biodiversity, by seeking positive correlation between the species richness of the chosen groups and the richness of other groups. Of necessity, however, comparisons are usually made at coarse spatial scale, often across widely divergent habitats or ecosystem, and between groups of organisms, which do not necessarily share the same, or even similar, ecological requirements (Lawton *et al.* 1998).

Indicator species can be a valuable tool for conservation research. Their use has been divided in two categories: - a) inventory studies and b) monitoring studies (Kremen 1992, Rodriguez *et al.* 1998). The former deals with evaluation of changes in habitats or ecosystem over time and the latter records distribution patterns of taxa or ecological units over geographical space (Rodriguez *et al.*1998). The present study tried to cover both the aspects with more emphasis in the latter.

Criteria for selecting potential study groups

Debinski and Brussard (1994) suggested following criteria for the selection of the potential indicator groups:

(a) Groups of taxa are chosen to be appropriate for the study area. For example, mammals would have been inappropriate since the sighting frequency is very negligible. Thus bird and butterfly have been chosen, as it is much easier to establish clear-cut levels of commonness and rarity for the area.

(b) As vast field has been already developed in these taxa, the groups are ameable to sampling and identification to the species level by non-specialists.

(c) The groups were chosen, taking in mind, that they are not directly exploited by humans, to avoid influence on their distribution and abundance.

(d) Both the groups are fairly found throughout the study area.

(e) Saleable species were chosen for the species (e.g. butterflies are more appealing to the public than spiders).

(f) The groups represent varied trophic levels and guilds, and also response to environmental changes.

(g) The life history and ecology of the groups are relatively well known.

Bird and butterfly satisfy most of these criteria for using as potential indicator species (Debinski & Brussard 1992). Birds are suitable, because they respond to habitat structure (MacArthur 1964) and represent several trophic groups or guilds (Steele *et al.* 1984). Moreover, butterflies show the potential as they are host specific herbivores whose diversity may correlate with plant diversity (Ehrlich 1983), and are well known for their taxonomy, broad distribution, and represent varied ecological guilds (Debinski & Humphrey 1997).

1.5. Hypothesis

Two broad hypotheses each for forest structure and bird and butterfly communities have been recognised for the study. These are:

Hypothesis 1: Intensive firewood and fodder extraction will modify tree species composition and age structure of temperate and sub-alpine forests in the following respects:

(a) Human interference in terms of firewood, fodder and timber are species and area specific.

(b) Woody tree diversity (H′) and species richness (d) values decreases with elevation and also vary in harvested forest stands.

(c) Density and standing biomass of species, which are preferred by local residents for firewood and timber, reduce in relation to harvested (open) or un-harvested (closed) canopy forest stands.

(d) Open canopy forests subject to human interference will be dominated by trees of larger DBH classes, compared to closed canopy forests and causes change in size and canopy structure.

(e) Net primary production will be higher in open forest due to less competition.

Hypothesis 2: Due to the above factors, forest bird and butterfly communities of the two ecological zones (lower forest and upper forest) will differ between open and closed canopy forest stands in terms of:

(a) Species composition, relative abundance and richness.

(b) Bird and butterfly community structure strongly related to forest types as per distinctiveness of their distribution.

(c) Birds and butterfly community structure differs altitudinally, irrespective of habitat differences, until a specific niche or guild is considered.

Key predictions to be tested are:

(a) The relative abundance of those species most adapted to human activity and disturbance will be greater in open canopy condition rather than closed canopy forest stands.

(b) Open canopy forest areas will contain higher species richness than closed canopy/dense forest area.

(c) Bird species dependent upon closed canopy coverage and tree layering will be absent or sparser in open canopy stand compared to old-growth closed canopy stand.

(d) Bird species richness will be higher in well-stratified forest than in the completely degraded one.

1.6. Aims and objectives

The primary aims of this study are to:

(a) Characterize forest stand structure under human disturbed (open) and relatively undisturbed (closed) canopy conditions along the Yuksam-Dzongri corridor.

(b) Estimate vegetation structure and productivity of two major forest types, warm-temperate forest (lower forest) dominated by *Quercus* spp. and *Castanopsis* spp., and cool temperate-subalpine (upper forest) forest typified by *Abies densa* and *Rhododendron* spp.

(c) Investigate bird and butterfly communities and guild structure in relation to habitat condition and forest types.

(d) Develop bird and butterfly species lists indicating seasonal and altitudinal occurrence along this trekking route.

1.7. Limitations

The present study has tried to cover wide subject areas with pertinent issues as socio-cultural set-up, dependency on forest for natural resources, species preference for firewood, fodder and timber, impact on forest vegetation, investigation of bird and butterfly communities living therein and their association with the vegetation. Most of the data have been collected as primary from the field. Sensitive issues like firewood extraction area and consumption rate, fodder demand, number of livestock and landholding size were difficult to achieve. People's perception was not hostile as the investigation was made for the reserve area utilisation. They were reluctant to provide actual information on many vital issues associated with resource extraction. In some issues, which were not clear to my understanding was crosschecked with available secondary data as well. But, some of the secondary data considered were old and many records were either incomplete or completely different from the present scenario.

Another constraint was inaccessibility of the areas due to steep slopes in many parts of the corridor and adjoining areas. Unpredicted weather conditions and natural hazards like landslide, continuous rain and extreme cold weather disrupted the work plan and many times the schedule was missed or covered later. Collection of data for butterfly became difficult due to wide variation in weather and elevation. Distributions of butterfly species were sparse to very sparse with the gain in elevation. This led me to drop the sampling schedule for the second year.

Similarly, sampling for birds was also not easy. Point Count Method, which was initially thought to carry out simultaneously with Line Transect, was not recommendable. The values of species richness and diversity were much less and fluctuating and many common species were missed in the Point Counts. Thus, after one year of trial and error, Line Transect Method was found to be more reliable for further study. Sampling schedule for bird and butterfly, which was initially thought to cover for three seasons viz. winter, summer and monsoon, was followed only in winter and summer. This was considered due to the fact that in monsoon, a constant rain and fog have disrupted the bird visibility and butterfly activity. As a result, data consideration for the monsoon seemed to obscure the trend with biases.

1.8. Thesis organise

This thesis emphasises on three broad aspects of the study area, namely a) human interference on the natural resources, b) impact of human interference on vegetation structure and biomass productivity and c) assessment of consequences of human disturbances on bird and butterfly communities. The thesis starts with introduction as chapter I with an overview of study, hypothesis and background of the present study along with limitations faced therein. Chapter II and III provide review of literature and description of study area, respectively. Human interferences such as firewood, fodder and timber extractions are elaborately discussed in chapter IV with an overall idea of resources use pattern by communities and tourism enterprises. Species preferences and quantification of their annual consumption by the communities and the tourism enterprises were further added in this chapter. Bird and butterfly communities were considered to assess their indicator quality for biodiversity assessment; in order to do this, knowledge of habitat quality was important. Therefore, vegetation structure and woody biomass productivity are dealt first to understand the habitat type in chapter V. The vitally important chapter, i.e. chapter VI gives the accounts on bird community structure along the prescribed habitat conditions in the trekking corridor. Bird-habitat relationships, along with migratory groups, feeding guilds and selective species are dealt in chapter VII. Butterfly community as well as their habitat association is dealt in chapter VIII. This chapter also provides the indicator properties of bird and butterfly as one of the main objectives of the entire study. The concluding chapter IX adds on management and conservation implications for the area with recommendations. Finally, appendices on list of birds, butterflies and the NTFPs are also presented.

CHAPTER II

Chapter II

Review of literature

2.1. Introduction

Human disturbances such as firewood extraction, fodder lopping, grazing, tourism and recreational activities, and infrastructure and industrial development have brought concern for global biological resources management. Such human exerted (artificial and directional) pressures have turned into important factors having great impact on species rich tropical communities of moist evergreen and semi-evergreen forests. As a result, 18 Biodiversity *Hotspots* that feature exceptional threats of destruction were prioritized (Myers 1990). Unless immediate decisive steps are taken to follow the conservation activities in these wilderness areas, pragmatic assumption foretell that much of the biodiversity will be lost within a few decades.

The idea of community in ecology has been one of the most ambiguous topics followed by debates and arguments (Wiens 1989, Peters 1991). The most inclusive of all definitions is that it consists of all organisms in a given area. But this definition is restricted to spatial, trophic, taxonomic and life form level (Roughgarden & Diamond 1986, Javed 1996). So far, studies on community structure of organisms signify their characteristics and properties of the assemblages of specific population (Konomandy 1989) or group of populations that occur together (Rickelf 1990). Communities are discrete assemblage, which closely integrated but lacked internal organization (Clement 1916).

Study of community ecology is not a recent one. Many valuable literatures in different fields of community studies are available since the beginning of the twentieth century. Studies of Lack (1933), Kendeigh (1934) and Odum (1950) made remarkable contribution in the field of community studies. In the present work many aspects of human disturbances on natural resources of Yuksam-Dzongri trekking corridor in Khanchendzonga Biosphere Reserve were dealt with their cumulative effect on vegetation structure, bird and butterfly communities and their relationship with vegetation. As a result, quite a good number of literatures are required for baseline information. Therefore, the present study will consider only important and relevant information from available literatures in three broad headings such as (a) human disturbances on vegetation structure, (c) bird community and their association with habitat and (d) butterfly community and their association with habitat.

2.2. Human disturbances on vegetation structure

Human disturbances on natural resources are the largest single cause of loss of biological diversity (Hannah *et al.* 1995). Since the balance between natural forest and human dominated landscapes will determine the future of biological resources over large area of our earth, it is therefore important to know the degree of conversion of natural areas by disturbances in human dominated landscapes and the area of recreation (Hannah *et al.* 1995, Rai & Sundriyal 1997). Preservation of natural communities has historically consisted of measures for protecting them from physical disturbance but there has been considerable debate on the definition of disturbance (Rykiel 1985, Andel & Berg 1987) and varies between one and other's concept (Pickett & White 1985, Petraitis *et al.* 1989). Disturbance is an important component of many ecosystem and variations in disturbance regime can affect community structure and ecosystem functioning either by damaging the natural habitat (Hume 1976) or by bringing about subtle changes (Block 1989, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996).

Human disturbances are major constraints in maintenance of species diversity at microhabitat and their associate taxa (Souce 1984). Different components of disturbances like chopping and lopping of trees for firewood and fodder, grazing, trampling and leaf litter removal affect the vegetation structure and recreational quality (Khadka 1984, Mahat *et al.* 1987, Hobbs & Huenneke 1992, Gill *et al.* 1996, Rai & Sundriyal 1997). Though Tourism has become the most important civil industry in the world, the consequent impact on recreational quality can not be overruled. Natural resources and wilderness of Himalaya has made these areas a potential tourists destination. Some valuable documentation has been already came forward on the effect of Tourism in Nepal (Bjonness 1980, Byers 1986, Baskota & Sharma 1994) and Sikkim Himalaya (Rai & Sundriyal 1997). A strategic concept on Ecotourism may play an important role to minimise such impacts with the participation of local community and associated stakeholders (Sharma *et al.* 2000).

Selection of species for firewood, fodder and timber is a common activity in the Himalaya (Mahat *et al.* 1997, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996). Tree cutting by selection has more visible impact in accessible areas than that of inaccessible areas. However, many plant communities and species depend on disturbance, especially for regeneration (Pickett & White 1985), diversity (Dolman & Sutherland 1991) and species composition (Harrison 1981). All these components act on 'intermediate disturbance stage' for most of the communities and species (Fox 1979).

Moreover, the disturbance components themselves are not in balance and individual components have different levels of effects in different physiography and in many cases results are additive and even the actions are synergistic. Thus the results may be fatal to the plant community and also to individual species (Cole 1995, Hobbs & Huenneke 1992). As long as the collection of firewood, fodder, leaf litter and trampling in forest remains within replenishing capacity of forest ecosystem, effect of disturbances are invisible. But if the disturbances are excessive, the degradation becomes non-linear or irreversible (Singh *et al.* 1997, Singh 1998). It is possible that such impacts may be pronounced and complex in species rich tropical habitats such as moist evergreen and semi-evergreen forests, which are globally acknowledged as reservoir of biological diversity (Myers 1990).

Studies of population structures and dynamics of woody vegetation in the Himalaya are a few (Saxena & Singh 1982, Singh & Ramakrishnan 1982, Shukla & Ramakrishnan 1984; Khan *et al.* 1986, Khan & Triphati 1987, Sundriyal & Bist 1988, Ramakrishnan 1991, 1992,). But little assessment on human interference has been made (Khan & Tripathi 1987, Khan *et al.* 1987, Ramakrishanan 1991, Toky & Ramakrishanan 1983, Sharma *et al.* 1992, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996, Rai *et al.* 1994, Uma Sankar *et al.* 1998). Northeastern states of India contain extensive moist evergreen and semi-evergreen forests (Champion & Seth, 1968). Currently human interference such as unregulated logging and conversion of forests to agricultural land are said to be responsible for wide spread environmental degradation and loss of nearly two thirds of the estimated 340,000 sq km forest area that existed in the Eastern Himalayas (Myers 1988, 1990).

Most of the forests in Sikkim are still considered to support good diversity, but in last few decades, there have been visible changes in the landscape and species composition at certain locations (Sundriyal *et. al.* 1994, Sundriyal & Sharma 1996) and most of the areas in the region have been seriously considered for conservation (Rao 1995). Quite an extensive studies on temperate natural forest (Sharma *et al.* 1992, Sundriyal & Sharma 1996) and Sub-tropical natural forest (Sundriyal *et al.* 1994) have been undertaken in Sikkim. A wide variety of species are used for subsistence livelihood for which the communities totally or partially depend on the natural resources from the forests. To date, the demands of fuel, timber and fodder were met from forests, but the increasing demands have been causing a major concern for the resource management (Sundriyal *et. al.* 1994, Sundriyal & Sharma 1996).

2.3. Bird community and their association with habitat

Being ecologically diverse and sensitive to various kinds of perturbation, birds are widely used as predictor of the quality of environment and health of the forest they live in (Debinski & Brussard 1992, 1994, Sankar Raman 1995, Javed 1996). In recent years birds have been receiving due attention since pioneering work on relationship between habitat structure and bird community by Robert MacArthurs and collaborators (MacArthur & MacArthur 1961, MacArthur 1964). In their studies, structural aspects of habitats were used to predict relationship with diversity of birds. Other way, diversity of avian community is directly related to either resources diversity or number of ways in which resources can be partitioned (Cody 1975).

Study on bird and habitat relationship is an age-old trend in ecology. Ample literatures are available in this field with new approaches and new findings. A series of researches were undertaken and results were obtained from 1960s. In such endeavour Karr (1968) and Willson (1974) worked out the relationship between vegetation cover and bird diversity indices at Champaign, Vermilion and Piatt counties, Illnois. In this study, bird species diversity was found to have positive and linear relationship with the foliage height diversity and curvilinear relationship with the percentage of ground cover vegetation. Karr

& Roth (1971) added to the relationship on bird species diversity and vertical layering of the foliage. Young (1977) explained the relationship of tree diameter diversity with bird community.

Wiens & Rotenberry (1981) and James & Warmer (1982) worked on relationship of bird with the crown cover of forest. Subsequently, Verner & Larson (1989) studied on breeding bird species in mixed-conifer forest of the Sierra Nevada in California. They reported that bird species richness significantly correlated with tree species diversity, shrub patchiness, total crown volume, tree crown volume and size of the patch. Thereafter series of papers came out on new relationship of bird and habitat. In this trend, relationship of bird to foraging strategies (Poulin *et al.* 1994, Cale 1994); trophic level (Airola & Barnett 1985), size of habitat (Bellamy *et al.* 1996) and many other relationships were documented for the knowledge on bird community.

Moreover, bird species exhibit strong associations with some special habitat components that can influence their richness and diversity. These include plant taxa (Balda 1969, Holms *et al.* 1979, Wiens & Rotenberry 1981, Rice *et al.* 1984, Robinson & Holms 1984, Rotenberry 1985, Sherry & Holms 1985, Terborgh 1985), tree species richness or diversity (Winternitz 1976, Young 1977, James & Wamer 1982) and size of the study area (Verner & Larson 1989).

Literatures on bird species association with respect to human interference are few. Block (1989) in his study dealt with spatial and temporal pattern of resource use by birds in California oak woodlands. He suggested that the resources use pattern or distribution of species depended on stratification of forest. Hutto (1989) recorded in west Mexican Tropical Deciduous forest and found a significant difference in bird species of secondary growth forest and un-disturbed forest. Others like John (1988) and Michael and Thornburg (1971) focused on effects of hardwood extraction on bird population.

Numbers of literatures are emerging in the field of influence of human activities on bird communities. Thomson *et al.* (1992) documented on breeding birds of Missouri Ozark forest. They compared the bird in two stands with and without clear cutting. They suggested that the clear cutting creates more areas as edges in the forest and results in decline of forest interior species that are dependent on mature forest habitats, whereas other forest interior species use early and mid-successional stands.

Thiollay (1992) investigated composition and structure of bird community from the rainforest of French Guinea in northeastern Amazonia from logged and un-logged areas. In his study, an overall 27-30% decrease in species richness, abundance and frequency from un-logged to logged area as a result of human disturbance was recorded. In addition to this, 42% of species decreased or disappeared from primary forest after logging.

Willson *et al.* (1994) documented the effect of habitat size on bird community from fragmented south-temperate rainforest of Chile. Their findings focused on the inverse relationships between habitat size on diversity and abundance of bird. They suggested that bird conservation could be achieved through management of forest leaving small stands of forest and corridors between the forest patches.

Kilgo *et al.* (1997) studied the influence of hardwood fragmentation on breeding birds in South Carolina. They set experimental plots at hardwood stand surrounded by agricultural land and hardwood stands surrounded by alpine forest. In their result, they found that the bird abundance were higher at the stand surrounded by agricultural land. Moreover, presence of a surrounding pine forest apparently increased the suitability of some area sensitive species but decreased the suitability of several edge species.

Very recently, Bolsinger (1998) from an extensive wildlife research concluded that forest clearance for production of forage and urban and semi-urban development caused changes in woodland community and wildlife living therein. In the same year, Schulte and Niemi (1998) documented on bird community organization in burned and logged forests and found higher richness and number of individuals (territorial male/ha) in burned forest than logged forest.

Aigner (1996) and Aigner *et al* (1998) have made rewarding contribution in which they focused on bird community with more emphasis on response of species to habitat change as a result of firewood extraction. The results indicate that the small-scale firewood harvest that reduced 25% of the basal area with preserved nest cavity and granary trees have minimal negative short term effect on more common bird species during the breeding season. But they suggested that the uncommon birds detection should not be ignored.

Restrepo and Gomez (1998) studied the response of understorey birds to anthropogenic edges in a Neotropical montane forest of Columbia. Their study emphasised on the guild at forest edges and in interior forest gradient. The result has documented that the larger-scale human disturbances influence in a complex manner in distribution of birds. Both temporal and spatial disturbances have significant contributions on bird distribution.

Saab (1999) studied breeding birds in cottonwood riparian forest of South Fork of the Snake River in Southeastern Idaho, U.S.A. He addresses a series of predictions about species' distributions that incorporated the different spatial scales. High species richness has been observed in natural and heterogeneous landscapes and in relatively open canopies. He concluded that landscape patterns have the greater influence on distribution and occurrence of most of the species compared to habitat conditions.

Trezcinski *et al.* (1999) have determined the relative importance of the independent effects of forest cover and fragmentation on the distribution of forest breeding birds. They found that the effect of the forest fragmentation is greater on the distribution of the forest breeding birds than the forests cover. But they suggested that the primary focus for conservation of bird should be on maintenance of forest cover, which has the major influence.

In the same year Hobson and Schieck (1999) undertook a study on bird communities in forest with wildfire and harvested plots in north-central Alberta, Canada. They have suggested that in forest harvest practices better approximate natural disturbances processes are more likely to conserve biodiversity.

Recently, Schieck *et al.* (2000) studied an effect of vegetation dispersion on bird communities in mixed boreal forest of Alberta, Canada. Their findings suggest that the retention of snags and residual trees in clumps would maintain the diversity of bird as that of old-undisturbed natural forest.

Though the Indian subcontinent is gifted with a rich diversity of bird life and an equally diverse set of habitat types, our knowledge of general bird ecology is still elementary (Ali & Ripley 1987). But there is an imperative need for uncovering the complexity of community of tropical birds (MacArthur 1972), as what we know today of bird community structure and dynamics are largely based on works in temperate areas and a comparative study is needed for better understanding of bird community structure in other climatic areas.

Very little work has been done for community and habitat interaction on bird from India. Gaston (1982) studied the effect of grazing on birds of Rajasthan. Beehler et al. (1987) worked on the birds of Eastern Ghats at disturbed habitats.

Katti (1989) studied the bird community of lower pine forest in Dachigam National Park. He concluded that unlike the majority of temperate examples where the pattern of bird communities was greatly influenced by structural complexity of vegetation, the

Lower Dachigam birds seemed to respond to a number of factors like food resources diversity and distribution, apart from structural diversity. Price (1990) studied in the same area on impact of forest loss on birds. In the same year Price and Jamdar (1990) made an exploratory study on birds of Kashmir, and Sundaramoorthy (1991) studied the ecology of birds of Keoladev National Park. Subsequently, Daniels (1989) studied on bird community of Uttara Kannada district and focused on conservation related to land use and plant species diversity.

Rai (1991) found in his study on breeding-bird communities of Rajaji National Park, an inverse linear correlation between foliage height diversity and birds species diversity. He observed that the vastly diverse habitats of tropical areas had a significant assortment of floristic as well as structural attributes that tend to reveal gradient but no well-defined patterns.

Daniels *et al.* (1992) from their study in humid tropical forest of Western Ghats found that the bird species richness was inversely related to woody plant species diversity and vertical stratification of the vegetation. They also pointed out that bird community of drier vegetation (represented in plantation) showed the commoner trend of a positive correlation between bird species richness and vertical stratification.

Khan *et al.* (1993) came with exploratory study on bird community structure of Aligarh. Sarkar Raman (1995) made rewardable study on birds of Mizoram in different age gradient habitat on *Jhum* cultivation. He has focussed on the relationship of bird community on vegetation of different graded *Jhum* stands.

Javed (1996) in his study from Rajhaji National Park elaborately discussed on bird community structure and tested the relationship between bird species diversity and foliage height diversity. In his study, he found maximum density of birds at wooded grassland followed by riparian habitat and lowest in grassland and Sal forest. In addition to these, guild structure and habitat models were focused as additional information.

In recent year Shafiq *et al.* (1997) studied the bird community structure of Kumaon hill. The results documented have focussed on the effect of disturbances and habitat conditions on bird diversity and density at different habitat conditions. They found that the bird species diversity was higher at disturbed habitat compared to habitat with little or no human interventions.

Thus, it is apparent from above review of literature that the study of bird community and interactions with habitat were covered in bits and pieces from India. The study have been undertaken only in Indian peninsular area (Beehler *et al.* 1987, Daniels 1989, Daniels *et al.* 1990, 1991, 1992, Price 1990, Johnsing & Joshua 1994), Western Arid region (Gaston 1982, Sundaramoorthy 1991), Central Himalaya (Jaipal 1997, Shafiq 1997), Central India (Khan *et al.* 1993) and small area of northeastern state (Sankar Raman 1995).

2.4. Butterfly community and habitat association

Literatures on butterflies in general are quite extensive and most of them deal with a range of aspects including migration and seasonal variation (Gilbert & Singer 1975, Vane-Wright & Ackrey 1984) and conservation (Cheverton & Thomas 1982, Bowman *et al.* 1990, Jones *et al.* 1987, Hanski *et al.* 1995, Hill *et al.* 1995). But studies on butterfly community and habitat interactions are meagre and very little works are available in this field (Gilbert & Singer 1975, Gilbert 1984). In most of the recent works, either birds or bird and butterflies were used as "indicator taxa" for biodiversity assessments. Butterflies are particularly suitable for studying the processes of the ecosystem recovery, conservation to vegetation succession and dynamics of their changes (Kremen 1992).

Cheverton and Thomas (1982) assessed the effect of landuse on the density and diversity of butterflies from Panama. Butterfly density was found higher at open areas, whereas the diversity was higher at hardwood forest. Plantation of indigenous tree species was recommended to restore the degraded habitat. The authors also speculated that the butterfly diversity was directly related to plant species diversity.

In the year 1987, Martin and his co-workers worked on butterfly and bird of Madeira and La Gomorra and suggested that these two taxa were highly influenced by the human caused disturbances.

Kremen (1992, 1994) used butterflies as ecological indicators in the southeastern montane rainforest of Madagascar. His conclusion demanded that butterflies were poor predictors of habitat quality as there was no biological relationship between the vegetation and species richness nor with the environmental factors. Interestingly, butterfly diversity was found to correlate with average diversity of flowering plants.

Debinski and Brussard (1994) also used butterfly and bird as predictor of habitat quality. Their work from Glacier National Park, Montana concluded that selection of bird and butterfly, as "indicator taxa" was a sound approach for biodiversity assessment.

Hill *et al.* (1995), from their study on butterflies of Buru, Indonesia have suggested that butterfly species richness, abundance and evenness are significantly higher in un-logged forest compared to logged forest. It was suggested that higher diversity of butterfly in un-logged forest indicated the better quality of forest. Thus butterfly was recommended as "indicator taxon" for biodiversity assessment.

Beccaloni and Gaston (1995) working on butterflies of Neotropical forest suggested that ithomiine butterflies could be used as better predictors of habitat quality as species richness of ithomiine was positively and strongly related to the overall species richness of butterflies of the area.

William and Kareiva (1997) worked on butterfly of Oregon for the development of database and forwarded the conclusion by stating that a mathematical analysis can provide a powerful analytical tool in the service of nature based conservation efforts.

Later on Debinski *et al.* (1998) used the same approach for Greater Yellowstone Ecosystem. In this study also they found statistical high positive relationship with the habitat variables. The interpretation suggested that the strong relationships were due to habitat and host-plant specificity of butterflies and structural complexity of birds. Further more, their findings suggested that regardless of mentioned parameters, diversity of vegetation was an asset for both birds and butterflies.

In recent years Lawton and his co-workers (Lawton *et al.* 1998) made an exclusive study of bird, butterfly and other four wide spread taxa in Mbalmayo Forest Reserve of Cameroon in different mosaic habitat types. On their concluding part they mentioned that the managed forest (plantation with native tree species, established by partial forest clearance) might help to maintain diversity of both invertebrates and vertebrates. Moreover, study on only familiar groups as bird and butterfly does not indicate the changes in the diversity of other associated groups. Thus, interpretation with only familiar groups may give misleading picture. They also suggested that wide range of taxa are required to consider for monitoring changes in biodiversity resulting from forest modification or destruction.

In India, except for early taxonomic work on regional basis, very few scientific works exist. A countable number of literatures came forward for publication. Larson (1987) published his butterfly work from South India in which he discussed swallowtail communities with ecological analysis of 19 Papilionidae from the Western Ghats. Nair (1997) worked on Impact of teak plantation on forest butterfly communities in Parabikulum, Southern Western Ghats. In his study, he made a gradient analysis for butterfly on plantation in respect to their plantation age.

Mohanraj and Veenakumari (1996) reviewed the work on host plant, phenology and status of Swallowtails in the Andaman and Nicobar Islands and brought strong recommendations for management and conservation strategies.

In recent studies Singh and Singh (1998) studied on the butterfly of *Quercus leucotricophora-Cedrus deodara* forest of the Western Himalaya. In the study, they emphasized on the status, habitat use, dominant nectar plants and larval food plants of 35 species. All the species were found dependent on the areas where food and nectar plants were abundant.

In the same year Uniyal and Mathur (1998) made an exploratory survey on butterflies of The Great Himalayan National Park, Western Himalaya. The suggestions were made that Nymphalidae were the most dominant group in the areas. Analysis on altitudinal distribution has suggested that Nymphalidae and Papilionidae were the two groups with wide rage of distribution.

In Sikkim, though many explorers made visits to the area, most of them were in late nineteenth or early twentieth century. Noted entomologist like De Niceville (1881, 1882, 1883, 1885), Elwes (1882), Elwes and Moller (1888), Gammie (1877) and Sanders (1942) have made extensive documentation of butterflies of Sikkim.

Recently Haribal (1992) brought out book exclusively on Sikkim butterflies. The book describes about 700 species covering their habitat, distribution and food plants. In the context of birds, history in Sikkim dates back to the nineteenth century. An account on birds for Sikkim was made by Blandford (1871-72, 1872, 1877). During the same period a publication on the birds of Sikkim along with Punjab and Sind province appeared (Brooks 1880). Thereafter, several naturalists and ornithologists visited and made notes on the natural resources and wildlife of Sikkim (Stevens 1923-1925, Ludlow & Kinnear 1937, 1944, Gammie 1877). Ali (1989) made an exclusive and pioneering documentation for birds of Sikkim.

There was no baseline data on bird and butterfly communities and their habitat use pattern from the Sikkim Himalaya. Thus, this study, though in a regional scale, attempts to document some aspects of bird, butterfly and habitat interactions.

CHAPTER III

Chapter III

Study area

3.1. Sikkim

The Himalaya is the youngest and structurally most complicated mountain system of the world that extends from the Indus in the west to the Brahmaputra in the east measuring about 2500 km in length and width ranging from 240 to 340 km. It has a great variation in eco-biogeography, giving rise to different eco-climatatic zones that harbours a large number of biological wealth. India is one of the 12-megadiversity countries in the world with 45,000 species of plant (the total may be closer to 60,000 as several parts of India are still unexplored) and 81,000 species of animal with about 400,000 un-described organisms (Anonymous 1998, Khoshoo 1991, Mohan Ram 2000). Out of the 18 biodiversity *Hotspots* that feature exceptional concentration of species with high level of endemism and faced exceptional threats of destruction, two are located in India. Of these, 'Eastern Himalayas" is one of the two such *Hotspots* of India (Myers 1990).

The Eastern Himalaya is considered as the stretch of extremely rugged mountains between 26°30′ to 28° north latitude and 87° to 97°30′ east longitude. It covers the area between Singalila Ridge in the west to eastern part of Arunachal Pradesh including Bhutan. The region supports a wide biodiversity due to complex physiography, bioclimatic zonations and their location at the convergence of the Palaearctic and Oriental Zoogeographical Realms (Ives & Messerli 1989).

Sikkim is a small Indian state, belonging to the Eastern Himalaya. It is situated at the western edge of the Eastern Himalaya that falls between 27°4′46″ to 28°7′48″ north latitude and 88°58″ to 88°55′25″ east longitude covering an area of 7,069 sq km. Nepal encircles it in the west, Bhutan and Chumbi Valley of Tibetan Autonomous Region of the People's Republic of China in the east, Darjeeling Gorkha Hill Council of West Bengal in the south and Tibetan plateau of Tibetan Autonomous Region of the People's Republic of China in the north. The abounding forest of Sikkim exhibits bewildering diversity of plants and animals with 43% forest covering (Anonymous 1994). About 29% of the total geographical area of the state is reserved as protected and areas with one Biosphere Reserve and five Wildlife Sanctuaries. Tista and Rangit are the two main rivers of the state.

3.2. Khanchendzonga Biosphere Reserve

Khanchendzonga Biosphere Reserve (KBR) lies in northwestern part of Sikkim (Fig. 3.1). Owing to high possession of flora and fauna, Khanchendzonga National Park (KNP) was commissioned on 26th August 1977 with an initial area of 850 sq km. This was later expanded to 1784 sq km in May 1997 on account of its intact continuous tract of mountain land reserved for conservation of native wildlife with many rare and endangered species (Lepcha 1997). The park occupied as much as 25.11% of the total geographical area of the state with a range of elevation from 1829 to 8550 m amsl. Recently, on 7th February 2000, the Ministry of Environment and Forests, Government of India notified KNP as Biosphere Reserve. The erstwhile KNP area came under conservation management category II with a National Geographical Province 2.38.12, covering Himalayan highlands (Sharma 1997). The newly notified KBR area includes settlement at Bakhim and Tshoka within the conservation area. Other settlements such as Sakyong, Chungthang, Menshithang, Lachung, Monguthang and Yuksam surround the area. Yuksam, a major settlement, and Yuksam-Dzongri trekking corridor within KBR have been the focus area for the present study, which come under the most popular tourism destination in Sikkim (Fig. 3.2).

3.3. Yuksam and Yuksam-Dzongri trekking corridor

Sikkim, as a whole, is considered to be sacred by the Sikkimese Buddhists. The cultural fabric of the Sikkimese society is dependent on the conservation of the entire sacred landscape of the interacting ecosystems. According to the sacred text "Neysol", the area below Mount Khanchendzonga in West Sikkim (*De-mo-dzong* or present Yuksam) is the most sacred of all, being the abode of the Sikkimese deities. The air, water, soil and biota are all raised to the people of Sikkim, because of their interconnection that are perceived to exist between them (Ramakrishna 1996).

Yuksam-Dzongri trekking corridor of west district (Fig. 3.2), the major trekking trail of Sikkim, is unique of its kind. This corridor is a stretch of forest that lies between two destinations that is Yuksam and Dzongri. The term 'corridor' was used following definition provided by Nicholls & Margules (1991) as "a narrow strip, stepping steps of hospitable territory traversing inhospitable territory providing access from one area to other". The corridor is 26 km long in distance from temperate to alpine zone and passes through Sachen, Bakhim, Tshoka and Phitang (Fig. 3.2). Its diverse tropical mixed broad-leaved forest, sub-alpine conifer-rhododendron forest, alpine meadows, cascading streams, sacred lakes, a wide variety of birds and flowering plants and panoramic view of the World's third highest mountain Mount Khanchendzonga provides all kinds of joy to the tourists. Ultimately the trail leads to Goecha La, a paradise of panoramic view of Mt Khanchendzonga surrounded by Mt. Pandim, Mt. Kabur, Mt Narsing and many other snow-capped mountains. Heterogeneity in culture and tradition, rich biodiversity, scenic beauty and historic religious places like Norbu Gang and Dubdi Monastery (Plate 5) have made this area an attractive place for tourists. Ecologists and environmentalists, earth scientists and nature lovers, botanists and zoologists, all are equally fascinated.

3.4. Physical features

3.4.1. Location and topography

Yuksam and Yuksam-Dzongri trekking corridor have been selected for the present study. Yuksam, a settlement and Yuksam-Dzongri trekking corridor lies within the KBR in the west district of Sikkim. The area extends from 27°19′13″ to 27°29′4″ north latitude and 88°9′18″ to 88°15′ east longitude (Fig 3.1). Yuksam village (Plate 1), a base for the trekkers and trailhead and the trail upto Dzongri in the KNP was designated as tourism zone (Lepcha 1997).

The corridor lies along the extensive forest areas with many pristine patches. Tshoka and Dzongri are situated at the ridge lifted out from Onglathang and Tekep La valleys (Plate 1). These two valleys nurture two main tributaries merging into Rathong River, which is one of the two main rivers of Sikkim. The general slopes of this corridor have directions from southwest, southeast and northwest. The area has diverse altitudinal variation starting from 1780 m (Yuksam) to 4000 m (Dzongri). A rise in altitude along the trail is mild upto Prek Chu and it increases abruptly thereafter. The rock is chiefly made up of Darjeeling Gneiss and comprised of high-grade gneiss containing quartz and feldspar with streaks of biotite (Geological Survey of India, 1984).

3.4.2. *Climate*

Climatic data (rainfall, temperature and humidity) were collected at three locations namely at Yuksam (1780 m), Tshoka (3000 m) and Dzongri (4000 m) during the study period (1997-99). The data revealed that temperate conditions prevailed at Yuksam, sub-alpine at Tshoka and alpine at Dzongri. The climate is moist, rain occurs almost round the year and divisible into three season viz., rainy (June to September), winter (October to February) and mild summer/spring (March to May). Mean annual rainfall was highest at Yuksam (3760 mm) followed by Tshoka (3648 mm) and Dzongri (2312 mm). At Yuksam, in an average 85% of annual rainfall occurred during the rainy season (Fig. 3.3). Similarly, at Tshoka it was 87% and at Dzongri 90.2%.

Minimum temperature of -3°C, 8°C and 4.4°C were recorded respectively at Dzongri, Tshoha and Yuksam in January. Summer temperatures at these halting places were mild ranging from 20°C to 24°C at Yuksam, 15°C to 16°C at Tshoka and 11° C to 13°C at Dzongri. The study area remained humid throughout year with

>90% humidity during the rainy season (Fig. 3.3). Great variation of temperature was observed along the corridor even on the same day due to extensive physiographic differences. The trail is unique that start from temperate climate passing through sub-alpine and reaching alpine zone in its 26 km stretch.

3.4.3. *Vegetation types*

Floristic wealth of the trekking corridor is rich and diverse, both in composition and value. Forests represent a variety of plant communities that include diverse vegetation types corresponding to variation in climate and edaphic factors. According to classification by Champion & Seth (1968), the area broadly comes under the sub-type 11b of northern montane temperate forest type and the group 12 of Himalayan moist temperate forest, sub-alpine scrub and pasture land. The corridor broadly has three forest types viz., temperate forest (1780-2730 m amsl), mixed conifer forest/sub-alpine (2730-3650 m) and alpine scrub and grasses (above 3650 m). Temperate broadleaf forest (Plate 2) is represented by *Quercus* spp, *Castanopsis* spp, *Acer* spp., *Juglans regia, Machilus edulis, Cinnamomum* spp. associated with *Rosa* sp., *Rubus* spp., *Berberis* sp. and *Viburnum* sp. as shrubs. There are a few patches of relatively pure stands of oak (*Quercus lamellosa*) with dense under storey of *Viburnum cordifolia, Eurya acuminata* and *Symplocos ramosissima* with mosses and epiphytes. Major part of the trekking corridor has mixed type of vegetation with well-marked strata of tree layers of different species. *Q. lamellosa* and *C. tribulloides* are the top canopy layer trees followed by *M. edulis, Acer* sp. and *S. ramosissima.* The range of forest at higher elevation of temperate belt has broad leaf tree species such as *Magnolia* spp, *Quercus* spp, and *Acer* spp. Some areas have pure top canopy stands of *Magnolia* associated with second storey species like *Rubus* sp, *E. acuminata* and tall forms of rhododendrons.

In mixed coniferous forest, the lower elevation range of sub-alpine belt is dominated by Himalayan hemlock (*Tsuga dumosa*) mixed with rhododendrons and *Betula.* As the elevation increases, the hemlock is replaced by silver fir (*Abies densa*) with dense undergrowth of rhododendrons associated with *Viburnum, Daphne* and *Eurya.* Most part of the forests have *A. densa* as dominant species, attaining height of 30-40 m with luxuriant undergrowth of rhododendrons (Plate 2). This forest is extensive with more species of rhododendrons at elevations above 3400 m.

Above 3650 m in the alpine condition (Plate 1), tree growth is completely arrested with bushy vegetation of xeromorphic species. A few stunted bushy species of rhododendrons mixed with tough clumps of *Juniperus., Berberis* and *Rosa* are common. Dzongri (4000 m) gives clear picture of dry alpine pasture (Plate 1). The vegetation in this zone is practically of scattered scrubs, often barren at higher elevation. Most of the species are stunted, thorny and scrub type. Two most dominating genera are *Juniperus* and dwarf forms of rhododendrons. The wide flattened area within the altitudinal range from 3800 to 4400 m represents alpine meadows with *Cyperus, Potentella, Juniperus* and also comprising of a wide variety of flowering plants. Further above, areas are with completely arrested growth of vegetation and often-barren rocky cliffs. Most of these areas are covered by snow perpetually.

3.4.4. *Wildlife*

Documentation of wildlife in the Sikkim Himalaya has not been updated after the works of Ali (1989) for birds, Avasthe & Jha (1999) for mammals and Haribal (1992) for butterflies. A wide variety of wildlife, including many threatened and endangered species inhabit KBR (Lepcha 1997). Some of these are shown in Plate 3. Incidental animal sighting records by the villagers have mentioned at least 19 species of noted wildlife, including endangered species such as snow leopard, red panda, musk deer and few rare and endangered birds (Table 3.1). According to villagers, commonly sighted animals in the area are Himalayan barking deer, Himalayan black bear, ghoral, clouded leopard and leopard cat. Other than these, Wildlife Section, Department of Forest, has reported Shapi from high altitude areas of KBR (Lachungpa, personal communication) and Lepcha (1994). Wildlife reports on KNP have brought about the presence Kiang (*Equus kiang polyodon*) and many rare and endangered species (Ganguli-Lachungpa 1994, Lepcha personal communication).

Yuksam-Dzongri trekking corridor houses a wide variety of bird species (Appendix A). The most common birds are bulbuls, warblers, magpies and thrushs. The state bird of Sikkim 'blood pheasant' was also recorded from the trail area. Rare birds like Satyr tragopan and monal were confirmed with sightings at about 2500 m on the way to Dzongri (Table 3.1). Some of the less sighted bird species at temperate locations are whitetailed nuthatch, Nepal parrotbill, redtail minla, spectacled barwing, Himalayan snowcock, eastern solitary snipe, yellowbellied fantail flycatcher, Nepal cutia, sultan tit etc (Appendix A).

3.4.5. People and their livelihood options

Sikkim is unique in its cultural heterogeneity. Many distinctive ethnic groups with their exclusive tradition and culture live in harmony. Lepchas are the aboriginal race of Sikkim (Plate 4). They are short people with fair complexes and charming face. They have culture and traditions of their own. Basically hunting and gathering are their tradition and have been living in the wild for ages. This way of life has enriched their knowledge on indigenous flora and fauna. They have their own nomenclature for almost all the flora and fauna of the locality. Bhutias are another ethnic race living in Sikkim (Plate 4). Buddhism is their religion and they follow different culture and traditions. Worship in Monastery is typical for the race. Another race is the Nepali, who arrived the province in late nineteenth century. Majority of Nepalis are Hindus and are dominant group representing 70-75% of the total population of Sikkim. They brought agriculture as their tool for livelihood and settled in different areas.

3.4.5.1. Community composition

A mixture of ethnic groups inhabits Yuksam. Literarily, ethnics of Sikkim are Lepchas, Bhutias and Nepalis. The dominant races in the Yuksam area were Nepalis with higher proportion of Subbas, followed by Bhutias, Lepchas and Tibetan Refugees who live mainly at Tshoka. Firewood, fodder and timber collections, interior forest grazing, non-timber forest produce (NTFP) collection and leaf litter collection for farm use are common practices among these ethnic groups (Plate 4). Beside these, tourism has been increasing in the area at rapid rate and more people are engaged in this profession.

Yuksam has 12 settlements including Tshoka with 274 families and 1572 population. Yuksam, with mixed ethnic groups, is the biggest settlement having 55 households with a population of 293 individuals (Table 3.2). This is followed by Tshong and Khongtay in which Nepalis are the dominant group. One settlement with 9 families resides at Tshoka on the trail occupying 13 ha area in the KBR. About 51% of the total households are dependent on forest found along the trail.

3.4.5.2. *Livelihood*

Primary occupation of the communities in the study area is farming while some are associated with tourism enterprise in the form of lodge operators, porters, yak men, cooks and naturalist guides. More than 81% of the inhabitants are engaged in agriculture. Involvement in government sector as a service holder accounts only 3% of the total population. Tourism, being secondary but substantial source of income for the local community, this sector bears extensive burden on the utilisation of natural resources of the area. About 15% of the total population of this area are involved in tourism sector (Maharana 1997-98, personal communication). Annually, about 2000 domestic as well as foreign tourists visit this corridor. More than 150 support staff, 140 Dzos (cross of cow and yak) and a dozen of horses are engaged in the corridor on an average of six times a year. Moving from one locality to another with yak and sheep herd is a traditional profession of some locals (Plate 5). Himalayan Mountaineering Institute (HMI) trainees also use locals as support staff and a large number of pack animals engaged generate additional income for the locals (Plate 5).

3.4.5.3. *Land use and land holding*

Land use demarcation along the corridor (Fig 3.4), estimated from Survey of India topo-sheets (1:50,000) and IRS-IA LISS II satellite data of 1988, shows that about 79% of corridor area is covered with forest. About 24% of the forest cover has been found as dense forest, 25% open forest, 45% degraded and pure rhododendrons, alpine scrubs and forest blank account for about 6%. Higher proportion of open forest and degraded land was recorded in temperate region compared to alpine region. Historically, Yuksam has been known as *Dema-zong*, meaning the land of paddy. Earlier, extensive areas were under paddy cultivation. In recent years more sustainable practice of large cardamom cultivation in agroforestry systems has replaced paddy fields. Based on Land Revenue Department record (1988) of 204 households, land possession and land holding size of different ethnic groups showed that 47% land belongs to Nepali community (Limbu, Chettri and Gurung) among 114 households. Bhutias, with 53 households had 37% and Lepcha with 37 households occupy only 15% land. It has been noted that about 3% of agricultural land are paddy field compared to 15% cardamom cultivation in agroforestry. Bhutias on an average have the highest landholding size (4.54 ha per family), followed by Nepalis (2.62 ha per family) and the lowest by Lepchas (2.59 ha per family).

3.4.5.4. Livestock

Income of the Yuksam people mostly comes from composite source of agriculture, horticulture, tourism and animal husbandry. Livestock rearing was mainly done to produce milk, meat, manure, cheese and to use as pack animals along the trekking corridor. The animals include cattle (26%), goat (18%), sheep (7%), dzo (7%), yak (3%), horses (1%) and pigs (15%) in the study area (Table 3.3). Livestock size depends upon the farm size, family size and involvement in tourism. The collected data on livestock reveal that more number of sheep belonged to Gurung community, and yak and Dzo to Tibetan refugees and Bhutias.

In the recent years (1996-1998), the number of cattle, sheep and dzos has increased by 85%, 5%, and 27%, respectively (Table 3.3). This attributes to growing tourism activities in the area in which these animals provided high economic benefits to the local people. On the other hand, the number of yaks, horses and pigs decreased by 6%, 29% and 5% respectively (Table 3.3). Horse number has decreased substantially as this is not a suitable pack animal at high altitude trekking compared to Dzos whose number has increased.

3.5. History

The aboriginal inhabitants of Sikkim are the Lepchas. Their origin is obscure, due to lack of documentation on their entity in Sikkim. It was thought that they migrated to the present abode along the foothills of Himalaya from the east and not from Tibet across this range (Dozey 1989). The Lepchas (Plate 4) with small clans came under the protection of the descendent of Khye Burmsa who lived in Sikkim sometime in the 13th century.

Buddhism is the state religion and introduction of Budhism among the Lepchas in Sikkim certainly dates back to Lha-tsum's arrival, about in the middle of the seventeenth century AD (Foning 1991). The next race to enter Sikkim was the Tibetans, who came over in two waves. The first hailed from Tibetan monasteries of Sakya and Ralung and settled as ruling race, and is now dominating over the effeminate Lepchas. Due to the unrest going on in Tibet, the followers of the Nyingma sect have fled south towards Sikkim. The prominent saints who came to Sikkim in the 17th century were Lama Lhatsun Chempo, Gnadak Rinzing Chempo and Kathok Sempa chempo. 'Yuksam' was a meeting place of these learned monks who came to Sikkim from three different directions with an intention to establish Buddhism. These monks searched a fourth person as vision by Padma Sambhava and were brought to Yuksam and was consorted as the religious king of Sikkim in 1642 at Norbugyang (Plate 5) with the title of "chogyal" meaning "the king who rules with righteousness or dharma raja". The construction of Dubdi monastery (Plate 5) also took place someway around the same time. The Lama and the local people of Sikkim and Tibetans implicitly believe that Saint Padma Sambhava (Guru *Rim-bo-che*), found Sikkim during his journey to Tibet and personally consecrated every sacred spot including Yuksam in Sikkim (Waddell 1993).

