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 $P<0.05$

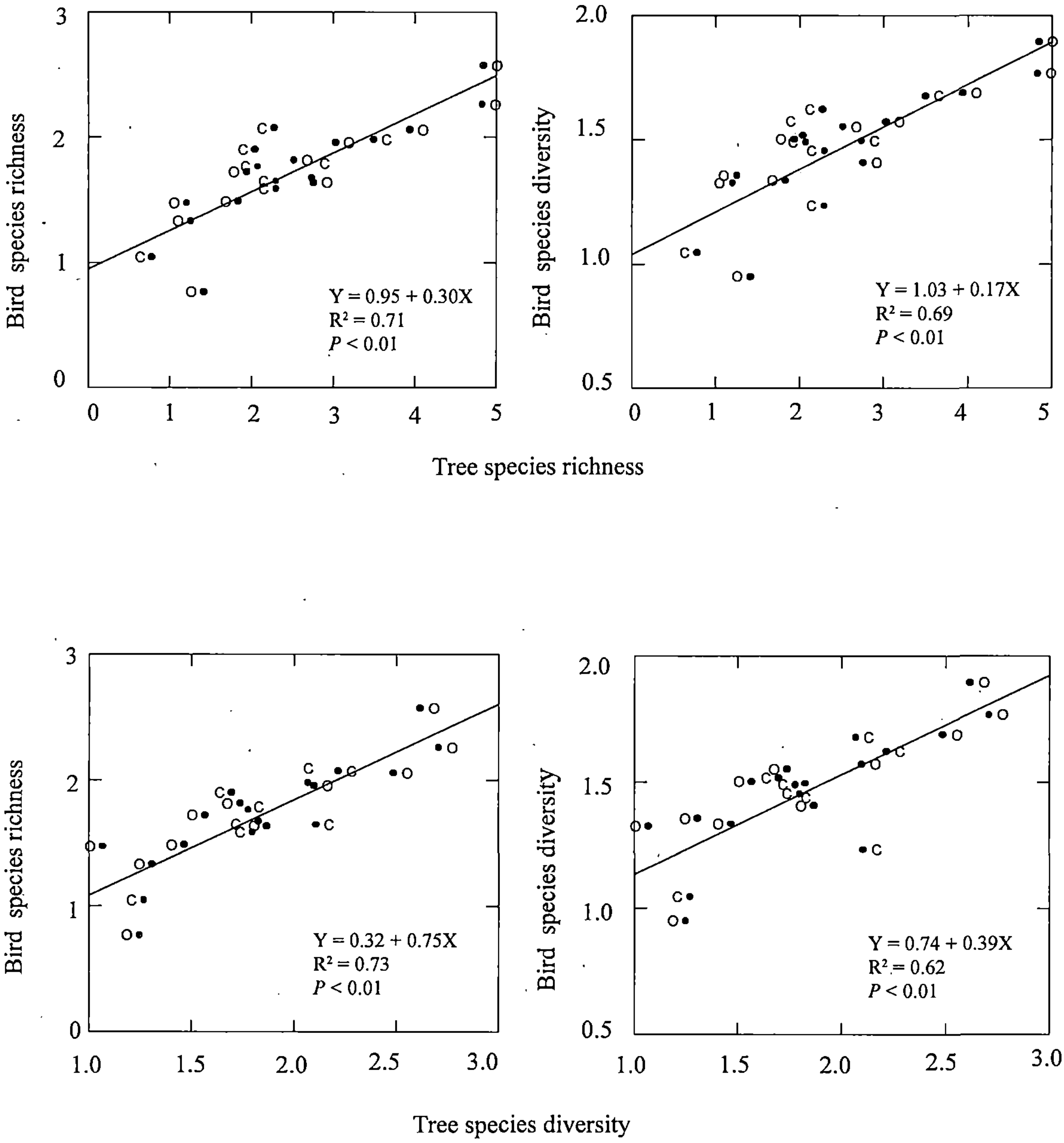
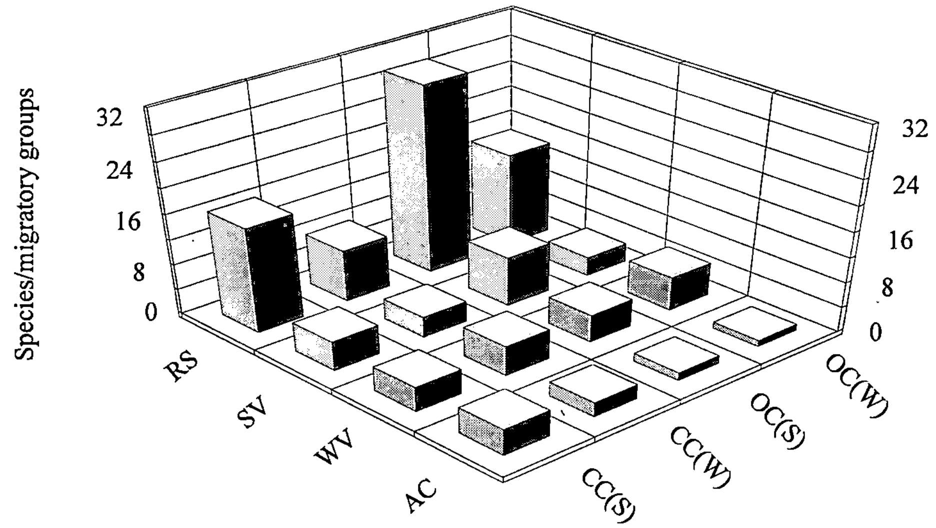
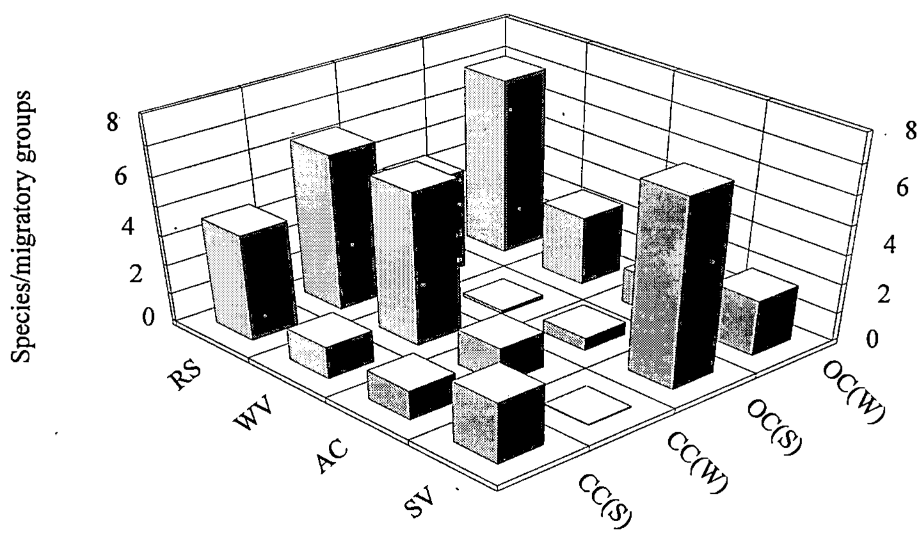


