Bird community structure along a trekking corridor of Sikkim Himalaya: A conservation perspective

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Bird community structure along a trekking corridor of Sikkim Himalaya: a conservation perspective

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Abstract

Bird community structure was studied in the Yuksam–Dzongri trekking corridor of the Sikkim Himalaya, India. Nineteen transects with a total of 266 samplings were made in the forests along the corridor during June 1997 to June 1999. Human utilised forest (open canopy forest) and relatively unutilised forest (closed canopy forest) were designated for the study at two ecological zones, i.e. lower forest (1780–2350 m a.s.l.) and upper forest (2350–3600 m) depending on the natural resources utilisation pattern by local community living in the area and for tourism purposes. There were visible changes in the open and closed canopy forests in diameters at breast height class distribution of trees leading to distinct variation in the habitat types. Among the 143 species of birds observed during the study, a handful of species were found as habitat specific and about 40% were common to all the four habitat types. Both bird species richness and diversity were higher at the open canopy conditions compared with closed canopy, but the differences were not statistically significant. On the other hand, both the indices showed strong and significant negative relationship with the elevation. These diversity indices were also significantly higher during the summer compared with the winter season. The open canopy conditions exhibited comparatively more species of birds that were perturbated by human settlements than those species found at the closed canopy (mostly forest interior) and vice versa. Though the study could not trace out the effect of patch size brought about by human caused disturbances, the Yuksam–Dzongri trekking corridor possesses diverse habitat types as well as bird species resulted from heterogeneous habitat conditions. It is therefore important to emphasise disturbance study for threshold level assessment so that generalists as well as forest interior species could be managed through conservation efforts.

Keywords: Forest types; Species richness and diversity; Habitat conditions; Seasonality

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; Safiq et al., 1997). Indian subcontinent is known for diverse and rich bird species whose taxonomy, distribution and their general habitat characteristics are well documented in India (Jerdon, 1862–1964; Bates and Lowther, 1952; Ali and Ripley, 1983). However, only a very little is known about bird community structure and their dynamics in India (Daniels, 1989; Khan et al., 1993; Johnsingh and Joshua, 1994; Javed, 1996; Safiq et al., 1997). Large scale habitat changes are occurring globally for fulfilling human needs that have caused habitat destruction, fragmentation and degradation, necessiting assessment on the impacts of such change on birds (Brash, 1987; Whitten et al., 1987; Khan et al., 1993). 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. Moreover seasonal monitoring is equally important to trace the dynamic movement of birds in such habitats (Green and Catterall, 1998).

The Eastern Himalaya (Khangchendzonga region) supports a wide diversity of birds resulting from complex physiography and bioclimatic zonation (Ives and Messerli, 1989) and also because of their location at the convergence of the Palaearctic and Oriental Zoogeographical

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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 (Bibby, 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 in the present study area (Chettri, 2000).

Bird studies in Sikkim date back to the 19th century and many accounts on birds of Sikkim are available (Bulger, 1869; Blandford, 1872; Gammie, 1877; Brooks, 1880; Ludlow and Kinnear, 1937, 1944; Mills, 1944; Maclaren, 1947, 1948; Sen, 1948, 1957). Ali's (1989) ornithological work in the region is the most exhaustive to date. However, only a few more recent survey reports are available. 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 are worldwide problem and have increased during the last two decades in this trekking corridor due to growth in tourism and population. These have resulted in the fragmentation and deterioration of wildlife habitats and also affecting the natural beauty of the area. Vegetation structure showed remarkable changes in species composition at human disturbed locations compared with relatively undisturbed areas along the corridor (Chettri, 2000). This could have major negative impacts on wildlife. An exploratory monitoring of birds in the area that encompassed a wide range of altitude and diverse forest types is of special importance because of disturbances along the trek in recent years. This work would be useful for comparison in the follow-up study after a few more years of tourism in the area. The paper is an attempt to assess (1) bird diversity, (2) species composition and abundance and (3) seasonal variation on bird community structure at highly disturbed and relatively undisturbed forests along the Yuksam–Dzongri trekking corridor of west Sikkim. The study provides information on effects on bird community in relation to habitat management implications.

2. Methods

The Khangchendzonga area is a unique mountain ecosystem falling in three different national boundaries of India, Nepal and Tibetan Autonomous Region of the People's Republic of China and has many transboundary issues of common interest for management (Sharma, 1997). Yuksam–Dzongri trekking corridor (26 km long) encompasses elevation from 1780 to 4000 m (Fig. 1). The trail passes through Sachen, Bakhim and Tshoka in the south-western part of Khangchendzonga Biosphere Reserve in Sikkim, India. Yuksam is a trailhead for this corridor and leads to the Base Camp, Dzongri, Thangsing and Gocha La in the West Sikkim (Fig. 1). Yuksam (1780 m) has 11 settlements with 274 households comprising of 1573 people. One settlement with eight households is inside the biosphere reserve at Tshoka (3000 m) on the trail. The majority of the ethnic people of Yuksam are Subbas, followed by Bhutias, Lepchas, Nepalis and Tibetan Refugees mostly at Tshoka. The primary occupation of the people is farming while some are associated with tourism in the form of lodge operators, porters, yakmen, cooks and guides for trekking. Firewood and fodder collection, interior forest grazing and leaf litter collection are common practices among the different ethnic groups. Tourism is increasing in the area at a rapid rate (Rai and Sundriyal, 1997) and more people are engaged in this profession. Annually, about 2000 domestic and foreign tourists visit the area. More than 150 support staff, 140 dzos (cross of cow and yak) and 12 horses (pack animals) operate in this trekking trail on an average of six times a year. The Himalayan Mountaineering Institute (HMI) conducts training for about 500 trainees annually in the area. Trekking tour staff including porters hired by travel agents and HMI trainees collect firewood for cooking and heating purposes all along the corridor. This has been one of the major factors of the forest destruction.

Four sampling stands were selected along the Yuksam–Dzongri trekking corridor (Fig. 1). Dominant trees and selective important species of all stand types are presented in Table 1. Out of these four stands, two were located at warm temperate broadleaf forest having an elevation range 1780–2350 m and we designated the area as lower forest (LF). Settlements around Yuksam generally depend on this forest for firewood, fodder and timber. The other two stands were located at cool-temperate and sub-alpine zone having an elevation range 2350–3600 m, were designated as upper forest (UF). Settlement from Tshoka and tourism depend on this forest.