Yuksam is an area, which the people of Sikkim perceive as the very basis of their present culture. Padma Sambhava, who is highly revered and worshiped by the Sikkimese Buddhists is considered to have blessed Yuksam and surrounding landscape, by having placed within it a large number of hidden treasures *ters* and it is believed that (*ters*) will only be slowly revealed to enlighten Lamas and discovered at appropriate time. Yuksam region is considered to have 109 hidden lakes. Both the visible and less obvious notional lakes identified by religious visionaries are said to be presiding deities, representing good and evil. Propitiating these deities with different ceremonies is considered to be the path for conservation in all respects (Ramakhrisnan 1996). Conserving and protecting these treasures from polluting and disturbing influences is considered to be vitally important for human welfare. Any major disruption to the river system would disturb the entire system of the area.

Later, the yak and sheepherder used the Yuksam-Dzongri corridor and Dzongri pasture for grazing. Since 1960s, the Himalayan Mountaineering Institute (HMI) started to used the trail for basic and advance training in Rathong Glacier. Later, a nine-house Tibetan settlement established at Tshoka in the late 1960s. The magnificently diverse landscapes and rich cultural heritage of Sikkim have contributed to rapid growth of adventure tourism since 1990. After relaxation of government rules, there has been a tremendous increase in visitor number to this small trekking corridor causing disturbances to both physical environment and biological resources (Rai & Sundriyal 1997).

Table 3.1. Important wildlife of Yusam-Dzongri corridor reported by the community of Yuksam and their threat categories from IUCN data.

Common Name	Scientific Name	Ecological zone	Local name	Schedule/ part	Status
Barking Deer	*Muntiacus muntjak* Zimmermann	*ST*	Ratwa	III	T
Bharal	*Pseudois nayaur* (Hodgson)	*AL*	Nervati	I	V
Clouded leopard	*Neofelis nebulosa* Griffith	*ST*	Nigalay Chituwa	I	E
Common Langur	*Presbytis entellus* Dufresae	*TE*	Hanuman Bander	II/1	C
Ghoral	*Nemorhaedus goral* Hardwicke	*TE*	Himal ko goral	III	R
Great tibetan sheep	*Ovis ammom hodgsoni* Blyth	*AL*	Tibet ko Bheran	I	E
Hill fox	*Volpes v. montana* Linn.	*AL*			
Himalayan Black Bear	*Selenarctos thibetanus* (Cuvier)	*TE*	Konthe Bhalu	II/2	V
Himalayan thar	*Hemitragus jemlahicus* Smith	*AL*	Thar	I	E
Himalayan yellow throated marten	*Martes flavigula* Boddaert	*ST*		II	E
Indian porcupine	*Hystrix indica* Kerr	*ST*	Dumsi	IV	C
Indian wild pig	*Sus scrofa* Linn.	*ST*	Bandel	III	IK
Marbled Cat	*Felis marmorata* Martin	*TE*	Jungali Biraloo	I	E
Musk deer	*Moschos charysogaster*	*AL*	Kasturi	I	E
Orange belled squirrel	*Dremomyths lokhriah* Hodgson	*ST*	Lotharkay	IV	C
Red Panda	*Ailrus fulgens* Cuvier	*TE*	Kudo	I	E
Serow	*Capricornis sumatraensis* (Bechstein)	*AL*	Thar	I	V
Snow leopard	*Uncia uncia* Schreber	*AL*	Semu	I	E
Tibatan wolf	*Canis lupus* Chanko	*AL*		II/2	V

Contd…3.1

Birds: Common name	Species	Ecological zone	Local name	Schedule/part	Status
Blood pheasant	*Ithagenus cruentus* (Hardwick)	*AL*	Chilimen	I	V
Crimson horned pheasant	*Tragopan satyra* (Linn.)	*AL*	Daphe	I	R
Forest eagle owl	*Budo nepalensis*	*ST*	Lat Kusyal	I	E
Himalayan golden eagle	*Aquila chrysaetos daphanea*	*AL*	Sunaulo Giddha	I	E
Lammergeier	*Gypaetus barbatus*	*AL*	Budo Giddha	I	E
Monal pheasant	*Lophophorus impejanus* (Latham)	*AL*	Monal	I	E
Snow partridge	*Lerwa lerwa*	*AL*	Larewa		T
Snow pigeon	*Columba leuconata*	*ST*			T
Sparrow hawk	*Accipiter niscus*	*ST*		I	E
Tibetan snowcock	*Tetragaolus tibetanus*	*AL*		1	E
White breasted dipper	*Cinclus cinclus*	*AL*		I	R

AL = alpine, ST = sub-tropical, TE = temperate, E = endangered, V = vulnerable, T = threatened, C = common, R = rare

Table 3.2. Settlement wise households and population in the Yuksam – Dzongri trekking Corridor

Settlements	Number of Households	Total Population
Tshoka*	9	57
Geychen *	18	120
Norbugang*	21	122
Khongtay*	38	242
Yuksam*	55	293
Kopchey	12	67
Mantabong	22	138
Tshong	42	171
Topsing	21	135
Gufa Danra	6	35
Dostang	12	78
Mangsabong	18	114
Total	**274**	**1572**

* Settlements dependent on corridor forest for resources

Table 3.3. Livestock numbers during 1996-1998 in Yuksam and Yuksam-Dzongri trekking corridor.

Livestock	Years			Increase (%)
	1996	1997	1998	
Dzo	96	101	122	27
Yak	83	70	78	-6
Horse	31	31	22	-29
Cattle	245	267	454	85
Goat	361	399	311	-14
Sheep	441	435	461	5
Pig	273	254	260	-5
Total	**1530**	**1557**	**1708**	**63**

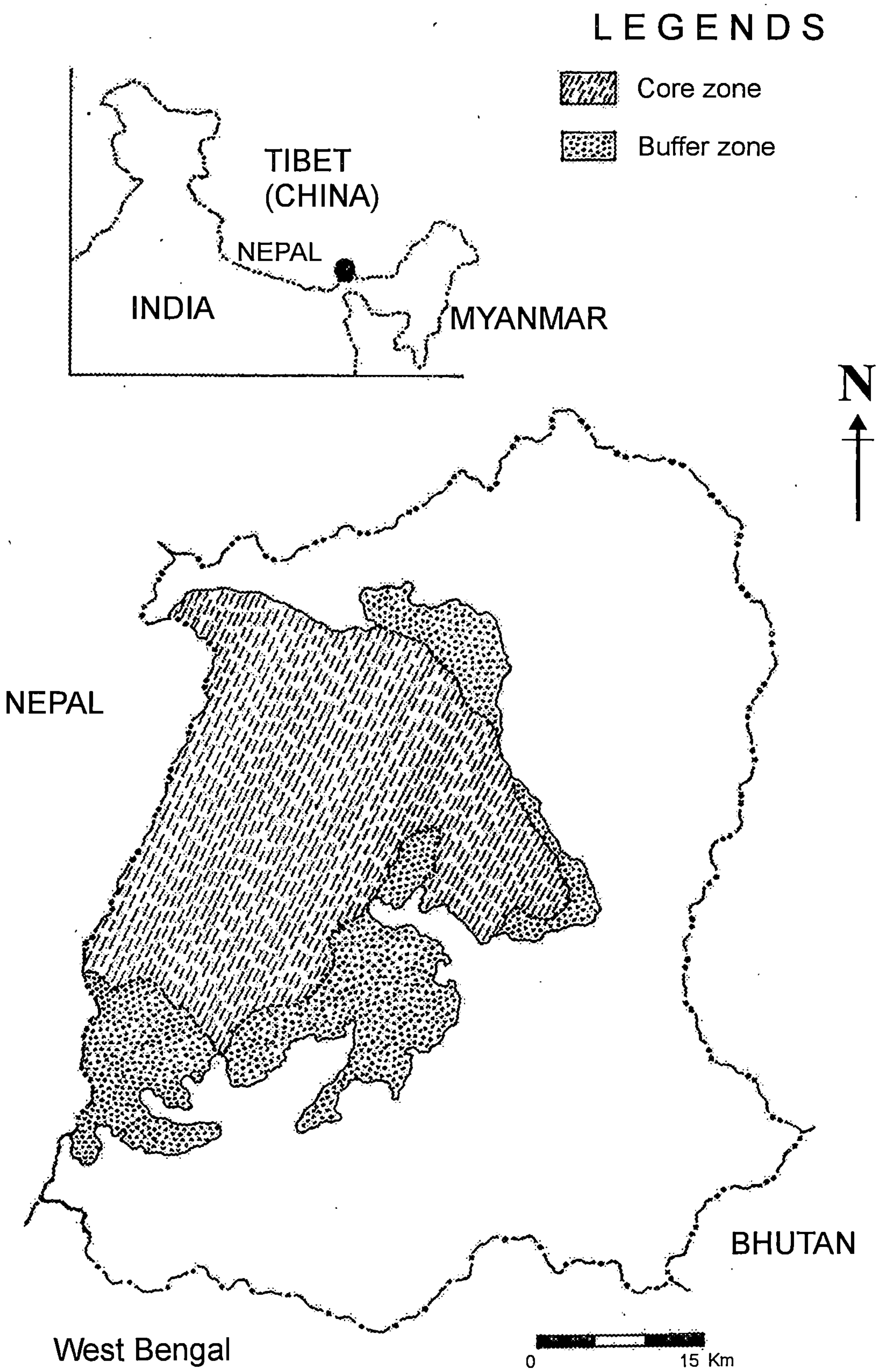


Fig. 3.1. Location map showing the Khanchendzonga Biosphere Reserve in Sikkim

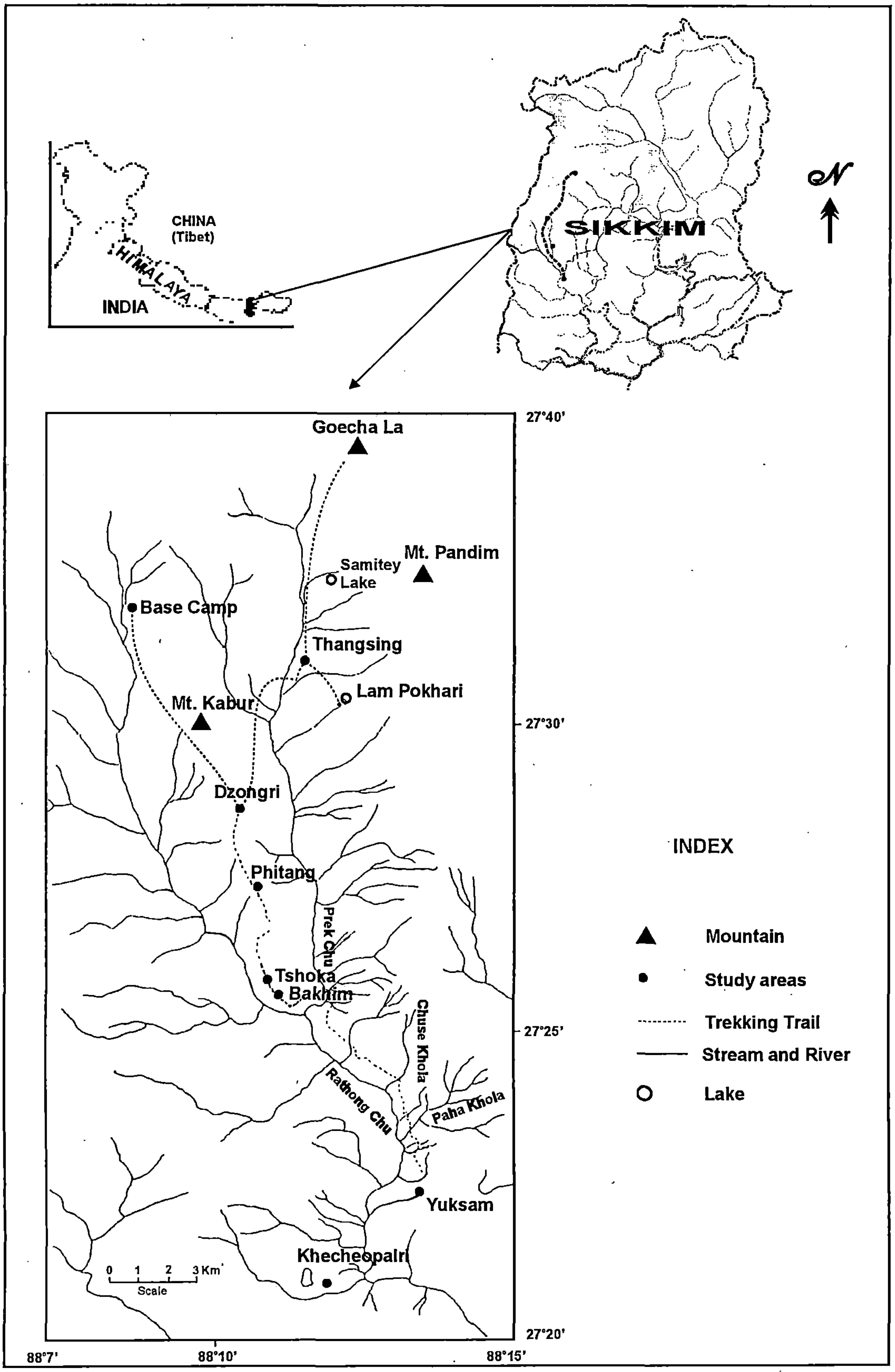


Fig.3.2. Location map of Yuksam-Dzongri trekking cooridor in the Khanchendzonga Biosphere Reserve

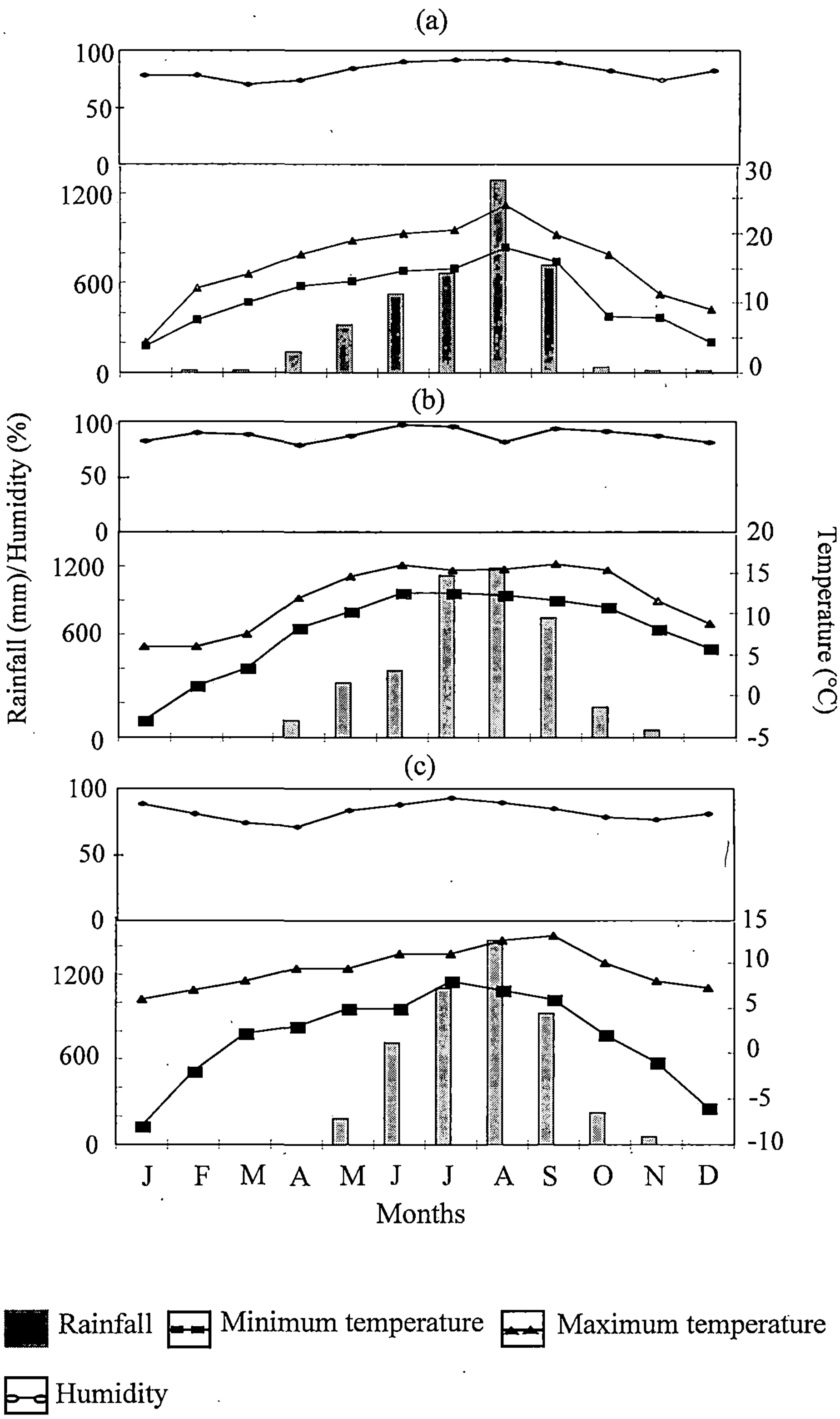


Fig. 3.3. Temporal variation of temperature, rainfall and humidity at three major halting places (a = Yuksam, b = Tshoka, c = Dzongri).

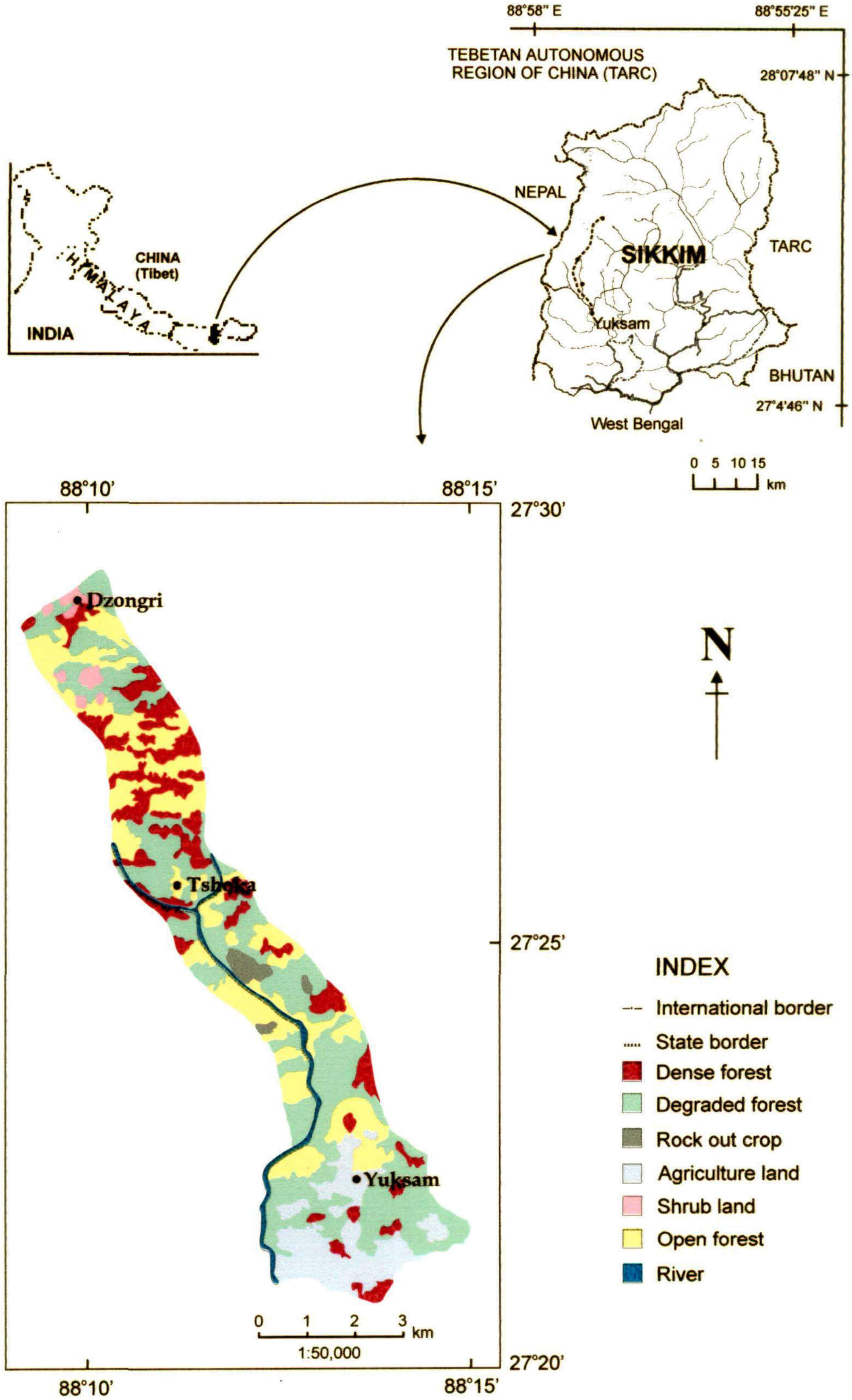


Figure 3.4. Map showing land use area of Yuksam-Dzongri trekking corridor.

CHAPTER IV

Chapter IV

Human disturbance on forest resources

4.1. Introduction

Among the major resources available to man are lands; comprising of soil, water and habitat for associated plants and animals. However, disturbance or change of natural habitat is the largest single cause of loss of biological diversity (Hannah *et al.* 1995). The use of biological resources should be sustainable because man's existence depends upon their higher productivity (FAO 1994). However, these resources are vulnerable to deterioration and degradation due to improper use. Subsistence farm economy of million of peasants in the tropical Asia is inherently dependent on forests, which form the major source of firewood, fodder and timber. Forest degradation in tropical Asia has been rampant. Most of the tropical mature forests in Asia accounts below standard standing biomass (< 350 Mg ha^{-1}) and only a few mature forests (6%) show biomass estimates over 400 Mg ha^{-1} (Brown & Lugo 1982, Brown *et al.* 1991). Tropical Asia alone has lost 14% of its forest area within a time span of 100 years (from 1850-1950) and it has further shrunk by 15.8% from 1950 to 1980 (WRI & IIED 1987). Forest loss in Southeast Asia was 7% during the same period (Thapa & Weber 1990).

Firewood is reported to support energy requirement of 1.4 thousand million people, and is expected to rise to 2.5 thousand million by 2010 (FAO 1994). In the Himalaya, 76% of the total energy consumption is derived from firewood, due to free and easy access to forest and for simplicity in its use (Openshaw 1980, Wallace 1981, Eckholm *et al.* 1984, Blaikie 1985). Wood is widely used energy source for cooking and heating purposes by the families of most of the tropical Asian countries (Bajracharya 1980, 1983, Lanly 1982, Fox 1984, Mahat *et al.* 1987, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996). Diminishing of the forest resources has been aggravating the pressure on livelihood, directly by causing shortage of firewood and fodder (Thapa & Weber 1990). The ever increasing human and livestock population in rural areas are exerting powerful pressure on land resources to meet the requirements of food, fuel, fodder, timber and other human needs. In the process, over exploitation and improper use of these resources have resulted in the disappearance of forests, erosion of soil and deterioration of fragile ecosystems.

Sikkim possesses 43% of its total geographical area under forest cover of which 34% is dense forest (Anonymous 1994). Majority of the people in Sikkim depend on forests for firewood, fodder, and timber, and substantial portion of these come from agroforestry systems and farm residues. About 5 Mg ha^{-1} of woody biomass is removed for firewood annually from the forests (Sharma *et al.* 1992). The firewood are used by community for different purposes such as cooking (69%), animal feed preparation (9%), house warming (7%), water heating (7%), local wine and beer preparation (6%) and on festivals (2%). Most of the houses are made up of woods and fragmentation of families leads to construction of many new houses each year consuming substantial woody biomass from forests (Sundriyal *et al.* 1994). Balance of land use, resource utilisation and conservation has been recently perturbed in Sikkim due to population growth and fragmentation of farm families (Rai *et al.* 1994). Tourism, a fast growing industry for the state, imparts additional pressure on the resources (Rai & Sundriyal 1997). Firewood demands by tourism and associated activities in the mountains are believed to have considerable impact on the forest vegetation and wild life (Bjonness 1980, Byers 1986, ERL 1989, Gurung 1990, Banskota & Sharma 1994). Though the firewood demand in the area for tourism is seasonal (March-May and September-November), and alternative energy use for tourism purposes has become mandatory, firewood use by support staff and by some travel agents are still continuing.

Collections of firewood and fodder have been the two major factors causing destruction of forests (Thapa & Weber 1990). Firewood consumption in the area has been mainly for meeting community requirements and for supporting tourism based enterprises. A rapid depletion of forest resources has led to environmental degradation all over the Himalaya (Thapa & Weber 1990, Singh & Singh 1992). The balance between natural habitat and human dominated landscapes will determine the future of biological diversity conservation over large areas of the planet. It is therefore, important to map and quantify the degree of human conversion of natural habitats by human interventions including tourism in human dominated landscapes (Hannah *et al.* 1995, Rai & Sundriyal 1997).

4.2. Human disturbance and its consequences

It is unanimously agreed upon the rapid degradation of forest caused by rural populations. Much of the villagers contribute to the degradation due to a combination of increased requirement for the rapidly growing population and open access to resources (Sharachandra 1993). The result imparts immense pressure on the natural resources.

In the present study "human disturbance" refers to resources extracted by human beings directly or indirectly for their subsistence living. Firewood collection, fodder lopping and timber extraction assigns direct interference in which humans are personally involved for such activities. On the other hand, pack animals, seasonal livestock grazing and seasonal movements of animals by herders are indirect interference since pressure is imparted by the animals but as a part for the need for human livelihood. Large-scale commercial and industrial exploitation has immediate visual impacts on forests while pressure exerted by human interference may not be obvious in short period. However, their impact in forest is profound and often they cause irreparable damage to the ecosystem. Effects of firewood collection, fodder lopping, timber extraction and livestock grazing are manifold and cumulative, which directly modify the ecological processes.

Many literatures are available on the impact of human interference on forest in the Himalaya (Friends 1983, Byers & Banskota 1993, Sundriyal *et al.* 1994, Garkoti & Singh 1995, Sundriyal & Sharma 1996, Sharma *et al.* 1998, Uma Shankar *et al.* 1998). Therefore, a careful study of impact in this direction is necessary and the knowledge of functioning to such interference would be important information for management to planners. This chapter deals on (a) resource extraction areas, (b) preferred species for firewood, fodder and timber and their quality, (c) extraction pressure in terms of annual firewood, fodder and timber demands and (d) assessment of disturbance parameters along the corridor.

4.3. Methods

In the preliminary phase of this study, forest use pattern by the communities and their perception regarding the preference of species for firewood, fodder and timber were investigated. An extensive Participatory Rural Appraisal (PRA) technique was applied for information gathering (Pretty *et al.* 1995). Matrix ranking tool from PRA was applied for collection of information on preference and availability of firewood, fodder and timber species. Resource extraction mobility map was used for mapping resources extraction pressure areas including information on grazing regime and NTFP extraction. This information was triangulated with other local persons who were not present at the time of PRA. Frequency of resources extraction was monitored from the trailhead of forests. All the head loads were recorded by their sex, age and the forest from where these were collected. In case of animal used, the numbers of animals were recorded and the quantity was estimated with 60 kg yak^{-1} and 30 kg $horse^{-1}$ as standard weight. A total of 71 days spread over all seasons were randomly sampled for collection during 1997. Frequency of collection was calculated on the basis of number of persons encountered during the sampling.

Preference ranking scores (higher the preference higher the scores) for fodder and firewood species were also evaluated and verified by laboratory analysis. Samples like branches of 2-3 cm diameter of 21 enlisted woody tree species for firewood and 25 species with palatable parts for fodder were collected from the field during December and January 1997-98. The collected samples were brought to laboratory within 36 hours in polythene bags. Fresh weight of samples were determined and then dried in hot air oven at 80^{0}C for 24 hours. Dry weight was taken for all the samples for estimation of moisture. Firewood density (specific gravity) was determined through water displacement technique from the dry weight. Samples were ground in an electric grinder to pass through 2 mm mesh sieve. Three samples of each species were considered for analysis. Moisture, dry matter content (DM), nitrogen, and crude protein (CP) of fodder species were estimated following Anderson & Ingram (1993). Samples were burnt in an oxygen bomb calorimeter to determine their calorific value (Leith 1973). Ash was determined by weighing 2 gm of samples and burnt in a muffle furnace at 550°C. Quality of any green fodder can be primarily judged on the basis of palatability, DM, CP, and available energy (Saha *et al.* 1997). As calorific value and CP are directly related, and ash content and moisture content inversely, a relationship was developed with the relative values of these components to get the fodder value index (FoVI) by developing the formulae given below for getting the gross idea of fodder quality.

$$\text{FoVI} = \frac{\text{Calorific value (kJ/g) x crude protein (g/g)}}{\text{Ash content (g/g) x Moisture content (g/g)}}$$

Calorific value, ash content, moisture and specific gravity (density) of species were used for calculation of Firewood Value Index (FVI) of different species following the formula given by Purohit and Nautiyal (1986):

$$\text{FVI} = \frac{\text{Calorific value (kJ/g) x density (g/cm}^3\text{)}}{\text{Ash content (g/g) x Moisture content (g/g)}}$$

Firewood consumption patterns by different stakeholders were analysed by weight method following Fox (1984). Firewood was weighed at each of the stratified sampling for households and direct observation for the stakeholders on three separate seasons, namely summer, monsoon and winter. These data were used to estimate the per capita consumption and then multiplied by total member in a household or stakeholders to get daily requirement. The data were standardised on yearly basis. Fodder demand for the total livestock was calculated by standardised consumption rate following Sundriyal (1995). Livestock fodder consumption standard rate used are 1.5 kg day^{-1} for pig, 15 kg day^{-1} for goat, 15 kg day^{-1} for sheep, 25 kg day^{-1} for horse, 30 kg day^{-1} for cattle, 35 kg day^{-1} for dzo and 35 kg day^{-1} for yak. Total fodder demand in the area was enumerated using animal numbers and consumption rate.

Disturbance parameters were checked in the field after triangulation of information gathered from PRA. Four sampling stands, two at lower forest (LF) in the elevation ranging from 1780 to 2350 m amsl (settlement of Yuksam generally depend on this forest) and two at upper forest (UF) in the elevation from 2350 to 3400 m (settlement of Tshoka and tourism enterprises depend on this forest). Nineteen permanent plots measuring 30 x 40 m size were sampled following the procedure of by Sundriyal *et al.* (1994), Sundriyal & Sharma (1996) and Metz (1997). Plots were laid in close canopy forest (>40% canopy cover), that remained relatively unused and distantly located from the settlements, and open canopy forest (<40% canopy cover) that were used and located near the settlements (see Chapter V for detail). Disturbance parameters were measured in 5 x 5 m randomly placed subplots numbering five within 30 x 40 m plots. Number of lopped branches, chopped trees, cattle dung, and trampling impressions were recorded from each subplot. Depth of sandy soil, dry leaf litter, clay and humus were also measured by digging 100 cm^2 pits upto 50 cm depth at the centre of each plot.

4.4. Results

4.4.1. *Forest resources utilisation pattern, preferences and consumption*

Communities of Yuksam practised a well-demarcated pattern for forest resource extraction. Out of the twelve settlements, two namely, Tshoka and Gyachen exclusively and other three partially used the corridor forest. Rest seven settlements used Pahakhola-Thaktu forest, Dubdi forest and Chihan Dara forest for firewood, fodder and timber collection (Fig. 4.1). Apart from these settlements, Himalayan Mountaineering Institute trainees, tourism related enterprises such as individual tourists, travel agents, porters, yakmen and trans-humans (yak and sheep herders) also depended on the natural resources of this corridor. Frequency analysis showed that the firewood collections were mainly made in winter during November to March (Fig. 4.2). Tourism enterprises (travel agencies and the support staff) related collection of the firewood occurred mainly in two peak tourist seasons during March to May and August to December. Chopped trees frequency analysis showed a low pressure on 10-20 cm diameter at breast height (DBH) class, medium pressure in 50-60 cm and high pressure on 20-50 cm class (Fig. 4.3).

4.4.1.1. *Firewood, fodder and timber - Species preference*

Baseline information gathered using PRA tools showed that the communities living at Yuksam and Tshoka used a wide variety of plant species for firewood, fodder and timber (Tables 4.1 & 4.2). Due to ability to recognise and knowledge on quality of species, the communities living in these areas practised resource collection with preference in species and compensated with other species if the preferred species were not available.

Preference for pairwise ranking on firewood, fodder and timber are presented in Table 4.1 and Table 4.2. Eleven woody tree species were listed as widely used firewood from the pair wise preference ranking at Yuksam. *Quercus lamellose* ranked the highest followed by *Schima wallichii, Eurya acuminata,* and *Castanopsis hystrix, Beilschmiedia sikkimensis* and *Prunus cerasoides.* Likewise, 22 plant species were enlisted with their preference ranking for fodder from Yuksam. Among these species 59% were tree fodder, 14% shrubs, 18% herbs and 9% climbers. *F. roxburghii* was the highest ranked species followed by *Pavetta indica, Saurauia napaulensis* and *Ficus nemoralis.*

Species preferences were quite different for the Tshoka community as they depended on cool temperate and sub-alpine species. *Q. lamellosa* ranked higher for firewood followed by *Q.*

lineata, Rhododendron arboreum and *Betula alnoides. Sorbus* sp. and *Symplocos ramosissima* ranked as the least preferred species. *Litsae elongata, Arundanaria* sp. and *Dedrocalamus* sp. have high ranking as fodder plants. *Acer laevigatum, A. oblongum* and *Magnolia* sp. were among the least preferred species. Among the timber species, *Michelia exelsa* ranked the highest followed by *Juglans regia* and *Q. lamellose* by the Yuksam community and *Abies densa* as the highest followed by *Acer oblongum* and *Q. spicata* by the Tshoka community. *Alnus nepalensis* although being the least preferred species; it was used widely because of its availability. At Tshoka, *B. alnoides* and *Magnolia campbellii* were among the least preferred species.

4.4.1.2. *Firewood and fodder-Quality*

The data collected on firewood characteristics of 21 widely used woody tree species from Yuksam and Yuksam-Dzongri trekking corridor is presented in Table 4.3. Almost all the rhododendrons were found to have high calorific value. Among them, *Rhododendron fulgen* showed the highest value followed *by R. grande, R. decipiens, R. arboreum, R. falconeri* and *R. barbatum*,. Ash content was the lowest in *R. lanatum*. Comparatively, *R. decipiens, R. barbatum, R. fulgen* and *R. arboreum* had higher ash content. Among the other species, higher calorific value was found in *P. cerasoides* followed by *Schima wallichii, C. hystrix* and *Quercus* *lamellose*. Ash content among these species was the lowest in *Eurya acuminata* and *Symplocos ramisissima*. High moisture content was recorded in *S. ramosissima* and *S. wallichii*. Overall, biomass-ash ratio was the highest for *R. lanatum* followed by *R. decipiens, R. barbatum*, and *R. arboreum* and the lowest value was in *Acrocarpus fraxinifolius*. Among the species with high calorific value, *R. lanatum* had the highest wood density (0.78 g cm^{-3}). Among the rhododendrons, *R. arboreum* showed the highest FVI value with low ash content, high density and low moisture. Other three species of rhododendrons namely, *R. lanatum, R. decipiens* and *R. barbatum* also had higher FVI values. Among the other species, *Quercus* sp., *Symingtonia populnea* and *P. cerasoides* were found to be highly desirable firewood when compared with *E. acuminata, Q. lamellose* and other non-rhododendron species. The least desirable species were *S. ramosissima, A. fraxinifolius* and *Alnus nepalensis* due to their low density and high ash contents (Table 4.3). Basically all the species with high calorific value showed low nitrogen content than the species with low calorific value.

Table 4.4. shows some selected fodder species, preferred and widely utilised by the local community of Yuksam with their calorific and fodder values. Among the 25 selected fodder species, 40% were the tree fodder, 24% shrubs, 28% herbs and 8% climbers. Among these species, the highest calorific value was in *Crysopogon*

gryllus followed by *Arundanaria hookeriana, Brassaiopsis mitis, Prunus cerosoides* and *Thysanolaena maxima.* Tree leaves were found to contain high dry matter (DM) than shrubs, herbs and climbers. For example, 40% of tree fodder contained more than 40% DM compared to 33% in the shrubs and only 29% in herbs. The highest DM containing trees, shrubs, herbs and climbers were *Quercus lamellose, Glochidion acuminatum, Quercus* sp (trees), *Arundanaria* spp. (shrubs), *Imperata cylindrical* (herb) and *Ichnocarpus frutecens* (climber). Majority of species contained > 10% ash in the DM. Species with high protein content (>10%) were nearly 40% in the tree species, 50% in shrubs, 29% in herbs and 100% in the climbers. Fodder value index showed that *Quercus* sp. had the highest value followed by *I. frutecens, F. roxburghii, Litsae elongata* and *Q. lamellosa.* Species such as *A. hookeriana, T. maxima, Brassaiopsis mitis, Saurauia nepaulensis* and *Ficus nemoralis* showed moderate values (Table 4.4).

4.4.1.3. Firewood, fodder and timber -consumption

Collections of firewood from forests are mainly made during the winter season. Frequency of collection was recorded highest during the month of January and minimum in September (Fig. 4.2). The data from the field revealed that frequency of chopping trees for firewood was the highest for medium sized trees followed by small tree and large trees (Fig. 4.3). The total demand for the firewood for community as well as other tourism enterprises was estimated to be 2433 Mg year^{-1}. About 55% of the total demand is met from trail forests both for community and tourism purposes (Table 4.5). Domestic cooking is the major consumer of fuelwood followed by water heating and other purposes. Consumption ranges from 2264 Mg year^{-1} by community and lowest of 1.02 Mg year^{-1} by pack animal operator. On an average the hotel and lodges consumed about 40 to 50 kg of fuelwood per day. A large quantity of fuelwood was used by HMI during training courses for cooking and otherwise (Table 4.5). There were visible changes in the fuelwood consumption pattern among the stakeholders during different seasons (Table 4.6). Higher fuelwood consumption was recorded during the winter season for almost all the stakeholders. The estimated value revealed that community alone used three times more fuelwood in winter compared to the summer (Table 4.6).

Four sources of firewood supply were identified in the study area such as (a) homestead surroundings, (b) privately owned wooded (agroforestry system) area, (c) community used forest (khasmal), and (d) reserve forest and biosphere reserve. Both private owned forest and government forest met most of the demands of firewood (Fig. 4.4). About 76% of firewood was procured from government forests including biosphere reserve and only 21% came as support from the private forest. Homestead surroundings provided *Jhikra* (3%) that included portion of old wooded fences, dried bamboo pieces as it catches fire soon, and agricultural residues as maize and millet stacks, especially for livestock feed preparation. About 79% of the total household depend upon the firewood for cooking and other purposes followed by 14% of the households on kerosene oil, 4% on electricity and 3% of the household depend on LPG.

Amount of the firewood consumption was the highest in winter (29±10.1 $kg^{-1}day^{-1}family^{-1}$) and lowest in summer (18±6.9 $kg^{-1}day^{-1}family^{-1}$). The mean daily consumption of the wood was found 25.5 $kg^{-1}day^{-1}family^{-1}$ for an average household size of 6.28 individuals with per capita of 3.45 kg at lower elevation and 4.17 kg at higher elevation.

On the basis of standard values for livestock, the total demand of fodder was found 1209 Mg yr^{-1} for the entire livestock present in the study area (Table 4.7). During 1996-98, a net increase of 63% fodder demand was estimated. Fodder demand for cattle was the highest (41%) followed by sheep (21%) and goat (14%). The demand for dzo, yak, pig and horses were respectively 13%, 8%, 1% and 2% of the total.

Large number of trees with <10 cm DBH were used as timber for house construction and renovation just in a time interval of 3-5 years (Table 4.8). Use of medium sized trees (20-40 cm DBH) and large trees (30-70 cm DBH) were comparatively low and in greater time interval of 5-7 years and 15-25 years, respectively.

4.4.2. Disturbance parameters

Values of disturbance parameters and their standard deviations are given in Table 4.9. Number of lopped branches and chopped trees were high in the open forest condition and low in the close canopy forest. Other indicators of disturbance like depth of humus, depth of dry leaf litter and depth of clayey soil were higher in the dense forest showing less interference. Trampling impression and dung numbers were higher in open forest condition where animals were usually stalled overnight.

4.5. Discussion

People of Yuksam use four main forest areas for resources. Compared to other three forests, high pressure was observed in the KBR corridor forests. A wide variety of plant species was used by their preference as firewood, fodder and timber from the farmland and forests. Dependency on forest for firewood was higher compared to other parts of Sikkim (Sharma *et al.* 1992). Forests have immense pressure for firewood, fodder and timber as a settlement is located at the vicinity of the biosphere reserve and tourism sector is flourishing in uncontrolled and unmanaged direction.

Local preference of firewood is an age-old trend in the Himalaya, but assessments of such knowledge with scientific support are countable (Purohit & Nautiyal 1986). For ideal firewood, high heat of combustion, high density of wood, low ash contents and other combustion properties are most desirable. Also, chemical analysis can indicate the gross feeding potential of the feeding stuff (Narayanan & Dabadhao 1972) and provides important information about their qualities (Bajracharya *et al.* 1985, Purohit & Nautiyal 1986). It is therefore, felt important to assess the qualities as per preference. The pattern of species preference for use depends upon the quality of the firewood, season of the collection and time required for drying it before use. People of Yuksam depend on the reserve for selective species of their choice for firewood or timber. The selection of high quality species for fuelwood, fodder and timber has declined the number of such trees along the corridor. On the other hand, Tshoka community completely depended on the reserve for all forest based resource requirements.

Among the temperate species *Quercus* sp. and *S. populnea* were found to have high FVI and almost all the rhododendrons from sub-alpine forest corresponded with the preference ranking. High ranked species for warm-temperate and cool temperate-sub alpine forest matched with the scientific properties. Similar study was also carried out in the Central Himalaya (Purohit & Nautiyal 1986). Nitrogen contents in almost all the lower ranking species were higher. These attributed that higher nitrogen contents emit more nitrogen oxides from the wood during combustion reducing the acceptability as good wood (Purohit & Nautiyal 1986, Nautiyal & Purohit 1988). Due to low ash content, high density and low moisture, *R. arboreum* was found to be the most desirable firewood with highest FVI value.

Among the enlisted species for fodder from Yuksam, all the higher ranked species were tree fodder except *I. Frutecens. Quercus* sp, although have high fodder values were not used commonly and their preference ranking was not higher. However, in the Central Himalaya *Quercus* is regarded as preferred fodder generally in winter under crises when other fodder plants were not amply available (Purohit & Sammant 1995). Shrubs, herbs and climbers showed comparatively low preference ranking as also reported by Bajracharya *et al.* (1985). This is attributed to the seasonal availability of species. Among the 25 fodder species enlisted *Quercus* sp., *I. frutecens, F. roxburghii and L. elongata* were found to have high quality of fodder with comparatively high calorific value and other characteristic (see also Saha *et al.* 1997, Rajhan 1977). In spite of high calorific values, many shrubs and herbs species had low feed value due to higher moisture contents and low protein. Calorific values of fodder were found to have wide variation between species to species. The present findings revealed that the quality of fodder does not depend solely on one parameter like calorific values or the protein contents, but on the combination of qualities, which resulted in deciding the high feed value of fodder. The result corresponded with the report made by Bajracharya *et al.* (1985) and Bajracharya & Chaudhary (1986). Chemical composition of fodder differed from place to place as observed from reports of Mamlay (Sharma *et al.* 1992), other parts of Sikkim (Sinha 1982, Balaraman 1987, Balaraman *et al.* 1990, Balaraman & Goyal 1991, Saha *et al.* 1997) and Nepal (Bajracharya *et al.* 1985, Bajracharya & Chaudhary 1986). This attributed to ecological factors including soil and climate, which influence the chemical composition of fodder plant (Wolf 1972). Most of the tree species ranked higher as fodder by the local community corresponded with > 30% dry matter and < 10% ash (Rajhan 1977), suggesting that the local knowledge of preference are compatible with scientific attributes for the selection of better fodder. Inspite of high crude protein content and comparatively high calorific value, the fodder value of *F. nemoralis* was found relatively low due to high ash content. Chemical properties and fodder value index of species such as *F. roxburghii, F. nemoralis* and *P. cerasoides* matched with the higher ranking preference of these species by the people. Other species such as *Artemesia vulgaris, E. sessile* and *Rhaphidophora* sp, showed low rank in preference as well as low values in chemical properties. The sequence of preferences was not in the order of fodder values showing variation from the matrix scores. This variation brought some doubt for chemical properties and preference ranking. Therefore, the chemical properties and preference rank agreement seems to be questionable for most of the fodder species, thus the authenticity on the information of quality of plants provided by the community should be considered with caution (Bajracharya & Chaudhary 1986).

Firewood collection and stocking for rainy season by the villagers have been common in the area. A huge amount of firewood and fodder extraction has been recorded in the area. Firewood was collected either from felled trees or from chopped branches. Collections are made by head-loads either by putting into a *Doko* (bamboo basket) or by tying with rope or bark of Argeli (*Edgeworthia gardeneri*). Men, women, children and even dzos are engaged for carrying the firewood loads from the forest to villages. The pressure for natural resources on the trail forest is comparatively higher than the other surrounding forests. Tourism activities and the pressure of different stakeholders are also noteworthy. Such pressure at the high altitude area may result severe degradation in future bringing about considerable impact on the forests and wildlife (Bjonness 1980, Byers 1986, Baskota & Sharma 1994).

Present study revealed that the forests remained undisturbed at steeper slopes and forest degradation has increased at the forests where human interference was more pronounced. Such areas are located at gentle slope and near the human habitation or campsites (personal observation). This indicates that the resources were generally used from the forest that was situated in gentle slopes. This was mainly because of easy access to forest sites of gentle slope (Brown *et al.* 1991). Chopping of trees and lopping of branches whose numbers were higher at disturbed areas have significantly disrupted the canopy structure leading to open conditions.

4.6. Conclusion

Forest based resources are the integral part of the Himalayan livelihood. Yuksam-Dzongri trekking corridor of the Khangchendzonga Biosphere Reserve in Sikkim has faced immense human pressure on its natural resources in the recent years. Rapid increase in tourist number and livestock has caused threat to the forest resources of the area. Large amount of firewood, fodder and timber extraction by the community as well as tourism enterprises is deteriorating the quality of forests. Selection of species by preference is widely practised in the area. Interestingly, local preference and the chemical properties have shown that the local knowledge is compatible with scientific attributes for most of the species. Extraction of firewood, fodder and timber for community and tourism purposes was observed all along the trekking corridor but has been more pronounced near the major settlement of Yuksam. Tourism related pressure on the forest was distinctly noticeable at Tshoka, the first camping site on the trail. Removal of selective canopy species for firewood, fodder and timber has changed the forest quality.

Indicators of disturbances are pronounced at the open forest due to the result of immense human as well as grazing pressure. Therefore, management of trekking corridor forests should be oriented in such ways that pressure on preferred canopy species is minimised. Area should be encouraged for assisted natural regeneration and simultaneously discouraging continued pressure. Enterprises and community should be made aware of the legal status of KBR. The use of alternative sources of energy should be encouraged for improvement of the forest conditions to make the area more attractive and valuable in terms of biodiversity.

Table 4.1. Pair-wise ranking scores of preferred species used as firewood, fodder and timber at Yuksam, west Sikkim.