Fig.7.1. Tree and bird diversity indices in the forests showing significant relationships between tree species richness, tree species diversity and bird species diversity and bird species richness (O = open canopy condition, C = closed canopy condition) of Yuksam-Dzongri trekking corridor.

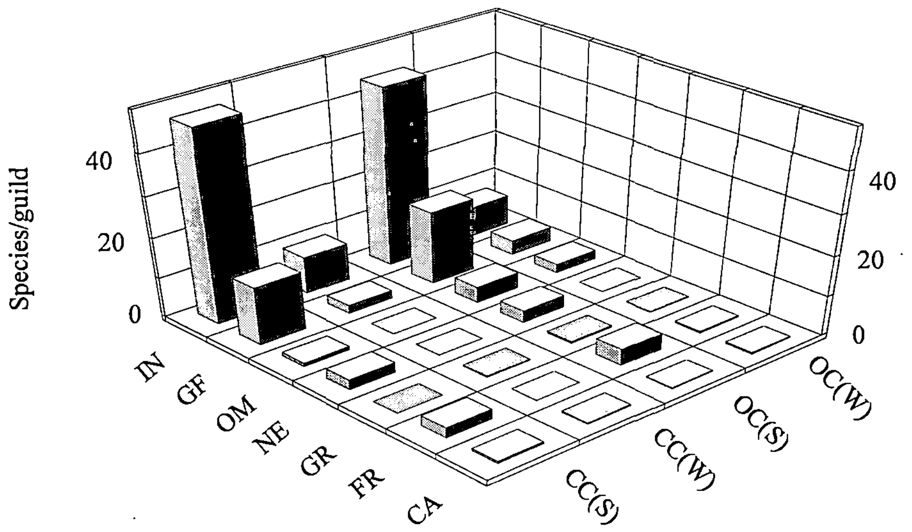


(a)

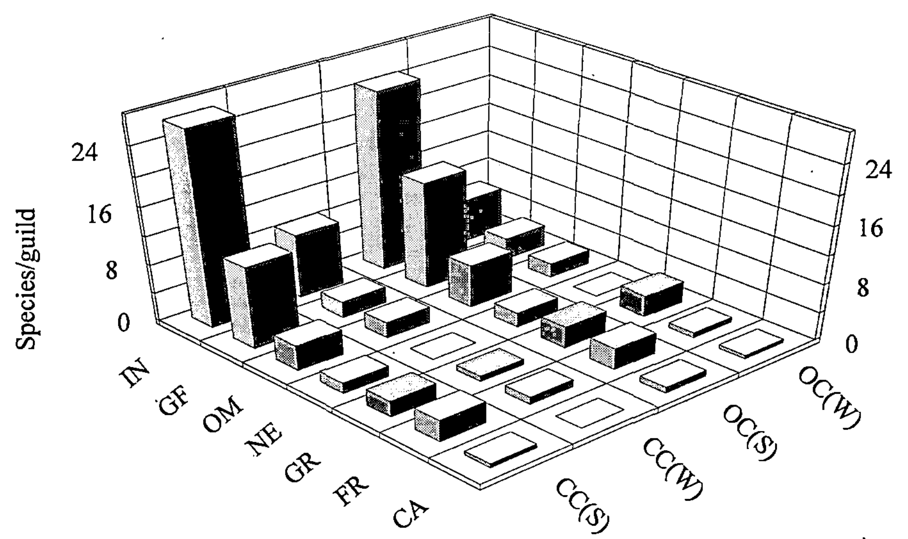


(b)

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.