2.1. Vegetation surveys

A total of 19 permanent plots measuring 30×40 m were laid along the trekking corridor. The plots relatively undisturbed and distant from the settlement with $>40\%$ canopy cover, were designated as closed canopy forest (CC), while the plots extensively disturbed located near the human settlement with $<40\%$ canopy cover, were designated as open canopy forest (OC). Trees in the permanent plots were identified and their diameters at breast height (dbh) were measured using diameter

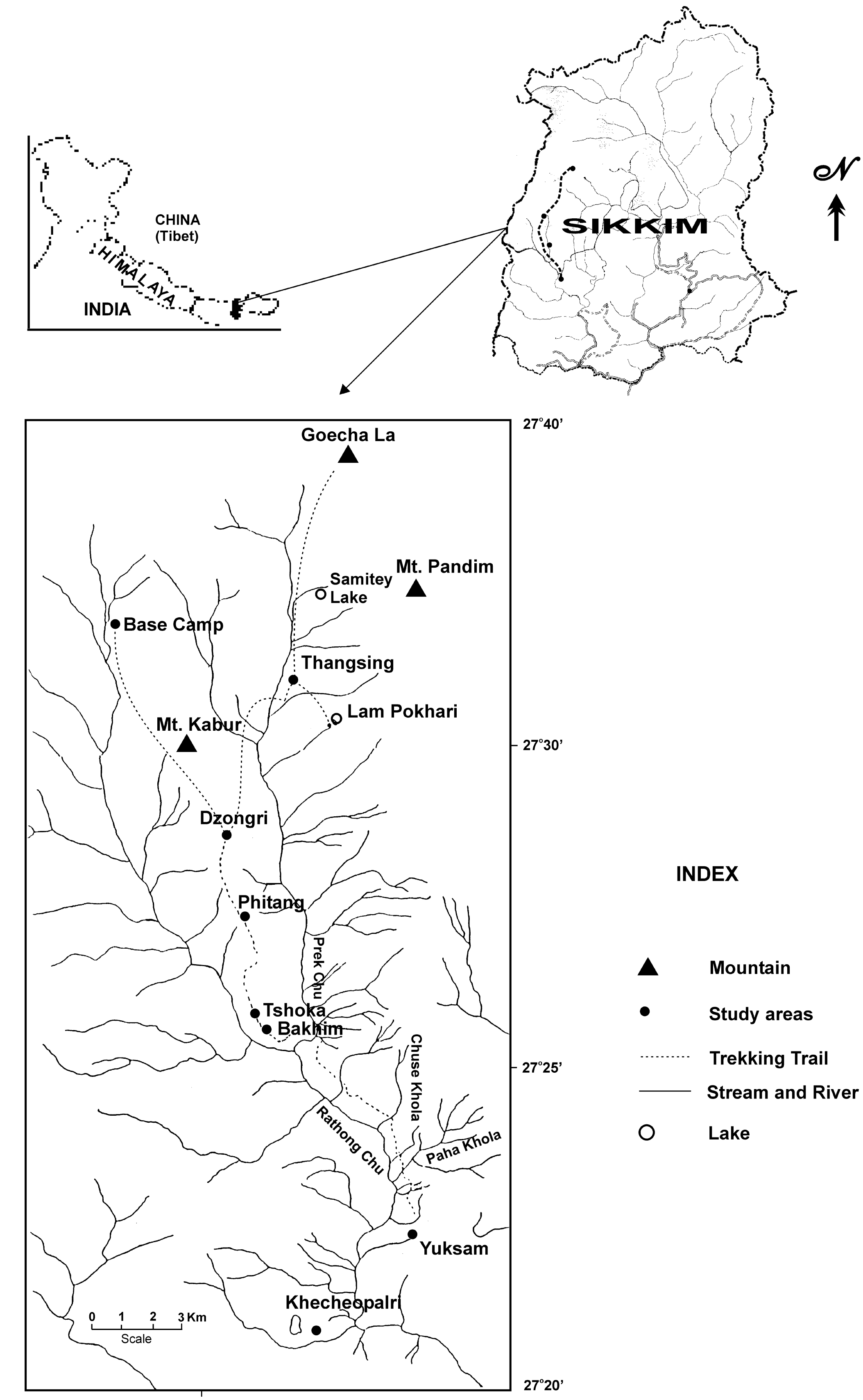

Fig. 1. Location map showing the Yuksam–Dzongri trekking corridor in west Sikkim.

tape. Trees were separated into 10 dbh classes, and density of each dbh class was compared between CC and OC. Tree height was measured using a clinometer. Nine height classes of trees (1–5, 6–10, 10–15, 16–20, 21–25, 26–30, 31–35, 36–40 and >40 m) and their abundance were recorded in the four stands that were used for drawing tree height profile following Sankar Raman (1995) and Javed (1996) with necessary modifications.

2.2. Bird surveys

The bird counts were conducted in 19 transects each measuring 100×40 m crossing each of the permanent plots (four each at closed canopy stand of LF and UF, five at open canopy stands at LF, and six at UF) during summer (May–August) and during winter (October–February) following Hawrot and Niemi (1996), with necessary modifications. Three observations were made at each transect in a season during 1997–1998 (year 1) and 1998–1999 (year 2). Total numbers of transects surveyed were 266 (56 each in closed canopy stand of LF and UF, 70 in open canopy stand of LF, and 84 at UF). Bird surveys were made between 06:00–09:30 h in the mornings, when wind was weak, to avoid tree branch movement for more accurate bird enumeration. Observations were not made during rainfall and foggy days to avoid bird visibility problem. During the sampling, all birds seen or heard in each transect were recorded and enlisted according to Oriental Bird Club's list (Inskipp et al., 1996). The Line Transect Method was selected because of its robustness and sampling efficiency (Burnham et al., 1980) and ease of sampling compared with other methods (Verner, 1985; Javed, 1996). The enlisted species were catagorised into different guilds depending on their feeding habit and the migratory pattern following information gathered from existing literature and personal observations (Ali, 1989). All the species that are common near the human settlements were considered as generalist species, and the species that were restricted to the forest interior were considered as forest interior species (Ali and Ripley, 1983). Frequency of occurrence was used to identify species that were restricted to specific habitat in closed canopy and open canopy conditions in the LF and UF following Hagan et al. (1997). Species diversity (Shannon–Wiener's index), richness (Margalef species richness) and Simpson index of dominance (Simpson index) were estimated in each transect following Hayek and Buzas (1997).

2.3. Data analysis

Abundance of bird species was estimated from the recorded number in each 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. Differences in the abundance between habitats for species present at >3 transects were considered for GLM

Table 1
List of selective important species and dominant tree composition under closed and open canopy habitat conditions at the lower and upper forest types in the Yuksam–Dzongri trekking corridor

Forest type/elevation	Habitat condition	Tree domination	Selective important species
Lower forest 1780–2350 m	Closed canopy	*Quercus-Cinnamomum*	*Quercus lamellosa, Cinnamomum impressinervium, Beilschmiedia sikkimensis, Quercus lineata, Eurya acuminata, Machilus edulis, Symplocos* spp., *Impatients, Elatostemma*, etc.
	Open canopy	*Quercus-Castanopsis*	*Quercus lamellosa, Castanopsis* spp., *Eurya acuminata, Machilus edulis, Betula cylindrostachys, Viburnum cordifolia, Mahonia sikkimensis, Symplocos* spp., *Elatostemma sessile, Galinsuga, Polygonum*, etc.
Upper forest 2350-3600 m	Closed canopy	*Quercus-Acer, Abies-Rhododendron*	*Acer papilio, Quercus lamellosa, Abies densa, Rhododendron falconeri, R. arboreum, R. grande, Magnolia campbelli, Impatients, Oxalis, Frageria*, etc.
	Open canopy	*Abies-Rhododendron*	*Abies densa, Rhododendron arboreum, Magnolia campbelli, Prunus nepaulensis, Betula alnoides, Rosa* sp., *Frageria nubicola, Frageria* sp., *Viola, Porochetus*, etc.