Place/species (local name)	Firewood	Fodder	Timber
Acer laevigatum (Putli)	-	4	4
Alnus nepalensis (Uttis)	2	-	1
Amoora wallichii (Laali)	-	5	-
Artemesia vulgaris (Teteypaty)	-	9	-
Arundinellan nepalensis (Kharuki)	-	16	-
Beilschmiedia sikkimensis (Tarsing)	5	-	2
Betula cylidrostachys (Saur)	-	4	4
Castanopsis hystrix (Patle katus)	4	-	7
Cedrela toona (Tooni)	-	6	7
Cryptomeria japonica (Dhuppi)	2	-	-
Dendrocalamus spp (Bans)	-	1	1
Edgeworthia gardneri (Argeli)	0	-	-
Elatostemma sessile (Gagleto)	-	14	-
Eurya acuminata (Jhinguni)	8	0	-
Ficus nemoralis (Dudhilo)	-	19	-
Ficus roxburghi (Nebara)	-	22	-
Imperata cylindrical (Seeru)	-	10	-
Machilus edulis (Kaulo)	7	3	5
Machilus odoratissima (Lali kaulo)	6	-	5
Juglans regia (Okhar)	-	-	11
Michelia exelsa (Chanp)	-	-	10
Pauzolzia viminea (Chiple)	-	15	-
Paveta indica (Kanyu)	-	21	-
Prunus cerosoides (Panyun)	5	17	-
Prunus nepaulensis (Arupate)	2	-	3
Quercus lamellose (Bajrant)	10	-	9
Rhaphidophora sp (Kanchirna)	-	6	-
Rubia manjith (Majhito)	-	0	-
Saurauia nepaulensis (Gagoon)	-	20	8
Schima wallichi (Chilaune)	9	-	6
Symingtonia populnea (Pipli)	-	2	8
Thysanolaena maxima (Amliso)	-	17	-
Viburnum cordifolia (Asare)	7	3	-
Weigtia gigantia (Bauni kat)	-	2	2

Table 4.2. Pair-wise ranking scores of preferred species used as firewood, fodder and timber at Tshoka, west Sikkim.

Species (local name)	Firewood	Fodder	Timber
Abies densa (Gobre salla)	4	-	11
Acer oblongum (Phirphire)	4	1	8
Acer papilio (Kapase)	3	1	-
Arundanaria sp. (Parang)	6	9	-
Betula alnoides (Saur)	8	3	4
Cyperus sp. (Bukki)	-	7	-
Dendrocalamus sp.(Bans)	1	8	-
Litsae elongata (Pahenli)	2	10	-
Magnolia campbellii (Ghoge chanp)	6	-	4
Magnolia sp. (Phusre chanp)	6	1	-
Prunus rufa (Lekh panyun)	-	4	-
Quercus lamellosa (Bajrant)	10	4	7
Quercus lineata (Phalant)	11	-	8
Rhododendron arboreum (Lali guras)	6	-	-
Rhododendron barbatum (Curling)	6	-	-
Rhododendron falconeri (Curling)	4	-	-
Sorbus sp. (Pansi)	2	-	-
Symplocos ramisissima (Kharane)	1	3	-

Tabble 4.3. Wood energy, density, ash and firewood values index (FVI) of 21 woody tree species of Yuksam and Yuksam-Dzongri trekking corridor.

Species (local name)	Calorific value (kJ/g)	Ashfree calorific value (kJ/g)	*Density* (g/cm^3)	Biomass /ash ratio	Moisture (%)	Ash (%)	N (%)	FVI
Rhododendron arboreum (Lali guras)	19.63	19.72	0.69	222.22	25	0.49	0.21	11057
Rhododendron lanatum (Bhutle guras)	18.79	18.82	0.78	625.00	54	0.26	0.22	10439
Rhododendron decipiens (Jhukaune guras)	19.81	19.87	0.67	303.03	49	0.33	0.26	8202
Rhododendron barbatum (Lal chimal)	17.84	17.91	0.75	263.16	47	0.38	0.29	7492
Quercus sp (Ainte)	17.72	17.81	0.77	196.07	41	0.51	0.40	6525
Rhododendron fulgen (Chimal)	20.10	20.20	0.62	217.39	45	0.46	0.17	6020
Symingtonia populnea (Pipli)	17.78	17.92	0.89	129.87	45	0.77	0.17	7645
Rhododendron falconeri (Korling)	19.21	19.30	0.65	217.39	49	0.46	0.17	5539
Rhododendron grande (*Patle korling*)	19.98	20.15	0.68	120.48	42	0.83	0.19	3897
Prunus nepualensis (Arupate)	18.32	18.46	0.76	123.46	47	0.81	0.33	3657
Eurya acuminata (Jhiguni)	16.64	16.75	0.72	151.51	50	0.66	0.37	3630
Quercus lamellose (Bajrant)	18.25	18.47	0.86	86.21	39	1.16	0.31	3469
Prunus cerasoides (Panyun)	19.93	20.15	0.73	89.28	44	1.12	0.27	2952
Viburnum cordifolium (Asare)	16.64	16.84	0.69	87.71	38	1.14	0.47	2650
Beilschmiedia sikkimensis (Tarsing)	15.63	15.79	0.68	102.04	41	0.98	0.25	2645
Castanopsis hystrix (Jat katus)	18.49	18.78	0.88	64.51	43	1.55	0.38	2441
Symplocos glomerata (Kholmen)	11.81	11.89	0.66	151.51	54	0.66	0.22	2187
Schima wallichii (Chilaune)	19.15	19.41	0.96	73.53	66	1.36	0.23	2048
Symplocos ramosissima (Kharane)	15.09	15.24	0.67	149.25	76	0.97	0.30	1371
Acrocarpus fraxinifolius (Mandane)	16.05	16.46	0.58	39.52	48	2.53	0.32	766
Alnus nepalensis (Uttis)	15.87	16.25	0.45	42.55	54	2.35	0.33	563

Table 4.4. Leaf energy, nutrients and fodder value index (FoVI) of 25 widely used fodder species of Yuksam and Yuksam-Dzongri trekking corridor.

Species (local name)	Calorific value (kJ/g)	Ashfree calorific value (kJ/g)	Moisture (%)	Dry matter (%)	Ash (%)	Nitrogen (%)	Crude protein (%)	FoVI
Quercus sp. (Ainte)	17.36	17.93	51.8	48.2	3.2	1.53	9.6	101
Ichnocarpus frutecens (Dudhe lahara)	18.86	19.6	64.4	35.6	3.8	1.88	11.7	90
Ficus roxburghii (Nebaro)	18.60	19.53	66.7	33.3	4.8	2.35	14.7	85
Litsaea elongata (Pahenli)	19.35	20.69	57.8	42.2	6.5	2.25	14.1	73
Quercus lamellosa (Bajrant)	18.23	17.06	35.0	65.0	6.4	1.24	7.7	63
Arundanaria hookeriana (Parang)	20.85	22.15	52.0	48.0	5.9	1.38	8.6	58
Thysanolaena maxima (Amliso)	20.04	21.99	62.0	38.0	8.9	2.54	15.8	57
Brassaiopsis mitis (Phutta)	20.23	21.32	72.2	27.8	5.1	1.38	8.6	47
Crysopogon gryllus (Salimo)	22.66	24.68	60.0	40.0	8.2	1.41	8.8	41
Saurauia napaulensis (Gagoon)	18.23	20.14	61.1	38.9	9.5	2.09	13.1	41
Imperata cylindrica (Seeru)	18.92	20.45	53.4	46.6	7.5	1.36	8.5	40
Ficus nemoralis (Dudhilo)	19.92	22.42	70.0	30.0	11.2	2.24	14.0	36
Pantapanax leschenaultii (Chinde)	19.11	20.64	63.9	36.1	7.4	1.36	8.5	34
Bambusa nutans (Malla Bans)	19.23	21.06	66.2	33.8	8.7	1.42	8.87	30
Aconogonum molle (Thotne)	19.98	22.6	67.5	32.5	11.6	1.78	11.1	28
Prunus cerasoides (Panyun)	20.04	22.59	67.7	32.3	11.3	1.69	10.6	28
Arundanaria racemosa (Mallingo)	18.86	22.05	43.3	56.7	14.5	1.37	8.6	26
Glochidion acuminatum (Lati kat)	17.23	19.21	53.7	46.3	10.3	1.30	8.1	25
Solanum aculeatissum (Bhede ghans)	18.61	20.63	61.7	38.3	9.8	1.26	7.9	24
Elastostemma sessile (Thulo gagleto)	15.73	17.11	77.3	22.7	8.1	1.56	9.7	24
Cauteleya spicata (Pani saro)	18.04	20.31	78.8	21.2	11.2	1.78	11.1	23
Artemesia vulgaris (Tetey pattey)	17.17	19.33	75.9	24.1	11.2	1.70	10.6	21
Rhaphidophora sp. (Kanchirna)	18.17	22.21	76.0	34.0	12.6	1.69	10.6	20
Eragrostis tenella (Banso)	17.67	21.42	54.2	45.8	17.5	1.46	9.12	16
Leucanthus pedicularis (Sanu gagleto)	14.73	18.69	75.5	24.5	21.2	1.94	12.13	11

Table 4.5. Fuelwood consumption for different purposes by stakeholders

Stakeholder	Purposes: Cooking ($Mg\ yr^{-1}$)	Water-heating ($Mg\ yr^{-1}$)	Other purposes ($Mg\ yr^{-1}$)	Total ($Mg\ yr^{-1}$)
Community	1896	260	109	2264
Hotel/lodges	86	12	3	100
HMI	37	6	0.2	44
Travel agent	6	1	0.2	7.2
FIT's	1.4	0.3	1	1.9
Pack-animal operator	0.8	0.08	2	0.98
Porter	13	0.6	2	15.6
Total	2040.2	279.9	116.5	2432.68

HMI = Himalayan Mountaineering Institute, FIT's = Free and independent trekkers

Table 4.6. Stakeholder wise seasonal fuelwood consumption pattern

Stakeholders	Consumption (Mg day^{-1})			Average (Mg day^{-1})	Annual (Mg day^{-1})
	Summer	Rainy	Winter		
community	378.32	756.64	1128.76	6.20 [1]	2264
Hotel/lodges	16.72	33.45	49.90	0.27 [2]	100
HMI	2.30	13.07	28.51	0.24 [3]	44
Travel agent	0.16	3.40	3.56	0.010 [4]	7.2
FIT's	0.65	0.00	1.30	0. 001 [5]	1.9
Pack-animal operator	0.086	0.41	0.53	0.002 [6]	0.98
Porter	280	6250	8.85	0.002 [7]	15.6

1, 2: Community and hotel consumption per day 3, 4: Per group, 5, 6, 7: per person

Table 4.7. Livestock number, increase during 1996-1998 and fodder consumption estimation from Yuksam and Yuksam-Dzongri trekking corridor.

Livestock	Years		Fodder consumption (Mg yr^{-1})	Increase in fodder consumption (%)
	1996	1998		
Dzo	96	122	156	27
Yak	83	78	100	-6
Horse	31	22	20	-29
Cattle	245	454	497	85
Goat	361	311	170	-14
Sheep	441	461	252	5
Pig	273	260	14	-5
Total	**1530**	**1708**	**1209**	**63**

Table 4.8. Timber use pattern of the community of Yuksam and Tshoka

Characteristics	Dimensions
Large size poles	
Time interval (years)	15 – 25
Tree number	2 - 5
Average (DBH) size (cm)	40 – 70
Wood volume required (m^3)	2.35 – 4.77
Medium size poles	
Time interval (years)	5 – 7
Tree number	10 – 15
Average size (DBH) size (cm)	20 – 40
Wood volume required (m^3)	2.16 – 7.1
Small size poles (mainly bamboo)	
Time intervals (years)	3 – 5
Number of poles required	80 – 120
Average(DBH) size (cm)	< 10
Wood volume required (m^3)	8.16 – 15.1

Table 4.9. Disturbance at two forests conditions along Yuksam-Dzongri trekking corridor. Values are mean ±SE

Disturbance parameters	Forest conditions	
	Open forest	Close forest
Chopped Branch (per ha)	15.68±3.68	4.96±0.16
Chopped Tree (per ha)	14.40±2.88	0.80±0.52
Naturally fallen tree (per ha)	7.20±4.16	6.72±2.21
Cow dung (per 25 m^2)	1.63±0.25	0.30±0.06
Dzo dung (per 25 m^2)	0.58±0.12	-
Horse dung (per 25 m^2)	0.13±0.07	-
Sheep dung (per 25 m^2)	0.40±0.23	-
Trampling (per 25 m^2)	77.27±9.87	21.60±2.7
Dry litter (depth in cm)	0.73±0.31	4.50±0.58
Humus (depth in cm)	0.40±0.21	2.62±0.28
Clayey soil (depth in cm)	1.25±0.94	5.22±0.64

- Not found

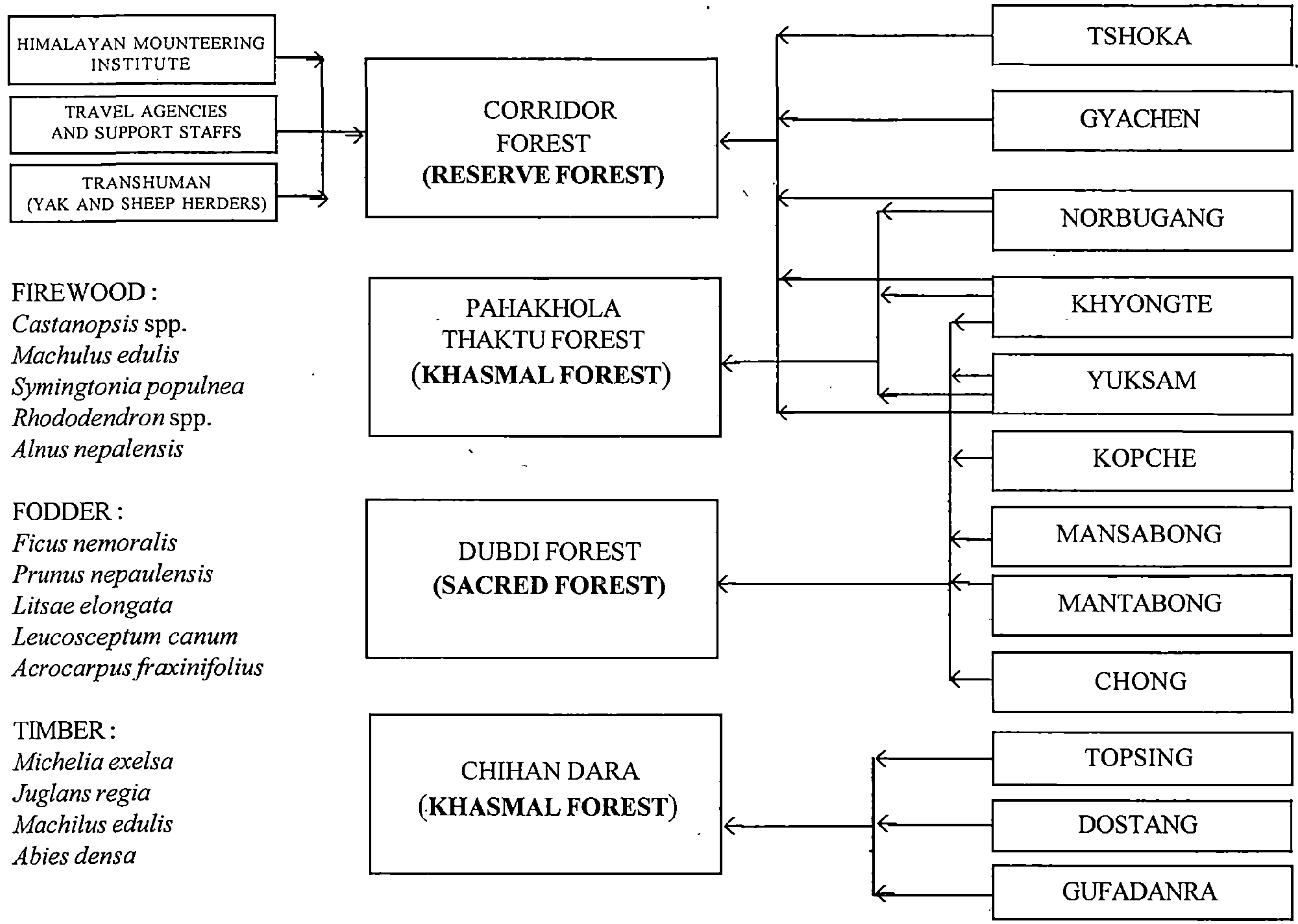


Fig. 4.1. Tourism/HMI, transhuman and settlements based user groups of firewood, fodder and timber and their linkage with four major forest locations surrounding Yuksam and along Yuksam-Dzongri treeking corridor in Khanchendzonga Biosphere Reserve. Some of the preferred and utilized species of firewood, fodder and timber are listed.

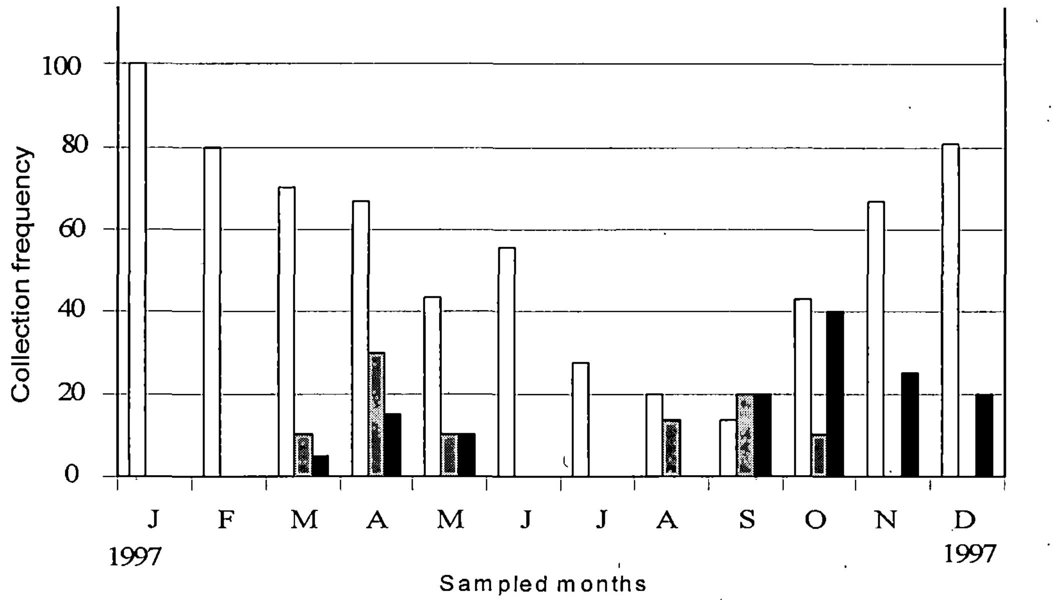


Fig. 4.2. Monthwise fuelwood collection frequency of community, portor and tourism agencies along Yuksam-Dzongri trail. Frequency is expressed in percentage calculated based on collection encounter by authers during field visits. Blank block = Community, grey shaded = porter and dark shaded = Tourism agencies.

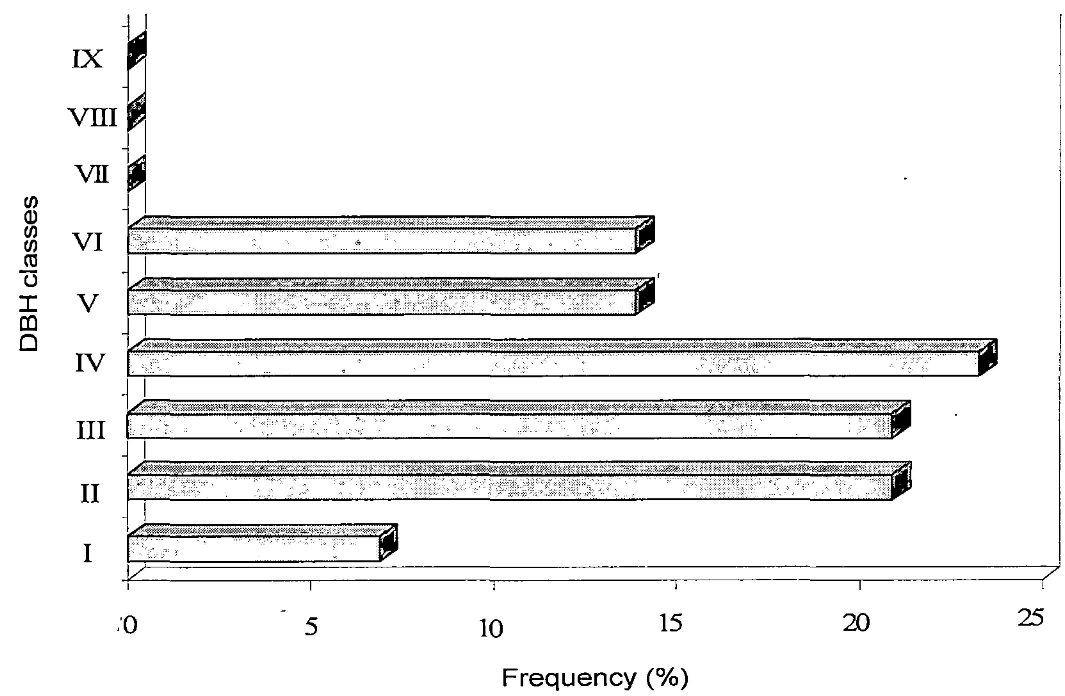


Fig. 4.3. Chopped tree frequency of different DBH classes showing low pressure (< 5%), medium pressure (5-15%) and high pressure (>(15%) on medium sized (20cm-50cm) tree along Yuksam-Dzongri trail. DBH class (cm) I = 10-20, II = 20-30, III = 30-40, IV = 40-50, V = 50-60, VI = 60-70, VII = 70-80, VIII = 80-90 and IX = 90-100.

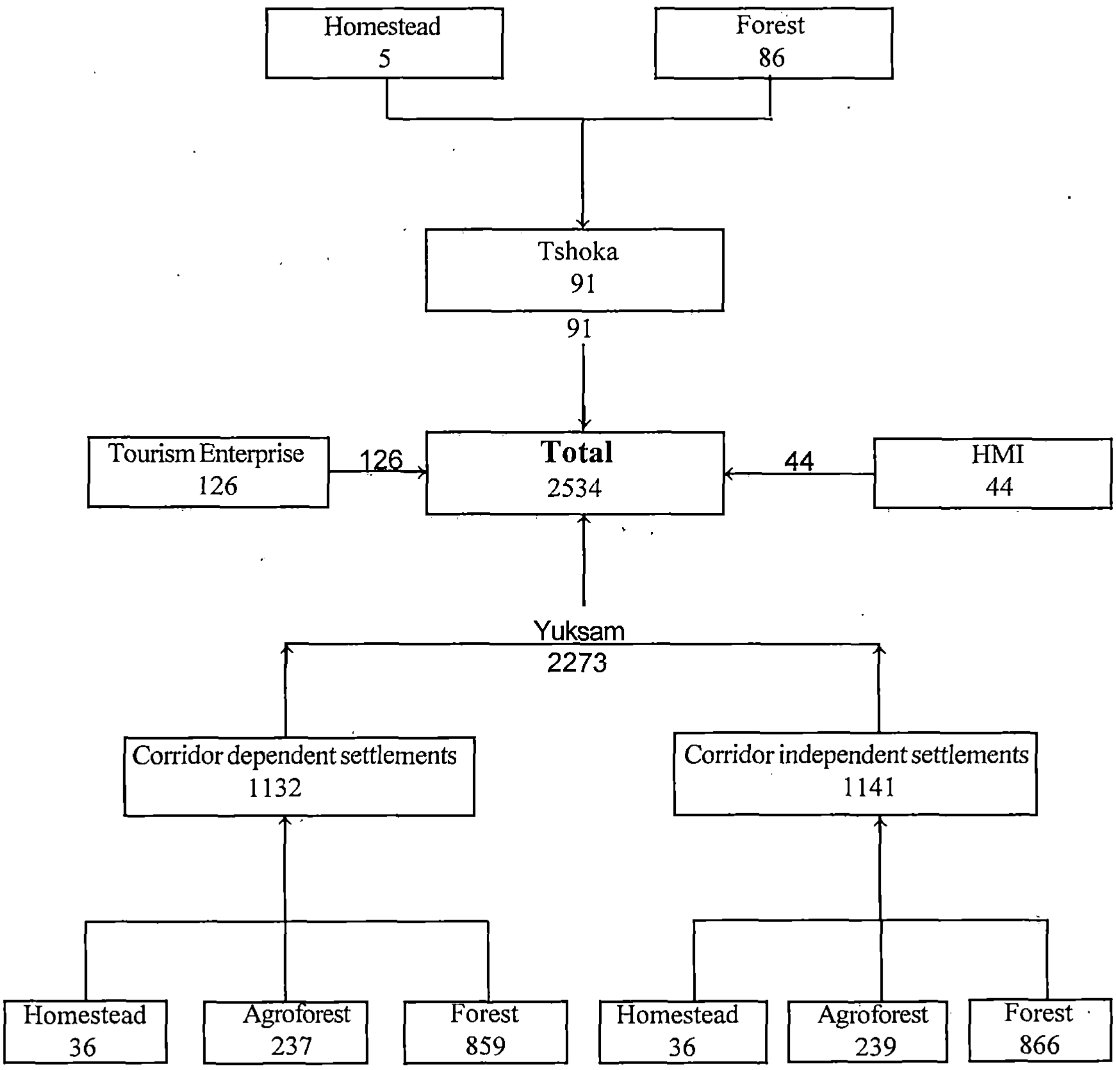


Fig. 4.4. Annual firewood consumption (Mg) from different landuse sources for Yuksam and Tshoka settlements and non community use (tourism and Himalayan Mountaineering Institute courses) along Yuksam-Dzogri forest corridor.

CHAPTER V

Chapter V

Vegetation structure, regeneration, woody biomass and productivity

5.1. Introduction

The Himalayan chain is a unique storehouse of precious biotic and abiotic reserves that stretches from Indus to Bhramaputra (Sahu 1986). It is not only mammoth of cultural symbol but also an important determinant in shaping our economy, milieu and climate (Pant 1980). India endows most of the Himalayan region with bounties of nature and culture evolved and preserved through process of civilisation, and contains some of the most restricted and threatened ecological systems on earth. Most of the spectacular and rugged mountain range of the Himalaya is biologically unexplored, thus the biological diversity of entire Himalaya is not properly known. The Himalaya offers an array of forest types with high biodiversity below the timberline, and is the cradle of major rivers of India. Most of these areas are now very much in the gamut of developmental process. Heavy demographic pressure with ever increasing demand for agriculture lands, firewood, fodder and cattle grazing and with developmental schemes like hydro-electric projects and extension of roads into hitherto trackless areas, have committed ecological aggression against environment. These activities have been leading to substantial reduction of forest cover, which in turn leading to serious ecological disasters such as soil erosion, landslides, loss of soil fertility and catastrophic floods (Saxena & Singh 1982b).

Extensive studies of Himalayan forest structure have been made by several authors (Tewari & Singh 1981, Ralhan *et al.* 1982, Saxena & Singh 1982a, 1982b, Saxena *et al* 1982, Singh & Ramakrishnan 1982, Shukla & Ramakrishnan 1984, Khan *et al.* 1986, Khan & Tripathi 1987, Sundriyal & Bist 1988, Ramakrishnan 1991, Singh & Singh 1992, Metz 1997). As the forest efficiency depends on the type, quality and stratification of vegetation, a qualitative evaluation of vegetation is a pre-requisite (Saxena & Singh 1982a). A detail description of canopy profile is also important for the study of forest condition because canopy organisation acts as a platform of interaction between forest and atmosphere for model of light interception (Anderson 1966, Miller 1967), photosynthetic capacity (Schulze *et al.* 1977) and evaporation (Lindroth & Haldin 1986). The product of interaction determines the quality of forest ecosystem.

Sikkim is widely acknowledged as India's most significant biodiversity *Hot Spot* (Kumar 1993, Shenga 1994) and one of the world's most critical centre of biodiversity (Myers 1990, WCMC 1992) with 550 species of orchids (95 genera), 36 species of rhododendrons (45 varieties), 4000 species of flowering plants, 9 species of conifers, 300 species of ferns and allies (WII 1997), and 175 species of Wild edible plants (Sundriyal & Rai 1996, Sundriyal 1999). In the last few decades there have been a continuous decline of species composition and density of plants at certain locations in Sikkim (Sundriyal *et al.* 1994). Urban development, tourism impact, profitable and non-profitable forest produce collections are the primary threats to biodiversity in the Sikkim Himalaya (Sharma *et al.* 1992, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996, Rai & Sundriyal 1997). Now emphasis has been given for conservation of biodiversity in most of the areas in the Himalaya (Rao 1995).

However, very few studies have been undertaken on natural resources in the Sikkim Himalaya (Sundriyal *et al.* 1994, Sundriyal & Sharma 1996). The tree species, their density, productivity and vegetation complexity and resource exploitation patterns have a direct impact on the wildlife (Willson 1974, Maratha & Louis 1998, Bland, 1993). The present chapter provides the information obtained from the investigation on vegetation structure and biomass productivity in two (open and closed) forest types along the popular Yuksam-Dzongri trekking trail in west Sikkim. The relationship of some structural components of forests to the bird and butterfly community will be dealt with in Chapters VI, VII and VIII.

5.2. Methods

Depending on elevation the trekking corridor forests have been divided into two zones namely lower forest ranging from 1780–2350 m amsl (LF) and upper forest ranging from 2350–3500 m amsl (UF). The resources from LF is utilised by the communities, particularly of Yuksam for their daily requirements and some are also used for tourism purposes by non-residents. The hydro-power project labourers also used these forests until 1997 when the project was scrapped. On the other hand, at UF, Tshoka community and tourism related enterprises depend for various resources, either for recreation or for utilisation.

The study of vegetation parameters was undertaken in closed canopy (CC) and open canopy (OC) forests with respect to their canopy cover percentage. Based on the resources extraction intensity the OC forest was designated for utilized or CC forest as less utilized. Furthermore, OC having <40% canopy cover and CC having >40% canopy cover were considered based on mapping following IRS-IA LISS II satellite data of 1988. Rectangular plots of forest with topographical homogeneity were used (Sundriyal *et al.* 1994, Sundriyal & Sharma 1996, Metz 1997). Sampling stands with permanent plots measuring 30 m x 40 m were laid in both LF (CC = 4, and OC= 5) and UF (CC= 4, OC = 6) between 1780 m and 3400 m asml. Total number of permanent sample plots laid were 19 all along the trail. Trees in each plot were identified, marked at 1.3 m as diameter at breast height (DBH) for annual increment measurement. The DBH was measured using specific diameter tape. Height of the trees was estimated using clinometer. Stems having >10 cm diameter at 1.3 m height from the ground were considered as trees, stems <10 cm but >2.5 cm diameter as saplings and <2.5 cm diameter stems as seedlings. Saplings and seedlings were recorded in 5 m x 5 m subplots numbering five in each stand.

All tree species listed from the stands were used for calculating an importance value index (IVI), which was the sum of relative abundance, relative frequency and relative dominance. Shannon-Wiener's index of species diversity and concentration of dominance were estimated following Hayek & Buzas (1997). The ratio of abundance/frequency (A/F) was used to interpret distribution pattern of the species (Whitford, 1949). If A/F ratio was < 0.025, the distribution was regular, between 0.025-0.05 it was random and if > 0.05, it was contagious (Curtis & Cottam, 1956). Canopy depth of all trees was estimated by subtracting first branch height from the total height.

In forests, vertical and horizontal architecture of canopy structures were assessed non-destructively, with ground level observation. Sampling of forest structural profile was made on each of the above-mentioned four forest conditions. In order to include maximum number of dominant species in the diagram, a 30 m line stripe was found sufficient to have three sections of 30 m each except for one forest with two 30 m stripes and one with 40 m. Samplings were undertaken at gentle slope (<20°), medium slope (20-30°) and steep slope (>30°) of the site. A rough sketch of the tree profile was made at the field. Depending on the tree dimensions like tree height, crown depth and crown area, a final profile diagram was sketched for two forest zones considering both the forest types of each zone from the corridor. Canopy depth of all trees was estimated by subtracting first branch height from the total height. Canopy index for tree layers were calculated by dividing sum of canopy area of each stratum by total sampled area. Height and canopy depths of shrub were excluded as no measurement was made. The quotient of slenderness (SG) for canopy trees (top canopy tree A_1 and under canopy tree A_2) in each stand was calculated by formulae given by Brunig and Heuveldop (1976).

In order to have a better understanding of the forest, foliage profile structure of four forest conditions were drawn for eight height classes of woody tree species. Trees were categorised into eight height classes and their abundance was considered for the abundance profile drawing following Sankar Raman (1995) and Javed (1996) with certain modifications.

Woody biomass of standing trees were calculated by tallying DBH with height and using allometric relationships of different species from Sikkim (Sundriyal *et al.* 1994, Sundriyal & Sharma 1996) (Table 5.1). Woody biomass removal was estimated from 10 random 20 m x 20 m plots from each representative condition. Girth at the base of each stump was measured and converted to DBH; the tree height class was derived by matching its calculated DBH to the mean height of similar-sized trees as measured in the permanent plots. Biomass of all the removed trees was calculated from allometric relationship following Sundriyal *et al.* (1994) and Sundriyal and Sharma (1996). These data were compared with the estimates of firewood extraction and consumption which again, were done through systematic household interviews. Annual increments on DBH and heights of the trees were recorded for two successive years (1998-1999). Since some of the trees were removed in the marked plots, net primary productivity (NPP) was calculated considering the standing and removed biomass. However, for net ecosystem productivity (NEP) removed biomass was subtracted and productivity of only standing trees was calculated (Binkley & Arthur 1993, Sundriyal & Sharma 1996).

Stands were identified with the help of local community and all the trees were marked on 3rd to 5th January 1997 in the LF and 19th to 23rd April 97 in UF. The stand regeneration status, ground vegetation and shrub data were collected during April and May for summer and during November for the winter. The annual increment in the DBH was measured on 19-21st January in 1998 and 23-25th January 99 for LF and during April 98 and April 99 in UF.

5.3. Results

5.3.1. Vegetation structure

5.3.1.1. Diversity

Species diversity, species richness and concentration of dominance of woody vegetation are presented in Table 5. 2. In the LF, tree species diversity was greater in the OC (H′=5.5) than in the CC (H′=2.04), whereas at the UF, it was higher in the CC (H′=2.8) compared to that of OC (H′=2.5). Values of species richness were greater at OC both the lower and upper forests. The values of concentration of dominance varied at different sites and were greater in the sites dominated by a few species.

5.3.1.2. Regeneration

Out of 56 species only twenty species of trees were found regenerating at the LF accounting 43% of the total species at the closed and 47% at the open canopy forest (Table 5.3.1). Nineteen out of 32 species were found regenerating in the UF accounting 56% of the total species at the closed and 58% at the open canopy forest (Table 5.3.2). Number of regenerating individuals markedly declined in the open forests at both LF and UF showing poor regeneration of canopy trees. The secondary species like *Symplocos* spp and *Eurya acuminata* occurred with higher densities of seedlings and saplings at almost all sites. Comparatively, regeneration of *Quercus lamellosa* and other commonly used species was relatively higher in the closed canopy forest at the LF. Similarly, *Rhododendron falconeri* and *R. arboreum* showed relatively higher regeneration in closed canopy forest at the UF. Interestingly, *Abies densa,* the dominant species of the UF, was regenerating poorly at both closed canopy and open canopy forests.

5.3.1.3. Woody tree species composition and distribution pattern

Comparative values of woody tree abundance, abundance by frequency ratio, density of woody trees, basal area and the importance value index (IVI) are given in the Tables 5.4.1, 5.4.2, 5.4.3 and 5.4.4. The open canopy forest of the LF showed markedly reduced IVI values and basal area for the species with high firewood preference compared to those of the close canopy forest (Tables 5.4.1 & 5.4.2). The species like *Quercus lamellosa, Q. lineata* and *Castanopsis* spp. had lower IVI values in the open forest. The species like *Cinnamomum impressinervium* and *Beilschmiedia sikkimensis* were totally absent in the open canopy forest. It appeared that many fodder tree species (*Leucosceptum canum, Sterculia villosa,* and *Acrocarpus fraxinifolius*) were left safely at the stands for annual extraction of fodder. At the UF, the IVI and basal area values of used species were also low. The species like *A. densa, Acer papilio, R. grande* and *L. elongata* showed low values of basal area and IVI in the open forest compared to those of closed canopy forest. *C. impressinervium* and *R. falconeri* were absent in the open forest of the UF (Tables 5.4.3 & 5.4.4). Densities of trees reduced from 435 trees ha^{-1} in the closed canopy forest to 206 trees ha^{-1} in the open canopy forest at the LF. Likewise, at the UF it reduced from 319 trees ha^{-1} in the closed canopy forest to 222 trees ha^{-1} in the open forest. The basal area of the tree species was also reduced from 59 m^2ha^{-1} in the closed canopy forest to 23 m^2ha^{-1} in the open forest at the LF, and from 50 m^2ha^{-1} in the closed canopy forest to 40 m^2ha^{-1} in the open forest at the UF.

The analysis of distribution pattern using A/F ratio indicated that three species namely *Quercus spicata, Elaeocarpus sikkimensis* and *Engelhardtia spicata* showed regular distribution in the closed canopy at the LF. Among the rest of the species, 12 showed random and 15 contagious distribution. The open canopy forest of the LF showed five species (*Symplocos ramisissima, Eurya acuminata, Quercus spicata, Glochidion acuminataum* and *Pantapanax leschenaulti*) having regular distribution, 21 random and 17 contagious. The distribution pattern of species in the UF under the closed canopy showed six species having random distribution, 17 contagious and none for regular distribution. In the open canopy forest of the UF only one species was found with random distribution, 23 contagious and none in regular distribution catagory.

Density of DBH classes showed L shaped distribution for the closed canopy forests at both the LF and UF indicating good regeneration and structural strata of different sized trees. The distribution pattern was skewed for the open canopy forest at both the LF and UF (Figs 5.1.1 & 5.1.2) as they showed fewer small DBH class trees. Tree population structure of the most dominant canopy and sub canopy species are presented in Figs 5.2.1 and 5.2.2. At the open canopy forest, *Q. lamellosa* showed higher density with bigger trees compared to the closed canopy forest. The species showed almost uniform distribution of all the stage classes, but proportionate numbers of seedlings and saplings have decreased in closed canopy. In case of open canopy forest, proportionate distribution of *Q. lamellose* showed upright pyramid except for small class trees. Similarly under closed canopy, in the case of *Machilus edulis* small class tree density reduced indicating distortion and consequence threat (Fig. 5.2.1). All dominant and "other species" also showed substantial reduction in the density of higher tree stage classes in the open canopy forest. Notably, the densities of small and large trees were markedly reduced at the open canopy forests of both the LF and UF. Density of total species in different stage classes formed an upright pyramid showing proportionate distribution in both close and open canopy forests. Density of large trees in the open canopy decreased compared to closed canopy that could be a sign of caution. At the UF, small sized trees of *A. densa* were almost missing in both the closed canopy and open canopy forests, which appeared as a worrying factor. At the LF, only 39% and 12% attained sapling and tree stages respectively under the closed canopy, and 45% and 10% at the open canopy forest. Similarly at the UF, 23% and 9% at closed canopy, and 28% and 10% in the open canopy forest reached sapling and tree stages, respectively.

5.3.2 *Forest canopy structure and woody plant dominance profile*

Foliage height profile of open canopy forest at LF showed a pattern with remarkably low abundance at 11-15 m height class. Sequence of abundance was the highest in the height class of 1-5 m followed by 6-10 m and 26-30 m (Fig. 5.3a). Above 15 m, the height classes showed disproportionate abundance. The data supported the general concept that the rise in altitude, the abundance decreased. At closed canopy, the profile showed similar pattern with high abundance of low height class trees except the class 11-15 m height class (Fig. 5.3b). The entire profile showed a disproportionate distribution and the values were remarkably low in open canopy compared to those of closed canopy forest.

Foliage profile abundance of open canopy at UF revealed that trees of 6-10 m height were more abundant compared to 1-5 m class. The profile showed disproportionate distribution among the height classes like the LF at open canopy. Trees with 1-5 m height were less abundant and had disproportionate distribution among the other height classes (Fig. 5.4a). Interestingly, height class of 36-40 m was relatively high in this stand. The data of closed canopy from the UF showed that 6-10 m height class was abundant in the stand (Fig. 5.4b). Overall abundance was remarkably low for this stand.

The data on canopy dimensions are presented in Table 5.5. Canopy depth at close canopy of LF was the highest at steep slope for the strata A_2 and A_1. The highest canopy index was found at gentle slope for the stratum A_2 and at steep slope for the stratum A_1. Total canopy index was in the descending order of steep slope>gentle slope>medium slope. The highest SG value was recorded at medium slope followed by steep slope and gentle slope. At open canopy, index of stratum A_1 was higher at all three positions. Combined canopy index was recorded the highest at medium slope for both the strata. The total combined canopy index was the highest at steep slope followed by gentle slope and medium slope. On the other hand, the value of tree stability was highest at medium slope followed by steep slope and gentle slope.

Comparatively high canopy depth for the stratum A_2 was recorded at steep slope at close canopy of UF and that of the stratum A_1 in gentle slope. Canopy indices were found highest at medium slope for the strata A_2 and also A_1 at close canopy of UF. Combined total canopy index was also highest at medium slope followed by steep slope and gentle slope. Quotient of slenderness was found high at gentle slope followed by medium slope and steep slope. At open canopy of UF, total combined canopy index was the highest at gentle slope followed by steep slope and medium slope. Canopy was sparse at gentle and medium slopes but closed at the steep slope. Tree stability value was in the order of steep slope>medium slope>gentle slope.

5.3.3. *Standing woody biomass, productivity and extraction*

Woody biomass standing state, net primary woody biomass productivity, extraction and net ecosystem productivity are presented in Table 5.6.1 and 5.6.2. *Q. lamellosa* shared 37-40% of the standing woody biomass and 18-28% net primary productivity (NPP) of the stands in both the closed and open canopy forests. The standing woody biomass were 704 Mg ha^{-1} and 399 Mg ha^{-1} in the close and open canopy forests respectively at the LF, and 382

Mg ha^{-1} and 306 Mg ha^{-1} in the closed and open canopy forests at the UF. The NPP of woody biomass was greater (16.26 Mg ha^{-1} year^{-1}) at the open canopy forest compared to the closed canopy forest (11.35 Mg ha^{-1} year^{-1}) at the LF. The NPP of the UF showed a contrasting result showing greater (13.5 Mg ha^{-1} year^{-1}) value in the closed compared to open canopy forest (11.3 Mg ha^{-1} year^{-1}).

Annual extraction of nearly 50% of the NPP was recorded from both closed canopy and open canopy of the LF. In the UF, 46% of NPP removal was recorded from the open canopy and 21% from the closed canopy forest. Extraction of *Q. lamellosa* was the highest in both the closed and open canopy forests followed by *B. sikkimensis, A. laevigatum* and *Quercus* sp (Table 5.6.1). Extraction of woody biomass was the highest (7.8 Mg ha^{-1} year^{-1}) in the open canopy of the LF followed by the open canopy forest of the UF (5.2 Mg ha^{-1} year^{-1}) and least from the closed canopy forest of the UF (2.8 Mg ha^{-1} year^{-}). Distributions of woody biomass in different DBH classes were found to have uneven pattern (Figs. 5.6.1 & 5.6.2). In the closed canopy at the LF, the highest biomass value of 73 Mg ha^{-1} was recorded for 60-70 cm DBH class and the lowest value of 4.3 Mg ha^{-1} was recorded for 90-100 cm DBH class. Likewise in the open canopy forest of the LF, the highest biomass value of 201 Mg ha^{-1} was recorded for >100 cm DBH class and the lowest value of 7 Mg ha^{-1} for 60-70 cm DBH class. In the closed canopy forest of UF, the highest biomass value of 66 Mg ha^{-1} was found for 10-20 DBH class and the lowest value of 14.4 Mg ha^{-1} for 90-100 cm DBH class. Similarly, in the open forest 93 Mg ha^{-1} was found as the highest in >100 cm class and 5 Mg ha^{-1} was recorded in 20-30 cm DBH class at the UF.

5.4. Discussion

Yuksam-Dzongi trekking corridor forest showed a high woody tree species diversity with a range of 2.04-5.52. High diversity and species richness in the open forest at LF may be due to invasion by new species in the resultant canopy gaps as emphasised by Hobbs and Huenneke (1998) or due to disturbances during intermediate stage of succession, which favours the secondary species to develop (Fox 1979). Many secondary species were recorded in open canopy forest at the LF.

Regeneration determines the future quality of the forest (Veblen 1992). The two forest sites along the corridor show poor regeneration and the quality of forest has been degrading slowly but steadily. High regeneration of secondary species indicates that the area will be slowly taken over by them. At the LF, the highest number of seedlings and saplings of secondary species have been recorded in both the closed and open canopy forests. Regeneration of secondary species such as *E. acuminata, S. ramosissima* and *V.*

cordifolia has been abundant. *S. ramosissima* has regenerated in both open and closed canopy conditions, thereby has been dominating in areas between the elevation of 2400 and 2700 m. Canopy opening or canopy species death leads to *S. ramisissima* domination (Metz 1997). "Other species" group had comparatively lesser number of seedlings and saplings. Regeneration of *Q. lamellosa* and a few other commonly used species were observed good at certain patches in closed canopy forest. The regeneration of *R. falconeri, R. arboreum* and *Magnolia campbellii* have been fairly good in the closed canopy of UF. At this forest, extraction pressures on the forest-based resources were comparatively low resulting in better regeneration.

Interestingly, *A. densa,* the dominant species of the UF has shown very poor regeneration along the trail and even in some relatively untouched areas. This may be due to specific niche microsite conditions that are not suitable for the regeneration of this species. A possible reason for the poor survival of species may be due to higher slope and lower water holding capacity as gentle slope experiences lesser soil washout and favours survival of seedlings. Sampled plots have shown a mean slope of 49°, which is regarded as steep, and also high trampling that possibly has reduced the water holding capacity. Steep slope and poor water holding capacity of the sites attributed to poor regeneration of *A.*

densa. Although seedling number has been high for most of the species at all the sites, the sapling survival has been substantially low. Consequently the number of small and large trees has also reduced causing irregular distribution. This indicates that forest along the trail suffers from instability of plant species population (Veblen 1992). The reason for such instability may be due to selective harvesting of lower DBH class trees and high intensity of grazing and trampling along the trail causing continued disturbances (Singh *et al.* 1997, Singh 1998).

Density of trees in the close canopy forest has been within the range reported for other broad-leafed temperate Himalayan forests. But in the open forest, the density has been lower (Saxena & Singh 1982, Rawat & Singh 1988, Sharma & Ambasht 1991, Sundriyal & Sharma 1996, Bhandari *et al.* 1997, Metz, 1997). However, overall density in the present study is lower than that reported for tropical forests (Foster & Reiner 1983). Basal areas of these forests are also comparable to other Himalayan forests (Saxena & Singh 1982a, 1982b, Rawat & Singh 1988, Sundriyal *et al.* 1986, Sharma & Ambasht 1991, Sundriyal & Sharma 1996, Bhandari *et al.* 1997, Metz 1997).

Present study reveals that the open forest cover has been extensive at lower forest area suggesting that excessive pressure have caused this situation. The forests remained denser at steeper slopes and canopy opening is more pronounced at gentler slopes. On the other hand, canopy structure has been more disturbed near the human habitations or campsites with sparsely distributed shrubs and seedlings. Canopy cover in medium slopes were poor at open conditions. The structure of forest varies from stand to stand. Such inter-stand variation in tree structure, crown geometry and canopy architecture are quite common (Anderson 1961, Brunig & Heuveldop 1976, Saxena & Singh 1982). Moreover, from the figures 5.3 and 5.4, it is revealed that the effective area due to inclination could be responsible for low density of woody trees in steep slope than in gentle slope (Sharma & Ambasht 1982).

Almost at all the stands, there was no distinct stratification of height layers due to presence of wide range of tree with different heights. The closed canopy architecture with well marked strata of different forests and positions acts as filtering layer as it intercepts light, precipitation and reduces the momentum of large particles such as rain dropping from remarkable heights (Parker *et al* 1989). From the field observation it has been revealed that lower forest has been subjected to intense human pressure. As a result, the tree structure and canopy architecture has been disturbed at gentle slopes. Poor development of herbaceous plants in some stands may be because of the tendency of inverse relationship between the canopy cover (of tree and shrub layer) and development of herb layer (Smith 1956, Zobel *et al.* 1976, Killingbeck & Wali 1978).

