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				
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	*P* value	*P* value	*P* value
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				
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	*P* value	*P* value	*P* value
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				
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	*P* value	*P* value	*P* value
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				
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	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
*$P<0.05$, ** $P<0.01$

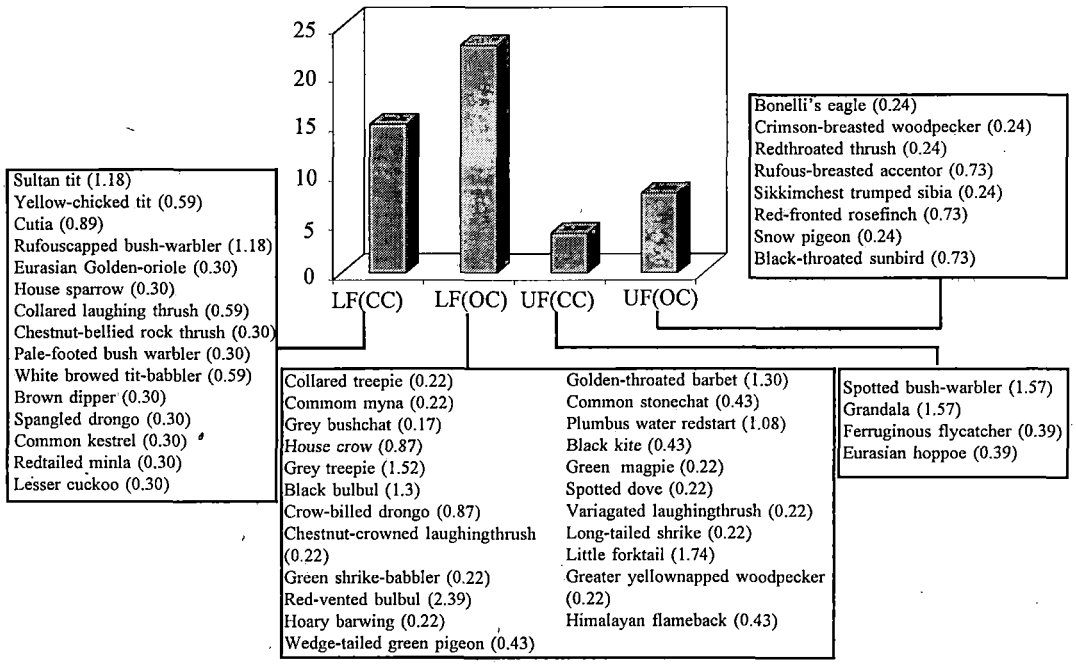

Fig. 6.1. Bird species with frequency observed only at specific habitat types at Yuksam-Dzongri trekking corridor. (LF= lower forest, UF = upper forest, CC = closed canopy and OC= open canopy).