(general linear model). Effects of habitat conditions, forest types and their interaction were analysed keeping other attributes as random (Schutte and Niemi, 1998). Variations in species composition between the habitat types were tested with replicated goodness of fit (*G*-test) following Sokal and Rohlf (1981).

Simple regressions were applied to examine diversity trends with the elevations. Analysis of variance (ANOVA) was performed on density for variations between year, seasons, forest types and habitat conditions. Seasonal changes in bird species diversity and richness were tested with a two-tailed *t*-test (Clergeau et al., 1988). Some differences in count certainly could bring out variation on observations, as many species were more easily detectable during specific time of the year than the others (Best, 1981; Avery and Riper, 1989). These differences probably resulted from the difference in seasonal behaviour (e.g. some species are more secretive while nesting) or environmental differences (CC provides more concealment than open canopy). Adequate number of samplings have evaded the place for type I and type II errors (Block, 1989). All statistical analyses were performed using SYSTAT, Version 6 (1996), unless otherwise mentioned.

3. Results

3.1. Vegetation

Density of dbh classes showed obvious differences in distribution at the CC and open canopy conditions of both the LF and UF (Fig. 2). The distribution of dbh classes was more regular in the closed canopy condition compared with the OC, indicating good regeneration and representation of different size classes of trees. The distribution pattern was skewed for the open condition at both the LF and UF suggesting disproportionate distribution of the tree sizes.

Tree height profiles of the open canopy conditions were remarkably disproportionate in their distribution among different height classes compared with the closed canopy condition (Fig. 3). Trees with 1–5 m height were more abundant in the closed condition, whereas the medium height trees were fewer at both the open and closed conditions in the lower forest. Small trees (1–5 m) were comparatively fewer at the UF suggesting poor regeneration. Comparatively, 20–25 m height class trees were less abundant at the UF compared with the LF.

3.2. Bird species abundance

Over the 2-year period, 7149 bird detections (individuals) were made that represented 143 species during 266 visits distributed over 19 sampling transects placed at four 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 (Appendix). Grey-sided laughing thrush (9.90) was the most abundant species at the open canopy condition of the LF 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 the 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% of species differed significantly between the two forest types (LF and UF), 15% of species among the habitat conditions (CC and OC) and 20% of species as a result of their interaction (forest types and habitat conditions). Among the species showing significant differences between habitat conditions (Appendix), white-throated laughing thrush, grey-winged blackbird, grey-headed canary flycatcher, and black-faced laughing thrush 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 a 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 laughing thrush, Mrs Gould's sunbird and grey-winged blackbird were more abundant at the LF. Black-faced laughing thrush, plain-backed thrush, spotted nutcracker, yellow-billed blue-magpie, Eurasian tree-creeper and rufous-vented yuhina were among the abundant species at the UF (Appendix). Large hawk cuckoo, grey-hooded warbler, rufous sibia and verditor flycatcher differed significantly between the forest types showing higher abundance at the lower forest. Rufous bellied niltava, plain backed thrush, green-tailed sunbird, blue whistling thrush, black-faced laughing thrush, Darjeeling woodpecker, white collared blackbird and grey winged blackbird were the species whose abundance varied significantly between the habitat conditions as well as between the forest types (Appendix).

3.3. Habitat specificity

Of the 143 bird species, 10% of the species were restricted to the CC in contrast with 16% in the OC of LF (Fig. 4). At the CC of LF, the 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 such 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 the OC, 6% of the total species was recorded as specific to the habitat. Among them, rufous-breasted accentor, red-fronted rosefinch and black-throated sunbird showed higher frequency.

3.4. Bird community

Bird species diversity and richness were higher at both the forests in the open canopy condition (Table 2). Density of birds was also higher at the open canopy condition of LF (30±2.3 per transect) compared with

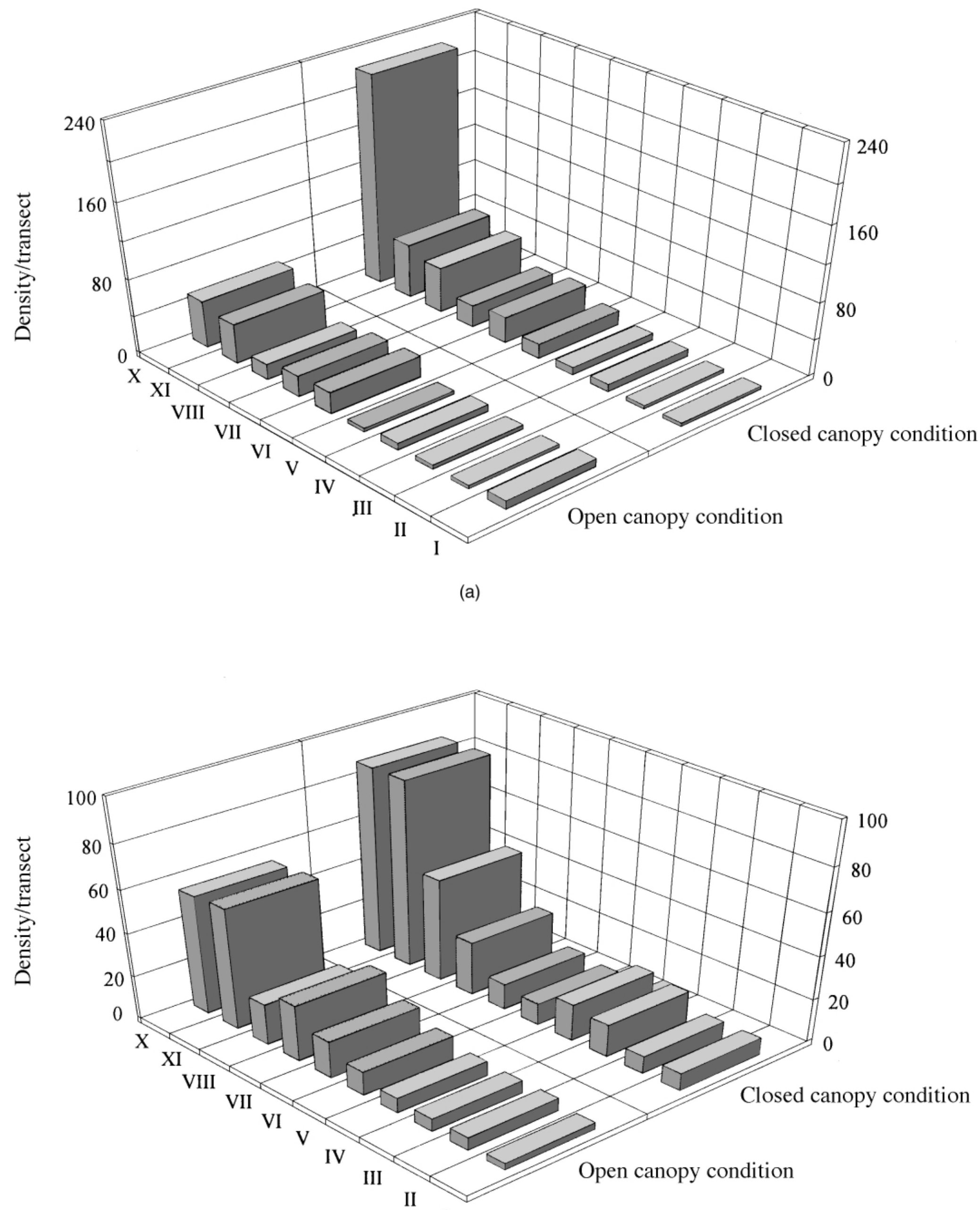

Fig. 2. Diameter class distribution of tree density in closed and open canopy conditions at (a) the lower forest and (b) the upper forest along the Yuksam–Dzongri trail. dbh classes (cm) I = 10–20, II = 20–30, III = 30–40, IV = 40–50, V = 50–60, VI = 60–70, VII = 70–80, VIII = 80–90, IX = 90–100 and X = > 100.