The canopy index, a relative measure of canopy cover of both the tree strata has been the highest at steep slope of UF at closed canopy forest and least at medium slope at open canopy forest. There has been no definite trend in the canopy cover index at the upper and lower forests and also at the open and closed canopy forests. The average canopy depth (across position and forest types) for A_1 stratum is the highest in the medium slope of LF open canopy forest and lowest in the steep slope of the closed canopy forest at UF.

Well-developed canopies of closed canopy forest influence the soil condition of the site as it is directly related to canopy cover (Packer 1951). These forest conditions reduce the terminal velocity of the raindrops dropping from top canopy trees and ultimately check the soil erosion (Lull 1964, Trimble & Weitzman 1954, Rai & Sharma 1998). Thus a forest having multilayered canopy with a high canopy index and a well stratified forest as found at closed canopy forests have a greater protective value as compared to a forest with fewer layers and low canopy index observed at open canopy forest (Kittredge 1948). Data on the quotient of slenderness (SG) indicates the stability of trees; lower the SG values higher was the stability (Brunig & Heuveldop 1976). From the present study, all the areas, especially the gentle slope are stable except at the upper closed canopy forest where the value at the steep slope was lower than the two other slope gradients.

Due to extensive lopping of middle height class trees, abundance of 11-15 m height class trees have been remarkably reduced even at the closed canopy at LF. This is obvious due to preference of smaller trees for firewood by the local people. At UF, 6-10 m height class trees have been abundant at both the closed and open canopy forests. However, abundance value of 1-5 m class has been comparatively high at the closed canopy forest. The low value of 26-30 m height class at upper forest attributes to suitable size of utilization of *Abies* for timber. High abundance value of 36-40 m class at the upper closed canopy forest was a result of abundant *Abies* trees, which are the only tree, attaining this gigantic height class.

The effects of the human intervention on forest biomass have shown a marked decline in accessible forest areas as also reported by Andrews (1961), FAO (1969), and Brown *et al.* (1991). Lesser number of stems with smaller DBH classes reflect the reduction of biomass in the open forests resulted by chopping and lopping of trees. A few large DBH class trees mainly have accounted for the most of the woody biomass of the open forest in contrast to more number of smaller trees (<50 cm DBH) in closed canopy forest. In fact, the medium sized trees are usually harvested illicitly. High extraction attributed to greater annual demand of firewood in the study area and is described in chapter III. Thus, huge demand of firewood caused deforestation that has accelerated soil erosion process and reduced soil fertility and productivity (Rai & Sharma 1998). The standing biomass of the LF under the closed canopy was much higher than that of the open. The present standing biomass values are comparable to those of temperate deciduous forest (Rodin & Bazilvich 1967) and that of the closed forest was higher than the standing biomass of certain forests in tropical areas (Ovington & Olson 1970, Johnson & Riser 1974, Singh & Ramakrishnan 1982, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996). The woody biomass values of UF are comparable to those of temperate pine and oak forest of the Himalaya (Negi *et al.* 1983, Chaturvedi & Singh 1987, Rawat & Singh 1988).

Net primary production has been higher in the open canopy forest compared to that of closed canopy at the LF. High productivity in the open forest of the warm temperate zone could be due to fast growth of species after opening of the canopy as a result of favourable temperature, higher rainfall and better illumination. The NPP values are comparable to those of temperate forests of other parts of Sikkim (Sundriyal *et al.* 1994, Sundriyal & Sharma 1996). In contrast NPP of the closed canopy forest has been higher than the open forest of the UF. The UF comprising of cool temperate and sub-alpine region does not show much difference of growth after opening of canopy. The ecosystem productivity of the present study sites is comparable with the temperate forest at the Mamlay watershed in south Sikkim (Sundriyal & Sharma 1996). Woody biomass distributions on DBH classes show higher pressure on lower classes in the open forest that matches the frequency of chopping the trees (Chapter IV, Fig. 4.3).

5.5. Conclusion

Forest based resources are the integral part of livelihood of Himalayan people. Yuksam-Dzongri trekking corridor in the Khanchendzonga Biosphere Reserve in Sikkim has been endowed with high biodiversity. Population growth and rapid increase in tourist number have caused threat to the forest resources and biodiversity. The dense forests have been reduced and degraded in most parts especially at the lower elevations where human interference is intensive. Extraction of firewood and timber for community and tourism purposes has been observed all along the trekking corridor, and it is more pronounced near the major settlement of Yuksam. Tourism related pressure on the forest has been more distinctly visible at Tshoka, the first camping site on the trail. Removal of selective canopy species for firewood and timber has changed the forest structure and also opened areas where secondary species invaded. Regeneration of canopy species has been relatively low due to invasion by secondary species, which is likely to dominate in future. Extensive disturbance, like resources extraction and livestock grazing seems to be incompatible to *Abies* forest due to impairment of normal growth and development. These disturbances may also encourage the invasion of *Rhododendron* spp. within the *Abies* zone until another disturbance allows other species to invade.

In the present study some of the highly used firewood and timber species show poor regeneration and may affect the future conditions of the forest and availability of fuelwood and timber resources of choice. Laws for the forest management and conservation exist, though these are not adequately enforced due to various technical reasons. Secondly, there was no adequate fuel alternative in the area until recently. After implementation of Sikkim Biodiversity and Ecotourism Project, people have realised the importance of resources in the corridor for sustainable tourism development. Initiation of conservation activities has been geared up and the communities have started participatory monitoring for resources and wildlife. In order to maintain biodiversity of the area, it is necessary to look for the specific niche depending on qualitative indigenous species for firewood, fodder and timber. The degraded areas need immediate attention for community management. Management of trekking corridor forests should be oriented in such a way that only the canopy species regeneration is encouraged. Compliance to the code of conduct for conservation by tourists, enterprises and communities especially on the use of alternative to firewood would enhance the restoration of natural forest condition and conservation of related biodiversity.

Table 5.1. Regression data relating wood biomass to tree dimension and specific wood density of the dominant and other species in the temperate forest at Mamlay watershed (source :Sundriyal *et. al* 1994, Sundriyal & Sharma 1996).

Species	Regression equation	df	*r*	*E*
Temperate forest				
Quercus lamellosa	Y = exp(-0.948 + 0.826 *ln* D^2 H)	27	0.947*	1.077
Castanopsis tribuloides	Y = exp(0.807 + 0.595 *ln* D^2 H)	38	0.908*	1.049
Symplocos theifolia	Y = exp(0.520 + 0.594 *ln* D^2 H)	17	0.935*	1.066
Eurya acuminata	Y = exp(1.165 + 0.514 *ln* D^2 H)	19	0.860*	1.073
Alnus nepalensis	Y = exp(-2.847 + 0.839 *ln* D^2 H)	8	.0.967*	1.030
Other species	Y = exp(-0.427 + 0719 *ln* D^2 H)	24	0.915*	1.120
Total species	Y = exp(- 0.427 + 0.719 *ln* D^2 H)	143	0.909*	1.049
Tropical forest	**Regression equation**	***n***	***r***	***P<***
Castanopsis indica	Y = exp(0.204 + 0.769 *ln* D^2 H)	52	0.906	0.001
Shorea robusta	Y = exp(- 1.768 + 0.945 *ln* D^2 H)	12	0.940	0.001
Schima wallichii	Y = exp(- 1.064 + 0.888 *ln* D^2 H)	32	0.960	0.001
Other species	Y = exp(- 0.277 + 0.906 *ln* D^2 H)	13	0.618	0.050
Total species	Y = exp(1.741 + 0.615 *ln* D^2 H)	135	0.615	0.001

Y = Woody biomass (bole and branch) (kg); D = diameter at breast height (cm); H = tree height (m); S = specific wood density (gm cm^{-3}); d.f. = degree of freedom; r = coefficient of correlation; E = relative error calculated as antilog of the standard error of the natural logarithm of the y value; * significant at P<0.001; exp = exponential

Table 5.2. Species diversity, stand dimensions and regeneration at lower and higher forests at Yuksam-Dzongri trail.

Species diversity and dimension	Lower forest		Upper forest	
	CC	OC	CC	OC
Shannon Weiner's diversity index (H')	2.04	5.52	2.8	2.5
Species richness [Margalef's (d)]	5.4	8.8	4.2	4.7
Concentration of dominance (cd)	0.05	0.13	0.02	0.03
Basal area (m^2 ha^{-1})	59	23	50	40
Density (tree ha^{-1})	435	206	319	222
Tree species (number $site^{-1}$)	30	43	23	24
Regenerating species (number $site^{-1}$)	13	13	13	14
Regeneration (seedlings ha^{-1})	3480	2642	3694	2100
Regeneration(saplings ha^{-1})	1360	1200	860	585

CC = closed canopy, OC = open canopy.

Table 5.3.1. Regeneration status (ha^{-1}) of some widespread tree species in the lower forest of Yuksam-Dzongri trekking corridor

Species (local name)	Closed canopy		Open canopy	
	Seedling	Sapling	Seedling	Sapling
Eurya acuminata (Jhiguni)	840	440	480	176
Symplocos ramisissima (Kharane)	460	240	352	272
Cinnamomum impressinervium (Malagiri)	420	40	-	-
Quercus lineata (Phalant)	380	80	-	-
Neonaucleo griffithi (Pahenli)	320	180	272	64
Viburnum cordifolia (Asare)	260	100	464	128
Castanopsis tribuloides (Musre katus)	240	80	48	-
Machilus edulis (Ghew kaulo)	180	60	224	112
Beilschmiedia sikkimensis (Tarsing)	100	40	-	-
Acer oblongum (Phirphire)	80	40	-	-
Quercus spicata (Arkhaulo)	80	20	-	-
Betula cylindrostachys (Saur)	80	20	-	-
Quercus lamellosa (Bajrant)	40	20	96	80
Engelhardtia spicata (Mahuwa)	-	-	320	16
Castanopsis hystrix (Jat katus)	-	-	224	144
Sterculia villosa (Odal)	-	-	130	
Alnus nepalensis (Uttis)	-	-	80	48
Mahonia sikkimensis (Chuletro)	-	-	80	48
Prunus nepaulensis (Arupate)	-	-	80	32
Andromeida elliptica (Angeri)	-	-	16	80

Table 5.3.2. Regeneration status (ha^{-1}) of some widespread tree species in the upper forest of Yuksam-Dzongri trekking corridor

Species (local name)	Closed canopy		Open canopy	
	Seedling	Sapling	Seedling	Sapling
Eurya acuminata (Jhiguni)	80	60	373	80
Quercus lineata (Phalant)	120	40	-	-
Machilus edulis (Ghew kaula)	-	-	227	40
Quercus spicata (Arkaulo)	-	-	27	-
Mahonia sikkimensis (Chuletro)	-	-	200	40
Prunus nepaulensis (Arupate)	-	-	133	53
Andromeda elliptica (Angeri)	60	20	-	-
Rhododendron falconeri (Korling)	880	180	67	26
R. grande (Patle korling)	520	60	40	40
R. arboreum (Lali guras)	520	180	253	67
Magnolia campbellii (Ghogen chanp)	400	40	400	80
R. barbatum (Lal chimal)	380	40	147	80
Litsaea elongata (Pahenli)	280	60	-	
Acer thomsoni (Kapase)	240	60	-	13
Sorbus sp. (Pansi)	120	40	-	-
Betula alnoides (Saur)	67	40	140	13
Abes densa (Gobre salla)	27	40	80	13
Acer laevigatum (Putli)	-	-	53	13
Quescus sp. (Ainte)	-	-	67	27

Table 5.4.1. Values of abundance (AB), abundance frequency ratio (A/F), density (DN, ha^{-1}), basal area (BA, m^2 ha^{-1}) and importance value index (IVI out of 300) of tree species in close canopy condition at Lower Forest along the Yuksam-Dzongri corridor

Species	AB	A/F ratio	DN	BA	IVI
Quercus lamellosa	5	0.067	31	22.2	51.6
Cinnamomum impressinervium	11	0.151	71	1.7	25.5
Beilscmiedia sikkimensis	14	0.270	56	4.2	24.3
Quercus lineata	14	0.280	58	2.2	21.4
Symplocos ramosissima	5	0.071	33	0.6	15.5
Eurya acuminata	3	0.040	21	1	12.9
Machilus edulis	3	0.050	10	3.6	12.8
Litsae elongata	5	0.090	19	2.4	12.6
Machilus odoratissima	4	0.070	15	2.5	11.9
Viburnum cordifolia	15	0.600	31	0.4	10.0
Quercus sp.	1	0.040	2	2.8	7.4
Engelhadtia spicata	1	0.010	2	1.5	7.3
Quercus spicata	1	0.020	4	1.2	7.3
Symplocos theifolia	9	0.360	19	0.4	7.1
Elaeocarpus sikkimensis	1	0.020	4	1	7.0
Ficus nemoralis	2	0.040	8	0.3	6.6
Castanopsis tribuloides	5	0.200	10	1	6.2
Nneonaucleo griffithi	2	0.080	4	1.7	6.0
Alnus nepalensis	1	0.040	2	2	5.0
Acer thompsoni	1	0.040	2	1.7	5.5
Prunus nepaulensis	1	0.040	2	1.2	4.7
Betula cylindrostachys	1	0.040	2	1.2	4.6
Michelia exelsa	2	0.080	4	0.5	3.9
Anthocephalus indicus	3	0.120	5	0.2	3.8
Rhododendron arboreum	2	0.080	4	0.2	3.4
Acer oblongum	2	0.080	4	0.1	3.3
Walchura tubulata	2	0.080	4	0.1	3.2
Unidentified (Chedang)	1	0.040	2	0.2	3.0
Quercus lanceafolia	1	0.040	2	0.3	3.0
Ilex sikkimemsis	1	0.040	2	0.06	2.7
Prunus nepaulensis	1	0.050	2	0.2	3.5
Total			**435**	**58.7**	**300**

Table 5.4.2. Values of abundance (AB), abundance frequency ratio (A/F), density (DN, ha^{-1}), basal area (BA, $m^2\ ha^{-1}$) and importance value index (IVI out of 300) of tree species in open canopy condition at Lower Forest along the Yuksam-Dzongri corridor

Species	AB	A/F ratio	DN	BA	IVI
Quercus lamellosa	5	0.059	32	6	49.5
Castanopsis sp.	5	0.113	15	3	24.4
Nyssa javanica	3	0.075	10	1.5	15
Eurya acuminata	2	0.019	10	0.4	13.2
Machilus edulis	3	0.063	8	0.7	10.3
Quercus sp.	3	0.150	5	1.3	10.2
Betula cylindrostachys	3	0.063	8	0.6	9.9
Engelhardtia spicata	2	0.050	7	0.6	9.1
Castanopsis hystrix	2	0.050	7	0.6	9.1
Acrocarpus fraxinifolius	2	0.100	3	1	7.8
Symplocos ramosissima	1	0.017	5	0.1	7.6
Neonaucleo griffithi	2	0.050	7	0.1	7.3
Gaguga gamblei	2	0.100	3	0.8	7.0
Cinnamomum sp.	2	0.380	5	0.2	6.9
Drypetes lancifolia	2	0.038	5	0.2	6.9
Machilus odoratissima	1	0.050	2	0.9	6.4
Cinnamomum cecidodaphne	3	0.150	5	0.5	6.2
Prunus nepualensis	2	0.100	3	0.6	6
Viburnum cordifolia	2	0.038	5	0.1	5.9
Mahonia sikkimensis	2	0.038	5	0.1	5.9
Glochidion acuminatum	1	0.025	3	0.2	5.7
Rhododendron arboreum	1	0.050	2	0.6	5.3
Pantapanax leschenaulti	1	0.025	3	0.1	5.2
Boemeria platyphylla	3	0.150	5	0.2	5.1
Quercus lineata	2	0.100	3	0.3	4.5
Andromeda elliptica	3	0.150	5	0.1	4.5
Castanopsis tribuloides	1	0.050	2	0.3	3.6
Sterculia villosa	2	0.100	3	0.1	3.6
Ficus nemoralis	2	0.100	3	0.3	3.5
Michelia exelsa	1	0.050	2	0.2	3.5
Alnus nepalensis	1	0.050	2	0.2	3.4
Caeseria glomerata	2	0.100	3	0	3.4
Macropanax undulatum	1	0.050	2	0.1	2.8

Continued Table 5.4.2

Species	AB	A/F ratio	DN	BA	IVI
Symplocos glomerata	1	0.050	2	0.1	2.8
Symingtonia populnea	1	0.050	2	0.1	2.7
Echaenocarpus dasycarpus	1	0.050	2	0.1	2.7
Rhus insignis	1	0.050	2	0.1	2.7
Leucosceptum canum	1	0.050	2	0.1	2.7
Castanopsis indica	1	0.050	2	0	2.5
Paveta indica	1	0.050	2	0.1	2.4
Eurya symplocina	1	0.050	2	0.1	1.4
Cedrela toona	1	0.050	2	0.1	1.4
Total			**206**	**23**	**300**

Table 5.4.3. Values of abundance (AB), abundance frequency ratio (A/F), density (DN, ha^{-1}), basal area (BA, m^2 ha^{-1}) and importance of tree species in close canopy condition at higher forest along the Yuksam-Dzongri corridor.

Species	AB	A/F ratio	DN	BA	IVI
Abies densa	13	0.520	27	15.4	41.9
Acer papilio	6	0.110	23	10.2	33.7
Rhododendron falconeri	13	0.260	54	2.30	27.9
Quercus sp.	3	0.050	10	7.08	23.6
R. arboreum	4	0.580	27	1.08	20.2
R. grande	8	0.150	31	2.05	20.2
Magnolia campbelli	2	0.028	13	2.40	18.2
R. barbatum	12	0.480	25	0.49	12.0
Betula alnoides	8	0.320	17	1.30	10.9
Symplocos theifolia	9	0.360	19	0.52	10.1
Litsae elongata	5	0.200	10	1.39	9.2
Unidentified (Seto phusre)	5	0.200	10	1.33	9.1
Unidentified (Phusre)	5	0.200	10	0.58	7.6
Cinnamomum impressinervium	4	0.160	8	0.44	6.7
Sorbus sp.	3	0.120	6	0.60	6.4
Quercus lineata	1	0.040	6	0.49	6.1
Unidentified (Lalo phusre)	3	0.120	6	0.19	5.5
Unidentified (Arare kanda)	2	0.080	4	0.48	5.5
Weigtia gigantia	1	0.040	2	0.23	4.3
Magnolia sp	2	0.080	1	0.64	6.4
Lauroceracus undulatum	1	0.040	2	0.13	4.1
Prunus nepaulensis	1	0.040	2	0.15	4.2
Andromeda elliptica	3	0.120	6	0.50	6.2
Total			**319**	**49.97**	**300**

Table 5.4.4. Values of abundance (AB), abundance frequency ratio (A/F), density (DN, ha^{-1}), basal area (BA, m^2 ha^{-1}) and importance of tree species in open forest at higher forest along the Yuksam-Dzongri corridor.

Species	AB	A/F ratio	DN	BA	IVI
Rhododendron arboreum	11	0.164	61	3.24	44.7
Mangnolia campbelli	8	0.153	32	6.42	37.4
Abies densa	9	0.539	13	11.58	36.8
Prunus nepaulensis	4	0.080	17	2.698	21.4
R. barbatum	6	0.120	25	0.57	19.7
Betula alnoides	6	0.180	13	1.88	16.9
Unidentified (Arare kanda)	7	0.419	10	3.99	16.7
Quercus sp.	2	0.060	6	3.43	15.9
Acer papilio	4	0.105	10	1.05	11.8
Symplocos theifolia	1	0.260	6	0.14	10.1
R. garnde	3	0.090	8	0.19	9.0
Acer thomsoni	1	0.030	2	0.68	7.8
Machilus edulis	3	0.179	4	1.04	6.9
Quercus lineata	1	0.015	1	0.11	5.8
Litsae elongata	2	0.119	3	0.57	5.1
Michelia sp.	1	0.059	1	0.64	4.6
Prunus rufa	2	0.119	3	0.32	4.5
Beilschmiedia sikkimensis	1	0.059	1	0.47	4.2
Unidentified (Lalo phusre)	1	0.059	1	0.3	3.8
Unidentified (Sanwar)	1	0.059	1	0.32	3.8
Machilus kurji	1	0.059	1	0.29	3.6
Sorbus sp.	1	0.062	1	0.1	3.3
Erhretia wallichiana	1	0.059	1	0.03	3.1
Mahonia sikkimensis	1	0.059	1	0.01	3.1
Total			**222**	**40.07**	**300**

Table 5.5. Canopy profile, canopy index and quotient of slenderness for two forests of Yuksam-Dzongri trekking corridor. (description of A_1 and A_2 in the text)

Forest zone	Forest condition	Location	Average canopy depth (m)		Canopy index (%) Strata			(SG)
			A_2	A_1	A_2	A_1	Total	A_2
Lower forest	Open canopy forest	Gentle slope	18.3	3.5	62.8	214.5	277.3	42.88
		Medium slope	16.1	7.3	109.1	127.4	236.5	65.8
		Steep slope	17.4	5.6	85.9	152.1	237.8	53.21
	Close canopy forest	Gentle slope	18.1	2.9	114.4	125.3	239.7	41.49
		Medium slope	18.1	4.3	122.6	161.3	283.9	59.05
		Steep slope	19.2	4.6	137.5	114.2	251.6	48.61
Upper forest	Open canopy forest	Gentle slope	14.2	5.9	142.0	109.2	251.2	42.84
		Medium slope	20.4	5.8	42.8	69.6	112.4	43.87
		Steep slope	14.3	3.6	72.8	192.4	265.2	47.88
	Close canopy forest	Gentle slope	14.2	5.5	151.2	91.5	242.7	43.27
		Medium slope	16.1	3.6	60.7	288.8	349.5	42.48
		Steep slope	19.9	2.8	67.6	252.5	320.1	41.47

SG = Quotient of slenderness

Table 5.6.1. Woody biomass standing state, net primary productivity, extraction and net ecosystem productivity at the two forest conditions of lower forest of Yuksam-Dzongri trekking corridor.

Species (local name)	Standing Biomass ($Mg\ ha^{-1}$)	Net Primary Production ($Mg\ ha^{-1}\ year^{-1}$)	Extraction ($Mg\ ha^{-1}\ year^{-1}$)	Net ecosystem productivity ($Mg\ ha^{-1}\ year^{-1}$)
Close canopy				
Quercus lamellosa (Bajrant)	261.68	2.01	1.12	0.89
Beilschmiedia sikkimensis (Tarsing)	78.44	1.88	0.72	1.16
Machilus edulis (Ghew kaulo)	36.37	0.45	-	0.45
Machilus odoratissima (Lali kaulo)	34.99	0.80	-	0.80
Acer laevigatum (Putli)	24.47	0.90	0.54	0.36
Others (25)	267.84	5.31	2.38	2.93
Total	**703.79**	**11.35**	**4.76**	**6.59**
Open canopy				
Quercus lamellosa (Bajrant)	158.97	4.57	2.28	2.29
Quercus sp. (Ainte)	33.88	1.58	1.12	0.46
Castanopsis hystrix (Patle katus)	33.50	0.25	-	0.25
Nyssa javanica (Lekh chilaune)	22.44	0.08	-	0.08
Garuga gambleii	9.54	1.12	-	1.12
Others (38)	140.83	8.66	4.36	4.30
Total	**399.16**	**16.26**	**7.76**	**8.50**

Table 5.6.2. Woody biomass standing state, net primary productivity, extraction and net ecosystem productivity at the two forest conditions of upper forest of Yuksam-Dzongri trekking corridor.

Species(local name)	Standing Biomass ($Mg\ ha^{-1}$)	Net Primary Production ($Mg\ ha^{-1}\ year^{-1}$)	Extraction ($Mg\ ha^{-1}\ year^{-1}$)	Net ecosystem productivity ($Mg\ ha^{-1}\ year^{-1}$)
Close canopy				
Abies densa (Gobre salla)	126.09	8.36	-	8.36
Acer papilio (Phirphire)	75.64	1.07	0.53	0.54
Quercus sp. (Ainte)	47.82	1.15	0.87	0.28
Magnolia campbellii (Ghoge chanp)	22.63	0.30	-	0.30
Litsae elongata (Pahenli)	11.74	0.16	-	0.16
Others (18)	98.5	2.45	1.4	1.06
Total	**382.42**	**13.50**	**2.8**	**10.7**
Open canopy				
Abies densa (Gobre salla)	95.46	0.40	-	0.40
Magnolia campbellii (Ghoge chanp)	53.13	1.06	0.63	0.43
Unidentified (Ararre kanda)	32.31	0.16	-	0.16
Quercus sp. (Ainte)	24.60	0.06	-	0.06
Betula alnoides (Saur)	16.82	0.74	0.62	0.12
Others (19)	84.04	8.91	3.93	4.98
Total	**306.36**	**11.33**	**5.18**	**6.15**

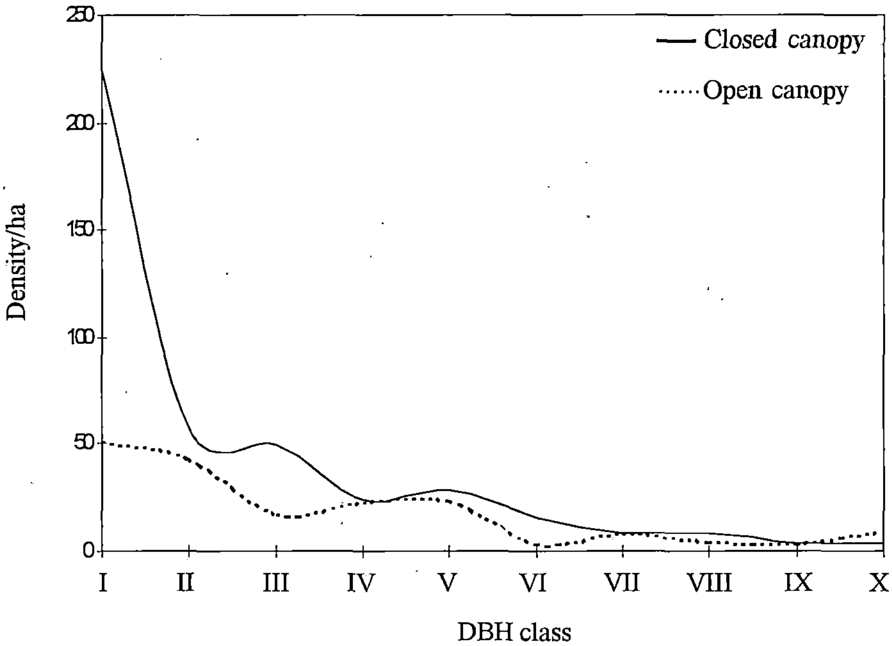


Fig. 5.1.1. Diameter class distribution of tree density in closed and open canopy conditions at lower forest along Yuksam-Dzongri trail. DBH classes (cm) I = 10-20, II = 20-30, III = 30-40, IV = 40-50, V = 50-60, VI = 60-70, VII = 70-80, VIII = 80-90, IX = 90-100 and X = >100.

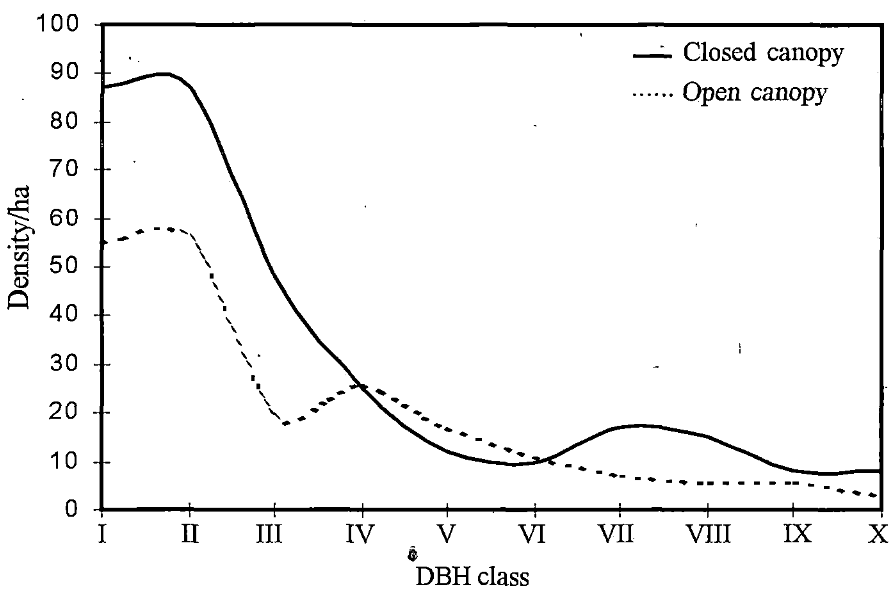


Fig. 5.1.2 Diameter class distribution of tree density in closed and open canopy conditions at upper forest along Yuksam-Dzongri trail. DBH classes (cm) I = 10-20, II = 20-30, III = 30-40, IV = 40-50, V = 50-60, VI = 60-70, VII = 70-80, VIII = 80-90, IX = 90-100 cm and X = >100.

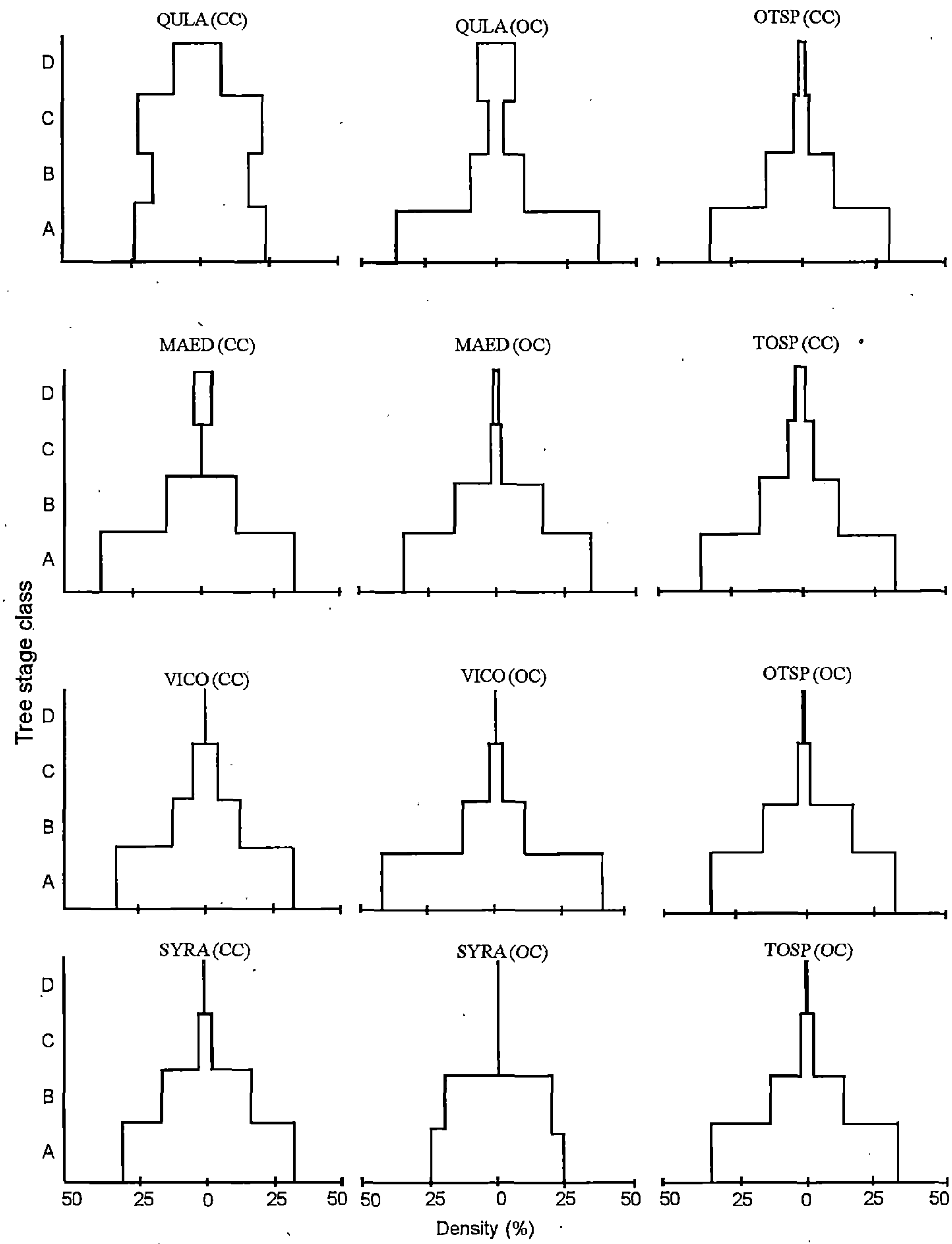


Fig. 5.2.1. Density of tree species, in different stage classes (A = seedling, height < 20 cm, B = sapling, height > 20 cm but diameter < 10 cm, C = small tree, diameter >10 cm but < 30 cm and D = large tree, diameter >30 cm) in lower forest. QULA = *Quercus lamellosa*, MAED = *Machilus edulis*, VICO = *Viburnum cordifolia*, SYRA = *Symplocos ramosissima*, OTSP = other species, TOSP = total species, CC = closed canopy and OC= open canopy.

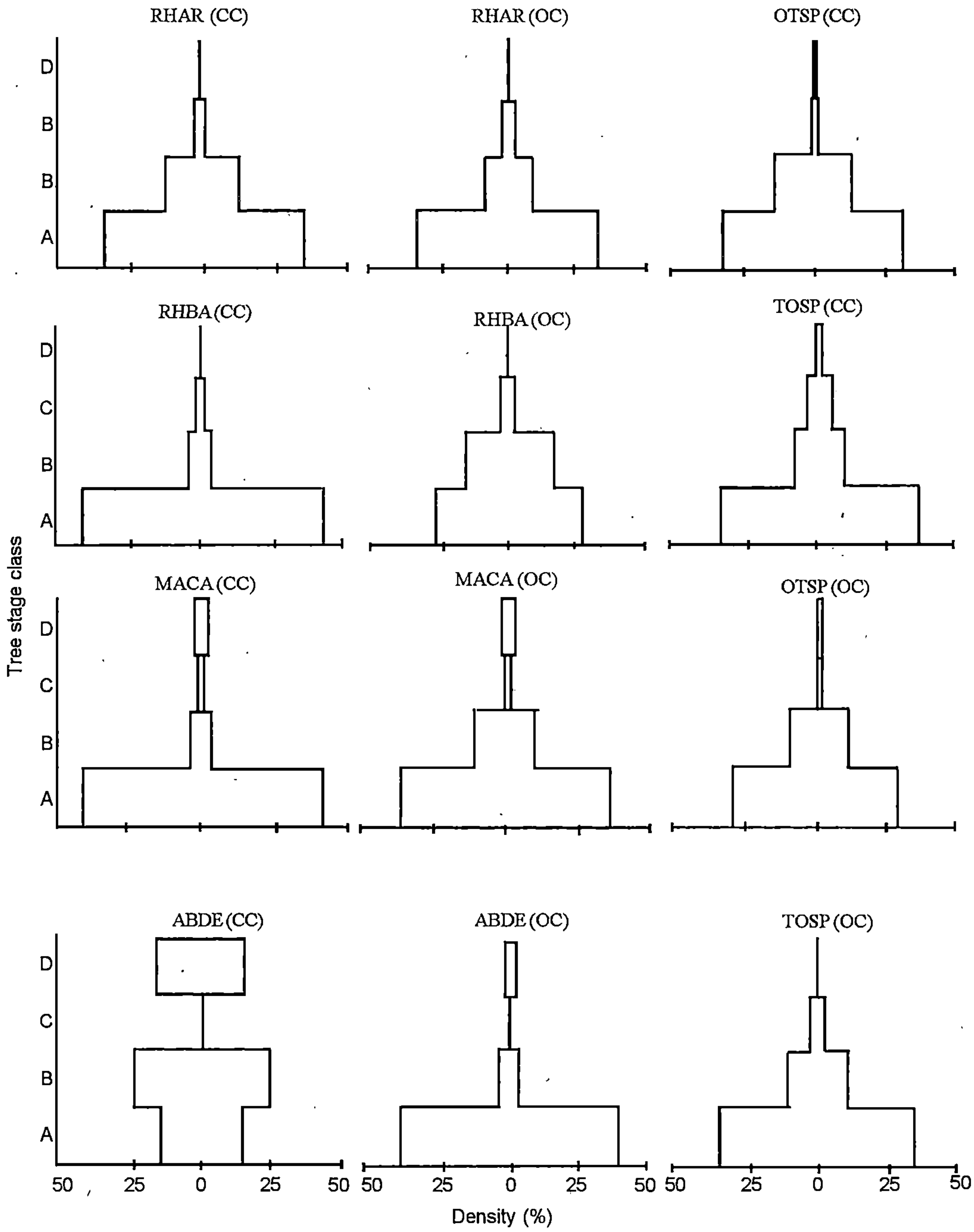


Fig 5.2.2. Density of tree species in different stage classes (A = seedling, height < 20 cm, B = sapling, height > 20 cm but diameter < 10 cm, C = small tree, diameter >10 cm but < 30 cm and D = large tree, diameter >30 cm) in sub-alpine forest. RHAR = *Rhododendron arboreum*, RHBA = *R. barbatum*, MACA = *Magnolia campbellii*, ABDE = *Abies densa*, OTSP = other species, TOSP = total species, CC = closed canopy and OC= opened canopy.

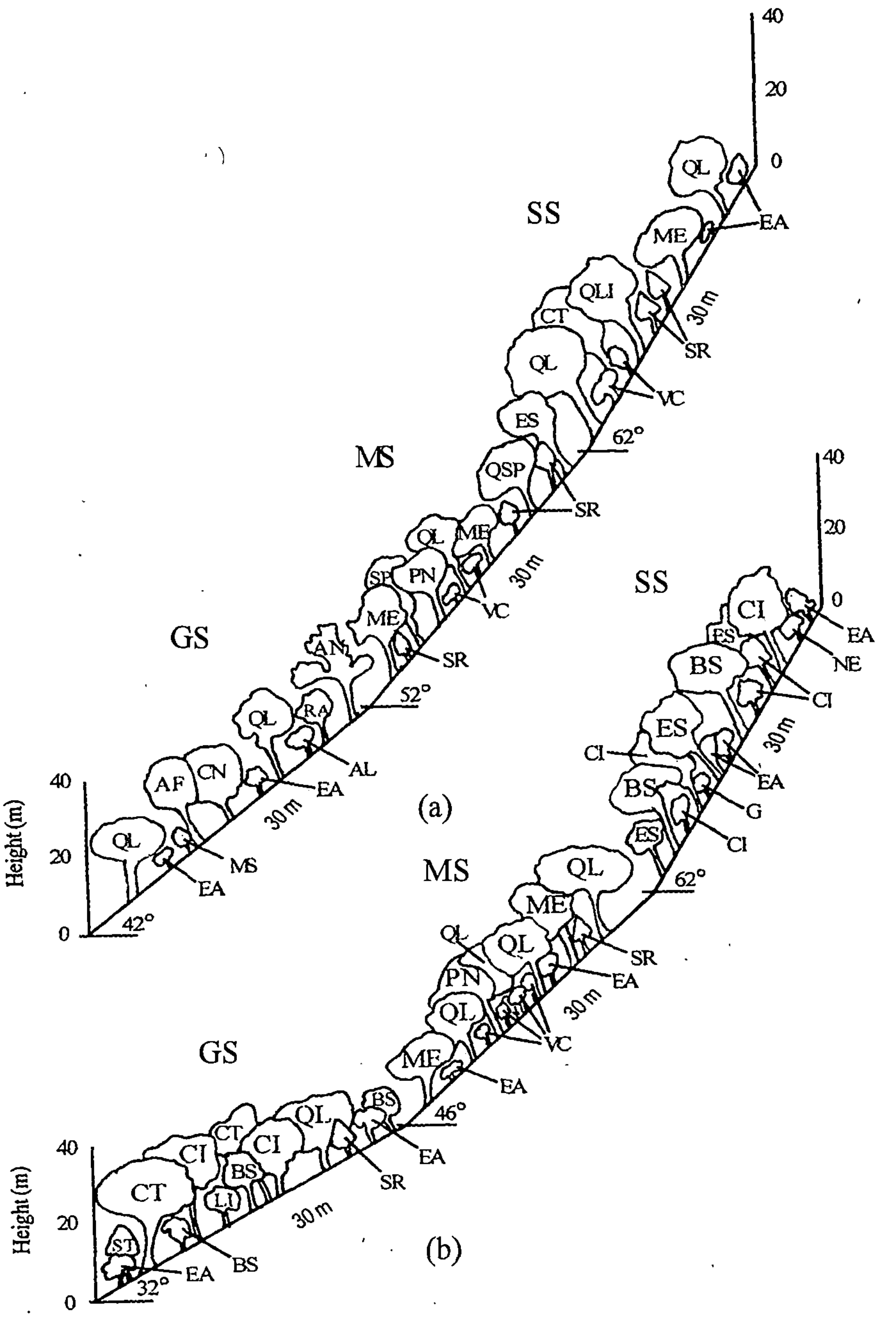


Fig. 5.3. Profile diagram for open canopy forest (a) and closed canopy forest (b) from the lower forest along the Yuksam-Dzongri trekking trail. Each profile diagram is made up of three sections as follows: GS = gentle slope, MS = medium slope and SS = steep slope. AF = *Acrocarpus fraxinifolius*, AN = *Alnus nepalensis*, BS = *Belschmiedia sikkimensis,* CT = *Castanopsis tribuloides*, CI = *Cinnamomun impressinervium*, CN = *Castanopsis* sp., EA = *Eurya acuminata*, ES = *Engelhardtia spicata*, ME = *Machilus edulis*, PN = *Prunus nepaulensis*, QL = *Quercus lamllosa*, QLI = *Quercus lineata*, QSP = *Quercus* sp., SP = *Symingtonia populnea,* ST = *Symplocos theifolia*, RA = *Rhododendron arboreum*, SR = *Symplocos ramosissima*, VC = *Viburnum cordifolia.*

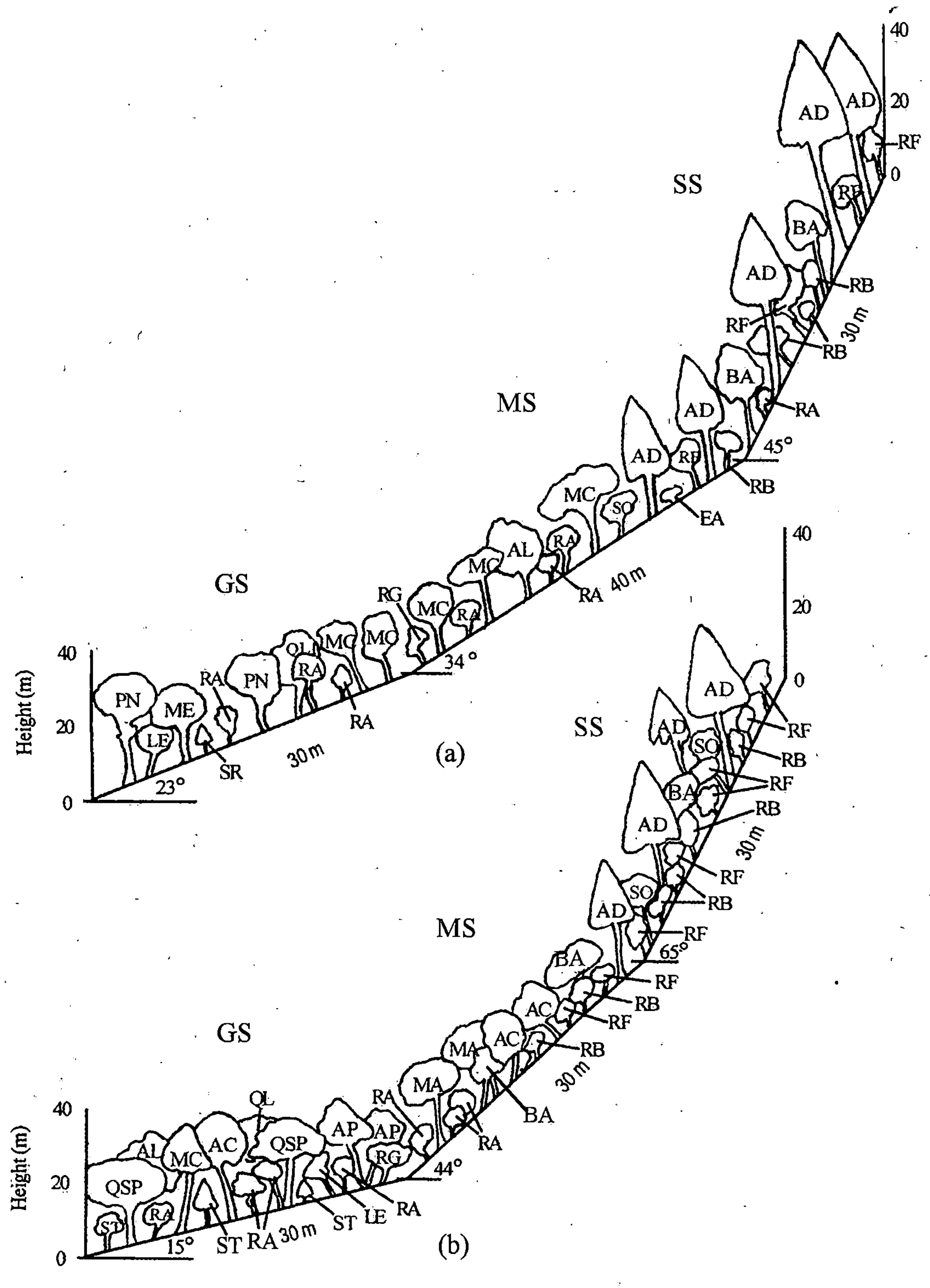


Fig. 5.4. Profile diagram for opened canopy forest (a) and closed canopy forest (b) from the upper forest along the Yuksam-Dzongri trekking trail. Each profile diagram is made up of three sections as follows: GS = gentle slope, MS = medium slope and SS = steep slope. AF = *Acrocarpus fraxinifolius*, AD = *Abies densa*, AL = *Acer laevigatum*, AP = *Acer papilio*, BA = *Betula alnoides*, EA = *Eurya acumunata*, LE = *Lisae elongata*, MA = *Magnolia* sp., MC = *Magnolia campbellii*, PN = *Prunus nepaulensis*, QL = *Quercus lamellosa*, RA = *Rhododendron arboreum*, RB = *R. barbatum*, RF = *R. falconeri*, RG = *R. grande*, SO = *Sorbus* sp, SR = *Symplocos ramosissima*, ST = *Symplocos theifolia*.