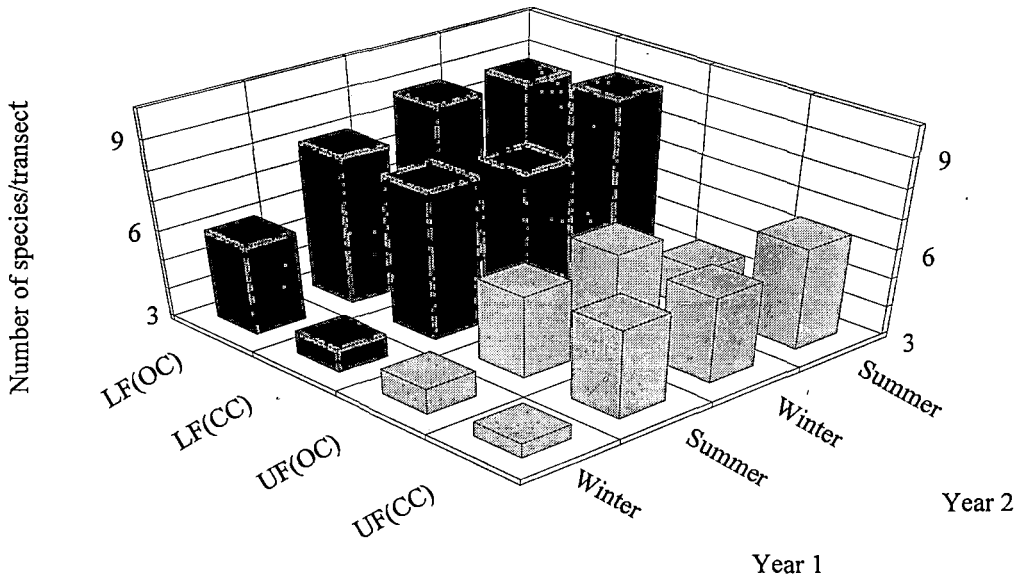

Fig. 6.2 Bird species number in summer and winter seasons for two years (Year1 = 1997-98, Year2 = 1988-99) in open and closed canopy conditions of the lower and upper forests in Yuksam-Dzongri trekking corridor. ANOVA: Year $F_{1,246} = 8$, $P<0.004$; Season $F_{1,246} = 7$, $P<0.008$; Forest type $F_{1,246} = 21$, $P<0.0001$, 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

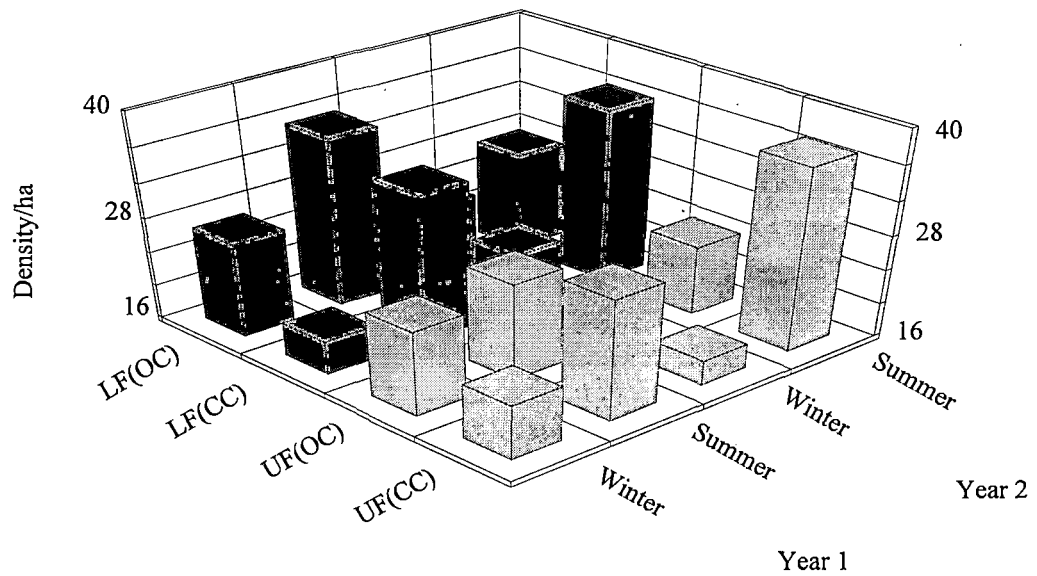

Fig.6.3. Bird density in summer and winter seasons for two years (Year1 = 1997-98, Year2 = 1988-99) in open and closed canopy conditions of the lower and upper forests in Yuksam-Dzongri trekking corridor. ANOVA: Year x Season $F_{1,246}$ = 16, $P<0.0001$; Year x Habitat condition $F_{1,246} = 5$, $P<0.016$; 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)