Table 2
Sample size, composition and structure of bird communities in different habitat conditions at the Yuksam–Dzongri trekking corridor

Bird variables	Lower forest[a]		Upper forest[a]	
	CC	OC	CC	OC
Sampling size (100 m transect)	56	70	56	84
Species recorded	82	86	64	77
Species per transect (mean±S.E.)	7±0.53	8±0.44	6±0.43	5±0.32
Individuals per transect (mean±S.E.)	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

[a] CC, closed canopy condition; OC, open canopy condition.

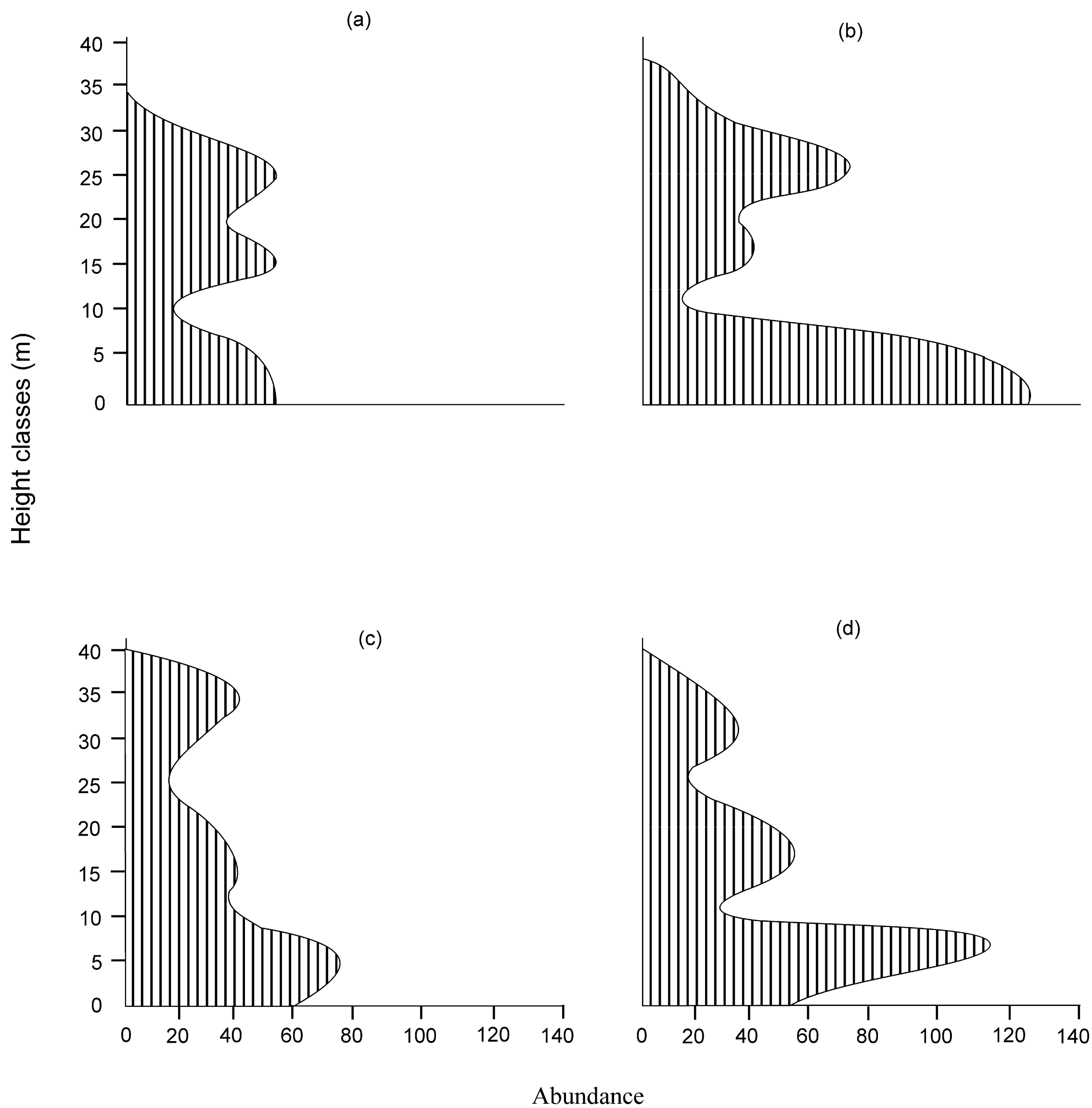

Fig. 3. Foliage height abundance in two forest types showing well-stratified forest at closed canopy compared with open canopy at the Yuksam–Dzongri trekking corridor. (a = lower forest, open canopy; b = lower forest, closed canopy; c = upper forest, open canopy and d = upper forest, closed canopy).

that of the closed canopy (28±2.7 per transect), and the values were reversed at UF (24±1.9 per transect) at the open canopy compared with the closed canopy condition (27±3.5 per transect). 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 were significantly different between the two-forest types (Table 3). Considerable dissimilarities in species assemblages exist between the two habitat conditions. Species assemblages differed significantly among the habitat conditions at the lower forest ($G=174$, $P=<0.01$) and upper forest ($G=595.32$, $P=<0.01$), 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 the year ($F_{1,246}=8.5$, $P=0.004$), season ($F_{1,246}=7.04$, $P=0.008$) and forest type ($F_{1,246}=21.1$, $P=0.0001$). Interactions between the year and season only ($F_{1,246}=8.1$, $P=0.005$, $LSD_{0.05}=2.29$) were found to be significant (Fig. 5). However, 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). 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

Table 3
Comparative assessment of bird community structure between habitat (closed canopy and open canopy) and forests (lower forest and upper forest) of the Yuksam–Dzongri trekking corridor

Variable	Effect of habitat condition				Effect of forest types			
	Mann–Whitney U-value[a]	X^{2c}	P		Mann–Whitney[b] U-value	X^{2b}	P	
Bird species richness	8788.0	0.61	0.43	CC < OC[d]	11876.0	29.74	<0.01	CC < OC[d]
Bird species diversity	8571.5	0.18	0.67	CC < OC	11527.0	23.84	<0.01	CC < OC
Bird abundance	8236.0	0.18	0.89	CC < OC	7015.0	6.21	0.01	CC > OC
Density	8461.0	0.06	0.81	CC < OC	9965.0	5.42	0.02	CC > OC

[a] $U_{0.05(2),154,108}$
[b] $U_{0.05(2),122,140}$.
[c] Chi-square approximation with d.f. 1.
[d] CC, closed canopy condition; OC, open canopy condition.