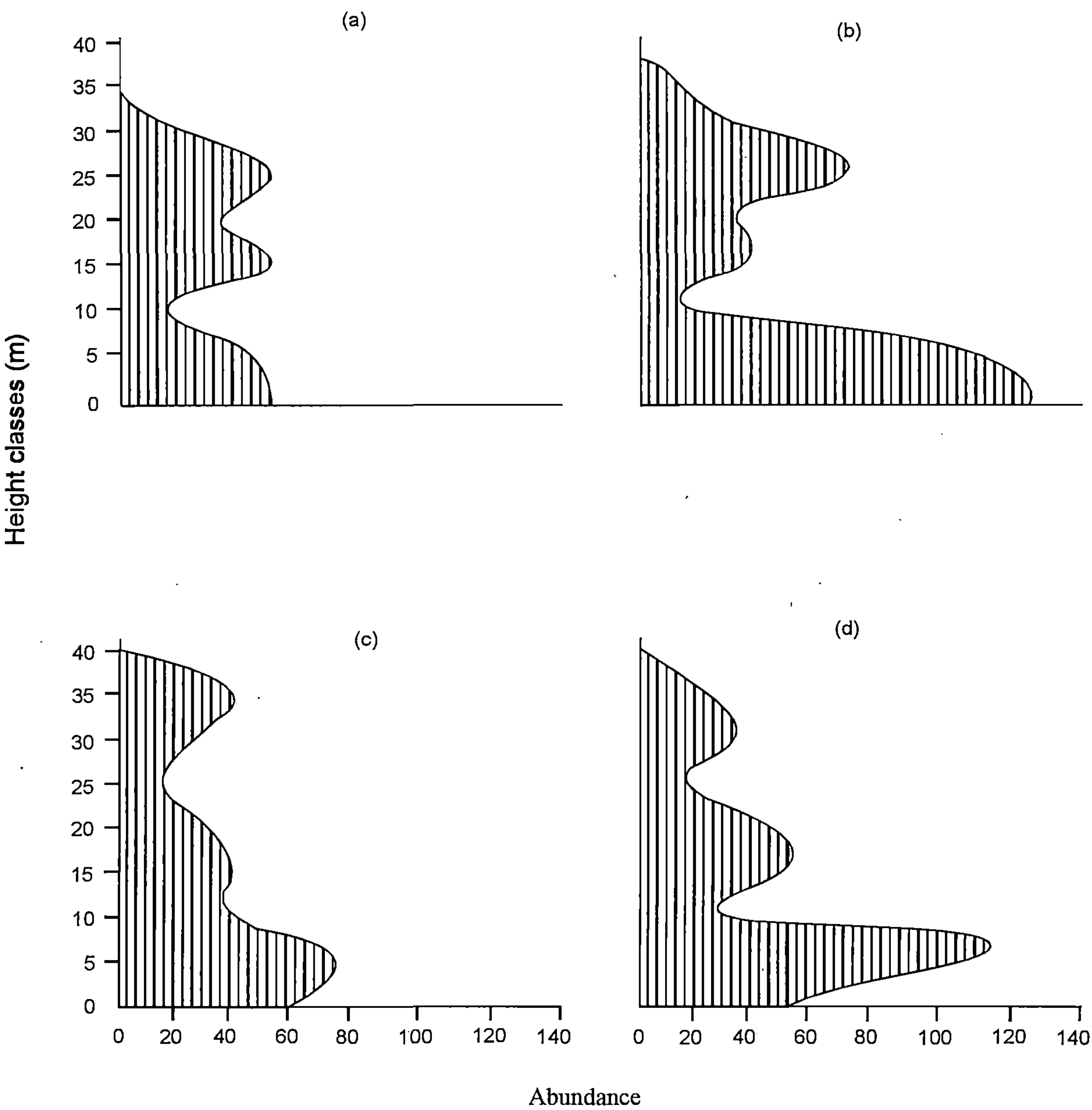


Fig. 5.5. Foliage height abundance in two forest types showing well stratified forest at closed canopy compared to open canopy at Yuksam-Dzongri trekking corridor. (a= lower open canopy, b = lower close canopy, c = upper open canopy and d = upper close canopy)

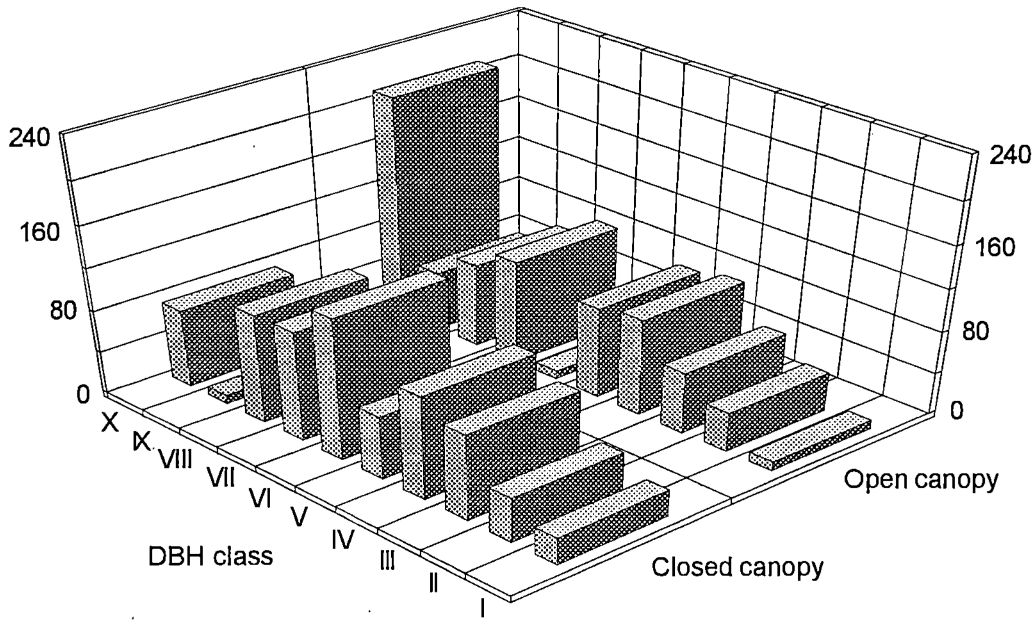


Fig 5.6.1. DBH class distribution of woody biomass (Mg ha^{-1}) in closed and open canopy forests at lower forest along Yuksam-Dzongri trail. DBH class (cm) I = 10-20, II = 20-30, III = 30-40, IV = 40-50, V = 50-60, VI = 60-70, VII = 70-80, VIII = 80-90, IX = 90-100 and X = > 100.

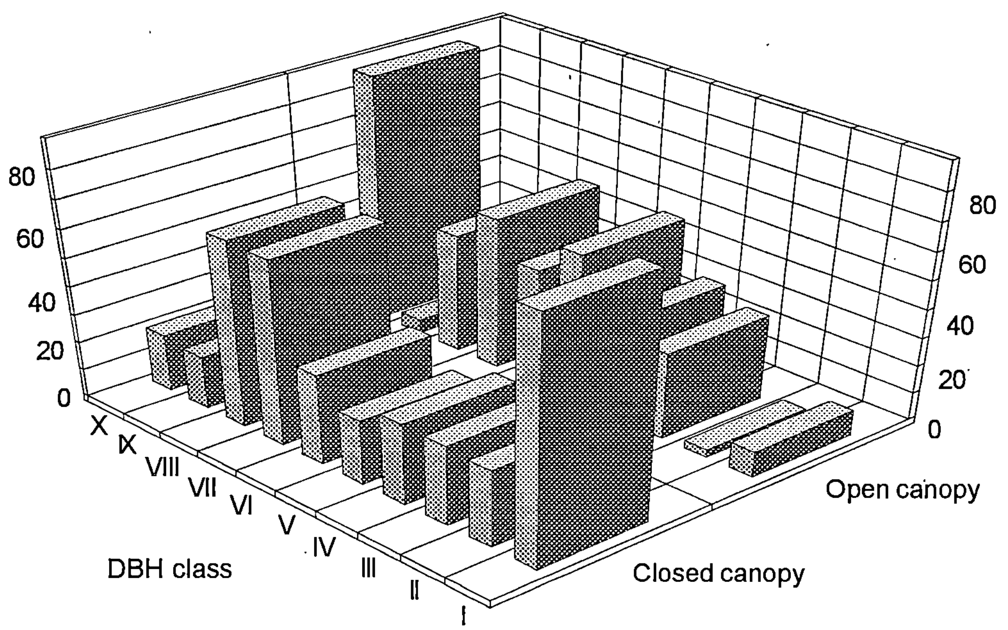


Fig 5.6.2. DBH class distribution of woody biomass (Mg ha^{-1}) in closed and open canopy forest at upper elevation forest along Yuksam-Dzongri trail. DBH class (cm) I = 10-20, II = 20-30, III = 30-40, IV = 40-50, V = 50-60, VI = 60-70, VII = 70-80, VIII = 80-90, IX = 90-100 and X = > 100.

CHAPTER VI

Chapter VI

Bird community structure

6.1. Introduction

Bird community evaluation has become an important tool in biodiversity conservation and for identifying conservation actions in areas of high human pressure (Kremen 1992, Shafiq *et al.* 1997). Indian subcontinent is known for diverse and rich bird species whose taxonomy, distribution and their general habitat characteristics are well documented (Ali & Ripley 1987, Bates & Lowther 1952, Jerdon 1862-64). However, only a very little is known about Indian bird community structure and their dynamics (Daniels 1989, Javed 1996, Johnsingh & Joshua 1994, Khan *et al.* 1993, Shafiq *et al.* 1997). Large scale habitat change are occurring globally for fulfilling human needs that have caused habitat destruction, fragmentation and degradation, necessitating assessment on the impacts of such change on birds (Brash 1987, Khan *et al.* 1993, Whitten *et al.* 1987). Determinations of bird population in different habitats are central to understanding the community structure and niche relationships, as well as for intelligent management of populations.

The Eastern Himalaya (Khangchendzonga region) supports a wide diversity of birds due to complex physiography and bioclimatic zonation (Ives & Messerli 1989) and also because of their location at the convergence of the Palaearctic and Oriental Zoogeographical Realms (Inskipp 1989). The area has been identified by the Birdlife International as a Priority I Endemic Bird Area since it supports 25 restricted range bird species, of which 21 are confined to the region (Bibbly 1992). Among eight species, which were considered to be at risk, and listed as rare, vulnerable or endangered in the region (Carpenter 1996), four species (satyra tragopan, Nepal cutia, short billed minivet and little pied flycatcher) have been recorded from the present study area.

Bird studies in Sikkim dates back to the 19th century, and many accounts on birds of Sikkim are available (Bulger 1869, Blandford 1872a,1872b, 1877, Gammie 1877, Brooks 1880, Ludlow & Kinnear 1937, 1944, Maclaren 1947, 1948, Mills 1944, Sen 1948, 1957). Ali's (1989) ornithological work in the region is the most exhaustive till date. However, only a few survey reports are available after this. Some recent works have added about 30+ species to the list (Ganguli-Lachungpa 1998). Although bird taxonomy, distribution and their general habitats have been documented, there have been no attempts for bird community study in Sikkim.

Yuksam-Dzongri trekking corridor in west Sikkim is an important tourist destination with great potential for bird watching. Disturbances such as firewood extraction, fodder lopping and cattle grazing have increased during the last two decades due to growth in tourism and population. This has resulted in the fragmentation and deterioration of wildlife habitats and also affected natural bounty of the area. Vegetation structure showed remarkable changes in species composition at human disturbed locations compared to relatively undisturbed areas along the corridor (see chapter V). This could have major negative impacts on wildlife. An exploratory monitoring on birds of the area is of special importance because of disturbances along the trek in recent years, encompasses a wide range of altitude and diverse forest types. This chapter is an attempt to assess (a) bird diversity, (b) species composition and abundance and (c) seasonal variation on bird community structure at highly disturbed and relatively undisturbed forests along the Yuksam-Dzongri trekking corridor of west Sikkim. This study will provide information on effects on bird community in relation to habitat management implications.

6.2. Methods

The bird counts were conducted at 19 transects each measuring 100 m x 40 m crossing each of the permanent plots [4 each at closed canopy stand (CC) of lower forest (LF) and upper forest (UF), 5 at open canopy stand (OC) of LF, 4 at CC of UF and 6 at OC of UF] during summer (May-August) and in winter (October-February) following Hawrot and Niemi (1996) with necessary modifications. Birds were identified in the field with the help of photoplates (Ali & Ripley 1994). Three observations were made at each transect in a season 1997-98 (year 1) and 1998-99 (year 2) with additional one observation each during the winter. Total number of transects surveyed were 266 (56 in CC of LF, 70 at OC of LF, 56 at CC of UF and 84 at OC of UF). Bird surveys were made between 06.00-09.30 h in mornings when wind was weak to avoid tree branch movement for more accurate bird enumeration. Observation during heavy rainfall and foggy days were not made to avoid bird visibility problem. During the samplings, all birds seen or heard in each transect were recorded (Hawrot and Neimi 1996). The Line Transect Method was selected because of its robustness and sampling efficiency (Burnham *et al.* 1980), ease of sampling compared to other methods (Verner 1985, Javed 1996). Each count was conducted with alternate timing in transects to bring about uniformity in records. Frequency of occurrence was used to identify the species that were restricted to specific habitat in closed canopy and open canopy conditions in lower and upper forests following Hagan *et al.* (1997). Species diversity (Shannon-Weiner's index), species richness (Margalef species richness), Simpson index of dominance (Simpson index), relative density and abundance from all recorded species were determined for each transect following Hayek and Buzas (1997).

6.2.1. *Data analysis*

Vegetation data from the permanent plots (Chapter V) were considered for statistical test. Highly correlated ($r < 0.05$) variables, following 'case to variables' ratio to be > 3:1 were used in General Linear Model (GLM) test (William & Titus 1988, Schultz & Niemi 1998). Within the model, the plot condition (closed and open canopy) was regarded as fixed effect and the other factors as random effect to see the difference in two forest conditions (Schultz & Niemi 1998). Data were analysed to describe habitat of the birds and to determine if bird exhibit discernable distribution patterns at temporal and spatial scales. Vegetation structure, forest profile and other attributes of the habitat have been dealt in chapter V. Only results on GLM were considered for differences in the context of bird habitat.

Species abundance for birds was estimated from the recorded data for each species score/transect. The score was estimated as:

$$P_{ij} = m_{ij}/n_j$$

Where m_{ij} is number of times recorded for species i and n_j is the total number of samples taken at site j. Difference in the abundance between the habitats for species present at >3 transects were considered for GLM. Effect of habitat conditions, forest types and their interactive influences were analysed keeping effects of other attributes as random (Schulte & Niemi 1998). Species compositional variations among the habitat types were tested with replicated goodness of fit (G – test) following Sokal and Rolf (1981).

Simple regressions were applied to examine diversity trends with elevation. Analysis of variance (ANOVA) was performed with density values for interactions between years, seasons, forest types and habitat conditions. Seasonal changes in bird species diversity and bird species richness were tested with a two-tailed t-test (Clergeau 1988). Some differences in count certainly could bring out variation on counting, as many species were easily detectable during specific time of the year than the other (Best 1981, Avery & Van Riper 1989). These differences probably resulted from difference in seasonal behaviour (e.g. some species are more secretive while nesting) or environmental differences (closed canopy forest provides more concealment than open). Adequate number of samplings with significant differences among the variables has not given place for type I and type II errors (Block 1989). All statistical analysis was performed using SYSTAT, Version 6 (1996), unless otherwise mentioned.

6.3. Results

6.3.1. Vegetation

Vegetation variables significantly varied between the closed canopy and open canopy conditions (Table 6.1). Among the 21 significantly differed variables, herb species richness was higher at open areas compared to closed canopy condition. First branch height, mean diameter at breast height, mean crown radius and mean height were also higher in the open canopy condition when compared between habitat conditions (Table 6.1). Disturbance factors such as number of lopped branches, chopped trees and trampling were significantly higher at the open canopy, while humus, dry litter and clay depths were higher under the closed canopy condition (Table 6.1).

6.3.2. Bird species abundance

Over two year period, 7149 bird (individuals) detection were undertaken that represented 143 species during 266 visits distributed over 19 sampling transects placed at 4 habitat stands. Of these 143 detected species, 40% (57) were common among the four stands. Ninety-eight species were present at >3 transects along the corridor (Table 6.2). Grey-sided laughingthrush (9.90) was the most abundant species at open canopy condition of the lower forest followed by stripe-throated yuhina (5.78) and grey-hooded warbler (4.12). In the closed canopy condition, stripe-throated yuhina (6.32) was the most abundant species followed by white-spectacled warbler (5.50), greenish warbler (3.33) and buff-barred warbler (3.25). Similarly, stripe-throated yuhina (6.00) was abundant at closed canopy condition at UF followed by coal tit (4.00) and grey crested tit (3.80). In the open canopy condition, smokey warbler (3.92) was abundant followed by brown-headed tit babbler (3.67) and grey-chinned minivet (3.61).

Analysis of variance within GLM revealed that 22% species differed significantly between the two-forest types (LF and UF), 15% species among the habitat conditions (CC and OC) and 20% species as a result of their interaction (forest types and habitat conditions). Among the species showing significant differences between habitat conditions (Table 6.2), white-throated laughingthrush, grey-winged blackbird, grey-headed canary flycatcher, and black-faced laughingthrush were more abundant in the open canopy condition. On the other hand, rufous-bellied niltava, white-tailed nuthatch, Mrs Gould's sunbird, whiskered yuhina and rufous-winged fulvetta were more abundant in the closed canopy condition. There was distinct partition on abundance of 32 species between the forest types (LF and UF). Among the noted species, grey-headed canary flycatcher, yellow napped yuhina, white-throated fantail, verditor flycatcher, rufous-bellied niltava, blue whistling thrush, white-throated laughingthrush, Mrs Gould's sunbird and grey-winged blackbird were more abundant at the LF. Black-faced laughingthrush, plain-backed thrush, spotted nutcracker, yellow-billed blue-magpie, Eurasian tree-creeper and rufous-vented yuhina were among the abundant species at the UF (Table 6.2). Large hawk cuckoo, grey headed flycatcher, verditor flycatcher, rufous-bellied niltava, black-face laughingthrush and yellow napped yuhina were differed significantly between the forest types and habitat conditions showing higher abundance at closed canopy condition (Table 6.2).

6.3.3. *Habitat specificity*

Out of 143 bird species, 10% of the species were restricted to the CC in contrast to 16% in the OC of LF (Fig. 6.1). At CC of LF, majority of species showed low frequency except the sultan tit (1.18) and grey-sided bush-warbler (1.18). The scenario at the OC of LF was also similar with few exceptions as red-vented bulbul (2.39), little forktail (1.30), grey treepie (1.52) and black bulbul (1.30). At the UF, only 3% of the total species were observed as unique for the CC. Spotted bush-warbler (1.57) and grandala (1.57) were among the species with comparatively higher frequency. Similarly, at OC of UF, 6% of the total species was recorded as specific to the habitat. Among them, rufous-breasted accentor, red-fronted rosefinch and black-throated sunbird had higher frequency.

6.3.4. Bird community

Bird species diversity and richness were higher at both the forests in the open canopy condition (Table 6.3). Density of birds was also higher at the open canopy condition (30±2.3 ha^{-1}) compared to that of the closed canopy (28±2.7 ha^{-1}) at the LF. The values reversed at the UF being lower at open canopy (24±1.9 ha^{-1}) compared to the closed canopy condition (27±3.5 ha^{-1}). Mann-Whitney *U* test of species richness, diversity, density, and bird abundance did not show any significant variation between the habitat conditions. In contrast, all these variables significantly differed between the two-forest types (Table 6.4). Considerable dissimilarities in species assemblages exist between the two habitat conditions. Species assemblages varied significantly among the habitat conditions both at the LF (G=174, P=0.01) and UF (G=595.32, P=0.01), and the difference was more pronounced (G=2738, P=0.001) between the two forest types (lower and upper forests).

Species composition (number of species per transect) varied significantly between years ($F_{1,246}$=8.5, P=0.004), seasons ($F_{1,246}$= 7.04, P=0.008) and forest types ($F_{1,246}$=21.1, P=0.0001). Interaction was found significant only for the year and season ($F_{1,246}$=8.1, P=0.005, $LSD_{0.05}$=2.29) (Fig 6.2). Density of bird showed strong interaction between the year and season ($F_{1,246}$=16.1, P=0.0001), year and habitat condition ($F_{1,246}$=5.9, P=0.016), season and forest type ($F_{1,246}$=3.8, P=0.056) and habitat condition, year and forest type ($F_{1,246}$=6.6, P=0.011, $LSD_{0.05}$=14.14) (Fig. 6.3). Bird species richness and diversity, and tree species richness and diversity showed strong negative and linear trend with increasing elevations. The relationships for bird species richness and diversity were stronger with increasing elevation than tree species richness and diversity (Fig. 6.4). The bird species richness and diversity varied significantly between the summer and winter season at all the habitats except at the close canopy of the UF (Table 6.5). Open condition (LF, t=2.50, df=68, P=0.016, and UF - t=3.05, df=82, P=0.003) of both the forest types showed a strong variation in bird species diversity.

6.4. Discussion

The Yuksam-Dzongi trekking corridor forest is highly diverse both in plants and birds. Tree DBH class density and height class abundance revealed that the open forests have a disproportionate distribution of trees in the areas with human disturbances, suggesting high pressure on lower DBH classes or smaller-height trees. Field observation revealed that the regeneration of canopy trees is poor due to grazing and trampling, which were comparatively more abundant at relatively undisturbed stands (see Chapter V). Vegetation structure (Chapter

V) suggests that human pressure has reduced the quality of the species composition in the open canopy forest providing accessible foraging ground for different bird species. Bird density was higher at the open canopy condition at the lower forest. This is obvious that an opening of canopy creates more ground for resources and all general species as well as species that are adjustable to such condition, will exploit the area (Block 1989, Daniels 1989). In the present study, the density has not been used for interpretation of habitat quality as the results may be misleading unless other attributes are considered seriously (Van Horne 1983, Vickery *et al.* 1992). Bird species richness as well as diversity were higher at the open canopy of the lower forest, but are not significantly different between the two habitat conditions. Comparatively, higher bird species richness although insignificant at the open condition of lower forest could be due to a pattern consistent with edge effect (Kilgo *et al.* 1997). Fleming and Giuliano (1998) from their experimental work in border-edge cut and uncut plots suggest that the species richness dose not differ significantly among the plots due to similar reasons. Daniels (1989) also supports this result. This may be due to the fact that the present study plots are undoubtedly smaller than the individual home ranges and probably that the plots are used by individuals relying on suitable habitat of surrounding forest (Aigner *et al.* 1998), or size of patches (open forest area) formed were small enough to bring about variation in bird species diversity (Schieck *et al.* 2000).

Significant differences in species assemblages between the open and closed canopy conditions could be explained by the fact that many common species have dominance on open canopy in association with some forest birds (MacArthur 1972). Generalists or common species like black drongo, red-vented bulbul, grey bushchat, green-backed tit including lemmon-rumped warbler, grey-headed canary flycatcher warbler, verditor flycatcher and house crow were more abundant at the open canopy condition, near human settlements, in association with other forest species. This suggests that they are habitat generalists that tend to be less sensitive to habitat changes than the forest interior birds (Telleria & Santos 1995).

In the open condition, where secondary tree species (*Symplocos ramoisissima, Viburnum cordifolia* and *Mahonia sikkimensis*) are dominant, showed fewer forest birds with more of the generalist species than in the closed canopy supporting a similar observation by Beehler *et al.* (1987) and Terborgh and Weske (1969). Many interior forest dwelling birds such as chestnut-tailed minla, white-spectacled warbler, buff-barred warbler, greenish warbler and little-pied flycatcher have higher abundance at the closed canopy condition where the structural complexity like vertical stratification with higher canopy coverage is maintained than at the open canopy condition. Fremark and Collins (1992) have also reported similar results for forest birds at habitat with greater overall forest cover than at the open areas. These results suggest that the open and closed canopy forest possesses wide structural differences in the context of forest stratification, which in turn provides habitat for breeding and feeding ground to a wide variety of species as per their habitat preferences (Javed 1996, Shafiq *et al.* 1997, Verner & Larson 1989). A significant seasonal change of bird species diversity and richness at different habitat types suggests that the bird species of this corridor have dynamic seasonal movement including that of long distance altitudinal migrants such as white capped redstart. It is apparent because about 40% of the total recorded species were common in all the four stands and majority are local migrants. Seasonal movements of species for food searching might have brought such fluctuations. There might be factors unrelated to habitat disturbances that contribute to the difference in bird assemblages between the closed and open canopy conditions. The principal differences among these sites were undoubtedly due to human pressure resulting change in vegetation structure and composition (Block & Morrison 1991, Block & Brennan 1993, Aigner *et al.* 1998). To maintain the bird community, further degradation of the habitat has to be minimised by regulating human activities (Johnsingh & Joshua 1994).

6.5. Conclusion

It is apparent from the above discussions that Yuksam-Dzongri trekking corridor exhibits diverse habitat types with diverse bird species. Wide ranges of habitats are available to birds and are equally utilised. Only a handful of bird species have restricted themselves to specific habitats, either to the open canopy or closed canopy in the lower and upper forests. This reflects that majority of bird use a variety of locally available habitats over their entire geographical range. Presence of a wide variety of species such as woodpeckers, flycatchers, tits, drongos and warblers indicates the richness of woodland birds in the area. Though there are distinct differences in the vegetation structure between the open and closed canopy conditions, differences in bird diversity are not significant. Bird species richness and density showed strong interaction with temporal as well as ecological complexities of forests but not with the habitat conditions. However, the individual species and species assemblage responses to their habitats are more convincing. This suggests that individual response and species assemblages to the available habitats provide better interpretation on habitat use than the diversity indices.

Present observation implies that the human disturbances at the open canopy forest might have brought about visible change in forest birds providing more open understorey for generalist species as observed in the lower forest. On the other hand, negligible change on generalist species was due to vegetation complexity at the upper forest because of less human interference. This condition has shown less effect on bird species diversity. It is apparent from the afore mentioned discussion that small-scale variation in diversity could be due to seasonal migratory behaviour of species looking for resources. Thus our short-term (2-year) observation could not trace out clearly the possible reason for such changes.

The study revealed that the forest interior species and general species have distinctness in their habitat use. Small-scale human pressure as firewood, fodders and timber extractions and grazing brought about subtle changes in available habitat for birds. It appears apparent that birds represent habitat not only by disturbance level but resource availability is the prime factor for maintenance and initiation of bird conservation. However, detailed study on effects of patch size created by disturbances and surrounding habitat is necessary to come to any conclusive interpretation. Though many environmental awareness programmes were conducted to community and tourism enterprises by the Sikkim Biodiversity and Ecotourism Project, more effective measures are needed to minimise human pressure on the natural resources of the area. Moreover large scale and long-term studies are necessary to evaluate the importance of site fidelity in obscuring effects in the short term and to describe the persistence of the effect.

Table: 6.1. Mean values of structural variables and diversity indices of designated habitat of birds (n=19) and their results of ANOVA in GLM from forest types and forest conditions from the Yuksam-Dzongri trekking trail, West Sikkim.

Vegetation variables	Lower forest		Upper forest		F	$P<$
	CC	OC	CC	OC		
Mean diameter at breast height (cm)	32.57	42.88	38.65	44.20	96.9	0.000
Mean basal area (m^2 ha^{-1})	57.26	35.96	51.80	40.15	35.1	0.000
Tree density (number ha^{-1})	435	208	320	228	55.6	0.000
Mean biomass (Mg ha^{-1})	704	399	382	306	22.9	0.000
Mean crown radius (m $tree^{-1}$)	6.04	7.37	6.12	7.58	98.4	0.000
Mean crown area (m^2 $tree^{-1}$)	41.21	54.89	39.72	59.53	59.3	0.000
Mean first branch height (m)	5.39	5.86	5.42	6.34	100.4	0.000
Drylitter depth (cm)	4.00	1.80	3.50	0.65	18.07	0.001
Humus depth (cm)	2.50	1.20	2.00	0.33	17.7	0.001
Trampling (number 25 m^{-2})	33.68	55.80	2.50	85.00	31.2	0.000
Clay depth (cm)	4.00	1.80	4.25	2.17	14.7	0.001
Chopped branch (number ha^{-1})	260	368	0	214	5.04	0.038
Herb species richness	1.59	2.55	2.37	2.78	134.9	0.000
Shrub density (number ha^{-1})	2000	1320	1300	1200	29.6	0.000
Chopped tree (number ha^{-1})	240	294	46	255	15.6	0.001
Tree with height <10 m (number ha^{-1})	237	73	181	107	46.7	0.000
Tree with DBH 10-40 cm (number ha^{-1})	204	178	221	144	37.2	0.000
Tree with DBH >30 m (number ha^{-1})	44	12	29	24	24.36	0.000
Tree with DBH 21-30 m (number ha^{-1})	123	88	46	39	27.5	0.000

CC= closed canopy condition, OC= open canopy condition.

Table 6.2. Mean and standard error (n=19) of bird numbers calculated from 14 pseudoreplicated samplings between the two forest types and forest conditions from the Yuksam-Dzongri trekking trail, West Sikkim.

Common name (scientific name)	Lower forest				Upper forest				FTxCT	CT	FT
	CC		OC		CC		OC				
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	*P* value	*P* value	*P* value
White-spectacled Warbler (*Seicercus affinis*)	5.50	3.77	3.60	2.54	2.00	1.68	1.33	1.33	0.02	0.02	0.01
Collared Grossbeak (*Mycerobas affinis*)	-	-	-	-	0.35	0.21	0.87	0.64	0.18	0.16	0.12
Chesnut-tailed Minla (*Minla strigula*)	0.19	0.12	-	-	1.00	0.53	-	-	0.02	0.02	0.09
Black Drongo (*Dicrurtus adsimilis*)	0.29	0.17	0.77	0.35	-	-	-	-	0.02	0.06	0.01
Golden-spectacled Warbler (*Seicercus burkii*)	0.25	0.18	0.20	0.12	-	-	-	-	0.04	0.06	0.03
Collared Treepie (*Dendrocitta frontalis*)	-	-	2.60	1.08	-	-	-	-	0.04	0.12	0.05
Rufous Sibia (*Heterophasia capistrata*)	0.44	0.13	2.22	0.60	0.04	0.04	-	-	<0.01	0.03	<0.01
Blackfaced Flycatcher-Warbler (*Abroscopus schisticeps**)	1.13	0.83	-	-	1.00	1.00	0.17	0.17	0.06	0.04	0.09
Black-faced Laughingthrush (*Garrulax affinis*)	0.11	0.11	0.07	0.04	0.14	0.05	0.46	0.08	<0.01	<0.01	<0.01
Blood Pheasant (*Ithaginis cruentus*)	-	-	-	-	3.44	1.28	0.92	0.92	0.02	0.03	0.04
Blue Rock Thrush (*Monticola solitarius*)	0.28	0.21	0.64	0.40	0.22	0.22	0.37	0.18	0.02	0.01	<0.01
Blue-fronted Redstart (*Phoenicurus frontalis*)	0.33	0.33	0.47	0.25	-	-	0.11	0.11	0.04	0.05	0.03
Blue-winged Laughingthrush (*Garrulax sqamatus*)	0.75	0.25	0.10	0.10	0.25	0.25	0.08	0.08	<0.01	<0.01	0.01
Blyth's Pipit (*Anthus godlewskii*)	0.13	0.13	0.03	0.03	0.22	0.18	1.94	1.02	0.12	0.11	0.07
Grey-creasted Tit (*Parus dichrous*)	-	-	-	-	3.80	1.86	2.00	1.02	0.01	0.02	0.01
Brownheaded Tit-Babbler (*Alcippe cinereiceps*)	0.50	0.50	-	-	-	-	3.67	3.47	0.38	0.33	0.29
Chestnutheaded Tit-Babbler (*Alcippe castaneceps**)	1.42	0.69	1.20	0.74	0.58	0.21	0.30	0.19	<0.01	<0.01	<0.01

Continued Table 6.2

Common name (scientific name)	Lower forest				Upper forest				FTxCT	CT	FT
	CC		OC		CC		OC				
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	*P* value	*P* value	*P* value
Russet Sparrow (*Passer rutilans*)	1.25	0.70	0.60	0.40	-	-	-	-	0.02	0.04	0.02
Coal Tit (*Parus ater*)	-	-	-	-	4.00	2.61	0.67	0.67	0.07	0.08	0.12
White-collared Blackbird (*Turdus albocintus*)	0.20	0.20	0.08	0.08	0.35	0.21	0.63	0.24	<0.01	<0.01	<0.01
Red-faced Liocichla (*Liocichla phoenicea*)	0.25	0.25	0.30	0.20	-	-	0.08	0.08	0.07	0.07	0.04
Darjeeling Woodpecker (*Dendrocopos darjellensis*)	0.18	0.07	0.07	0.04	0.86	0.46	0.71	0.24	<0.01	<0.01	<0.01
Gey Bushchat (*Saxicola ferrea*)	-	-	1.35	0.53	-	-	-	-	0.03	0.11	0.04
Daurean Redstart (*Phoenicurus auroreus*)	-	-	0.60	0.29	-	-	0.29	0.21	0.05	0.05	0.03
Euracsian Hoopoe (*Upupa epops*)	-	-	-	-	0.25	0.25	-	-	0.25	0.25	0.35
Spotted Nutcraker (*Nucifraga caryocatactes*)	-	-	-	-	0.60	0.24	0.43	0.13	<0.01	<0.01	<0.01
Fire-capped Tit (*Cephalopyrus flammiceps*)	-	-	-	-	1.50	0.87	1.00	1.00	0.12	0.11	0.11
Firetailed Sunbird (*Aethopyga ignicauda*)	0.63	0.38	0.40	0.24	0.38	0.38	0.33	0.33	0.02	0.02	0.02
Gey-winged Blackbird (*Turdus boulboul*)	0.44	0.16	0.08	0.08	0.28	0.24	0.38	0.09	<0.01	<0.01	<0.01
Goldcrest (*Regulus regulus*)	-	-	-	-	2.50	1.50	1.17	1.17	0.08	0.08	0.09
Golden-throated Barbet (*Megalaima franklinii*)	-	-	0.53	0.17	-	-	-	-	0.01	0.08	0.03
Grandala (*Grandala coelicolar*)	-	-	-	-	0.75	0.48	-	-	0.08	0.11	0.2
Great Barbet (*Megalaima virens*)	0.23	0.14	0.24	0.05	-	-	-	-	<0.01	0.02	<0.01
Green Shrike-Babbler (*Pteruthius xanthoclorus*)	-	-	0.80	0.80	-	-	-	-	0.37	0.41	0.31
Green-backed Tit (*Parus monticolus*)	0.08	0.05	1.73	0.57	-	-	-	-	0.01	0.07	0.02
Greenish Warbler (*Phylloscopus trochiloides*)	3.33	1.34	1.04	0.78	0.92	0.78	1.04	0.65	<0.01	<0.01	<0.01

Continued Table 6.2

Common name (scientific name)	Lower forest				Upper forest				FTxCT	CT	FT
	CC		OC		CC		OC		*P* value	*P* value	*P* value
	X̄	SE	X̄	SE	X̄	SE	X̄	SE			
Gre-hooded Warbler (*Seicercus xanthoschitos*)	3.65	1.21	4.12	0.72	1.05	0.63	-	-	<0.01	<0.01	<0.01
Grey-sided Laughingthrush (*Garrulax caerulatus*)	0.50	0.50	9.90	2.73	2.00	2.00	0.33	0.33	<0.01	0.03	<0.01
Rusty-fronted Barwing (*Actinodura egertoni*)	0.44	0.19	0.10	0.10	-	-	-	-	0.01	0.03	0.03
Black Bulbul (*Hypsipetes leucocephalus*)	-	-	1.07	0.39	-	-	-	-	0.02	0.09	0.04
Bluewhisling Thrush (*Myiophonus caeruleus*)	0.59	0.14	0.49	0.25	0.07	0.04	0.05	0.05	<0.01	<0.01	<0.01
Common Kestrel (*Falco tinnunculus*)	0.25	0.25	-	-	-	-	-	-	0.25	0.25	0.31
Grey Treepie (*Dendrocitta formosae*)	-	-	1.24	0.63	-	-	-	-	0.09	0.17	0.09
House Crow (*Corvus splendens*)	-	-	1.30	1.06	-	-	-	-	0.27	0.33	0.22
House Sparrow (*Parus domesticus*)	1.00	1.00	-	-	-	-	1.08	0.69	0.11	0.1	0.09
Indian Cuckoo (*Cuculus micropterus*)	0.25	0.15	0.16	0.07	-	-	-	-	0.02	0.03	0.01
Olive-backed Pipit (*Anthus hodgsoni*)	0.25	0.25	-	-	1.00	1.00	1.42	0.94	0.09	0.08	0.07
Long-billed Crow (*Corvus macrorhynchos*)	-	-	-	-	0.73	0.17	1.18	0.52	0.01	0.03	<0.01
Long-billed Thrush (*Zoothera monticola*)	0.08	0.08	0.47	0.33	0.58	0.34	0.67	0.34	0.01	0.01	<0.01
Large Hawk Cuckoo (*Cuculus sparverioides*)	-	-	0.55	0.05	0.06	0.06	-	-	<0.01	0.02	<0.01
Large Niltava (*Niltava grandis*)	0.13	0.13	0.50	0.39	-	-	-	-	0.17	0.21	0.13
Dark-sided Thrush (*Zoothera marginata*)	0.25	0.25	0.40	0.40	-	-	0.17	0.17	0.14	0.14	0.09
Littlepied Flycatcher (*Ficedula westermanni*)	2.00	1.17	0.40	0.40	-	-	-	-	0.04	0.06	0.06
Eurasian Tree-creeper (*Certhia familaris*)	0.06	0.06	0.05	0.05	0.34	0.20	0.31	0.12	<0.01	<0.01	<0.01
Marron-backed Accentor (*Prunella immaculata*)	-	-	-	-	0.83	0.83	0.61	0.33	0.09	0.09	0.08

Continued Table 6.2

Common name (scientific name)	Lower forest				Upper forest				FTxCT	CT	FT
	CC		OC		CC		OC		*P* value	*P* value	*P* value
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE			
Mrs. Gould's Sunbird (*Aethopyga gouldiae*)	0.75	0.53	0.70	0.12	0.38	0.24	0.58	0.29	<0.01	<0.01	<0.01
Dark-breasted Rosefinch (*Carpodacus nipalensis*)	-	-	-	-	0.50	0.50	1.06	0.68	0.14	0.12	0.09
Green-tailed Sunbird (*Aethopyga nipalensis*)	0.30	0.19	0.68	0.27	0.25	0.25	0.13	0.07	<0.01	<0.01	<0.01
Rufous-gorgetted Flycatcher (*Musicapa strophiata*)	0.56	0.33	0.90	0.56	0.63	0.63	0.13	0.09	0.02	0.02	0.02
Buff-barred Warbler (*Phylloscopus pulcher*)	3.25	1.56	0.60	0.60	-	-	-	-	0.02	0.04	0.04
Lemmon-rumped Warbler (*Phylloscopus proregulus*)	2.00	1.22	3.60	1.83	0.75	0.75	-	-	0.01	0.03	0.01
Pink-browed Rosefinch (*Carpodacus rhodochorus*)	-	-	-	-	0.50	0.32	0.39	0.25	0.05	0.06	0.04
Plain-backed Thrush (*Zoothera mollissima*)	0.09	0.09	0.09	0.04	0.39	0.14	0.61	0.19	<0.01	<0.01	<0.01
Plumbus Water Redstart (*Rhyacornis fuliginosus*)	-	-	0.40	0.17	-	-	-	-	0.04	0.12	0.05
Common Raven (*Corvus corax*)	0.17	0.17	-	-	0.17	0.17	0.39	0.25	0.08	0.06	0.06
Redbilled Leiothrix (*Leiothrix lutea*)	-	-	0.60	0.32	-	-	0.46	0.46	0.15	0.13	0.09
Redbreasted Rosefinch (*Carpodacus puniceus*)	-	-	-	-	-	-	0.83	0.65	0.35	0.31	0.26
Red-headed Bullfinch (*Pyrrhula erythrocephala*)	-	-	-	-	1.35	1.10	1.47	0.74	0.05	0.06	0.03
Black-throated Tit (*Aegithalos concinnus*)	1.88	1.30	2.00	1.38	-	-	-	-	0.05	0.08	0.03
Red-vented Bulbul (*Pycnonotus cafer*)	-	-	0.71	0.30	-	-	-	-	0.04	0.13	0.05
White-browed Shrike-Babbler (*Pteruthius flaviscapis*)	0.33	0.19	-	-	0.17	0.17	-	-	0.03	0.03	0.08
Black-browed Tit (*Aegithalos iouschistos*)	-	-	-	-	2.25	1.34	0.56	0.44	0.04	0.06	0.08
Rufous-bellied Niltava (*Niltava sundara*)	0.66	0.06	0.13	0.10	0.13	0.13	0.21	0.08	<0.01	<0.01	<0.01

Continued ***Table 6.2***

Common name (scientific name)	Lower forest				Upper forest				FTxCT	CT	FT
	CC		OC		CC		OC		P value	P value	P value
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE			
Scarlet minivet (*Pricrocotus flammeus*)	1.44	0.63	1.10	0.51	-	-	-	-	<0.01	0.02	<0.01
Short-billed Minivet (*Pricrocotus brevirostris*)	0.50	0.50	1.10	0.98	0.38	0.22	0.71	0.45	0.06	0.04	0.03
Rufous-vented Tit (*Parus rudeventris*)	0.11	0.07	0.05	0.04	3.32	1.83	2.24	1.13	0.02	0.02	0.01
Black-headed Mountain-Finch (*Leucosticte brandti*)	-	-	-	-	0.21	0.21	0.52	0.28	0.09	0.09	0.06
Rufous-vented Yuhina (*Yuhina occipitalis*)	0.13	0.13	-	-	2.66	1.19	2.42	1.06	<0.01	0.02	<0.01
Smokey Warbler (*Phylloscopus fuligiventer*)	-	-	-	-	1.25	1.25	3.92	3.53	0.31	0.26	0.22
Snow Pigeon (*Columba leuconata*)	-	-	-	-	-	-	2.25	1.80	0.36	0.32	0.26
Straighted Bulbul (*Pycnonotus straitus*)	0.06	0.06	0.45	0.28	-	-	-	-	0.11	0.17	0.09
Straighted Laughingthrush (*Garrulax straitus*)	0.80	0.57	1.36	0.45	-	-	-	-	<0.01	0.03	<0.01
Streaked Spiderhunter (*Aracnothera magma*)	0.50	0.50	1.00	0.77	-	-	-	-	0.13	0.16	0.09
Stripe-throated Yuhina (*Yuhina gularis gularis*)	6.32	2.09	5.78	2.06	6.00	1.15	3.83	1.52	0.33	<0.01	<0.01
Tickle's Leaf Warbler (*Phylloscopus affinis*)	1.32	0.52	3.06	1.29	0.14	0.14	0.81	0.75	<0.01	0.02	<0.01
Verditor Flycatcher (*Eumyias thalassina*)	0.25	0.09	0.86	0.15	-	-	0.05	0.05	<0.01	<0.01	<0.01
White-browed Tit-Babbler (*Alcippe vinipectus*)	1.06	0.66	-	-	0.50	0.50	2.13	1.60	0.12	0.11	0.09
White-capped Water Redstart (*Chaimarrornis lecocephalus*)	0.13	0.13	0.30	0.27	-	-	0.17	0.08	0.09	0.14	0.06
Spotted Laughing Thrush (*Garrulax occellatus*)	0.06	0.06	0.15	0.13	0.13	0.13	0.25	0.21	0.17	0.18	0.13
White-tailed Nuthach (*Sitta himalayansis*)	0.57	0.19	0.18	0.11	0.52	0.38	0.23	0.11	<0.01	<0.01	<0.01
White-throated Fantail (*Rhiphidura albicollis*)	0.98	0.28	0.75	0.29	-	-	0.09	0.09	<0.01	<0.01	<0.01

Continued Table 6.2

Common name (scientific name)	Lower forest				Upper forest				FTxCT	CT	FT
	CC		OC		CC		OC				
	X̄	SE	X̄	SE	X̄	SE	X̄	SE	*P* value	*P* value	*P* value
White-throated Laughingthrush (*Garrulax albogularis*)	0.88	0.59	0.73	0.52	1.33	0.41	0.67	0.19	<0.01	<0.01	<0.01
White-winged Grossbeak (*Mycerabas carnipes*)	-	-	-	-	0.25	0.25	0.67	0.44	0.16	0.14	0.11
Yellow-bellied Fantail (*Rhiphidura hypoxantha*)	0.83	0.50	0.80	0.80	-	-	0.22	0.22	0.08	0.09	0.06
Yellow-bellied Warbler (*Abrocopus superciliaries*)	2.00	1.22	3.60	1.83	-	-	0.75	0.75	0.85	0.06	0.06
Yellow-billed Blue Magpie (*Urocissa flavirostris*)	0.17	0.17	0.25	0.17	0.96	0.60	2.03	0.58	<0.01	<0.01	<0.01
Whiskered Yuhina (*Yuhina flavicollis*)	2.41	0.71	2.28	0.68	0.13	0.13	0.48	0.15	<0.01	<0.01	<0.01
Grey-chinned Minivet (*Pericrocotus solaris*)	-	-	2.00	1.55	-	-	3.61	2.17	0.11	0.09	0.07

CC= closed canopy condition, OC= open canopy condition, FT = forest types, CT = canopy types.

Table: 6.3. Sample size, composition and structure of bird communities in different habitat conditions at Yuksam-Dzongri trekking corridor.

Parameters	Lower forest		Upper forest	
	CC	OC	CC	OC
Sampling size (100 m transect)	56	70	56	84
Species recorded	82	86	64	77
Species per transect (mean±SE)	7±0.53	8±0.44	6±0.43	5±0.32
Individuals per transect (mean±SE)	28±2.7	30±2.4	27±3.5	24±1.9
Shannon Weiner's diversity (H')	3.65	3.72	3.52	3.69
Margalef's species richness index	10.3	11.2	8.7	10.1
Pielou's eveness index	0.83	0.84	0.85	0.85
Simpson index of dominance	0.045	0.040	0.049	0.036

CC= closed canopy condition, OC= open canopy condition.

Table: 6.4. Comparative assessment of bird community structure between habitat (treatment) and sites (lower forest and upper forest) of Yuksam-Dzongri trekking corridor.

Variable	Treatment effect			Forest type effect		
	Mann-Whitney* *U*-value	$X^{2\#}$	*P*	Mann-Whitney! *U*- value	$X^{2\#}$	*P*
BSR	8788.0	0.61	0.43	11876.0	29.74	<0.01
BSD	8571.5	0.18	0.67	11527.0	23.84	<0.01
BABUN	8236.0	0.18	0.89	7015.0	6.21	0.01
RDEN	8461.0	0.06	0.81	9965.0	5.42	0.02

(BSR = bird species richness, BSD = bird species diversity, BABUN = bird abundance and RDEN = relative density of bird).
*Count number $U_{0.05(2),154,108;}$!Count number $U_{0.05(2),122,140;}$ $^{\#}$ chi-square approximation with df 1

Table: 6.5. Comparison of bird species richness (BSR) and bird species diversity (BSD) between summer and winter winters in Yuksam-Dzongri trekking corridor.