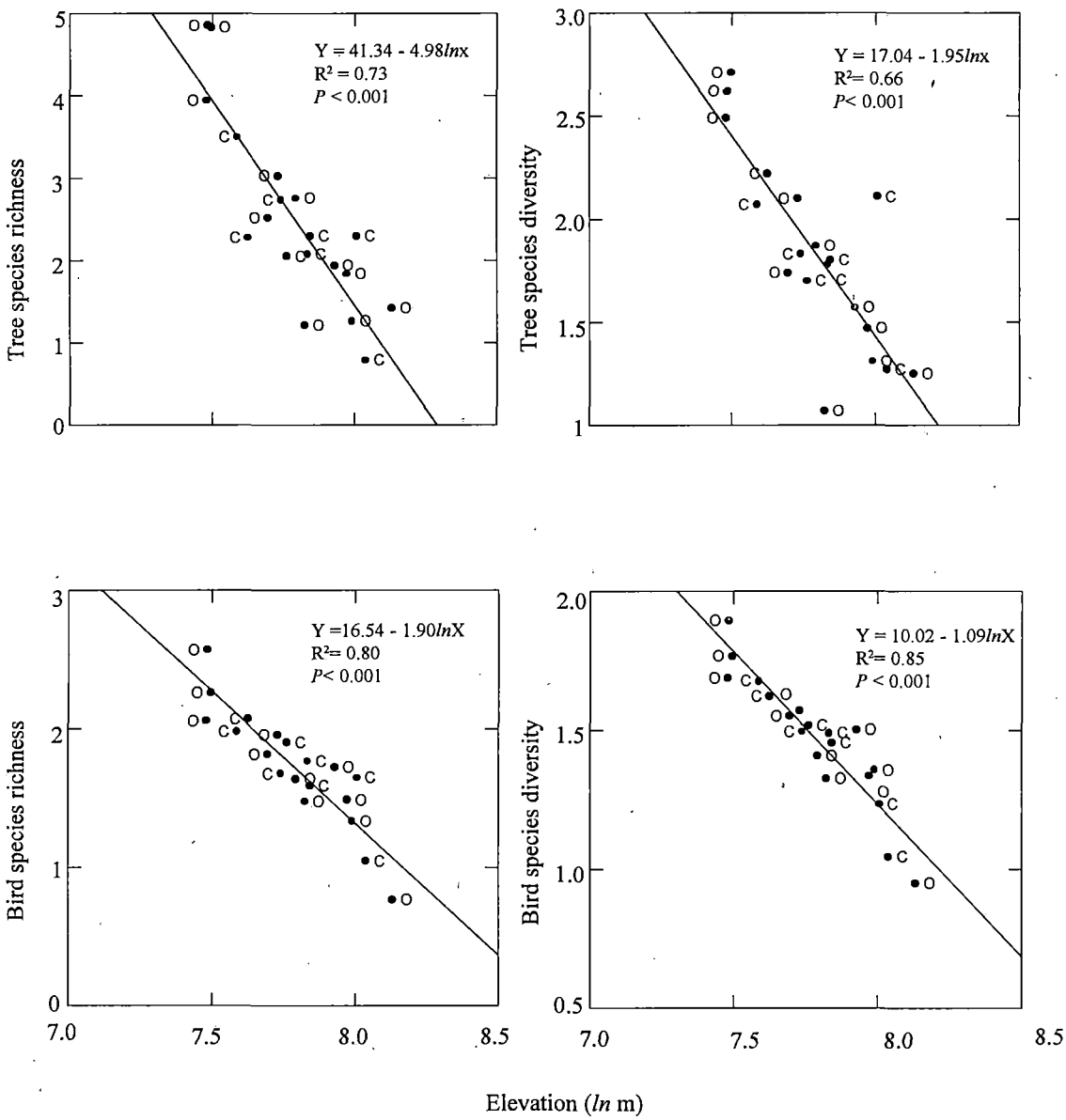

Fig 6.4. Relationship on woody tree species richness and diversity and bird species richness and diversity with elevation in the forests (O = open canopy condition, C = closed canopy condition) of Yuksam-Dzongri trekking corridor. (Elevation transformed to natural log)