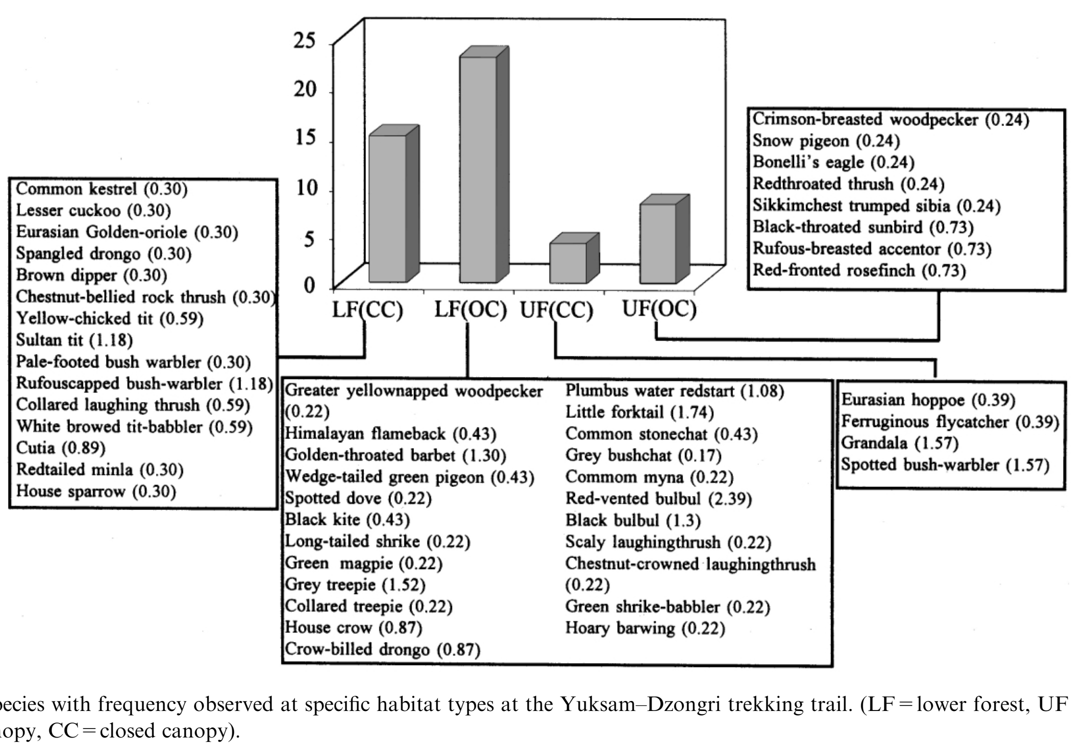

Fig. 4. Bird species with frequency observed at specific habitat types at the Yuksam–Dzongri trekking trail. (LF = lower forest, UF = upper forest, OC = open canopy, CC = closed canopy).

diversity were stronger with increasing elevation than tree species richness and diversity (Fig. 7).

3.5. Seasonal variation of bird community

The bird species richness and diversity varied significantly between the summer and winter seasons at all the habitats except at the closed canopy of UF (Table 4). The open canopy conditions at both the forest types (LF-$t=2.50$, d.f.$=68$, $P=0.016$, and UF-$t=3.05$, d.f.$=82$, $P=0.003$) showed a strong variation in bird species diversity.

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

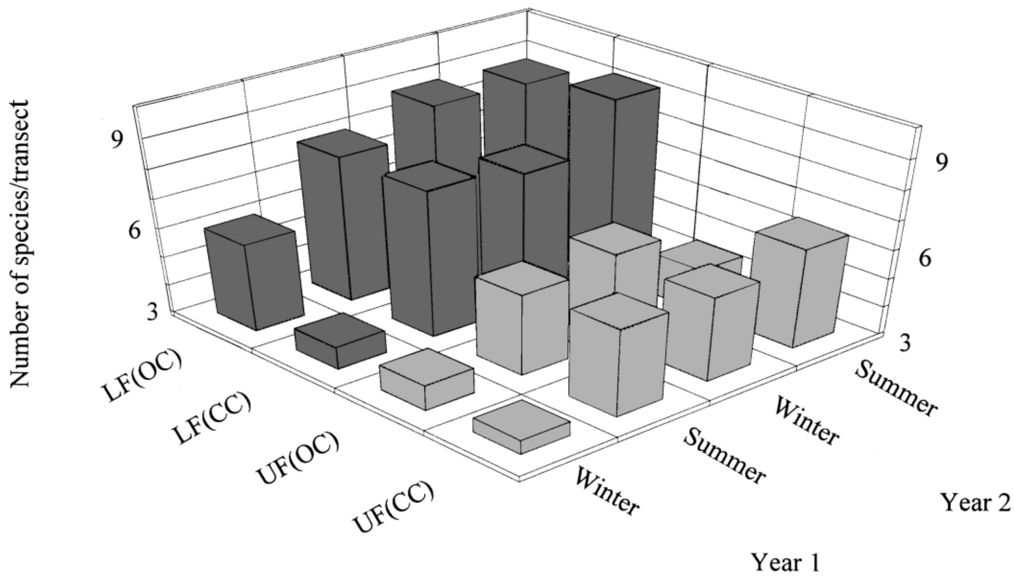

Fig. 5. Bird species composition in breeding and non-breeding seasons for two years (Year 1 = 1997–1998, Year 2 = 1988–1999) in the open and closed canopy conditions of the lower and upper forests in the Yuksam–Dzongri trekking corridor. ANOVA: Year $F_{1,246}=8.5$, $P<0.004$; Season $F_{1,246}=7.04$, $P<0.008$; Forest type $F_{1,246}=21.1$, $P<0.0001$, Year×Season $F_{1,246}=8.1$, $P<0.005$; other interaction not significant, $LSD_{(0.05)}=2.29$. (LF = lower forest, UF = upper forest, OC = open canopy, CC = closed canopy).