Forest type	Habitat condition	Bird variables	*t*-statistic		df
Lower forest	closed	BSR	$t = 2.50$ SE = 0.75	$P = 0.016$* CI (0.049-1.354)	50
		BSD	$t = 2.65$ SE = 0.49	$P = 0.011$* CI (0.117-0.879)	50
	Open	BSR	$t = 2.31$ SE = 0.53	$P = 0.024$* CI (0.072-0.992)	68
		BSD	$t = 2.70$ SE = 0.39	$P = 0.009$** CI (0.102-0.681)	68
Upper forest	Closed	BSR	$t = 0.686$ SE = 0.22	$P = 0.780$ CI (-0.4250-0.867)	54
		BSD	$t = 1.78$ SE = 0.32	$P = 0.081$ CI (-0.042-0.696)	54
	Open	BSR	$t = 3.42$ SE = 0.58	$P = 0.001$* CI (0.245-0.927)	82
		BSD	$t = 3.05$ SE = 0.39	$P = . 0.003$** CI (0.138-0.650)	82

T-test for pair samples
*$P<0.05$, ** $P<0.01$

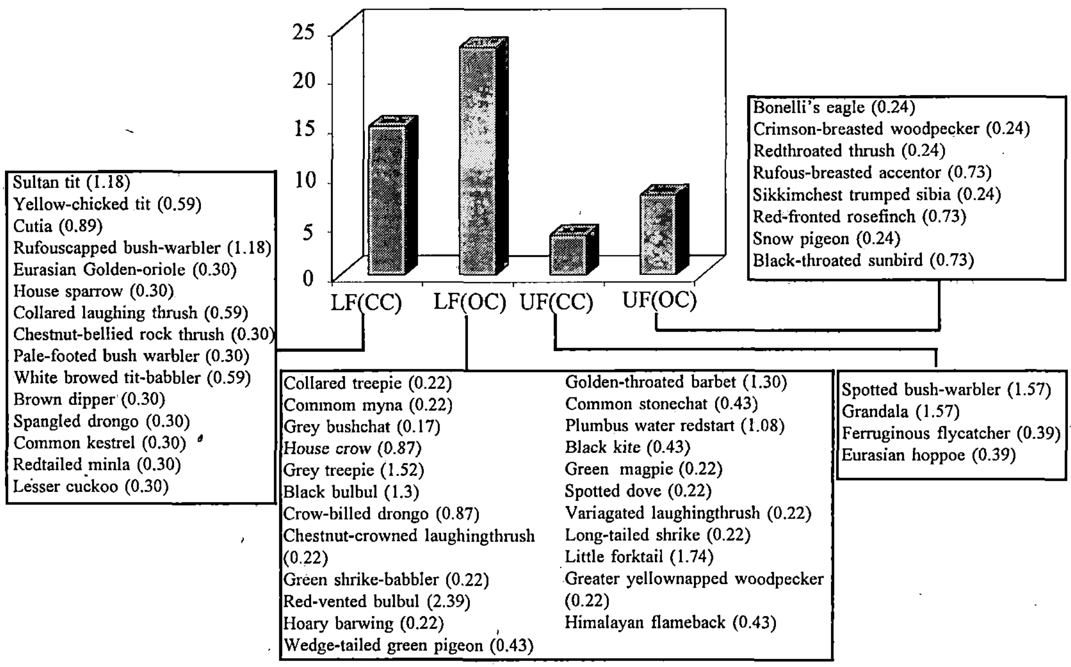


Fig. 6.1. Bird species with frequency observed only at specific habitat types at Yuksam-Dzongri trekking corridor. (LF= lower forest, UF = upper forest, CC = closed canopy and OC= open canopy).

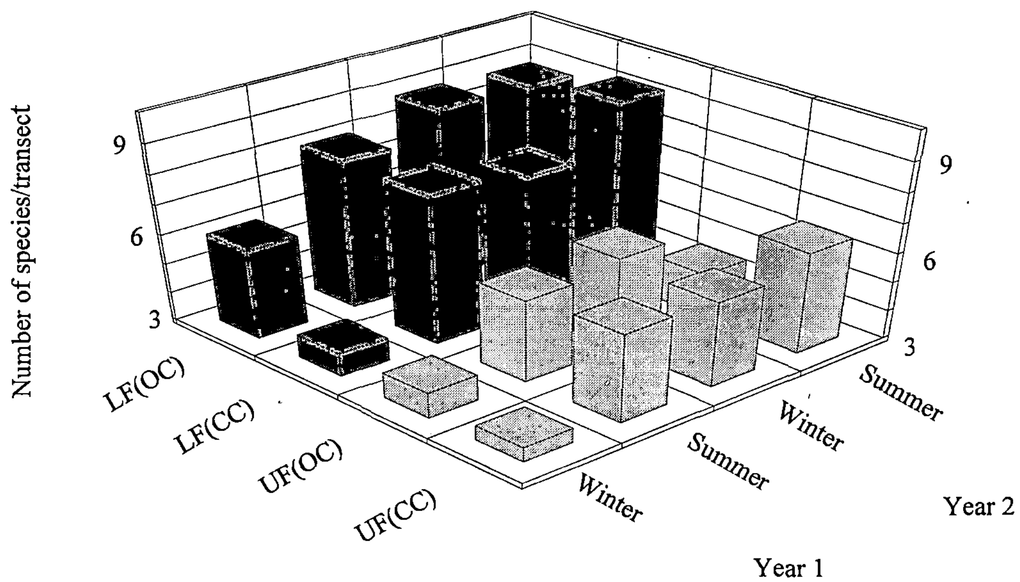


Fig. 6.2 Bird species number in summer and winter seasons for two years (Year1 = 1997-98, Year2 = 1988-99) in open and closed canopy conditions of the lower and upper forests in Yuksam-Dzongri trekking corridor. ANOVA: Year $F_{1,246}$ = 8, P<0.004; Season $F_{1,246}$ = 7, P<0.008; Forest type $F_{1,246}$ = 21, P<0.0001, Year x Season $F_{1,246}$ = 8, P< 0.005; other interactions not significant, LSD $_{(0.05)}$ = 2.29. (LF = lower forest, UF = upper forest, CC= closed canopy, OC= open

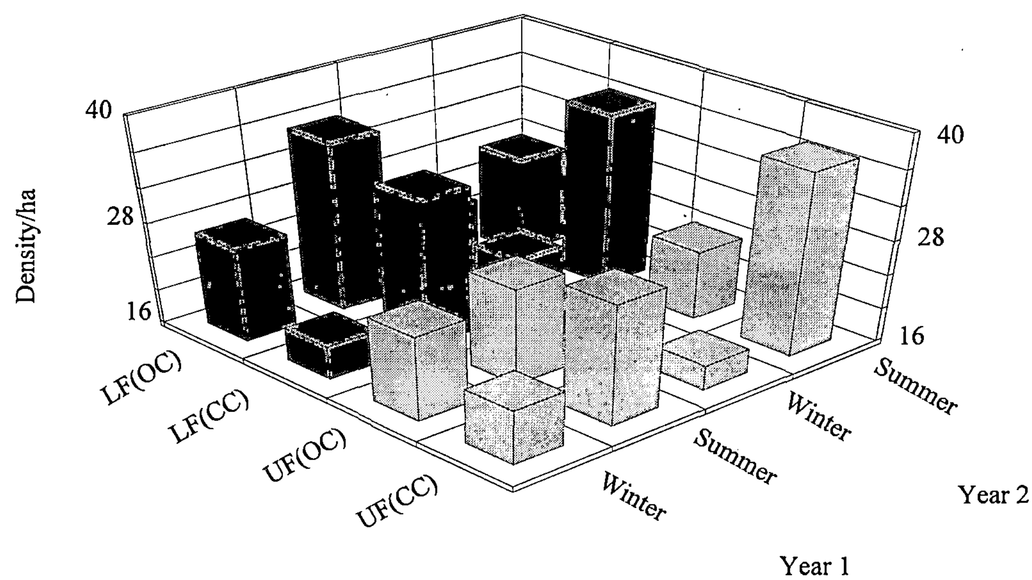


Fig.6.3. Bird density in summer and winter seasons for two years (Year1 = 1997-98, Year2 = 1988-99) in open and closed canopy conditions of the lower and upper forests in Yuksam-Dzongri trekking corridor. ANOVA: Year x Season $F_{1,246}$ = 16, P<0.0001; Year x Habitat condition $F_{1,246}$ = 5, P<0.016; Season x Forest type $F_{1,246}$ = 3, P<0.056, Habitat condition x Year x Forest type $F_{1,246}$ = 6, P< 0.011; other interaction not significant, LSD $_{(0.05)}$ = 14.14 (LF = lower forest, UF = upper forest, CC= closed canopy, OC= open canopy)

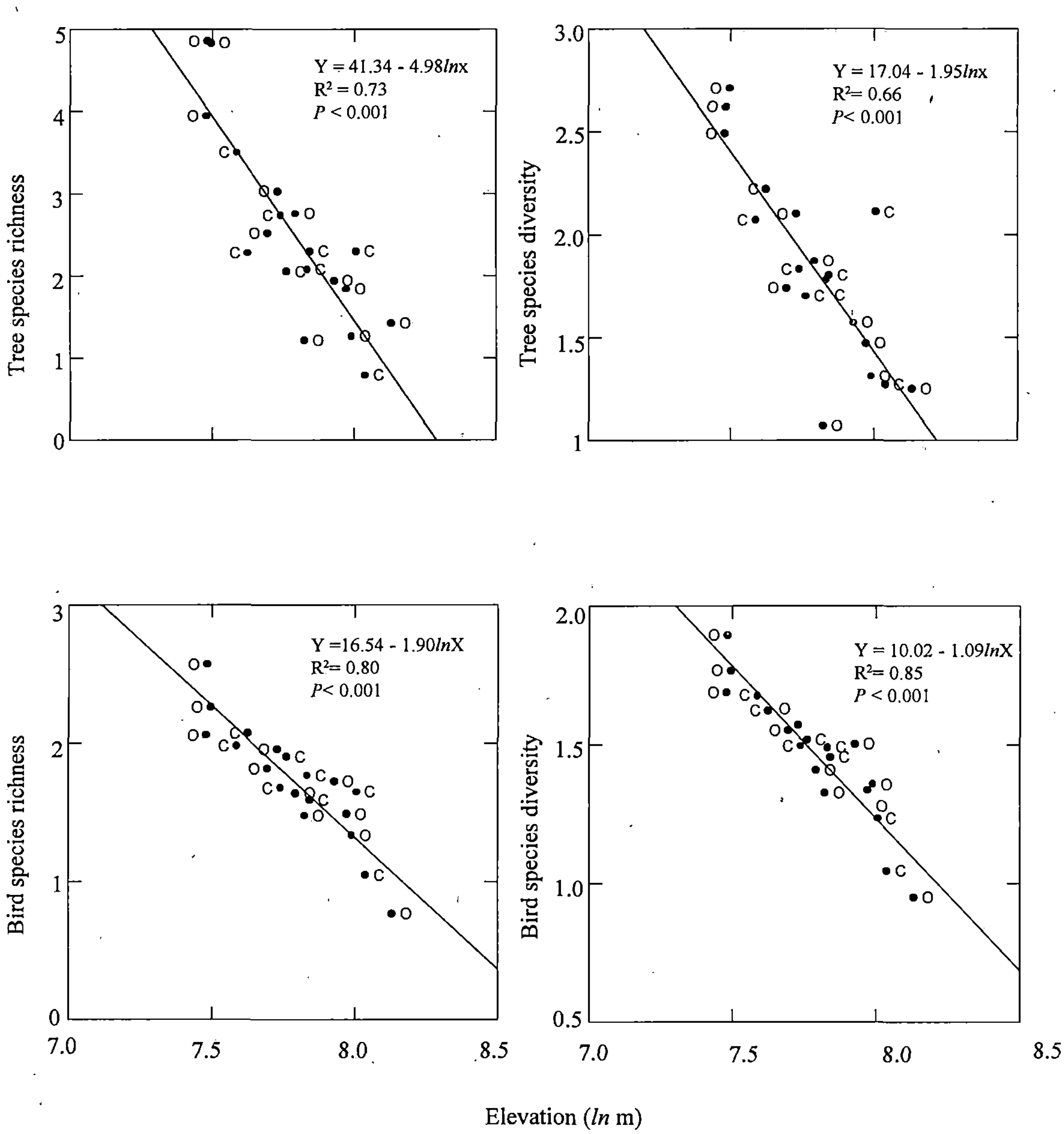


Fig 6.4. Relationship on woody tree species richness and diversity and bird species richness and diversity with elevation in the forests (O = open canopy condition, C = closed canopy condition) of Yuksam-Dzongri trekking corridor. (Elevation transformed to natural log)

CHAPTER VII

Chapter VII

Bird-habitat relationships and guild structure

7.1. Introduction

Contrary to often sporadic and unpredictable natural phenomena, the human population exert tremendous and continued pressure on wildlife habitats. Human induced disturbance may range from gross change in physical landscape to subtle manipulations, but identification of areas of high conservation interest requires substantial time and effort for detail inventories. Therefore, conservationists are interested in selecting efficient and a few of indicators for measuring and monitoring biological diversity (Kremen 1992, Pearson & Cassola 1992, Predergast *et al.* 1993, Faith & Walker 1996). One strategy for biodiversity assessment is therefore, to focus monitoring on indicator organisms, but guidelines are lacking for selecting appropriate species or groups (Kremen 1992). Birds have been considered as good predictor of biodiversity, which serve as indicators of overall changes in habitat quality (Debinski & Brussard 1994, Wong 1985), because they respond to habitat structure (MacArthur & MacArthur 1961) and represent several trophic groups or guilds (Steele *et al.* 1984).

The rapid deforestation of tropical forests and large scale human disturbance has increased concern about their effect on vegetation structure and bird communities (Terborgh 1980, Schulte & Niemi 1998). Study on habitat is the cornerstone of modern ecology because of strong relationship between animals and measurable habitat (MacArthur & MacArthur 1961, Niemi & Hanowski 1984, Block 1989). It is evident that resource harvests by people causes thinning of woodlands (Bolsinger 1988, Griffin & Muick 1990), affects vegetation structure and composition (Block & Morrison 1991, Block & Brennan 1993), reduces canopy volume and brings about changes in the age and size distribution (Sundriyal *et al.* 1994, Sundriyal & Sharma 1996, Aigner 1996, Aigner *et al.* 1998). These affect the occupancy and resource use pattern of bird communities (Block & Morrison 1991, Block & Brennan 1993). Bird species diversity, is a reliable index of quality or "health" of ecosystem and the relationship of wildlife to habitat conditions (Debinski & Brussard 1994, Javed 1996). In order to understand why distribution vary in the way they do and to develop any means of making accurate predictions of future changes in the population features, we must know how populations relate to the underlying habitat (Wiens & Rotenberry 1981). The combination of bird censusing with habitat measurements permits to evaluate not only the variation in abundance of the bird species over the region sampled but also to associate these variations with change in habitat composition and structure (MacArthur & MacArthur 1961, Kremen 1992, Javed 1996).

Yuksam-Dzongri trekking corridor is one of its kind in Sikkim with rich biodiversity and scenic beauty of world's third highest mountain (Mt. Khanchendzoga). A wide variety of birds, trees, rhododendrons, medicinal plants and other high altitude flowering plants attract about 2000 trekkers annually in the area (Sharma *et al.* 2000). Disturbances such as firewood extraction, fodder lopping and cattle grazing have increased during the last two decades due to growth in tourism and population that have resulted in fragmentation and deterioration of wildlife habitat and natural beauty of the area (see chapter V). This could have major negative impacts on wildlife. An exploratory monitoring on bird and habitat relationships is of special importance because of disturbances along the corridor in recent years. As described in previous chapters, the study area had shown immense human pressure along the corridor. Therefore, the effect of habitat modification due to human exerted pressure on bird community-habitat relationship and bird guild structure in those modified habitats is the central theme for this chapter. The present chapter was outlined to understand (a) differences in vegetation structure between habitat conditions (b) relationships between bird species diversity and richness with that of tree species diversity and richness, and (c) relationships of bird considering community structure, migratory groups and feeding guilds with habitat conditions for evaluation of indicator attribute.

7.2. Methods

Vegetation variables reflecting stand structures and complexity were used for statistical analysis (chapter VI, Table 6.1). Bird diversity indices used in chapter VI were used for analysis of habitat-bird relationship. Number of bird species, density, abundance and seasonal changes were analyzed separately for the relationship with habitat attributes. Recorded species were categorized into migratory groups as resident (species breeding or within the breeding range), summer migrants (species *en route* to breeding or wintering grounds), winter migrants and incidental species (rarely detected and not regarded as regular components) following Ali (1989), Ali and Ripley (1987) and personal observation. Classification of birds into categories based on migratory status can be arbitrary; therefore, feeding guilds were also considered (Saur *et al.* 1996). Feeding guilds were categorized into insectivores, nectarivores, granivores, carnivores, frugivores, general feeders and omnivores based on Ali and Ripley (1987) and field observations. Compositions of migratory as well as feeding guilds were tested for each season separately and significantly varied migratory groups and feeding guilds were treated separately for ANOVA (Blair 1999). I pooled sexes and ages of all species because my objective was to examine community-habitat or species-habitat associations. Further, sample size constrains precluded separating ages and sexes for most of the species. Species with highest frequency of occurrence (>40%) were selected for species-habitat associations by correlating with PCs. Species with highest frequency (>40%) were treated individually for their habitat preferences and indicator properties.

7.2.1. Data analysis

Data were analyzed to describe habitats of the birds and to determine whether bird exhibited discernible patterns of habitat use at temporal and spatial levels. Principal Component Analysis (PCA), a multivariate statistical technique, was performed to reduce the dimensions of vegetation variables by deriving 5 uncorrelated principal components (PCs) from a set of 21 significantly correlated variables (Javed 1996, Schultz & Niemi 1998). The vegetation components derived from the PCAs were used as the predictor (independent) variables and bird components were used as response (dependent) variables. Variables were not transformed prior to analysis as univariate normality of individual variables does not infer to multivariate normality (Block 1989) and these components are easily interpretable in biologically meaningful terms (Saab 1999).

Bird species diversity (BSD) and richness (BSR) from chapter VI were tested for regression with tree species diversity (TSD) and tree species richness (TSR) keeping BSD and BSR as constant. Seasonal changes on these relationships were analyzed with two-tailed *t*-test for different habitat types and seasons. Bird community attributes were correlated with the PCs with Pearson product moment correlation. Apart from community attributes, migratory groups, guild and selective individual species with higher frequency (>40%) response to vegetation structure were also considered for analysis. All statistical tests were performed in SYSTAT, version 6. (1996).

7.3. Results

7.3.1. Bird community-habitat relationship

BSR and BSD were plotted at all the transects against respective TSR and TSD (Fig. 7.1). Both the BSR and BSD showed positive and linear relationship with the tree species richness and diversity. But the relationships were not consistent at different habitat conditions, seasons and forest areas (Table 7.1). Tree species diversity was significantly related with bird species diversity during summer at closed canopy condition in LF but not in the winter. Similar variations were observed in the relationships at different habitat conditions (Table 7.1).

Five principal components from PCA on vegetation variables had eigen vectors above one and they together accounted 83% of the total variance. Among the components, PC1 explained 33% of variance followed by PC2 = 23%, PC3 = 14%, PC4 = 7% and PC5 = 6% of variance. The first principal component described a gradient of basal area including woody biomass and crown cover, which represented habitat with close canopy, higher woody biomass and high basal area. The habitat was positively correlated with crown radius, total tree density and negatively with tree density of <10 m height class suggesting lower number of smaller trees (Table 7.1). The second principal component described a gradient of dry litter depth and humus depth. The PC2, which showed negative correlation with clay depth, and positively with trampling, lopped branches and chopped trees, represented habitat with higher number of lopped branches and chopped trees with lower litter and humus depths, and higher trampling suggesting high disturbances. High loadings on PC3, which correlated positively with tree densities of 20-30 cm diameter class, 20-30 m height, herb species richness and negatively with 30-40 cm diameter class (Table 7.2). The PC3 represented diverse stand with higher herb as well as shrub and complex vertical stratification. Finally, PC4 and PC5 did not show high loadings for the vegetation attributes; thus, we considered only PC1, PC2 and PC3 for further analysis. These 3 PCs accounted 71% of the variance explained by the components.

BSR and BSD were significantly and positively correlated with PC3 (r=0.622, P=0.01 and r=0.651, P=0.01 respectively), which represented the tiered heterogeneity with diverse habitat. Similarly, bird evenness was also significantly related with PC3 (r=0.456, P=0.05). Bird density showed significant positive relationships with PC2 and PC3 (r=0.459, P=0.05 and r=0.515, P=0.05 respectively). This has suggested that the disturbed areas with vertical heterogeneity have higher bird density (Table 7.3).

7.3.2. *Bird guild and migratory status*

Migratory groups showed significant difference between the forest types and species compositions (species per migratory group) (Fig 7.2). The influence of forest type and migratory status was significant for the species composition. Feeding guilds showed significant difference between the two forest types, seasons and species composition (number of species per guild) (Fig. 7.3). Interactive effects were significant for forest types and season forest type and guild ($F_{6,210}$=19.3, P<0.001), habitat condition and guild ($F_{6,210}$=2.5, P<0.02), season and guild ($F_{6,210}$=114.4, P<0.001) and forest type , season and guild ($F_{6,210}$=14.2, P<0.001). These suggest that each of the spatial, temporal and species composition influences each other.

7.3.3. Seasonal changes in guild and migratory species

Owing to significant difference on migratory groups, each group was treated separately for ANOVA (Table 7.4). Incidental species significantly differed between the habitat conditions and season. Resident species richness was significantly influenced by season and the effect of interaction for forest type and season was biologically meaningful ($F_{1,30}$=4.03, P<0.05). There was a significant variation in summer visitors between the seasons as well as at different habitat conditions (closed and open canopy). Summer visitors showed weak but significant difference between the forest type, habitat condition and season. Effect of interaction was significant only for forest types and seasons ($F_{1,30}$=5.9, P<0.02). Similarly, winter visitors significantly differed between the lower and upper forest ($F_{1,30}$=8.11, P<0.001) (Table 7.4).

Due to significant difference among the feeding guilds, each guild was also treated separately for ANOVA (Table 7.4). Insectivores significantly differed between the forest types and seasons ($F_{1,30}$=13.3, P<0.001 and $F_{1,30}$=266.7, P<0.001 respectively). Significant interaction between forest types and season ($F_{1,30}$=30.9, P<0.001) indicates that forest types influenced the variation in number of species with the change in season. Apart from the influence on insectivores, forest types, habitat conditions and season also significantly influenced omnivores. None of the interactions were found meaningful for omnivore species. Similarly, species composition of frugivores, granivores, nectarivores and general feeder were significantly influenced by seasons (Table 7.4).

7.3.4. *Guild-habitat relationship*

Pearson product moment correlation on 3PCs with overall guild and migratory composition (total number of species per feeding guilds and migratory group) did not show biologically meaningful relationship with any of the components. But, the relationships became meaningful when these guilds and migratory groups treated separately. Among the migratory groups, only winter visitors were found to have significant relation with PC2 (r=0.398, n=38, P<0.05) and PC3 (r=0.349, n=38, P<0.05). Insectivores, omnivores, nectarivores and carnivores significantly correlated at least with one of the 3 components (Table 7.5). Insectivores were positively related with PC1 (r=0.411, n=38, P<0.05), omnivores were positively related with PC2 (r=0.445, n=38, P<0.01) and PC3 (r=0.457, n=38, P<0.01). Nectarivores were positively related with PC2 (r=0.679, n=38, P<0.01) and carnivores with PC3 (r=0.462, n=38, P<0.01).

7.3.5. *Selected species-habitat relationship*

Results on correlation of species with higher frequency (>40%) and the vegetation parameters (PCs) have revealed that only one species (white-throated laughingthrush, r=0.454, n=19,P<0.05) showed biologically meaningful relation with PC2 (Table 7.6). It reflected that white-throated laughingthrush prefer human disturbed habitat with canopy opening and shrubby vegetation. White-tailed nuthach showed positive relation with PC2 but the value was not biologically meaningful. The correlates with PC2 and PC3 were higher for Ticklle's warbler suggesting preference in disturbed and structurally sound habitat. Greenish warbler was negatively related with closed canopy and positively related to open canopy conditions (Table 7.6) suggesting habitat preference for open area rather than dense forest. Among the other five species (species with lower frequency) three species namely Collared grosbeak, Long-billled thrush and Mrs Gould's sunbird were significantly related to PC 2 suggesting open area as their habitat preference. Similarly, Smokey warbler was related negatively and Short-billed minivet positively with PC3 (Table 7.6).

7.4. Discussion

Erdelen (1984) has reported that in the temperate forests, only the stratification of vegetation influences bird diversity. Strong correlation on bird community attributes with PC3 suggests that bird diversity is directly related to the structural complexity in the form of trees, shrubs, and herbs. Moreover, in the present study, the bird species richness and diversity showed positive correlation with woody tree species diversity and richness. These suggest that apart from the vertical heterogeneity, bird community is also associated with plant species diversity (Winternitz 1976, Young 1977, James & Wamer 1982). These relationships differed at the spatial and temporal scale. This made the interpretation difficult, but the variations were possibly due to seasonality in migrants and phenological events of plant species.

In PCA, large number of vegetation variables for bird-habitat relationship was considered as it easily explained the relationship in better way than a few selected variables (Wiens & Rotenberry 1981). The three PCs explained distinct habitat conditions available to birds in the study area. Significant seasonal variations in the migratory groups reflected the phenological variation and resources availability. Relatively higher numbers of migrants in the opened condition of both the forest types suggest that human interference caused creation of mid successional stage by opening the area which are beneficial to the migrants. Hutto (1980, 1989) also made similar conclusions from disturbed vegetation of Western Mexico. The variations between the season, forest type and habitat condition, of summer visitors suggested behavioral sensitivity to spatial and temporal distributions. Habitat preference seems convincing for incidental species, which was greater in the opened conditions. Interestingly, winter visitors were strongly influenced by the forest types. In general, a significant decrease in number of summer migrants during the winter season was obvious as per their migratory behavior. Perhaps, most interesting was the significant decrease in resident species at different habitats during winter. It is speculated that the decrease was as a result of the wide range of habitat availability and their altitudinal movements as they go lower than the designated sites (1780-3600 m) during winter. However, it is important to have detail information regarding habitat and geographical distribution of migrants and landscape level study before drawing conclusions (Hutto 1989, Saab 1999).

A guild is a functionally related group of species that exploit the same class of resources in similar way (Kikawa & Anderson 1986). Many of the correlation on habitat variables with bird guild and migratory groups could not be explained with reference to available literature. Therefore, we forward speculative explanations. Correlation on insectivores with the PCs showed a positive relationship with close canopy where the vegetation was dense, higher canopy coverage and higher basal area. This could be due to abundant insects as a result of moist condition and dense foliage (Erwin 1982, 1988). On the other hand, nectarivores were related with habitat having more disturbances. This could be due to higher number of flowering plants at open areas (Fraga 1989). The carnivore was positively related to habitat having vertical complexities. Extensive field observations revealed that the habitat with well marked vertical stratification is an ideal situation for nesting birds and small mammals as prey for the carnivores. Granivores showed positive relationship with more disturbed and opened habitats. Granivores are especially prevalent and often restricted to early stages of ecological succession or open areas. This is due to their adaptive features to areas where seed production is higher. The open areas do have high seed productivity (Leck *et al.* 1989, Wiens & Johnston 1974), either in natural (Terborgh *et al.* 1990) or man-modified habitat (Karr 1976, Lopez-Ornat 1990). Forest openings generally have larger seed banks available to granivores (Diaz & Telleria 1996). This condition was prevalent in our study sites, as many small seeded herbs such as *Viburnum cordifolia, Mahonia sikkimensis* and fruiting herbs belonging to graminae were abundant in opened canopy condition in the lower forest and *Frageria nubicola, Rosa* sp. and many fruiting herbs in the upper forest. Omnivores were significantly related to open canopy habitat as well as with better stratification where resource (insects, seed, fruits and small mammals) availability was abundant. Relatively, higher number of frugivores at the open canopy condition, though did not show a significant relationship, could be because of visibility of fruits (Thomson & Willson 1978), greater predictability over time (Stiles 1975, Denslow *et al.* 1986) or sweeter (Aalders *et al.* 1969, Levey 1987). Among the migratory species only winter visitors were positively related to PC2 and PC3 suggesting that exploitation of the open areas as well as habitat with greater vertical complexity irrespective of their guild.

Species level bird-habitat relationships were not very convincing and interpretable. Though a few species with lower frequencies showed some remarkable relationship with the habitat types, species with higher frequency were not significantly related with habitat except one.

7.5. Conclusion

Human pressures such as firewood, fodder, timber extraction and grazing bring about subtle changes in habitats available to the birds. Response of organisms to these changes provides information not only on the viability of life support system but also on efficacy of management of areas with such pressures.

Ordination technique provided a predictive measure for biological diversity monitoring. The analysis could identify explainable relationship between bird components and habitat types. Guild represented preferences for diverse and vegetation rich habitats suggesting that they are directly related to habitat with high heterogeneity. Moreover, significant relationships between the bird species diversity and richness with tree species diversity and richness added more convincing relationships with the overall biodiversity.

Among the bird community, migratory groups, feeding guild and species level analysis showed that only a few feeding guilds represented as potential predictor for habitat quality. Bird species diversity and richness could not make interpretation explainable because they did not reflect any relationship with the undisturbed or disturbed conditions. There was a distinct pattern among the migratory groups with strong seasonality but the relationships with habitats were not convincing. Knowledge of structural features and local habitat conditions seems to be inadequate for understanding bird community dynamics. Among the feeding guilds, insectivores, nectarivores, granivores and omnivores showed specific habitat choice. Significant seasonal changes among the guilds revealed that seasons, forest types and habitat conditions influenced guilds. In the present study PCA helped to draw strong relationship between the habitat quality and the feeding guilds. Dramatic differences on birds in different habitat conditions reflected the heterogeneity in habitat qualities along the corridor. But, it became apparent that bird represents vegetation rich habitat and structural heterogeneity. These results supported the conclusion that though bird diversity also reflects tree diversity, guilds are better predictor for habitat quality and maintenance of habitat heterogeneity being more important for conservation of biological diversity.

Table 7.1. Comparision of plant species diversity (PSD) and plant species richness (PSR) with bird species richness (BSR) and bird species diversity (BSD), for summer and winter in Yuksam-Dzongri trekking corridor.

Forest type	Habitat	Season	Correlate	r_s-statistic
Lower forest	Closed canopy	Summer	PSD-BSR	0.40
			PSD-BSD	0.80*
			PSR-BSR	-0.60
			PSR-BSD	0.00
		Winter	PSD-BSR	1.00**
			PSD-BSD	0.20
			PSR-BSR	0.40
			PSR-BSD	0.80*
	Open canopy	Summer	PSD-BSR	0.80*
			PSD-BSD	0.60
			PSR-BSR	0.90**
			PSR-BSD	0.70*
		Winter	PSD-BSR	0.90**
			PSD-BSD	0.70*
			PSR-BSR	1.00**
			PSR-BSD	0.90**
Upper forest	Closed canopy	Summer	PSD-BSR	0.77*
			PSD-BSD	0.88*
			PSR-BSR	0.71*
			PSR-BSD	0.77*
		Winter	PSD-BSR	0.80*
			PSD-BSD	0.20
			PSR-BSR	0.63*
			PSR-BSD	0.16
	Open canopy	Summer	PSD-BSR	0.20
			PSD-BSD	0.40
			PSR-BSR	0.16
			PSR-BSD	0.63*
		Winter	PSD-BSR	0.54
			PSD-BSD	0.48
			PSR-BSR	0.43
			PSR-BSD	0.26

(*t*-test for pair samples)
*: $P \leq 0.05$, **: $P \leq 0.01$

Table 7.2. Principal component loadings for vegetation variables measured in 19 quadrats along Yuksam-Dzongri trekking corridor.

Vegetation variables	Principal components				
	PC1	PC2	PC3	PC4	PC5
Mean diameter at breast height	0.891	0.354	-0.084	0.057	0.150
Mean basal area	0.818	0.370	-0.269	0.046	0.220
No. of tree with height <10 m	-0.786	-0.151	-0.473	0.223	-0.059
Tree density	-0.784	-0.161	-0.102	0.506	0.101
Mean biomass	0.724	0.199	-0.394	0.251	0.299
Mean crown radius	0.656	0.467	0.489	0.227	-0.162
Mean crown area	0.645	0.512	0.433	0.180	-0.203
Mean first branch height	0.640	0.451	0.320	0.337	0.251
No. of tree with DBH 10-20 cm	-0.635	-0.132	0.232	0.299	0.084
Naturally falen tree	-0.587	0.118	-0.019	-0.129	0.545
Mean drylitter depth	-0.453	0.819	0.043	-0.218	0.111
Mean humus depth	-0.467	0.756	-0.113	-0.192	-0.171
Trampling	0.372	-0.750	0.265	-0.188	0.131
Mean clay depth	-0.430	0.729	0.209	-0.165	0.059
Chopped branch	0.230	-0.615	0.062	0.180	-0.189
Herb species richness	0.384	-0.603	0.081	-0.324	-0.280
Chopped tree	0.485	-0.544	0.386	0.079	-0.079
No. of tree with DBH >30 m	0.250	0.220	-0.794	0.308	-0.200
No. of tree with DBH 21-30 m	-0.280	0.354	0.708	-0.178	0.076
No. of tree with height >30 m	-0.433	-0.337	0.582	0.301	0.345
Shrub density	-0.466	0.203	0.355	0.443	-0.451
Per cent of total variance explained	33.1	23.0	14.0	6.6	5.5
Cumulative variance explained	33.1	56.1	70.1	76.7	82.1

Table 7.3. Correlation coefficient between bird community attributes and principal components for along Yuksam-Dzongri trekking corridor.

Community attributes	PC 1	PC 2	PC 3
Bird species richness	0.274	0.012	**0.622**
Bird species diversity	0.199	-0.012	**0.651**
Relative density	**0.459**	-0.060	**0.515**
Pielou's evenness	0.001	-0.060	**0.456**

Bold values are significant at $P<0.05$

Table 7.4. Three-way ANOVA on migratory/guild structure (number of species) for two forest types (lower, upper), canopy conditions (closed, open) and seasons (summer, winter) along the Yuksam-Dzongri trekking corridor

Guild/migratory status	Forest type (F)	Plot condition (P)	Season (S)	FxS
Accidental sightings	6.25**	NS	13.26**	NS
Residents	NS	NS	121.96**	4.03*
Summer visitors	3.99*	4.97*	10.23**	5.9*
Winter visitors	8.11*	NS	NS	NS
Insectivores	13.3**	NS	266.7**	30.9**
General feeders	NS	NS	70.5**	NS
Frugivores	NS	NS	34.7**	NS
Omnivores	5.3*	6.8**	5.9**	NS
Nectarivores	NS	NS	22.6**	NS
Carnivores	NS	NS	NS	NS
Granivores	13.3**	NS	NS	NS

*$P \leq 0.05$
**$P \leq 0.01$
NS = not significant

Table 7.5. Correlation coefficient between guild/migratory species and vegetation components

Guild/migratory status	PC 1	PC 2	PC 3
Insectivores	**-0.411**	0.136	-0.118
General feeders	0.169	-0.106	-0.064
Frugivores	0.119	0.000	-0.179
Omnivores	0.218	**-0.445**	**0.457**
Nectarivores	0.233	**0.679**	0.095
Carnivores	-0.094	0.070	**0.462**
Granivores	-0058	**-0.381**	0.027
Accidental sightinngs	-0.122	0.113	-0.150
Residents	-0.201	-0.220	0.109
Summer visitors	0.065	0.033	-0.187
Winter visitors	-0.138	**0.390**	**0.349**

Bold values are significant at $P<0.05$

Table 7.6. Correlation coefficient between selective bird species with higher frequency (>40%) and principal component along Yuksam-Dzongri trekking corridor.

Species/latin name	PC 1	PC 2	PC 3
Black-faced Laughnigthrush (*Garrulax affinis*)	0.059	-0.203	0.409
Collared Grossbeak (*Mycerobas affinis**)	-0.202	**-0.467**	0.204
Eurasian Treecreeper (*Certhia familiaries*)	-0.160	-0.303	0.009
Greenish Warbler (*Phylloscopus trochilodes*)	-0.354	0.299	0.030
Grey-headed Canary Flycather (*Culicicapa ceylonensis*)	-0.245	0.315	-0.036
Large-billed Crow (*Corvus macrorhynchos*)	-0.039	-0.347	0.252
Long-billed Thrush (*Zoothera monticola**)	0.437	**0.599**	0.238
Mrs Gould's Sunbird (*Aethopyga gouldiae**)	0.160	**0.602**	0.183
Rufous Sibia (*Heterophasia capistrata*)	0.200	-0.223	-0.015
Rufous-bellied Niltava (*Niltava grandis*)	-0.274	0.292	0.016
Rufous-winged Fulvetta (*Alcippe castaneceps*)	0.061	0.352	-0.215
Short-billed Minivet (*Pricrocotus brevirostris**)	0.046	0.229	**0.476**
Smokey Warbler (*Phylloscopus fuligiventer**)	0.013	-0.180	**-0.446**
Tickell's Leaf Warbler (*Phylloscopus affinis*)	0.279	0.391	0.363
Verditor Flycatcher (*Eumyias thalasina*)	0.159	0.210	0.292
White-tailed Nuthach (*Sitta himalayansis*)	-0.155	0.405	-0.083
White-throated Fantail (*Rhiphidura albocollis*)	-0.163	0.268	-0.061
White-throated Laughingthrush (*Garrulax albogularis*)	-0.002	**0.454**	-0.260
Yellow-billed Blue Magpie (*Urocissa flavirostris*)	0.267	-0.168	0.408

* = species with lower frequency (<40%), Bold values indicate significance at $P<0.05$

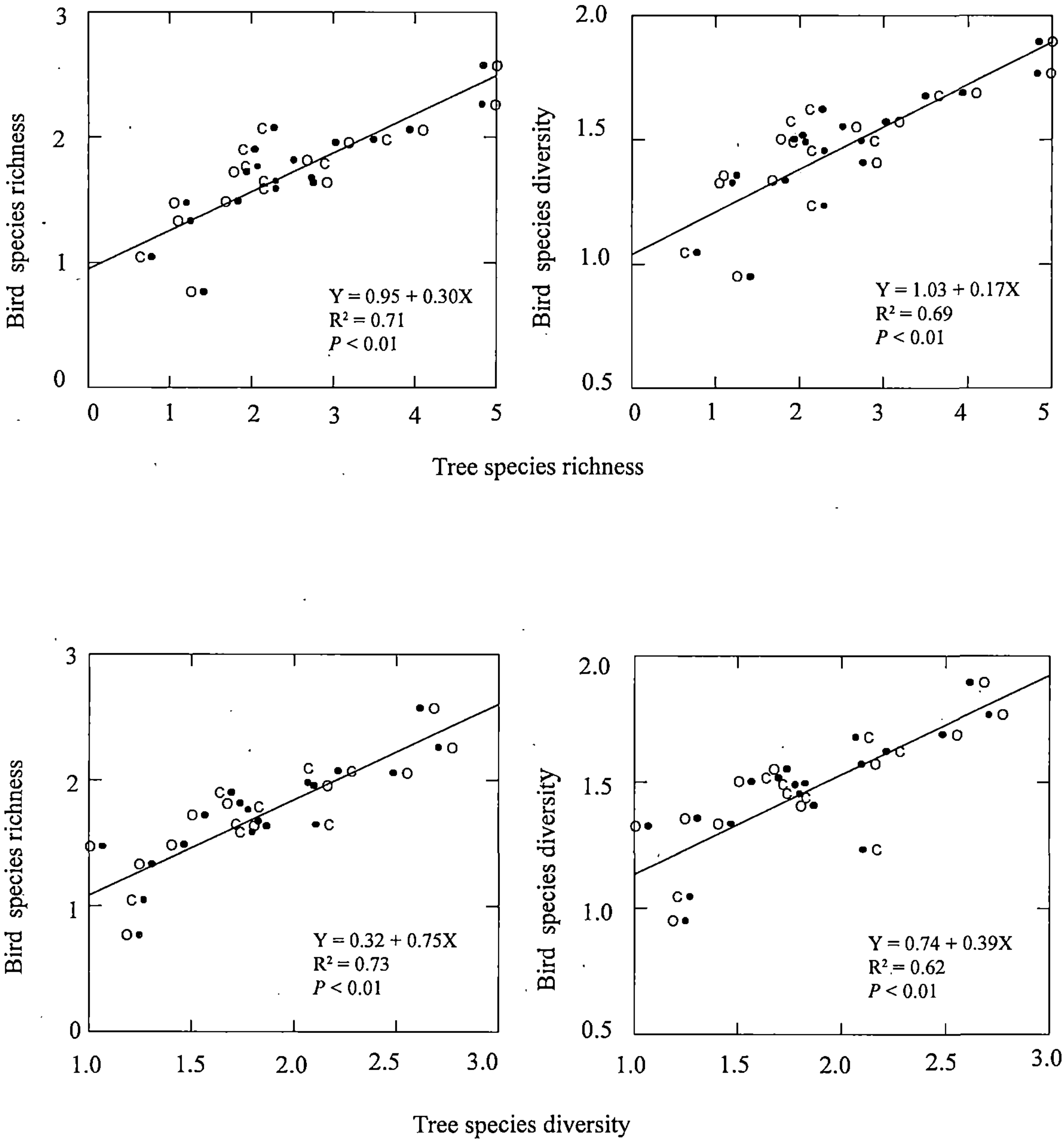
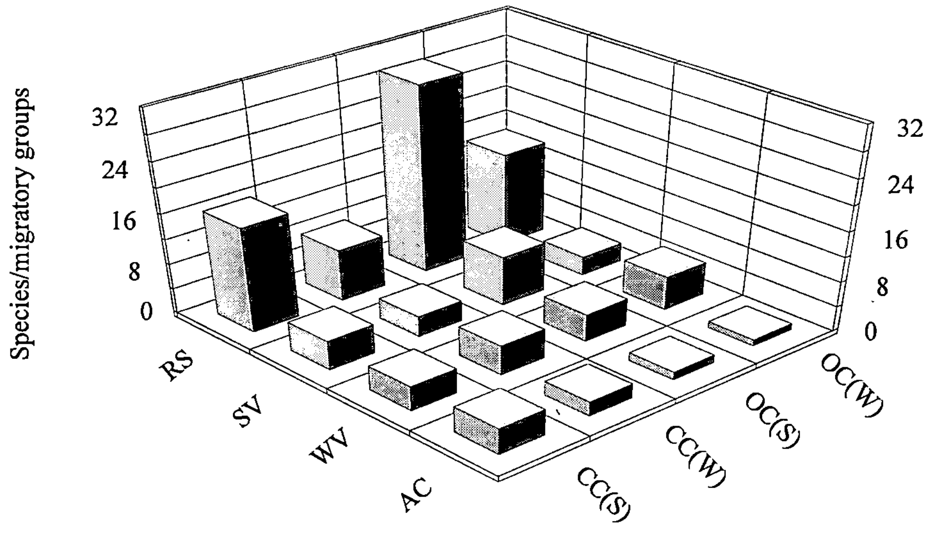
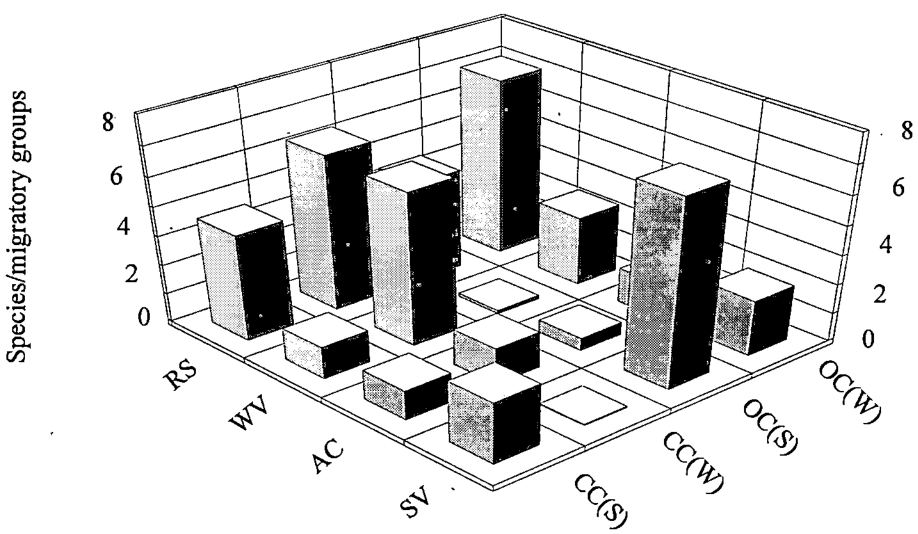


Fig.7.1. Tree and bird diversity indices in the forests showing significant relationships between tree species richness, tree species diversity and bird species diversity and bird species richness (O = open canopy condition, C = closed canopy condition) of Yuksam-Dzongri trekking corridor.

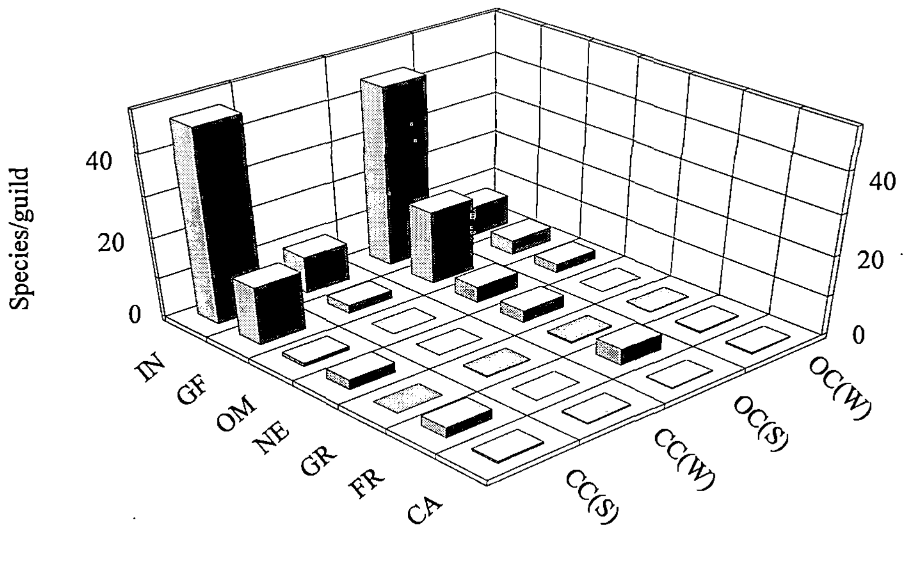


(a)

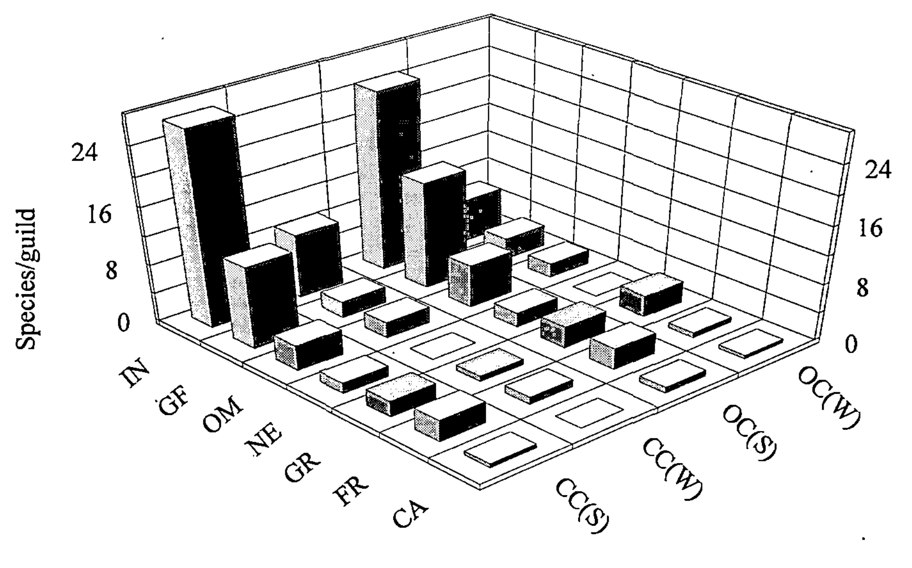


(b)

Fig. 7.2. Migratory species composition at (a) lower forest and (b) upper forest, and habitat conditions during summer and winter seasons along the Yuksam-Dzongri trekking corridor. ANOVA: Forest type $F_{1,210}$ =6.7 P<0.01; migratory groups $F_{3,210}$=5.5, P<0.001; forest type x season $F_{1,210}$=18.6, P<0.001; forest type x migratory groups $F_{1,210}$=19.3, P<0.001; habitat condition x migratory groups $F_{3,210}$=6.5, P<0.001. Other interactions not significant. $LSD_{(0.05)}$ = 0.23. (RS = residents, WV = winter visitors, AC = accidental sighting species, SV = summer visitors, CC = closed canopy condition, OC = open canopy condition, S = summer and W = winter).



(a)



(b)

Fig. 7.3. Guild composition at (a) lower and (b) upper forests and habitat conditions during summer and winter seasons along the Yuksam-Dzongri trekking corridor. ANOVA: Forest type $F_{1,210}$ =11.4, P<0.001; season $F_{1,210}$ =2965, P<0.001; guild $F_{1,210}$ =268, P<0.001; forest type x season $F_{1,210}$ =18, P<0.001; forest type x guild $F_{1,210}$ =19, P<0.001; habitat condition x guild $F_{1,210}$ =2, P<0.02; season x guild $F_{1,210}$ =114, P<0.001; forest type x season x guild $F_{1,210}$ =14, P<0.001. Other interactions not significant. $LSD_{(0.05)}$ = 0.49. IN = insectivores, GF = general feeders, OM = omnivores, NE = nectarivores, GR = granivores, FR = frugivores, CA = carnivores, CC = closed canopy condition, OC = opened canopy condition, S = summer and W = winter.

CHAPTER VIII

Chapter VIII

Butterfly community and habitat association

8.1. Introduction

Biotic inventories provide critical data for conservation planning, but frequently conservation decisions are made without surveys due to lack of time, funds, expertise or appropriate methodology. To set aside representative area around the globe, that will protect the fullest range of biological diversity requires far more complete knowledge of the distribution and abundance of organisms than currently available (Soule & Kohm 1989). Biodiversity surveys are becoming popular in protected areas (Debinski & Brussard 1992, 1994). A method for target taxon analysis is therefore proposed for streaming regional biotic inventories. Species rich taxon with adequate knowledge about natural history has been recommended to surrogate biological diversity (Kremen 1992, Blair 1999). Many researchers (Gilbert 1980, 1984, Pyle 1980, Brown 1982, Murphy *et al.* 1990, Kremen 1992) have suggested that butterflies are well suited as indirect measures of environmental variations because they are sensitive to local climate and light levels (Ehrlich *et al.* 1972, Weiss *et al.* 1987, 1988). Moreover, butterfly diversity surrogates measures of plant diversity as there are strong interactions between larvae and adult host plants (Kremen 1992). The use of butterfly in assessment of biological diversity has gained much ground in the recent years.

A variety of biotic and abiotic factors, such as distribution of food, shelter, microclimate or intra- and interspecific interactions influence the distribution of animals in a habitat. In butterflies, the distribution of food and microclimate are thought to be especially important (Douwes 1975, Murphy *et al.* 1984, Boggs 1987). Therefore, butterflies are widely used as indicator species by many researchers and conservationists (Cheverton & Thomas 1982, Kremen 1992, Pearson & Cassola 1992).

Himalaya is rich in all components of biodiversity. In the Himalaya, 80 per cent of the butterflies have been reported as forest species, of which about 60 per cent of them occur within the forests below 3,000 m. Inspite of high butterfly richness, no serious attempt has been made in Sikkim except a few general documentation (Haribal 1992, see also Chapter II). The present study is an attempt to survey the habitat use pattern of butterflies along the Yuksam-Dzongri trail. In the study, species composition, diversity indices and relationship with the habitat types were examined at the designated areas as described before. The results were then tested to answer the usefulness of bird and butterfly taxa as indicator species for biodiversity assessment.

8.2. Methods

Butterflies were monitored both by visual and baited trap methods at 19 transects each measuring 100 m crossing each of the permanent plots [4 each at closed canopy stand (CC) of lower forest (LF) and upper forest (UF), 5 at open canopy stand (OC) of LF, 4 at CC of UF and 6 at OC of UF] during summer (May-August) and in winter (October-February) for one year. Identification of specimens were made using the photoplates provided by Haribal (1992). The total number of sampling made was 114. At each permanent plot (see Chapter V), a station for butterfly observation was set and diversity indices and density were extrapolated from the collected data. Butterfly species were recorded by transect walk (modified from Pollard *et al.* 1975, Pollard 1977) with visual observations for two hours (morning 1100-12-00 and afternoon 1200 - 1300) in good weather days. Species that were not easily recognisable were identified with the help of fermented banana baiting (De Vries 1988). Each day trapped butterflies were collected for identification or marked and released after identification (Kremen 1992). The canopy foragers were observed with the help of a binocular.

8.2.1. Data analysis

The recorded data on identified species were considered for the analysis. Simple regressions were applied to examine diversity trends with elevation. Analysis of variance (ANOVA) was performed for interactions between forest types, habitat conditions and seasons for the species composition. Comparison of diversity indices for effect of forest types and habitat conditions were tested with Mann-Whitney U test following Hill *et al.* (1995) with some modifications. Pearson correlation and linear regression were used to evaluate the relationship between butterfly and habitat as well as with bird. All tests were made using SYSTAT (1996).

8.3. Results

8.3.1. Butterfly species composition

A total number of 391 butterfly individuals were recorded in 114 samplings during 1997-1998. These individuals represented 49 species under five families (Appendix B). The list of the species furnished in the Nymphalidae was the most dominant group (47%) followed by Papilionidae (24%), and Pieridae (18%) (Fig. 8.1). Mean number of species and densities at different forests are presented in Table 8.1. The highest number of species was recorded at open canopy condition of lower forest followed by closed canopy condition at LF and the least was at the closed canopy condition of upper forest (UF). Similarly, butterfly richness and density were also higher at the open canopy forests of LF and UF (Table 8.1). Seven species are exclusively found in the lower open forest, followed by six in lower closed canopy forest, three at open forest at the upper forest and only one in closed canopy forest at upper forest (Appendix B).

Butterfly species diversity, its richness and the evenness significantly differed between the forest types (Mann Whitney test values were U=2489.5, P<0.000, U=2070.5, P<0.009, U=2175.5, P<0.001) respectively (Table 8.2). On the other hand, the difference in butterfly species between the open and closed canopy conditions was significant (U=1799.5, P<0.21).

8.3.2. Seasonal change in butterfly species

Mean number of species of butterflies differed significantly between the forest types and habitat condition (ANOVA: $F_{1,106}$= 7.4, P<0.007 and $F_{1,106}$= 5.9, P<0.01) respectively (Fig. 8.2). Significant interaction between the forest types and seasons ($F_{1,106}$= 9.2, P<0.003) indicates that the forest types and seasons influenced the variation in number of species among the forest types with the change of the season. But, other interactions were not significant.

8.3.3. *Butterfly habitat relationship*

As predicted (Chapter I) both butterfly species diversity ($Y=9.58-1.2lnX$, $R^2=0.59$, $P<0.001$) and its richness ($Y=9.08-1.1lnX$, $R^2=0.30$, $P<0.01$) were significantly and negatively correlated with the rise in elevation (Fig. 8.3) showing decreasing trend with the rise of elevation. The regression drawn (Fig 8.3) on the diversity indices of 19 transects showed significant positive relationship between the tree species diversity and butterfly species diversity ($Y=-0.42+0.46X$, $R^2=0.53$, $P<0.001$) but the relationship among the species richness of these two groups were not significant ($Y=0.64+0.12X$, $R^2=0.12$, $P<0.15$). Pearson product moment correlation on 3PCs (see Chapter VII) extracted from the vegetation data showed significant positive correlation of butterfly diversity only with PC3. The correlation with the other components was not significant (Table 8.3).

8.3.4. *Indicator properties*

There were distinct variation of the habitat between the lower and upper forests and open and closed canopy conditions (Chapter V). Moreover, the relationships between the tree diversity indices and bird diversity indices were also significantly positive (Fig. 7.1). The overall trend in diversity indices in butterflies, birds and the trees were remarkably similar across the elevation and habitat types (Figs. 6.4, 8.4 and Tables 5.2, 6.3 and 8.1). Though the number of butterfly species was consistently lower, all the three groups (trees, birds and butterflies) were generally higher at the open canopy forest and showed a strong correlation among the groups (Table 8.4). Tree species diversity, bird species diversity and the butterfly species diversity had significantly positive correlation (Table 8.4) suggesting that they are directly related to each other.

8.4. Discussion

Butterfly diversity in the Yuksam-Dzongri trekking corridor is not rich as the bird. The record of only 49 species in the whole corridor suggests that the area is poor in butterfly habitat. Species are sparsely distributed along the corridor. Majority of species explored the lower forest as their habitat. A linear decrease in the diversity along the altitude suggests similar to cases of tree and bird species diversity. One of the reasons for such decrease could be due to remarkable decrease in temperature along the trail, which is an important factor for the survival of butterfly (Brakefield 1992). Higher number of butterfly species and their diversity at the lower forest suggest that the lower forest is much better habitat compared to the upper forest. Higher relative humidity due to shade trees and dense canopy cover limits the number of butterfly species and their mean density in the closed canopy forest. Because, at higher relative humidity the larvae are susecptible to viral and bacterial diseases leading to their death. Furthermore, lack of plant species diversity in the closed canopy condition limits the food resources of both larvae and adult. This finding is contrary to report of Hill *et al.* (1995). In their study, Hill and his coworkers stated that there was greater species richness in unlogged forest due to greater vegetation cover with more shade but they have overlooked the physical feature of the habitat such as temperature and humidity which creates the microclimate in the habitat. Moreover, in contrary to the present study, the vegetation structure such as tree height and basal area are similar in their field stations. Therefore, it was assumed that such variation in habitat conditions might have brought about the differences.

Butterfly species richness, its diversity and evenness were all significantly higher at the open canopy compared to closed canopy forest at LF. Increase in diversity at the open canopy forest suggests that the butterflies use the open canopy forest where the diversity of tree species is higher. As discussed in chapter V, VI and the VII, open canopy forests are diverse in their vegetation composition and stratification. Butterfly also used these habitat conditions more extensively than the closed canopy forest. Some previous studies have also demonstrated such reduction in diversity following more extreme form of forest disturbance

(Holloway *et al.* 1992). Raguso and Llorente-Bousquets (1990) found an apparent increase in butterfly diversity following fragmentation in habitats due to selective logging. The significant relationship between butterfly diversity indices and tree diversity indices suggested that there is a strong interaction between the two groups (Hill *et al.* 1995). This relationship is expected because butterfly species diversity is a function of plant species diversity as their food plants and these are the product of coevolution (Ehrlich & Raven 1964, Loertscer 1995).

Though birds and butterflies use the environment in very different ways, significant relationship between these two groups and the strong association with the habitat types in them have suggested that they are directly related to the habitat quality. Moreover, significant correlation among trees, birds and butterflies suggest that the bird or butterfly study surrogates to each other. Therefore, if the conservation planners are interested in species richness, diversity and habitat quality evaluation, either group would serve as an adequate measure for the other at regional level. But, one would not intuitively guess that the bird and butterfly communities, on the whole, would respond to habitat in all areas in the same pattern as these were recorded in the present study. The differences may come due to variation on geographical feature, weather and the vegetation types (Blair 1999). For example, Pearson and Cassola (1992) studied on bird and butterfly species in the North America and found a strong correlation. Later Flather *et al.* (1997) reported that the pattern of bird and butterfly association was much weaker when the study was conducted across the different latitudes.

It is important to assess the human impact as it influences either by changing the habitat or by the maintenance thereof (Jones *et al.* 1987, Hannah *et al.* 1995). Usefulness of target taxa in monitoring such natural areas for biodiversity assessments are well documented (Kremen 1992, Pearson & Cassola 1992, Debinski & Brussard 1994, Blair 1999). As far as the suitability of bird and butterfly in biodiversity assessment is concerned, many of the researchers have supported the view of their usefulness (Kremen 1992, Pearson & Cassola 1992, Debinski & Brussard 1994). In the present work, butterfly community structure could show a distinct variation even between the open and closed canopy conditions which was not much convincing in the case of bird community. This finding has suggested that butterflies are more sensitive to the habitat disturbance compared to the birds (Debinski & Brussard 1994). Therefore, both bird and butterfly can be used as an important tool in the natural area management where there are time and funds constrains. Simple records of butterfly or birds can be used to predict the quality of habitat as they showed strong correlation and also can surrogate other taxa until there is no drastic change in vegetation types or the microclimate due to major geographical difference.

8.5. Conclusion

The accelerating human pressure in Yuksam-Dzongri trail has changed the vegetation structure (Chapter V). Most of the closed canopy forests have already opened creating degraded patches. Still the degradation has not reached at the critical level as higher diversity is maintained in the open canopy condition along the trail. But the increasing demand of forest resources by community and the use of firewood for tourism related activities have threatened the future of this biologically rich area. Although, the area is not rich in butterfly species, the discussion so forth has cleared that the disturbance in the natural areas brings about changes in the biological diversity. Higher diversity in the open forest condition has reflected that the disturbance is within the intermediate level. Information on organisms of the area and their response to habitat change due to human disturbance provides the planning efficacy in the protected areas for maintenance of biological diversity.

Structural diversity in the forests and differences in elevation are important factors to explain distribution and community organisation. Moreover, use of ordination technique with firsthand conceptual models on the aim and objectives of the study are equally important to come to a proper conclusion. In the present study, the assessment of habitat and the relationship of bird/butterfly provided a valuable concept on usefulness of bird and butterfly in biodiversity assessment. The easy method, less effort and higher sensitivity of butterfly on habitat change have advantage over the bird which is an important message to all conservationists and forest managers to use it as indicator animal community.

Table: 8.1. Sample size, composition and species diversity indices of butterfly in different habitat conditions and forest types at Yuksam-Dzongri trekking corridor.

Parameters	Lower forest		Upper forest	
	CC	OC	CC	OC
Sampling size (100 m transect)	23	22	3	10
Species recorded	26	34	12	17
Species per transect (mean±SE)	2.0±0.3	2.8±0.2	1.6±0.2	1.9±0.2
Individuals per transect (mean±SE)	3.3±0.5	4.2±0.3	2.8±0.4	3.1±0.3
Shannon Weiner's diversity (H')	0.39	0.77	0.32	0.28
Margalef's species richness index	0.91	1.29	0.58	0.87
Pielou's evenness index	0.29	0.67	0.22	0.58

CC= closed canopy condition, OC= open canopy condition.

Table: 8.2. Comparative assessment of butterfly community structure between forest conditions (open and closed canopy) and forest types (lower forest and upper forest) of Yuksam-Dzongri trekking corridor.

Variable	Forest condition effect			Forest type effect		
	Mann-Whitney* *U*- value	$X^{2\#}$	*P*	Mann-Whitney! *U*- value	$X^{2\#}$	*P*
BTSD	1799.5	1.54	0.21	2489.5	24.4	0.000
BTSR	1961.5	4.8	0.02	2070.5	6.8	0.009
BTEV	1917.5	3.8	0.05	2175.0	10.3	0.001

(BTSR = butterfly species richness, BTSD = butterfly species diversity and BTEV = butterfly evenness).
*Count number $U_{0.05(2),54,60}$; !Count number $U_{0.05(2),66,48}$; # chi-square approximation with df 1

Table 8.3. Correlation coefficient between butterfly community attributes and principal components (PC) along Yuksam-Dzongri trekking corridor.

Community attributes	PC1	PC2	PC3
Butterfly species richness	0.015	-0.225	**0.524**
Butterfly species diversity	-0.264	-0.270	0.372
Pielou's evenness index	-0.123	-0.286	0.419

Bold value is significant at $P<0.05$

Table 8.4. Pearson correlation coefficient for overall tree, bird and butterfly diversity indices along the Yuksam-Dzongri trekking corridor (n=19, d.f.=17).

Diversity indices	TSR	TSD	BSR	BSD	BTSD	BTSR
Tree species richness (TSR)	-	0.926	0.842	0.834	0.767	0.343
Tree species diversity (TSD)	0.01	-	0.963	0.794	0.732	0.318
Bird species richness (BSR)	0.01	0.01	-	0.963	0.635	0.594
Bird species diversity (BSD)	0.01	0.01	0.01	-	0.615	0.611
Butterfly species diversity (BTSD)	0.01	0.01	0.01	0.01	-	0.377
Butterfly species richness (BTSR)	NS	0.01	0.01	0.01	NS	-

NS= not significant; Lower matrix = probability values; Upper matrix = correlation coefficients

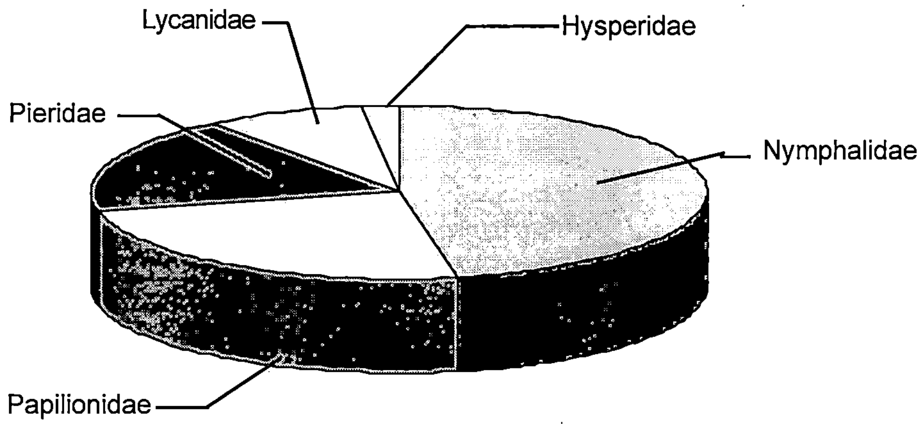


Fig. 8.1. Composition of butterflies of different families recorded from the Yuksam-Dzongri trekking corridor.

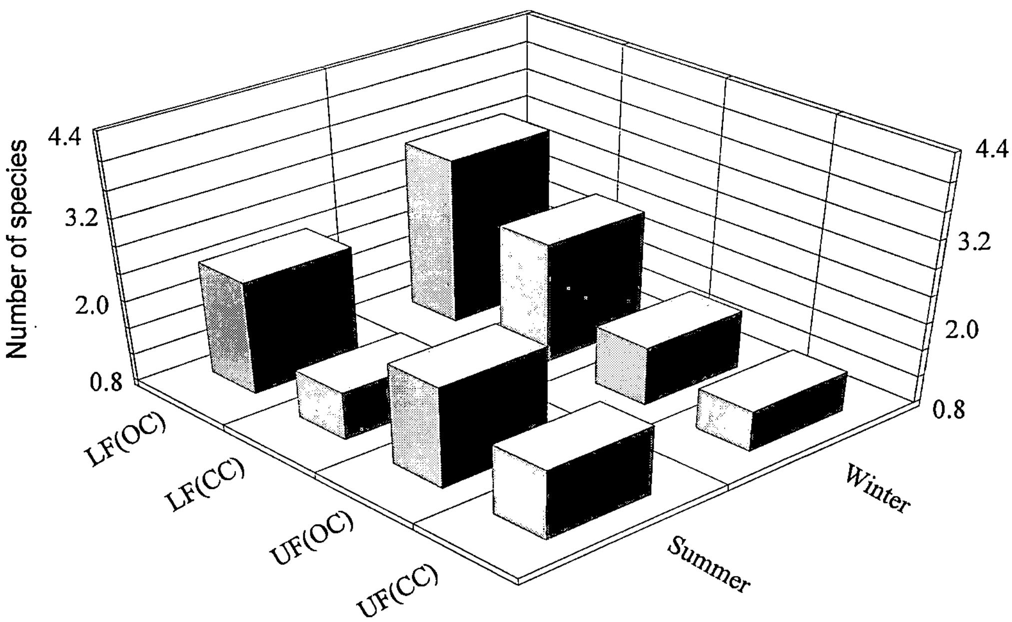


Fig. 8.2. Mean number of butterfly species in the summer and winter seasons during 1997-1998 in the open and closed canopy conditions of lower and upper forests in Yuksam-Dzongri trekking corridor. ANOVA: Forest types $F_{1,106}$=7.5, P<0.007, Forest condition $F_{1,106}$=5.9, P<0.01, Forest types x Seasons $F_{1,106}$=9.2, P<0.003; other interactions not significant, LSD $_{(0.05)}$=1.66.

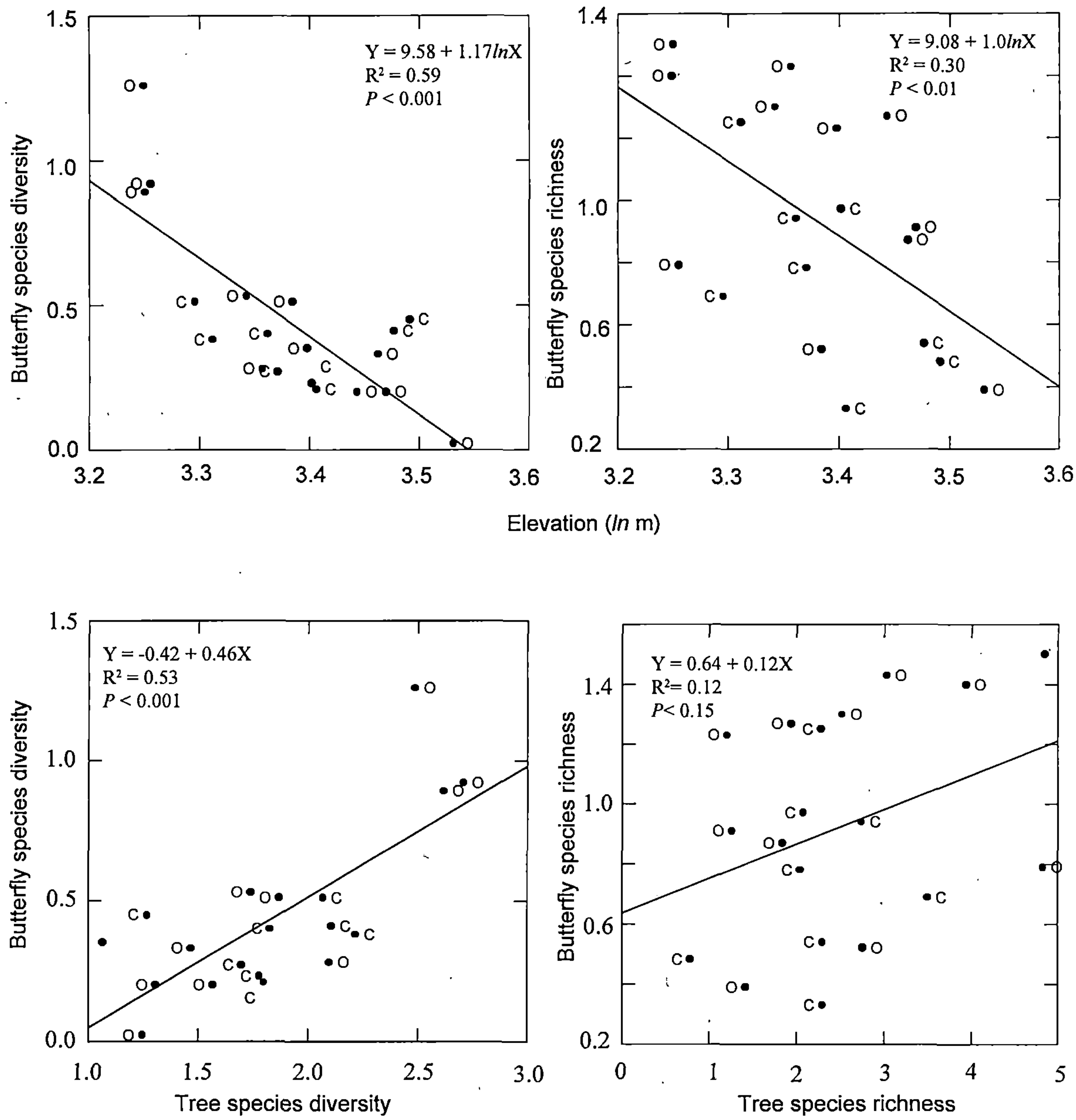
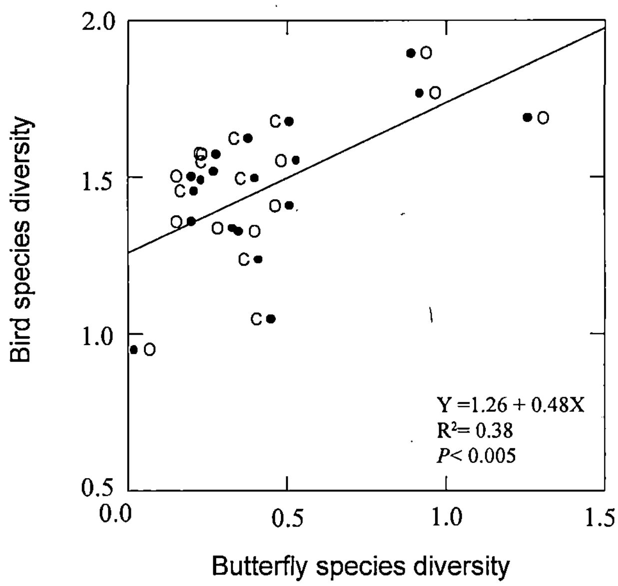


Fig 8.3. Relationship between butterfly diversity indices, tree diversity indices and elevation (O = open canopy condition, C = closed canopy condition) of Yuksam-Dzongri trekking corridor.



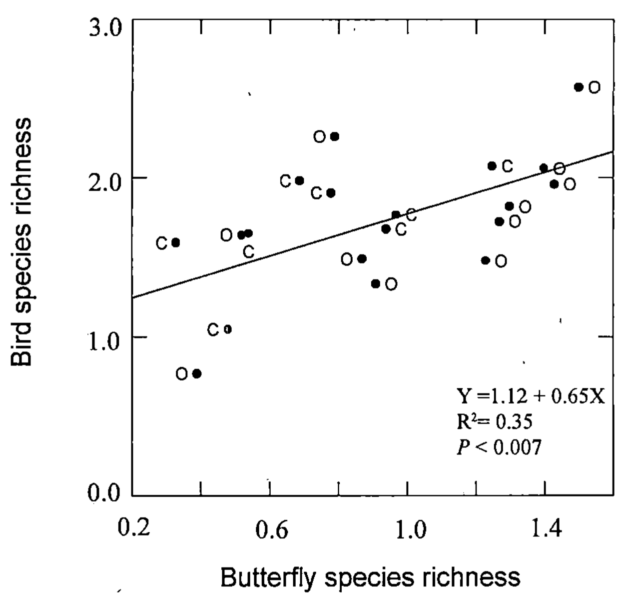


Fig. 8.4. Relationships between the bird abd butterfly diversity indices along the Yuksam-Dzongri trekking corridor (O = open canopy condition, C = closed canopy condition).

CHAPTER IX

Chapter IX

Biodiversity management and conservation implications in Khanchendzonga Biosphere Reserve

Sikkim, a land of mystic splendor has a high importance in the Eastern Himalaya. The extraordinary physical structure and weather have enriched the area with bounty of natural wealth. On the other hand, the rich tradition and culture of diverse ethnic groups is an additional charm for the state. High proportion of floral and faunal diversity has made Sikkim unparallel to rest of the Himalaya. The wide variety of trees, wild edibles, rhododendrons and orchids are the wealth of this tiny Himalayan State. It has been meeting and satisfying the resources need of majority of its population. But in the recent years, evidence of decline in species number and compositions are emerging. Irrational use of natural resources and substantial increase in population have brought about shortage for fuel, fodder and timber, affecting forests quality in many parts of Sikkim (Rai *et al.* 1994, Sundriyal *et al.* 1994, Sundriyal & Sharma 1996). The people have now started using less valued species for fuelwood as number of most preferred species in the forests have decreased. Indiscriminate felling of trees, plantation of exotic species like *Cryptomeria japonica*, lack of strict enforcement of protection conservation laws and use of enormous amount of wood in house construction, large scale cardamom curing following conventional method and fodder for increasing cattle numbers are the most common causes of forest destruction. Such uncontrolled, unregulated resource use pattern has brought about destruction, fragmentation and degradation of this biodiversity rich forest area. Human disturbances like firewood extraction, fodder lopping, cattle grazing, tourism, infrastructure and industrial development have been increasing since the past few decades. Immediate steps are needed to counter the effects of deforestation, fragmentation and degradation for the remaining wilderness.

The major cause of biodiversity loss is due to human actions, primarily land use pattern and resource utilisation, yet the practical technique for conducting such analysis does not exist (OTA 1987, Machlis & Forester 1993). Due to limited stage of knowledge, the relationship between human action and biodiversity is part of most biodiversity research agenda (OTA 1987, WRI 1992). To deal with these concerns there has been call for interdisciplinary and theory-ground research (Machlis 1990). A necessary step is to construction of specific, testable models, because the advance of scientific research relies heavily on the process of modeling (Pease & Bull 1992). Purely biological models are limited to investigating intervening variables and proximate causes. Thus, explanatory variables should be interdisciplinary (Machlis & Forester 1993). The studies of biodiversity component in the Himalaya are usually monotypic i.e. focusing to plant community, animal community or social study with resources utilization etc. The present study considered Conceptual models with flow diagram following Machlis and Forester (1993) to construct the theoretical concepts considering biological and social components. A study model (Fig 9.1) was prepared and implemented at regional level to assess the human pressure in the context of resource extraction with special reference to fuelwood (Fig 9.2), habitat conditions at two forests and its relation with bird/buterfly community structure (Fig 9.1).

Yuksam and Yuksam-Dzongri corridor provide habitat for a number of globally threatened wildlife and diverse bird and butterfly species (Table 3.1, Appendices A, B). The natural resources comprise of large number of species used as fodder, fuel, timber, medicine and non-timber forest produce (NTFP) (Table 4.1, 4.2, Appendices C). These resources are widely used by the inhabitants. The laboratory analysis of fuelwood and fodder quality revealed that the local knowledge of species selection has a great value. The knowledge has scientific basis and is used by the people since time immemorial. This rich knowledge is fading with the modernisation.

It is evident from the past experiences that a sustainable resource management depends on the manner and intensity of their exploitation. Yuksam-Dzongri trekking corridor faces immense pressure on its natural resources (Chapters IV & V). A visible symptom of forest deterioration has been already observed in the area. Huge demand of fuelwood, fodder (Chapter IV) and unmanaged grazing by large number of animal is responsible for the deterioration of this pristine and sacred land. Most of such mature forests of Sikkim were lost at an alarming rate during last few decades due to such human pressure (Sundriyal & Sharma 1996). The rise in tourist number in the trekking trail has added additional concern for conservation (Rai & Sundriyal 1997). Tourism related pressure on the forest has been more distinctly visible at Tshoka. Removal of selective canopy species for firewood and timber has changed the forest structure and also opened the areas. These open areas are now dominated by secondary species and regeneration of canopy species has been relatively low due to such invasion. Though the pressure of fuelwood use by tourists and HMI is comparatively negligible, a proper management of these trekking corridor is of prime need because it has already brought about a consequent depletion of forest resources in the protected areas of Sikkim. The pressure by communities has major impact on the resources that have aggravated on quality of the forests, directly by causing depletion and degradation. Tree DBH class density and height class abundance revealed that the open forests had a disproportionate distribution of trees in the areas due to human disturbances, suggesting high pressure on medium DBH classes or medium height trees. It was evident from the field observation that the regeneration of canopy trees was poor due to overgrazing and trampling, which were comparatively more abundant at relatively undisturbed stands (see chapter V).

The Sikkim Biodiversity and Ecotourism promoted eco-friendly tourism in the study area. Inprovement and compliance of code of conduct for conservation by the travel agents, visitors and the community have been adopted as a step towards reduction of firewood collection from the corridor. An increase of LPG use from 1% to 3% among the community and from 8% to 14% among the tourism related stakeholders was recorded during the period from 1996 to 1998. Similarly, stove and kerosene use increased from 5 to 14% among the communities and from 14 to 18% among the tourism-related stakeholders. There was a substantial reduction of firewood use from 93% in 1996 to 80% in 1998 among the communities and from 73% in 1996 to 49% in 1998 among the tourism enterprises (unpublished observation).

Sustainability factor scores on firewood, fodder and timber species were estimated following Charles (1994) considering resource stock, harvest impact and harvest relative to regeneration, the observation showed concern for fodder and timber species at the upper forest. The status and distribution of species in the lower forest are not in severe state but an immediate attention for restoration of degraded land is recommended.

The Yuksam-Dzongri trekking corridor forest is good in birding. A wide variety of species inhabit this area as their habitat. Vegetation structure (chapter V) suggests that human pressure has reduced the quality of forest in the open canopy and provided accessible foraging ground for common bird species leading to high bird density (Block 1989, Daniels 1989). Bird species richness as well as diversity were higher at the open canopy condition of the lower forest. Differences in species between the open and closed canopy conditions were due to dominance of many common species on open canopy in association with some forest interior birds (MacArthur 1972). The open canopy conditions for both the forest areas showed more generalist species and higher diversity, which is the indication of disturbances (Restrepo & Gomez 1998). This was substantiated by poor diversity at the closed canopy habitat. Generalists or common species were more abundant at the open canopy condition, near human settlements, suggesting that they are habitat generalists that tend to be less sensitive to habitat changes (Telleria & Santos 1995).

The interior forest dwelling birds have higher abundance at the closed canopy condition where the structural complexity like vertical stratification with higher canopy coverage is maintained as also reported by Fremark and Collins (1992). These observations suggest that the open and closed canopy forests have wide structural differences in the context of forest stratification, which in turn provides habitat for breeding and feeding ground to a wide variety of species as per their habitat preferences. Seasonal change of bird species diversity and richness at different habitat types suggests that the bird species of this corridor have dynamic seasonal movement. The principal differences on composition of birds among these sites were undoubtedly due to human pressure resulting in change of vegetation structure and composition (Block & Morrison 1991, Block & Brennan 1993, Aigner *et al.* 1998).

Yuksam-Dzongri trekking corridor exhibits different habitat types with diverse bird species. Wide ranges of habitats are available to birds and equally utilised by them. Only a handful of bird species has restricted themselves to specific habitats. Presence of a wide variety of species such as woodpeckers, flycatchers, tits, drongos and warblers indicates the richness of woodland birds in the area.

There was a distinct pattern of migration among the migratory birds but showed poor relationships with habitats.

Significant seasonal changes among the guilds revealed that seasons, forest types and habitat conditions influenced respective migratory groups/feeding guilds. In the present study principal component analysis helped to draw the relationship between the habitat quality and the feeding guilds. The analysis of relationship between the habitat condition and bird community represented a strong relationship between the guild and to the available habitats. High complexity in the habitat brought about more heterogeneity in the birds species composition. Moreover, significant relationships between the bird species diversity and richness with tree species diversity and richness have given ground for the use of bird as an indicator species for overall biodiversity assessment. Moreover, the feeding guilds such as insectivores, nectarivores, granivores and omnivores showed specific habitat choice. These feeding guilds represented as highly potential predictor for habitat quality.

A total number of 391 butterfly specimens belonging to 49 species were recorded in the study area. Nymphalidae (47%) was the dominant group followed by Papilionidae (24%), and Pieridae (18%). A linear decrease in the diversity along the altitude was observed. One of the reasons for such decrease could be due to the temperature variations along the trail, which is an important factor for the survival of butterfly (Brakefield 1992). The recorded data revealed that the lower forest as well as the open canopy condition were better habitat compared to upper forest or closed canopy conditions. This finding is contrary to report of Hill *et al.* (1995) who are of the opinion that the greater species richness in unlogged forest is due to greater vegetation cover with more shade and when there is no distinct differences in the vegetation structure. Therefore, it was assumed that such variation in habitat conditions might have brought about the differences.

Butterfly species richness, its diversity and evenness were all significantly higher at the open canopy compared to closed canopy forest at LF. Decrease in diversity at the open canopy forest suggests that the butterfly use the open canopy forest where the diversity of tree species is higher. Some previous studies have also demonstrated such reduction in diversity following more extreme form of forest disturbance (Raguse & Llorente-Bousquets 1990, Holloway *et al.* 1992). The significant relationship between butterfly diversity indices and tree diversity indices suggests that there is a strong interaction between the two groups (Hill *et al.* 1995).

Significant correlation among trees, birds and butterflies suggest that the bird or butterfly study surrogates to each other. But, such type of relationship may not be consistent and some differences may come due to variation on geographical feature, weather and the vegetation types (Pearson & Cassola 1992, Blair 1999 Flather *et al.* 1997).

Usefulness of target taxa in monitoring such natural areas for biodiversity assessments are well documented and supported for suitability of bird and butterfly in biodiversity assessment (Kremen 1992, Pearson & Cassola 1992, Debinski & Brussard 1994). In the present work, butterfly community structure could show a distinct variations even between the open and closed canopy condition which was not much convincing in the case of bird community (Chapter VI). This finding has suggested that butterfly are more sensitive to the habitat disturbance compared to the bird (Debinski & Brussard 1994).

Conservation implications

Yuksam-Dzongri trekking corridor is an important destination for tourists. The tourism related activities such as trekking and training courses of Himalayan Mountaineering Institute (HMI) provide substantial economic support to the local people. The growth in tourism and the population have brought about considerable pressure in the natural resources of this area. It is evident that human disturbance hold special importance as it opens up the canopy system to invaders and modify the sequence of ecological development so that dominant species can reproduce and other species can invade (Metz 1997). But the pressure so far in the area seems to be severe as some specific firewood (*Quercus* spp., *Castanopsis* spp., *Rhododendron arboreum, R. barbatum* and *Betula alnoides*) and timber species (*Michelia excelsa, Castanopsis tribuloides* and *Abies densa*) in the corridor have considerably reduced in their number. Wide area of the trekking corridor have already turned into as an open forest and the local community have already downgrade their species choice for firewood from *Quercus* spp., *Symintonia populnea,* and *Castanopsis* spp., to *Eurya acuminata* and *Alnus nepalensis.* Fodder scarcity in the high altitude areas during the winter is not the new problem. Wildlife sightings in the area reduced considerably in recent years. Therefore, a concise and proper management policies are needed to maintain the natural cornucopia. Some of the recommendable implications are appended below: -

- The pressure of fuelwood, fodder and timber by the community and the tourism enterprises should be minimised since the human disturbances in forest beyond replenishing capacity of forest ecosystem leads to non-linear or irreversible ecological disaster. Therefore, proper monitoring of resources is recommended.

- A regulated tourist flow within the carrying capacity should be followed to minimise the acute pressure and space crisis specially at the high altitude areas such as Tshoka, Dzongri, Base camp, Thansing etc.

- Government of Sikkim should strengthen the local NGOs such as Khangchendzonga Conservation Committee to regulate the tourist flow, compliance to the code of conduct by the tourists and their support staff, illegal felling, poaching, high valued medicinal plant extraction and the garbage management in the area.

- The Biodiversity Conservation Network (BCN) hypothesized that enterprise based ecotourism conserves the biodiversity. During Sikkim Biodiversity and Ecoutourism, the above hypothesis was tested at Yuksam. As a result, it was experienced that such initiations may conserve the biodiversity when certain conditions provide support. A follow up programs for skill development training to the locals, off season vegetable farming and a major awareness campaign should be carried out by the concern departments and the local NGOs.

- A regulated resources extraction within the threshold level should be followed as it enriched the biological diversity when they are at intermediate level. Such intermediate disturbance also benefits birds.

- Yuksam-Dzongri corridor possesses a mixture of habitat types for birds and butterflies. Conservation of habitat of these, which are integral part of the ecosystem, probably can be achieved only through adaptation of management practices by assessing approximate natural disturbance events. Therefore, the concern departments should come up with strategic plan to monitor the status of resources and the impact of tourism in these natural resources in a regular manner.

- The deployed staff of forest and tourism departments should be trained regularly for the assessment of biological diversity. Information of sightings of animals from tourists, support staff and yak and sheepherder should be gathered to compromise with the crises of manpower.

- A heterogeneous habitat types such as open forest, scrub land, grassland, dense forest etc. are needed to be maintained for the bird and butterfly diversity as various guild showed different habitat choice. Otherwise, one guild could be maintained only with the expense of others. Therefore, a constant pressure in one particular forest area should be avoided as it brings about degradation of habitat.

- Some important components of the stand structure following disturbance are availability of food resources for granivores.

Therefore, forest managers are suggested to adjust resource extraction by the community in such a way that both food resource productivity and habitat complexity (vertical stratification) are maintained.

- The easiest strategy as regular monitoring of birds or butterflies is also recommendable as they indicate the health of the forest they live in.

- The conservation of biological diversity, protection and maintenance of ecosystem and habitat heterogeneity are important rather than attempting to protect one species at a time. Therefore, a comprehensive and long term monitoring with an enormous amount of effort and variety of strategies are required to know the functional ecology of forest and their relationship with the coexisted species at landscape level.

- Bird and butterfly can be an important tool in the natural area management where there are time and funds constrains. Simple records of butterfly or birds can be use to predict the quality of habitat as they showed strong correlation and also can surrogate other taxa until there is no drastic change in vegetation types or the microclimate due to major geographical

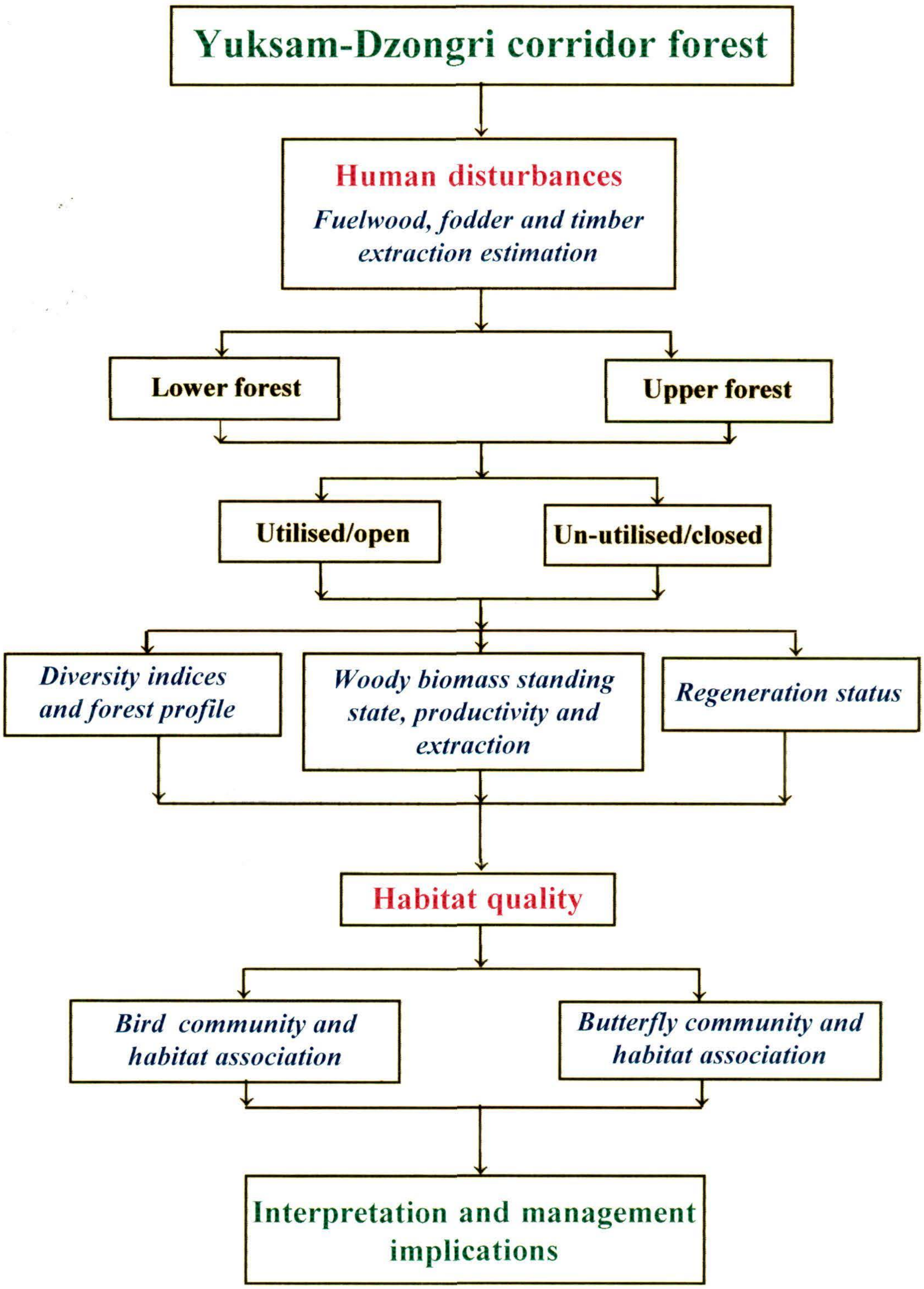


Fig. 9.1. Flow chart showing target components (*italised*) dealt for the assessment of habitat for bird and butterfly communities and their associations.