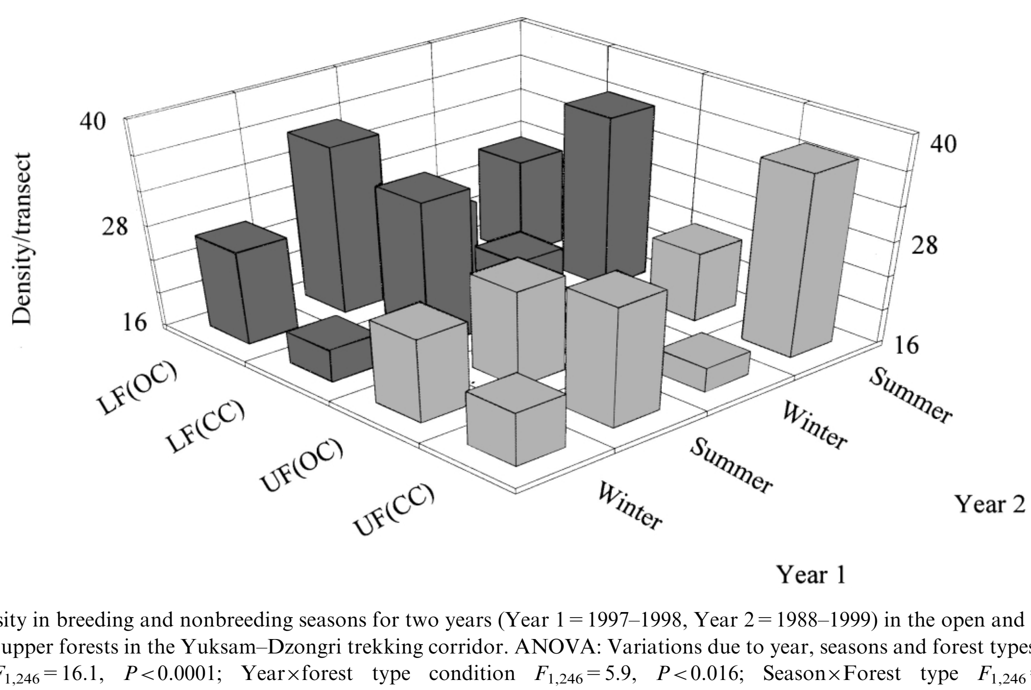

Fig. 6. Bird density in breeding and nonbreeding seasons for two years (Year 1 = 1997–1998, Year 2 = 1988–1999) in the open and closed conditions of the lower and upper forests in the Yuksam–Dzongri trekking corridor. ANOVA: Variations due to year, seasons and forest types were significant; Year×Season $F_{1,246}=16.1$, $P<0.0001$; Year×forest type condition $F_{1,246}=5.9$, $P<0.016$; Season×Forest type $F_{1,246}=3.8$, $P<0.056$, Year×Season×Year×Forest type $F_{1,246}=6.6$, $P<0.011$; other interaction not significant, $LSD_{(0.05)}=14.14$ (LF = lower forest, UF = upper forest, OC = open canopy, CC = closed canopy).

Table 4
Comparison of bird species richness (BSR) and bird species diversity (BSD) between summer (S) and winter (W) seasons in the Yuksam–Dzongri trekking corridor

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

[a] t-Test for pair samples.
$^{*}P<0.05$.
$^{**}P<0.01$.

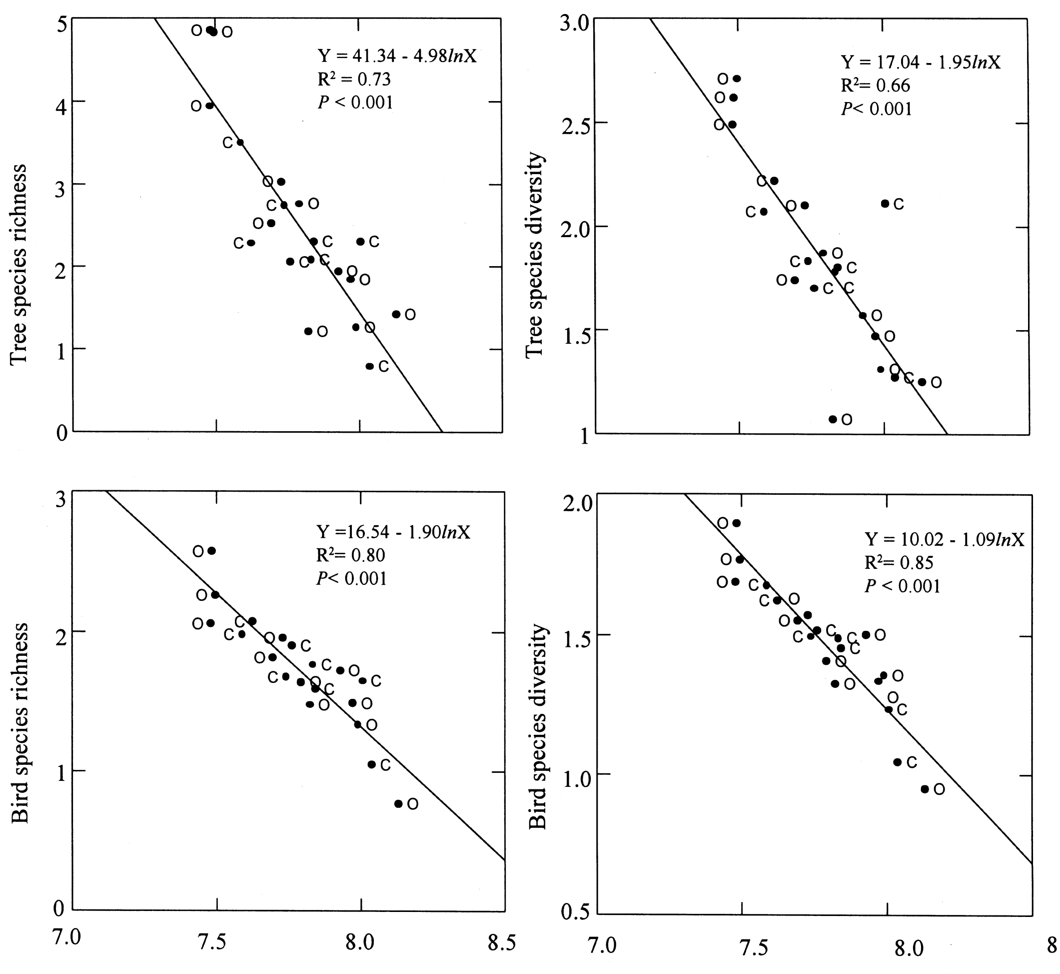

Fig. 7. Relationship on woody tree species richness and diversity, and bird species richness and diversity with elevation in the forests (O = open canopy and C = closed canopy) of the Yuksam–Dznogri trekking corridor. Elevation transformed to natural log.

high pressure on lower dbh classes or smaller-height trees. Field observation revealed that regeneration of canopy trees is poor at the disturbed stands due to grazing and trampling, which were comparatively more abundant at the undisturbed stands (Chettri, 2000). However, abundance of 1–5 m class trees at open canopy in the upper forest was relatively higher. This could be due to lower levels of firewood extraction because of low human pressure resulting in better regeneration. Lower abundance of medium height trees (11–20 m) at the open canopy and even at the closed canopy stands of the lower forest attributed preference for extraction of moderate sized trees as firewood by the local people. The pressure is higher at the LF which is in the vicinity of Yuksam settlement with a larger population residing here.

The vegetation structure 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 in the LF. 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 (Van Horne, 1983; Vickery et al., 1992). Bird species richness as well as diversity were higher at the open canopy conditions of the LF, but were not significantly different between the two conditions. Comparatively, insignificantly higher bird species richness at the open condition of lower forest could be due to a pattern consistent with the edge effect (Kilgo et al., 1997). Fleming and Giuliano (1998) from their experimental work in border-edge cut and uncut plots, suggested that the species richness does not differ significantly among the plots due to similar reasons. Daniels (1989) also reported similar results that supported the findings. The reason could be that the present study plots were undoubtedly smaller than the individual home ranges and probably that the plots were used by individuals relying on suitable habitat of surrounding forests (Aigner et al., 1998), or size of patches (open forest area) formed were small enough to bring about variation in bird species diversity (Kilgo et al., 1998).

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 the open canopy in association with some forest birds (MacArthur, 1972). Generalists or common species, e.g. 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 which is an indication of disturbances (Restrepo and Gomez, 1998). This has suggested that they are habitat generalists that tend to be less sensitive to habitat changes than the forest interior birds (Telleria and Santos, 1995). The open condition, where secondary tree species (*Symplocos ramisissima, 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 support that the open and closed canopy forest possesses wide structural pattern in context of forest stratification, which in turn provides habitat for breeding and feeding ground to the species as per their habitat preferences (Verner and Larson, 1989; Javed, 1996; Shafiq et al., 1997). 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 migrants (white capped-water redstart, Rufous-bellied niltava, stripe-throated yuhina, etc.). This is apparent as about 40% of the total recorded species were common in all the four stands and the majority being local migrants. Seasonal movements of species for food searching might have brought about such fluctuations. There might be other factors unrelated to habitat disturbances that contributed 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 in changes in vegetation structure and composition (Block and Morrison, 1991; Block and 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 and Joshua, 1994).

5. Conclusion

It is apparent from the earlier discussions that the Yuksam–Dzongri trekking corridor exhibits diverse habitat types, rich in bird species. A wide range of habitat types are available for birds that are equally utilised. Only a handful of bird species have restricted themselves to specific habitats, either to the open canopy or closed canopy conditions in the lower and upper forests. This reflects that the majority of birds use a variety of available habitats over their entire geographical range. The 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 statistically 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.

The open canopy conditions in both forest types showed more generalist species and higher diversity, which is an indication of disturbances and is substantiated by poor diversity at the closed canopy condition. Our observation implies that the human disturbances at the open canopy forest might have brought about visible change in forest birds, providing a more open understorey for generalist species as observed in the lower forest. On the other hand, with negligible change in vegetation complexity at the upper forest, the differences in bird community was due less to low human interference. This condition has shown less effect on bird species diversity. It is apparent from the aforementioned discussion that small-scale variation in diversity could be due to seasonal migratory patterns 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 pressures such as firewood, fodder and timber extractions and grazing, brought about subtle changes in available habitats for birds. It appears apparent that birds represent habitat not only by disturbance level but resource availability is another important factor for maintenance which needs to be kept in mind for bird conservation initiatives. A detailed study on effects of patch size created by disturbances and surrounding habitat is necessary to come to any conclusive interpretation. The high human pressure at the lower forest may lead to greater patch formation and edge extension in the long term, which have more impact on birds than plant species composition. Many environmental awareness programmes were conducted for the community and tourism enterprises by the Sikkim Biodiversity and Ecotourism Project; however, more effective measures are required for minimising human pressure on the natural resources of the area. Extensive and long-term studies are also necessary to evaluate the importance of site fidelity in obscuring effects in the short term and to describe the persistence of the effect.

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Appendix. Bird species abundance on 98 species that were encountered in > 3 transects and the result on ANOVA within GLM between two forest types and two habitat conditions from the Yuksam–Dzongri trekking trail, West Sikkim.

Code[a]	Common name (Latin name)	Lower forest[b]		Upper forest		FT×HC[c]	HC	FT
		CC	OC	CC	OC	*P*	*P*	*P*
64	Blood Pheasant (*Ithaginis cruentus*)	–	–	3.44	0.92	0.02	0.03	0.04
209	Darjeeling Woodpecker (*Dendrocopos darjellensis*)	0.18	0.07	0.86	0.71	<0.01	<0.01	<0.01
226	Golden-throated Barbet (*Megalaima franklinii*)	–	0.53	–	–	0.01	0.08	0.03
267	Great Barbet (*Megalaima virens*)	0.23	0.24	–	–	<0.01	0.02	<0.01
309	Eurasian Hoopoe (*Upupa epops*)	–	–	0.25	–	0.25	0.25	0.35
380	Large Hawk Cuckoo (*Cuculus sparverioides*)	–	0.55	0.06	–	<0.01	0.02	<0.01
384	Indian Cuckoo (*Cuculus micropterus*)	0.25	0.16	–	–	0.02	0.03	0.01
633	Snow Pigeon (*Columba leuconata*)	–	–	–	2.25	0.36	0.32	0.26
1050	Common Kestrel (*Falco tinnunculus*)	0.25	–	–	–	0.25	0.25	0.31

(*Continued on next page*)

Appendix (*continued*)