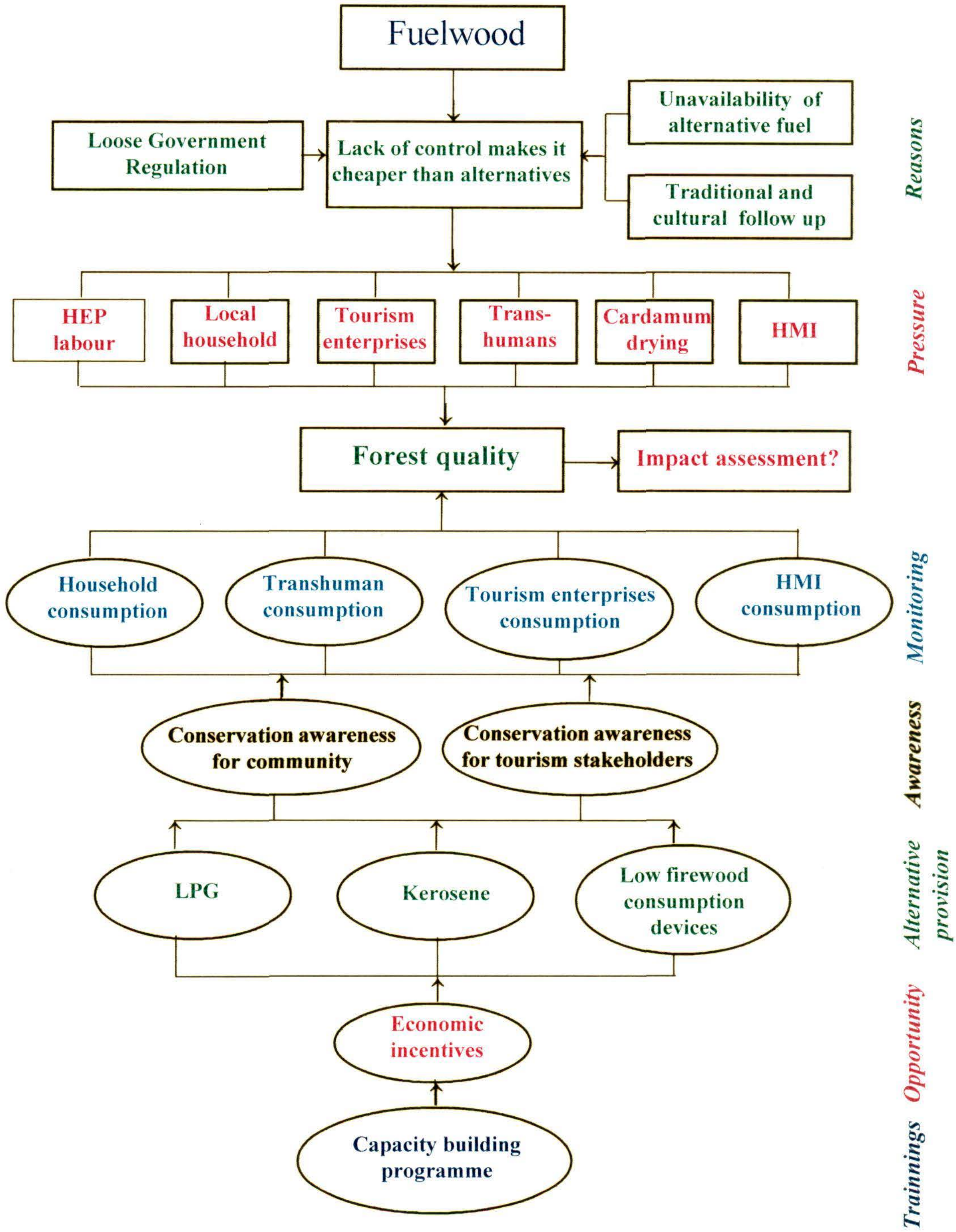


Fig. 9.2. Fuelwood pressure and project interventions: research and monitoring plan (HEP = Hydro Electric Project; HMI = Himalayan Mountaineering Institute)

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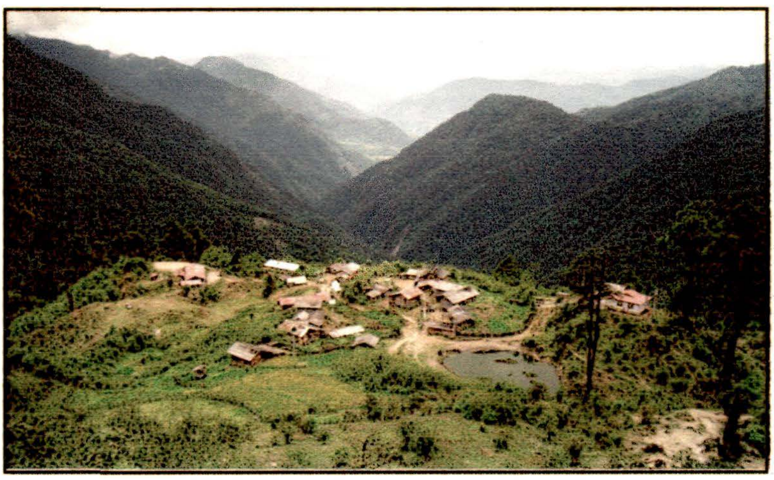
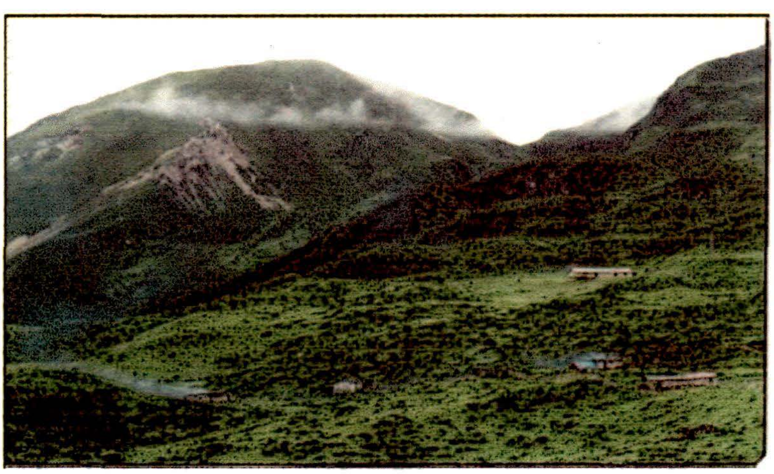
PHOTO PLATES

Plate 1

Yuksam settlement, a trail head for Dzongri



Tshoka settlement with a monastry, trekker hut and the lake



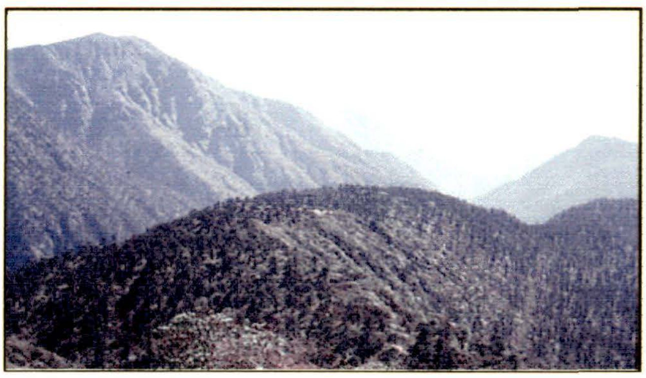
Alpine scrub land with Rhododendrons, Junipers and the permanent goth in the set at Dzongri

Photoplate 1. Two major settlements and Dzongri meadow of Yuksam-Dzongri Trekking trail

Plate 2

A pristine temperate broadleaved forest at some inaccessable areas of KBR

Sun set: a view through *Tsuga* forest from Tshoka (3000 m)



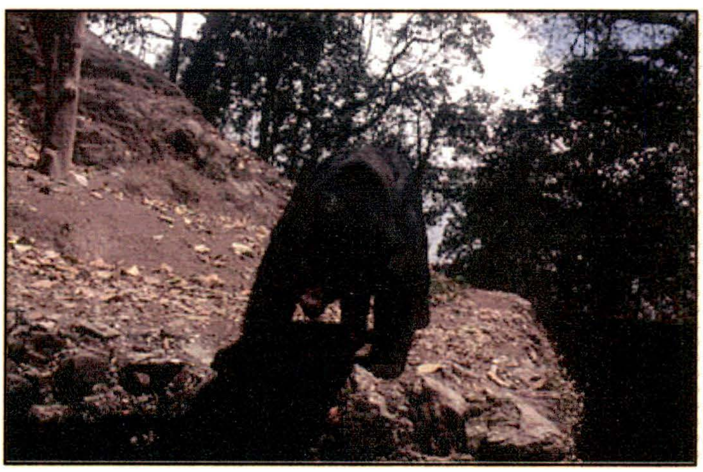
Abies-Rhododendron forest (3000 to 3800 m)

Cardamom field: additional habitat for some generalist bird and butterfly species to breed and feed upon

Photoplate 2. Vegetation and forest types in temperate and sub-alpine areas of the study sites

Red Panda (*Ailurus fulgens*): a endangered species of Khangchendzonga Biosphere Reserve

Black muntjak (*Muntiacus muntjak*) a temperate forest dwellers of the study area

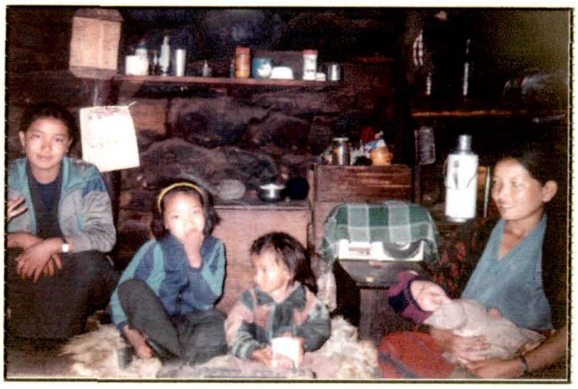


Himalayan black bear (*Selenarctos thibetanus*) the beast of the temperate forest

Photoplate 3. Some of the important wildlife of the study area

Plate 4

Lepchas: the arboriginal people of Sikkim



Transhuman Bhutia family at their summer halt

Fuelwood collection during the winter season at the trail head near Yuksam

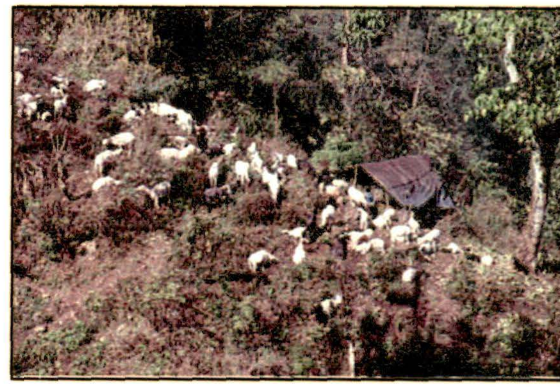
Tree fodder collection: a daily schedule of the locals

Substantial amount of timber collection was observed from the trail side forest

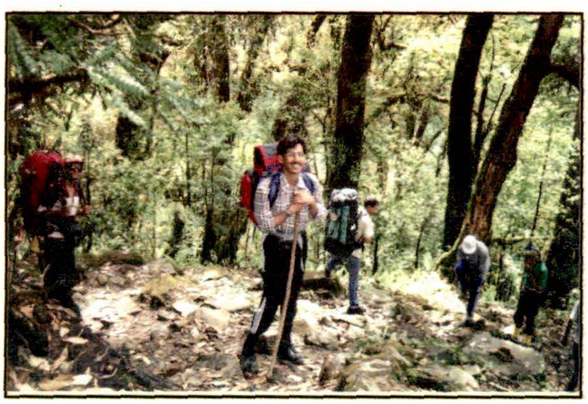
NTFP collection: Students use their time in such collection aftertheir school or on holidays

Photoplate 4. Local communities and some of their livelihood options in the study area

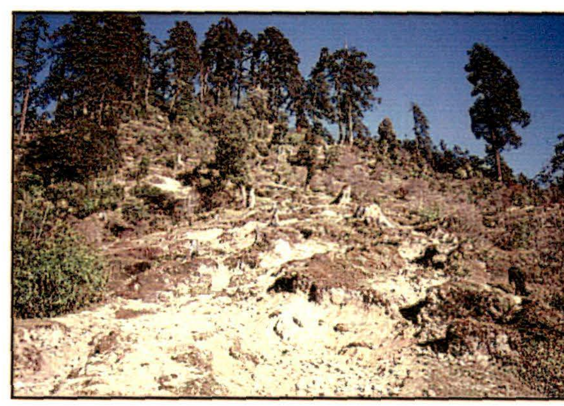
Dzos used as pack animal bring substantial income to local community



Sheep herd in the forest: A matter of concern

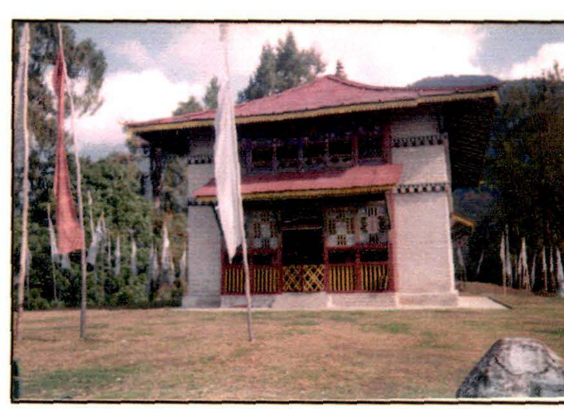


Tourism has become an integral livelihood option for Yuksam people



Continuous human pressure and trampling by the large number of animals along the trail are responsible for trail errosion

Norbugyang in Yuksam where the first Chogyal was enthorned by three religious leaders in 1642



Dubdi in Yuksam is one of the oldest monastry

Photoplate 5. Yuksam-Dzongri trekking trail show visible impacts of degradation however attractive historical, cultural and wilderness destinations still amuse visitors

Plate 6

Grey-winged blackbird
(*Turdus boulboul*)

Golden saphire (*Heliophorus brahma*) basking in the open area

Common kestrel (*Falco tinnunculus*)
a common raptor

Paris peacock (*Princeps paris paris*)
feeding on flower

White capped Waterredstart
(*Chaimarrornis lecocephalus*)
a common local migrants

Common sailor (*Neptis hylas varmona*)

Photoplate 6. Some common species of birds and butterflies sighted in Yuksam-Dzongri area

APPENDICES

Appendix A. List of birds of Yuksam-Dzongri trail and Khecheopalri and with their status, localities and habitats.

Common name	Scientific Name	Status	Localities	Habitat
Snow Partridge	*Lerwa lerwa*	R1	5	CO
Himalayan Snow Cock	*Tetraogallus himalayansis*	AS1	9	BO
Tibetan Snowcock	*Tetraogallus tibetanus*	AS1	5	CO
Blood Pheasant	*Ithaginis cruentus affinis*	R2	4,6,7	C
Satyr Tragopan	*Tragopan satyra*	R1	6	C
Himalayan Monal	*Lophophorus impejanus*	R1	7	C
Kalij Pheasant	*Lophura leucomelana*	R2	1,2	C
Bar-headed Goose	*Anser indicus*	W1	1,2	W
Rudy Shelduck	*Tadorna ferruginea*	W1	1	W
Common Teal	*Anas crecca*	W1	1	W
Mallard	*Anas platyrhynchos*	W1	1	W
Baer's Pochard	*Aythya baeri*	W1	1	W
Common Merganser	*Mergus merganser*	W1	1	W
Bay Woodpecker	*Blythipicus pyrrhotis*	AS1	1,2,3	D
Crimson-breasted Woodpecker	*Dendrocopos cathparius*	R1	2,3,4	D
Darjeeling Woodpecker	*Dendrocopos darjellensis*	R3	3,4,6	C
Greater Yellownaped Woodpecker	*Picus flavinucha*	R1	1,2	D
Himalayan Flameback	*Dinopium shorii*	AS1	2	D
Great Slaty Woodpecker	*Mulleripicus pulverulentus*	AS1	1	D
Great Barbet	*Megalaima virens*	R1	1,2,3	D
Golden-throated Barbet	*Megalaima franklinii*	R1	2	D
Blue-throated Barbet	*Megalaima asiatica*	R1	2	DO
Eurasian Hoopoe	*Upupa epops*	AS1	4	CO
Red Headed Trogon	*Harpactes erythrocephalus*	AS1	1,2	D
Large Hawk Cuckoo	*Cuculus sparverioides*	S3	1,2,3	CD
Indian Cuckoo	*Cuculus micropterus*	AS2	1,2,3	D
Oriental Cuckoo	*Cuculus saturatus*	S2	1,2,3	D
Common Cuckoo	*Cuculus canorus*	S2	1,2	DO
House Swifts	*Apus affinis*	S3	1,2	C

Cont. Appendix A

Common name	Scientific Name	Status	Localities	Habitat
Himalayan Swiftlet	*Collocalia brevirostris*	R2	3	C
Oriental Bay Owl	*Phodilus badius*	AS1	1	CD
Hodgson's Frogmouth	*Batrachostomus hodgsoni*	AS1	2	B
Oriental Turtle Dove	*Stroptopelia orientalis*	S2	1,2	DO
Spotted Dove	*Stroptopelia chinensis*	S3	1,2	CD
Snow Pigeon	*Columba leuconota*	R2	4,6	CO
Speckled Wood-Pigeon	*Columba hodgsonii*	R2	4	CD
Ashy Wood Pigeon	*Columba pulchricollis*	R1	2,3,4	D
Wedge-tailed Green Pigeon	*Treron sphenura*	R1	2	CD
Mountain Imperial-Pigeon	*Ducula badia*	R1	2,3	CO
Eurasian Woodcock	*Scolopax rusticola*	R2	2	BO
Solitary Snipe	*Gallinago solitaria*	AS1	6	BO
Black Kite	*Milvus migrans*	S1	1	CO
Lammergeier	*Gypaetus barbatus*	AS1	4,8	O
Himalayan Griffon	*Gyps himalayensis*	AS1	7	O
Crested Serpent-Eagle	*Spilornis cheela*	R1	2	?
Eurasian Sparrowhawk	*Accipiter niscus*	AS1	1,2,4	O
Black Eagle	*Ictinaetus malayensis*	R1	1,2	O
Bonelli's Eagle	*Hieraaetus fasciatus*	AS1	1	O
Mountain Hawk Eagle	*Spizaetus nipalensis*	R1	2,4	?
Common Kestrel	*Falco tinnunculus*	R2	4,6,7,9	O
Black-necked Grebe	*Podiceps nigricollis*	W1	1	W
Great Cormorant	*Phalacrocorax carbo*	W1	1	W
Blue-napped Pitta	*Pitta nipalensis*	AS1	2	DO
Brown Shrikes	*Lanius cristatus*	W2	1,2	CD
Long-tailed Shrike	*Lanius schach*	AS	2	O
Grey-backed Shrike	*Lanius tephronotus*	R2	1,2	BDO
Yellow-billed Blue-Magpie	*Urocissa flavirostris*	R3	3,4	C
Green Magpie	*Cissa chinensis*	R3	1,2	BD
Grey Treepie	*Dendrocitta formosae*	R3	1,2	CD
Collared Treepie	*Dendrocitta frontalis*	R2	1,2	CD

Cont. Appendix A

Common name	Scientific Name	Status	Localities	Habitat
Black-billed Magpie	*Pica pica*	AS1	4	CD
Spotted Nutcracker	*Nucifraga caryocatactes*	AS1	4	C
Red-billed Chough	*Pyrrhocorax pyrrhocorax*	AS1	4	DO
Yellow-billed Chough	*Pyrrhocorax graculus*	AS1	6,8	DO
House Crow	*Corvus splendens*	R3	1,2	CDO
Large-billed Crow	*Corvus macrorhynchos*	R3	1,2,4,6	CO
Common Ravens	*Corvus corax*	R1	6,7,8	CO
Eurasian Golden-Oriole	*Oriolus oriolus*	AS1	2	CD
Maroon Oriole	*Oriolus traillii*	R1	2,3	CD
Black-winged Cuckooshrike	*Coracina melaschistos*	AS1	2	CD
Grey-chinned Minivet	*Pricrocotus solaris*	R2	3,4	CDO
Short-billed Minivet	*Pricrocotus brevirostris*	R2	3,4	CDO
Scarlet Minivet	*Pricrocotus flammeus*	R1	2,3	CDO
Yellow-bellied Fantail	*Rhiphidura hypoxantha*	R1	3	DO
White-throated Fantail	*Rhipidura albicollis*	R3	2,3	CD
Black Drongo	*Dicrurus macrocercus*	R3	1,2	D
Ashy Drongo	*Dicrurus leucophaeus*	R2	1,2,4	DO
Crow-billed Drongo	*Dicrurus annectans*	S2	2	DO
Spangled Drongo	*Dicrurus hottentottus*	AS1	1	D
Brown Dipper	*Cinclus pallasii*	R2	3,4	W
White-throated Dipper	*Cinclus cinclus*	R1	7,8	W
Blue Rock Thrush	*Monticola solitarius*	AS1	4	BO
Chestnut-bellied Rock Thrush	*Monticola rufiventris*	R2	3,4	BCO
Blue Whistling Thrush	*Myiophonus caeruleus*	R3	1,2,3,4,6	DOW
Plain-backed Thrush	*Zoothera mollissima*	R2	4,5	O
Long-billed Thrush	*Zoothera monticola*	R1	4	BO
Dark-sided Thrush	*Zoothera marginata*	R2	2	O
Scaly Thrush	*Zoothera dauma*	R	4,5	BO
Dark-throated Thrush	*Turdus ruficollis*	AS2	4	BDO
White-collared Blackbird	*Turdus albocinctus*	R2	4	BCO

Cont. Appendix A

Common name	Scientific Name	Status	Localities	Habitat
Grey-winged Blackbird	*Turdus boulboul*	R2	3	CO
Dark-throated Thrush	*Turdus ruficollis*	W1	3,4	CO
Indian Grey Thrush	*Turdus unicolor*	R1	1,2	CO
Dark-sided Flycatcher	*Muscicapa sibrica*	S2	1,2	C
Ferruginous Flycatcher	*Musicapa ferruginea*	AS1	2,3	D
Little Pied Flycatcher	*Ficedula westermanni*	R1	2	BD
Rufous-gorgetted Flycatcher	*Ficedula strophiata*	R1	2,3,4	BD
Verditor Flycatcher	*Eumyias thalassina*	S3	1,2,3	BDO
Pale Blue Flycatcher	*Cyornis unicolor*	R2	1,2	BD
Large Niltava	*Niltava grandis*	R2	2	BO
Rufous-bellied Niltava	*Niltava sundara*	R3	1,2,3,4	BCD
Grey-headed Canary Flycatcher	*Culicicapa ceylonensis*	R2	1,2,3,4	DO
Grandala	*Grandala coelicolor*	AS1	6	BO
Little Forktail	*Enicurus scouleri*	R2	1,2,3	W
Slaty-backed Forktail	*Enicurus schistaceus*	R1	1,2	W
Spotted Forktail	*Enicurus maculatus*	R3	1,2	W
Green Cochoa	*Cochoa viridis*	R1	1	BD
White-capped Water Redstart	*Chaimarrornis lecocephalus*	R3	1,2,3,4,6	OW
Daurian Redstart	*Phoenicurus auroreus*	S2	2,3	BW
Blue-fronted Redstart	*Phoenicurus frontalis*	R1	3	BW
Black Restart	*Phoenicurus ochruros*	S1	2	O
Plumbus Water Redstart	*Rhyacornis fuliginosus*	R2	3	W
Common Stonechat	*Saxicola torquata*	R1	1,2	BO
Grey Bushchat	*Saxicola ferrea*	R3	1,2	BO
Common Myna	*Acridotheres tristis*	R3	1,2	D
Hill Myna	*Gracula religiosa*	R2	1,2	DO
White-tailed Nuthatch	*Sitta himalayensis*	R3	3,4	CD
Eurasian Tree-creeper	*Certhia familiaris*	R2	4	C
Winter Wren	*Troglodytes troglodytes*	R1	8	OW
Black-throated Tit	*Aegithalos concinnus*	R2	1,2	BDO

Cont. Appendix A

Common name	Scientific Name	Status	Localities	Habitat
Black-browed Tit	*Aegithalos iouschistos*	R1	4	CDO
Fire-capped Tit	*Cephalopyrus flammiceps*	R1	4	C
Yellow-cheeked Tit	*Parus spilonotus*	AS1	2	D
Grey-crested Tit	*Parus dichrous*	R2	4	CO
Cole Tit	*Parus ater*	R2	4,6	CO
Green-backed Tit	*Parus monticolus*	R3	1,2,3	BCO
Rufous-vented Tit	*Parus rudiventris*	R2	4,6,8	CO
Sultan Tit	*Melanochora sultanea*	AS1	2	D
Barn Swallow	*Hirundo rustica*	S1	3	DO
Goldcrest	*Regulas regulas*	R3	4	C
Black Bulbul	*Hypsipetes leucocephalus*	R3	1,2,3,4	DO
Red-whiskered Bulbul	*Pycnonotus jocosus*	AS1	2	BO
Red-vented Bulbul	*Pycnonotus cafer*	R3	1,2	DO
Straited Bulbul	*Pycnonotus striatus*	R2	3	DO
Chestnut-headed Flycatcher-Warbler	*Tesia castaneocoronata*	R1	2	D
Pale-footed Bush Warbler	*Cettia pallidipes*	R1	2	BO
Brownish-flanked Bush Warbler	*Cettia fortipes*	R2	2	BO
Grey-sided Bush-Warbler	*Cettia brunnifrons*	R2	3,4	BO
Spotted Bush-Warbler	*Bradypterus thoracicus*	S2	2	BDO
Brown Bush-Warbler	*Bradypterus luteoventris*	S1	1,2	D
Smokey Warbler	*Phylloscopus fuligiventer*	S2	6	BO
Tickell's Leaf -Warbler	*Phylloscopus affinis*	S1	1,2,3	BDO
Buff-barred Warbler	*Phylloscopus pulcher*	R2	4,6	BC
Lemmon-rumped Warbler	*Phylloscopus proregulus*	R2	2,3	BC
Greenish Warbler	*Phylloscopus trochiloides*	R3	4,6	CD
Ashy-throated Warbler	*Phylloscopus maculipennis*	R1	4,6	BC
Inornate Warbler	*Phylloscopus inornatus*	W2	3,4,	CD
Golden-spectacled Warbler	*Seicercus burkii*	R1	3,4	BC
White-spectacled Warbler	*Seicercus affinis*	R3	2,3,4	BDO
Grey-hooded Warbler	*Seicercus xanthoschitos*	R3	1,2,3	BC

Cont. Appendix A

Common name	Scientific Name	Status	Localities	Habitat
Yellow-bellied Warbler	*Abroscopus superciliaries*	R2	3,4,5	BCD
White-throated Laughingthrush	*Garrulax albogularis*	R3	1,2,3,4	CB
White-crested Laughingthrush	*Garrulax leucolophus*	R3	1,2	BCO
Greater Necklaced Laughingthrush	*Garrulax pectoralis*	R2	2	DO
Lesser Necklaced Laughingthrush	*Garrulax monileger*	R2	3	BO
Striated Laughingthrush	*Garrulax striatus*	R3	1,2,3	BC
Spotted Laughingthrush	*Garrulax ocellatus*	R1	4,6	BCO
Black-faced Laughingthrush	*Garrulax affinis*	R2	1,2,3	DO
Chestnut-crowned Laughingthrush	*Garrulax erythrocephalus*	R2	4,6	BC
Red-faced Liocichla	*Liocichla phoenicea*	R2	2	BC
Grey-sided Laughingthrush	*Garrulax caerulatus*	R2	2	O
Variagated Laughingthrush	*Garrulax variagatus*	R2	1,2	BCO
Blue-winged Laughingthrush	*Garrulus sqamatus*	R2	2	BO
Silver-eared Mesia	*Leiothrix argentauris*	R1	1,2	BD
Redbilled Leothrix	*Leiothrix lutea*	R3	1,2	BD
Cutia	*Cutia nepalensis*	AS1	2	D
Green Shrike-Babbler	*Pteruthius xanthoclorus*	R1	2,3	O
White-browed Shrike-Babbler	*Pteruthius flaviscapis*	R1	3	D
Rusty-fronted Barwing	*Actinodura egertoni*	R1	1,2	BD
Hoary Barwing	*Actinodura nipalensis*	R1	3	BC
Blue-winged Minla	*Minla cyaneuroptera*	R2	2	BD
Redtailed Minla	*Minla ignotincta*	R2	1,2	BD
Chestnut-tailed Minla	*Minla strigula*	R2	2	D
White Browed Tit Babbler	*Alcippe vinipectus*	R2	2,3	BDO
Rufous-winged Fulvetta	*Alcippe castaneceps*	R3	2	DO
Nepal Fulvetta	*Alcippe nipalensis*	R1	2	D
Rufous Sibia	*Heterophasia capistrata*	R3	1,2,3	D
Rufous-backed Sibia	*Heterophasia annectens*	AS1	2	D
White-naped Yuhina	*Yuhina bekeri*	R3	3,4	DO
Whiskered Yuhina	*Yuhina flavicollis*	R2	1,2,3	BD

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Cont. Appendix A

Common name	Scientific Name	Status	Localities	Habitat
Stripe-throated Yuhina	*Yuhina gularis*	R2	4	BC
Rufous-vented Yuhina	*Yuhina occipitalis*	R2	2,3	BC
Black-chinned Yuhina	*Yuhina nigrimenta*	R1	1,2	BC
White Bellied Yuhina	*Yuhina zantholeuca*	AS1	1	BC
Fire-tailed Myzornis	*Myzornis pyrrhoura*	AS1	1,4	?
Oriental Skylark	*Alauda gulgula*	S1	2	DO
Yellow-bellied Flowerpecker	*Dicaeum melanokanthum*	AS1	1,2,3	D
Fire-breasted Flowerpecker	*Dicaeum ignipectus*	AS1	1,2	BO
Mrs Gould's Sunbird	*Aethopyga gouldiae*	R3	1,2,3	CDO
Green-tailed Sunbird	*Aethopyga nipalensis*	R2	1,2,3	CDO
Black-throated Sunbird	*Aethypyga saturata*	R1	3	BD
Firetailed Sunbird	*Aethopyga ignicauda*	R3	1,2,3	CDO
Little Spider Hunter	*Arachnothera longirostra*	AS1	3	O
Streaked Spiderhunter	*Arachnothera magma*	AS1	3	O
House Sparrow	*Passer domesticus*	R3	1,2,3	O
Russet Sparrow	*Passer rutilans*	R2	2,4	DO
Eurasian Tree Sparrow	*Passer montanus*	R2	2,3,4	O
White Wagtail	*Montacilla alba*	R2	2	W
Grey Wagtail	*Montacilla cinerea*	S2	1,2	W
Blyth's Pipit	*Anthus godlewskii*	AS	4	O
Olive-backed Pipit	*Anthus hodgsonii*	R2	1,2,3	DO
Rufous-breasted Accentor	*Prunella strophiata*	R1	4,6	DO
Marroned-backed Accentor	*Prunella immaculata*	AS1	4	O
White-rumped Munia	*Lonchura striata*	R1	2	O
Yellow-breated Greenfinch	*Carduelis spinoides*	R2	2	DO
Dark-breasted Rosefinch	*Carpodacus nipalensis*	R2	4,6	BO
Pink-browed Rosefinch	*Carpadacus rhodochrous*	R1	4	BO
Dark-rumped Rosefinch	*Carpodacus edwardsii*	R1	4,6,7	BO
White-browed Rosefinch	*Carpodacus thura*	R2	4	C
Red-fronted Rosefinch	*Carpodacus puniceus*	R1	5,6	CO
Scarlet Finch	*Haemotospiza sipahi*	AS1	3,4	CD

Cont. Appendix A

Common name	Scientific Name	Status	Localities	Habitat
Red-headed Bullfinch	*Pyrrhula erythrocephala*	R1	4	BO
Grey-headed Bullfinch	*Pyrrhula erythaca*	R1	7	BC
Black-headed Mountain-Finch	*Leucosticte brandti*	R2	6,7,8	BO
Collared Grosbeak	*Mycerobas affinis*	R2	6	BCD
White-winged Grosbeak	*Mycerobas carnipes*	R2	7,8	BCD

Status: R = Resident, S = Summer visitors, W = Winter visitors, AS = Accidental or casual sighting, 1 = Less common, 2 = Common, 3 = Very common, **Localities:** 1 = Khecheopalri, 2 = Yuksam, 3 = Sachen, 4 = Tshoka, 5 = Phitang, 6 = Dzongri, 7 = Thangsing, 8 = Samite, 9 = Lampokhari.

Habitat: A = Lakes, wetlands, streams etc., O=Open area (meadows, utility corridors, pasture), C = Conifer forest (Abies-Rhododendrons), D = Mixed forest, B = Bush, shrubs etc.

Appendix B. List of Butterfly species recorded from the sampled plots from Yuksam-Dzongri trekking trail

Common name	Scientific name	Family	Status	Habitat
Blue Peacock	*Princeps a. arcturus* (Westwood)	Papilionidae	FC	1,2,3
Common Blue Bottle	*Graphium s. sarpedon* (Linn.)	Papilionidae	C	1,2
Common Morman	*Princeps polytes romulus* (Cramer)	Papilionidae	R	3
Common Raven	*Princeps castor polas* (Jordan)	Papilionidae	R	1,2
Common Windmill	*Atrophaneura polyeuctes* (Doubleday)	Papilionidae	R	2,4
Glossy Blue Bottle	*Graphium cloanthus* (Westwood)	Papilionidae	R	2,3
Great Morman	*Princeps memnon agnor* (Linn)	Papilionidae	C	1
Paris Peacock	*Princeps p. paris* (	Papilionidae	C	1,2,3
Red Breast	*Princeps alcmenor* (C. & R. Fedler)	Papilionidae	C	1,2,3
Red Helen	*Princeps h. helenus* (Linn)	Papilionidae	C	1,2
Spangle	*Princeps protenor euprotenor* (Fruchtorfo)	Papilionidae	R	2
Spectacle Swordtail	*Pazala mandarinus paphus* (De Niceville)	Papilionidae	R	1
Common Albakross	*Appias albina darada* (C. & R. Felder)	Pieridae	FC	2
Common Brimestone	*Gonepteryx rhamni nepalensis* (Doubleday)	Pieridae	FC	3,4
Common Emigrant	*Catopsilia pomona* (Fabricus)	Pieridae	C	1,2
Great Orange Tip	*Hebormoia glaucippe* (Linn)	Pieridae	R	2
Hill Jezebel	*Delias belladona ithiela* (Butler)	Pieridae	FC	4
Indian Cabbage White	*Pieris canidia indica* (Evans)	Pieridae	C	1,2

Cont. Appendix B

Common name	Scientific name	Family	Status	Habitat
Plain Puffin	*Appias I. Indra* (Moore)	Pieridae	FC	1,2,3
Red Spot Jezebel	*Delias d. descombesi* (Boisduval)	Pieridae	C	1
Spot Puffin	*Appias lalage durvasa* (Moore)	Pieridae	FC	1,2
Common Cerulean	*Jamides c. celana* (Cramer)	Lycanidae	C	1,2,3,4
Dark Cerulean	*Jamides bochus* Stoll (Cramer)	Lycanidae	FC	2
Dark Judy	*Abisara fylla* (Doubleday)	Lycanidae	R	1
Golden Saphaire	*Heliophorus brahma* (Moore)	Lycanidae	C	1
Bright Eye Bushbrown	*Mycalesis nicotia* (Westwood)	Nymphalidae	FC	1,2
Chestnut Tiger	*Parantica sita sita* (Kollar)	Nymphalidae	C	1
Common Bushbrown	*Mycalesis persius blasius* (Fabricus)	Nymphalidae	C	1,2
Common Crow	*Euploea c. core* (Cramer)	Nymphalidae	C	1,2
Common Evening Brown	*Melanitis leda ismene* (Cramer)	Nymphalidae	FC	2
Common Maplet	*Chersonesia r. risa* (Doubleday & Hewit)	Nymphalidae	R	2
Common Sailor	*Neptis hylas varmona* (Moore)	Nymphalidae	C	1,2
Common Threewing	*Ypthima asterope maratha* (Moore)	Nymphalidae	FC	2,3
Common Tiger	*Danaus genutia* (Cramer)	Nymphalidae	C	1,2
Glassy Tiger	*Paratica uglea melanoides* (Moore)	Nymphalidae	FC	1,2,3
Indian Fritillary	*Argyreus hyperbius* (Johanssen)	Nymphalidae	C	1,2,3,4

Cont. Appendix B

Common name	Scientific name	Family	Status	Habitat
Indian Tortoise Shell	*Aglais cachmirensis aesis* (Kollar)	Nymphalidae	C	1,2
Darkbanded Bushbrown	*Mycalesis. mineus* (Moore)	Nymphalidae	C	1,2
Mountain Tortoise Shell	*Aglais utica rizana* (Moore)	Nymphalidae	C	3,4
Niger	*Orsotrioena m. medus* (Fabricus)	Nymphalidae	C	1,2
Orange Staff Seargeant	*Parathima coma* (Moore)	Nymphalidae	R	1
Pasha	*Herona m. marathus* (Doubleday)	Nymphalidae	FC	1,2
Plain Tiger	*Danaus chrysippus* (Linn)	Nymphalidae	R	2
Straight Banded Treebrown	*Neope verma sintica* (Fruhstorfer)	Numphalidae	C	1,2,3
Stripe Blue Crow	*Euploea m. mulciber* (Cramer)	Nymphalidae	FC	1,2
Yellow Coster	*Pareba vesta* (Fabricus)	Nymphalidae	C	1,2
Yellow Owl	*Neorina hilda* (Westwood)	Nymphalidae	R	3
Yellow Sailor	*Neptis ananta ochracea* (Evans)	Nymphalidae	FC	2,3
Chocolate Demon	*Ancistroides nigrita diocies* (Moore)	Hesperidae	FC	3

Appendix C. List of NTFPs with their distribution, status market and uses that were recorded from Yuksam-Dzongri trekking corridor and Khecheopalri watershed area (A = abundant, C = common, D = common but declining, R = rare, MR = markatable, NM = non-markatable, NA = data not available)

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Construction and local handicrafts							
Arundinaria hookeriana	Pareng	1200-2100 m	MR	40 per bundle Tama 10-15 per kg	Mats, house construction, baskets, young shoots as vegetables etc.	D	Whole year
Arundinaria intermedia	Tite nigalo	1200-2100 m	MR	40 per bundle Tama 10-15 per kg	Mats, baskets, house construction etc.	C	Whole year
Arundinaria racemosa	Maling	1850-2750 m	MR	40 per bundle	Mats, baskets, fencing, walking sticks, flute etc.	C	Whole year
Bambusa nutans	Mala bans	300-1550 m	MR	30/individual	House construction, support for prayer flags by Buddhist	D	Whole year
Cephalostachium capitatum	Gopey bans	600-2400 m	NR	30/individual	Fodder, bow and arrow preparation, flutes and straw for drinking local beer.	R	Whole year

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Dendrocalamus hamiltoni	Choya bans	Upto 1730 m	MR	30/individual Tama 10-15 per kg	Water pipes, water vessels, young shoots as vegetables, house construction, local handicrafts, fodder for cattle etc.	C	Whole year
Dendrocalamus hookeri	Chilley bans	Upto 1750 m	MR	30/individual	House construction, fencings, baskets, etc.	C	Whole year
Dendrocalamus sikkimensis	Bhalu bans	Upto 1800 m	MR	30/individual	Water vessel, house construction, local handicrafts etc.	R	Whole year
Edible fruits and other product							
Agaricus sivaticus	Kalunge chew	Upto 1300 m	MR	40 per kg	Used as vegetables.	C	April-September
Allium wallichii	Jungli piyaj	2200-4000 m	NM		Edible and aromatic	R	June-October
Bassia butyracea	Chewri	1200-1775 m	MR	2 per 5 pieces	Fruits edible, oil is extracted from thee seeds and used. Leaves are good fodder.	R	June-July
Bauhinia vareigata	Kiorala	Upto 600 m	NM		Flowers are eaten as curry, good fodder.	R	March-April
Castanopsis hystrix	Patle katus	1800-2400 m	MR	15 per kg	Fruits edible, fuelwood, leaves are good ingredients for composts.	A	Feb-April

Cont Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Castanopsis tribuloides	Musre katus	1700-2300 m	MR	60 per kg	Fruits edible, fuelwood, leaves are good ingredients for composts.	C	Feb-April
Cinnamomum impressinervium	Sisi	1220-1830 m	NR		Seeds edible	A	Whole year
Citrullus colocenthus	Indrenni	Upto 1900 m	MR	5 per piece	Fruits edible	D	Jan-March
Dioscorea hamiltoni	Ban tarul	Upto 2000 m	MR	20 per kg	Used as food.	C	Jan-Feb
Diplazium polypodiodes	Sauney ningro	Upto 2000 m	MR	5 per bundle	Used as vegetables.	C	May-July
Elaeocarpus lanceafolius	Bhadrase	1830-2450 m	MR	18 per kg	Fruits edible	D	April-June
Evodia fraxinifolia	Khanakpa	1200-2100 m	NM		Fruits used as pickles and as medicine for dysentery	C	Aug-Sep
Ficus infectoria	Kabra	Upto 1700 m	NM		Shoots are edible, good fodder.	C	Feb-March
Garcinia cowa	Kaphal	Upto 1725 m	MR	NA	Fruits edible, gums and resins are extracted for local use.	R	July-Sep
Girardinia palmata	Bhangre sisnu	1000-2500 m	MR	5 per bundle	Young leaves and shoots use as substitute for dal which are good for blood pressure patients.	A	July-Sep

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Pentapanax leschenaultii	Chinde	1750-3000 m	MR	10 per kg	Young shots edible, used as fodder.	D	March-April
Juglans regia	Okhar	1000-2000 m	MR	2 per piece	Fruit edible, bark-anthelminthic and detergent, leaves- astringent and tonic, oil of kernel cures skin diseases etc.	D	April-Sep
Laportia terminalis	Patle sisnu	Upto 2700 m	MR	8 per bundle	Young leaves and shoots use as substitute for dal which are good for blood pressure patients.	A	May-Aug
Machilus edulis	Lapche kawla	1220-2400 m	MR	1 per piece	Fruits edible, leaves are good fodder.	C	Nov-Dec
Machilus odoratissima	Lalikaulo	1500-2150 m	NM		Fruits edible, leaves are good fodder.	C	Nov-Dec
Mahonia sikkimensis	Chutro	1300-2700 m	NM		Berries edible	A	July-Aug
Pleurotus astratus	Chamrey	NA	NM		Used as vegetables.	C	NA
Pleurotus sajor	Kanney chew	1500-2450 m	MR	50 per kg	Used as vegetables.	C	Julu-Aug
Prunus nepaulensis	Arupate	1800-above	NM		Fruits edible, fairly good fodder and fuelwood.	C	March-Aug

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Pyrularia edulis	Amphi	600-1800 m	MR	NA	Fruits edible, posses wax in kernel and were use this wax for lighting.	D	NA
Pyrus pasia	Mehel	800-2400 m	MR	10 per kg	Fruit extracts used for curing blood dysentery	D	Nov-Dec
Quercus lineata	Phalant	1850-2700 m	NM		Acorns are good food for beer, fuelwood etc.	A	March-May
Quercus pachyphyla	Sungure katus	1830-3000 m	NM		Nuts edible, bark and acorns used as astringent	D	March-May
Rhus semialata	Bhakimlo	900-1850 m	MR	NA	Seeds use as medicine dysentery	A	July-Aug
Rubus ellipticus	Aselu	1000-2200 m	MR	40 per kg	Fruits edible	A	March-May
Rubus niveus	Kalo aselu		MR	40 per kg	Fruits edible	C	March-May
Spondias axillaris	Lapsi	300-1400 m	MR	20 per kg	Fruits edible, pickles are also prepared.	D	May-Oct
Symplocos theifolia	Kharanay	1800-3000 m	NM		In the past, people use to extract oil from the seeds for cooking.	A	July-Aug
Tupistra nutans	Nakima	1800-3000 m	MR	60 per kg	Flower are taken as curry	D	Sep-Oct
Utica spp.	Gharia sisnu	1000-2500 m	MR	5 per bundle	Dried plants are use to prepare paste and applied on minor fractures. Leaves and shoots use as substitute for dal.	A	April-July

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Unidentified	Kali ningro	Above 1750 m	NM		Used dysentery.	C	May-Sep
Unidentified	Jhari chew	1800-2000 m	NM		Used as vegetables.	C	May-Sep
Unidentified	Hieun chew	Above 2500 m	NM		Used as vegetables.	C	May-Sep
Unidentified	Katuse chew	Upto 1800 m	NM		Used as vegetables.	C	May-Sep
Unidentified	Kalamen uneu	1650-2450 m	NM		Used as vegetables.	C	May-Sep
Medicinal							
Abies densa	Gobrey salla	2550-3700 m	NM		Leaf extracts use in repeated doses for asthma, bronchitis and stomach trouble.	A	Whole year
Aconitum sp.	Bikma	2100-4000 m	MR	NA	High medicinal value, use in diaphoretic, diuretic, expectorant, febrifuge, diabetes,	D	July-Sep
Acorus calamus	Bonjho	1000-2000 m	MR	NA	Paste prepared from rhizome used in skin diseases, powder taken orally for cough, malaria and asthma	D	Whole year
Artemisia vulgaris	Titepate	800-2000 m	NM		Use in different medication as deobstruent, antispasmodic, obstructed menses and hysteria.	A	Whole year

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Astilbe rivularis	Buro okhati	1200-2100 m	MR	NA	Rhizomes chewed as areca nut and used as pain relief.	D	July-Aug
Bergenia ligulata	Pakhan bet	Upto 3000 m	MR	75 per kg	Roots use in analgesic, tridosha, piles, heart diseases, spleen enlargement and many other diseases.	D	Whole year
Bergenia purpurascens	Khokim	3400-4200 m	NM		Dried roots use in as substitute for tea and believe to give relief from body ache.		
Clementis buchananiana	Pinasay lahara	1800-2800 m	NM		Fresh roots are mashed and the effluvium is drawn through nose to cure sinusitis and nose-blocks.	D	Whole year
Dichroa febrifuga	Basak	900-2400 m	NM		Dried leaves orally taken in fever	C	July-Aug
Drymaria cordata	Abijalo	1000-2000 m	NM		Used in nose dysentery.	C	Whole year
Eupatorium adenophorum	Banmara, kalijhar	1000-2000 m	NM		Crushed juice from leaves are applied in cuts and bleeding spots immediately	A	Whole year
Heracleum nepalense	Chimphing	1550-3600 m	MR	3 per packet	Fruits are used as pickles, used as anti-typhoid, nausea and vomiting	D	Aug-Oct

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Hydrocotyle asiatica	Golpatta	1300-2000 m	NM		Fresh leaves are crushed and administered orally to relieve blood pressure and throat pain.	C	Whole year
Holboellia latifolia		2400-3200 m	R	NA	Fruits edible, stem used to make bangles, which are believe to give relief from orthopedic problems.		Whole year
Kaempfera rotunda	Bhuin champa	1300-2000 m	MR	NA	Tubers used as poultice in fracture, healing fresh woods and removes coagulated bloods from the body.	R	NA
Litsae citrata	Siltimur	Upto-2700 m	MR	NA	Dried fruits are used as medicine for nausea and giddiness, fresh fruits used as pickles.	D	Aug-Sep
Orchis latifolia	Panch aunle	3000-4000 m	MR	4 per piece	Paste made out of the tubers is applied over cuts and bruises. It is also used orally for body ache	R	Aug-Sep
Oroxylum indicum	Totala	Upto 1000 m	MR	10 per garland	Flower edible, root bark improves appetite, use in vomiting, asthma, bronchitis etc.	R	Aug-Dec

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Picrorhiza kurrooa	Kutki	3000-5000 m	MR	NA	Dried roots are used orally in malarial fever. It is also used as cathartic, purgative and dyspepsia.	D	Whole year
Piper longum	Pipla	Upto 1700 m	MR	60 per kg	Roots use in anthelminthic, improves appetite, abdominal pain. Fruits use for anti-diarrhoeatic, anti-dysenteric, piles, leprosy etc.	C	Whole year
Plantago major	Isabgol	Upto 1750 m	NM		Plant use as medicine for rheumatism, roots as astringent and fever, and seed in dysentery.	C	Whole year
Polygala arillata	Marcha	600-1800 m	MR	NA	Roots use for preparation of yeasts.	D	NA
Rheum emodi	Padamchal	3600-4500 m	D		Dried roots use as tea.	D	July-Sep
Rheum nobile	Kenjo	3600-4500 m	NM		Whole plant eaten used for pickles, have medicinal value.	R	July-Sep
Rhododendron arboreum	Lali guras	1500-3300 m	NM		Dried flowers use for curing dysentery	A	Jan-March
Rubia cordifolia	Majhito	1000-2000 m	MR	650 per ton	Color extracts are used in dying. Roots have medicinal value.	C	Whole year

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Rumex nepalensis	Halhalay	1800-3000 m	NM		Dried root is use in preparation of paste and taken orally in hepatistis. It is also applied during loss of hairs.	A	Whole year
Solanum xanthocarpum	Jungli bihin	Upto 1800 m	NM		Root use in bronchitis, asthma, fever, pains. Piles etc. Fruits increase appetite and good for heart diseases and fever. Fruits are burnt and use its smoke for relief from toothache.	C	Whole year
Swertia chirata	Chirato	1225-3000 m	MR	NA	Medicinal use for anthelmintic, antipyretic, antiperiodic, laxative, leucoderma, inflammation, ulcer, asthma piles etc.	D	March-Sep
Viscum articulatum	Harchur	300-2000 m	MR	80 per kg	Dried plants are use to prepare paste and applied on minor fractures.	R	Whole year
Zanthoxylum acanthopodium	Boke timur	Upto-2250 m	D	40 per kg	Medicine for ear diseases, headache, leucoderma, asthma and good appetizer	D	May-Sep

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Natural decorative							
Anaphalis contorta	Bukiphul	1700-2750 m	NM		Dried flowers are decorative and also used for preparation of pillow	A	July-Sep
Anaphalis triplinervis	Bukiphul	1850-2750 m	NM		Dried flowers are decorative and also used for preparation of pillow.	A	July-Sep
Lycopodeum clavatum	Nagbelli	1850-2750 m	NM		Entire plant is decorative and pollen is used as gunpowder.	C	Whole year
Pollinia mollis	Memkesh	1550-2450 m	NM		Flowers spikes are decorative	R	Whole year
Raphidophora sp.	Kanchirna	Upto-2000 m	NM		Planted as decorative, leaves good fodder, stems used as feed for pig and cattle.	A	Whole year
Fiber and broom species							
Daphne cannabina	Kagatay	1850-3000 m	MR	NA	Bark is used as ropes but also have potential for preparation of paper.	C	Whole year
Edgeworthia gardneri	Argeli	Upto 1850 m	MR	NA	Bark is used for preparation of paper, making ropes and even tying cattle.	C	Whole year

Cont. Appendix C

Species	Vernacular name	Distribution	Markatable/ non markatable	Market rate (Rs)	Uses	Status	Availability
Thysanolaena maxima	Amliso	Upto-2000 m	MR	Broom 1000 per ton.	Broom are prepared from the inflorescence,, fodder, soil binder and fuelwood after drying the sticks.	A	Whole year
Incense							
Juniperus recurva	Bhairun patay	3600 m above	MR	NA	Local Buddhist uses leaves as incense.	C	Whole year
Rhododendron setosum	Sunpatay	3600 m above	MR	NA	Local Buddhist uses leaves as incense.	C	Whole year