Code[a]	Common name (Latin name)	Lower forest[b]		Upper forest		FT×HC[c]	HC	FT
		CC	OC	CC	OC	*P*	*P*	*P*
1302	Yellow-billed Blue Magpie (*Urocissa flavirostris*)	0.17	0.25	0.96	2.03	<0.01	<0.01	<0.01
1310	Grey Treepie (*Dendrocitta formosae*)	–	1.24	–	–	0.09	0.17	0.09
1314	Collared Treepie (*Dendrocitta frontalis*)	–	2.60	–	–	0.04	0.12	0.05
1323	Spotted Nutcraker (*Nucifraga caryocatactes*)	–	–	0.60	0.43	<0.01	<0.01	<0.01
1328	House Crow (*Corvus splendens*)	–	1.30	–	–	0.27	0.33	0.22
1333	Long-billed Crow (*Corvus macrorhynchos*)	–	–	0.73	1.18	0.01	0.03	<0.01
1340	Common Raven (*Corvus corax*)	0.17	–	0.17	0.39	0.08	0.06	0.06
1411	Grey-chinned Minivet (*Pericrocotus solaris*)	–	2.00	–	3.61	0.11	0.09	0.07
1413	Short-billed Minivet (*Pricrocotus brevirostris*)	0.50	1.10	0.38	0.71	0.06	0.04	0.03
1415	Scarlet Minivet (*Pricrocotus flammeus*)	1.44	1.10	–	–	<0.01	0.02	<0.01
1418	Yellow-bellied Fantail (*Rhiphidura hypoxantha*)	0.83	0.80	–	0.22	0.08	0.09	0.06
1423	White-throated Fantail (*Rhiphidura albicollis*)	0.98	0.75	–	0.09	<0.01	<0.01	<0.01
1437	Black Drongo (*Dicrurtus adsimilis*)	0.29	0.77	–	–	0.02	0.06	0.01
1485	Blue Rock Thrush (*Monticola solitarius*)	0.28	0.64	0.22	0.37	0.02	0.01	<0.01
1491	Bluewhisling Thrush (*Myiophonus caeruleus*)	0.59	0.49	0.07	0.05	<0.01	<0.01	<0.01
1507	Plain-backed Thrush (*Zoothera mollissima*)	0.09	0.09	0.39	0.61	<0.01	<0.01	<0.01
1512	Long-billed Thrush (*Zoothera monticola*)	0.08	0.47	0.58	0.67	0.01	0.01	<0.01
1513	Dark-sided Thrush (*Zoothera marginata*)	0.25	0.40	–	0.17	0.14	0.14	0.09
1517	Rufous-gorgetted Flycatcher (*Musicapa strophiata*)	0.56	0.90	0.63	0.13	0.02	0.02	0.02
1520	White-collared Blackbird (*Turdus albocintus*)	0.20	0.08	0.35	0.63	<0.01	<0.01	<0.01
1521	Grey-winged Blackbird (*Turdus boulboul*)	0.44	0.08	0.28	0.38	<0.01	<0.01	<0.01
1586	Littlepied Flycatcher (*Ficedula westermanni*)	2.00	0.40	–	–	0.04	0.06	0.06
1593	Verditor Flycatcher (*Eumyias thalassina*)	0.25	0.86	–	0.05	<0.01	<0.01	<0.01
1598	Large Niltava (*Niltava grandis*)	0.13	0.50	–	–	0.17	0.21	0.13
1601	Rufous-bellied Niltava (*Niltava sundara*)	0.66	0.13	0.13	0.21	<0.01	<0.01	<0.01
1659	Daurean Redstart (*Phoenicurus auroreus*)	–	0.60	–	0.29	0.05	0.05	0.03
1661	Blue-fronted Redstart (*Phoenicurus frontalis*)	0.33	0.47	–	0.11	0.04	0.05	0.03
1662	White-capped Water Redstart (*Chaimarrornis lecocephalus*)	0.13	0.30	–	0.17	0.09	0.14	0.06
1663	Plumbus Water Redstart (*Rhyacornis fuliginosus*)	–	0.40	–	–	0.04	0.12	0.05
1669	Grandala (*Grandala coelicolar*)	–	–	0.75	–	0.08	0.11	0.2
1687	Grey Bushchat (*Saxicola ferrea*)	–	1.35	–	–	0.03	0.11	0.04
1743	White-tailed Nuthach (*Sitta himalayansis*)	0.57	0.18	0.52	0.23	<0.01	<0.01	<0.01
1756	Eurasian Tree-creeper (*Certhia familaris*)	0.06	0.05	0.34	0.31	<0.01	<0.01	<0.01
1764	Fire-capped Tit (*Cephalopyrus flammiceps*)	–	–	1.50	1.00	0.12	0.11	0.11
1771	Rufous-vented Tit (*Parus rudeventris*)	0.11	0.05	3.32	2.24	0.02	0.02	0.01
1773	Coal Tit (*Parus ater*)	–	–	4.00	0.67	0.07	0.08	0.12
1777	Grey-creasted Tit (*Parus dichrous*)	–	–	3.80	2.00	0.01	0.02	0.01
1780	Green-backed Tit (*Parus monticolus*)	0.08	1.73	–	–	0.01	0.07	0.02
1793	Black-throated Tit (*Aegithalos concinnus*)	1.88	2.00	–	–	0.05	0.08	0.03
1796	Black-browed Tit (*Aegithalos iouschistos*)	–	–	2.25	0.56	0.04	0.06	0.08
1817	Goldcrest (*Regulus regulus*)	–	–	2.50	1.17	0.08	0.08	0.09
1822	Straighted Bulbul (*Pycnonotus straitus*)	0.06	0.45	–	–	0.11	0.17	0.09
1837	Red-vented Bulbul (*Pycnonotus cafer*)	–	0.71	–	–	0.04	0.13	0.05
1879	Black Bulbul (*Hypsipetes leucocephalus*)	–	1.07	–	–	0.02	0.09	0.04
2008	Smokey Warbler (*Phylloscopus fuligiventer*)	–	–	1.25	3.92	0.31	0.26	0.22
2009	Tickle's Leaf Warbler (*Phylloscopus affinis*)	1.32	3.06	0.14	0.81	<0.01	0.02	<0.01
2014	Buff-barred Warbler (*Phylloscopus pulcher*)	3.25	0.60	–	–	0.02	0.04	0.04
2017	Lemmon-rumped Warbler (*Phylloscopus proregulus*)	2.00	3.60	0.75	–	0.01	0.03	0.01
2023	Greenish Warbler (*Phylloscopus trochiloides*)	3.33	1.04	0.92	1.04	<0.01	<0.01	<0.01
2043	Golden-spectacled Warbler (*Seicercus burkii*)	0.25	0.20	–	–	0.04	0.06	0.03

(*Continued on next page*)

Appendix (*continued*)

Code[a]	Common name (Latin name)	Lower forest[b]		Upper forest		FT×HC[c]	HC	FT
		CC	OC	CC	OC	*P*	*P*	*P*
2044	Grey-hooded Warbler (*Seicercus xanthoschitos*)	3.65	4.12	1.05	–	<0.01	<0.01	<0.01
2045	White-spectacled Warbler (*Seicercus affinis*)	5.50	3.60	2.00	1.33	0.02	0.02	0.01
2052	Black-faced Flycatcher-Warbler (*Abroscopus schisticeps*)	1.13	–	1.00	0.17	0.06	0.04	0.09
2053	Yellow-bellied Warbler (*Abrocopus superciliaries*)	2.00	3.60	–	0.75	0.85	0.06	0.06
2064	White-throated Laughing Trush (*Garrulax albogularis*)	0.88	0.73	1.33	0.67	<0.01	<0.01	<0.01
2069	Straighted Laughing Trush (*Garrulax straitus*)	0.80	1.36	–	–	<0.01	0.03	<0.01
2087	Spotted Laughing Thrush (*Garrulax occellatus*)	0.06	0.15	0.13	0.25	0.17	0.18	0.13
2088	Grey-sided Laughing Trush (*Garrulax caerulatus*)	0.50	9.90	2.00	0.33	<0.01	0.03	<0.01
2099	Blue-winged Laughing Trush (*Garrulax sqamatus*)	0.75	0.10	0.25	0.08	<0.01	<0.01	0.01
2104	Black-faced Laughing Trush (*Garrulax affinis*)	0.11	0.07	0.14	0.46	<0.01	<0.01	<0.01
2110	Red-faced Liocichla (*Liocichla phoenicea*)	0.25	0.30	–	0.08	0.07	0.07	0.04
2223	Redbilled Leiothrix (*Leiothrix lutea*)	–	0.60	–	0.46	0.15	0.13	0.09
2226	White-browed Shrike-Babbler (*Pteruthius flaviscapis*)	0.33	–	0.17	–	0.03	0.03	0.08
2227	Green Shrike-Babbler (*Pteruthius xanthoclorus*)	–	0.80	–	–	0.37	0.41	0.31
2231	Rusty-fronted Barwing (*Actinodura egertoni*)	0.44	0.10	–	–	0.01	0.03	0.03
2238	Chesnut-tailed Minla (*Minla strigula*)	0.19	–	1.00	–	0.02	0.02	0.09
2243	Chestnutheaded Tit-Babbler (*Alcippe castaneceps*)	1.42	1.20	0.58	0.30	<0.01	<0.01	<0.01
2244	White-browed Tit-Babbler (*Alcippe vinipectus*)	1.06	–	0.50	2.13	0.12	0.11	0.09
2247	Brownheaded Tit-Babbler (*Alcippe cinereiceps*)	0.50	–	–	3.67	0.38	0.33	0.29
2261	Rufous Sibia (*Heterophasia capistrata*)	0.44	2.22	0.04	–	<0.01	0.03	<0.01
2270	Whiskered Yuhina (*Yuhina flavicollis*)	2.41	2.28	0.13	0.48	<0.01	<0.01	<0.01
2272	Stripe-throated Yuhina (*Yuhina gularis gularis*)	6.32	5.78	6.00	3.83	0.33	<0.01	<0.01
2274	Rufous-vented Yuhina (*Yuhina occipitalis*)	0.13	–	2.66	2.42	<0.01	0.02	<0.01
2393	Mrs. Gould's Sunbird (*Aethopyga gouldiae*)	0.75	0.70	0.38	0.58	<0.01	<0.01	<0.01
2394	Green-tailed Sunbird (*Aethopyga nipalensis*)	0.30	0.68	0.25	0.13	<0.01	<0.01	<0.01
2401	Firetailed Sunbird (*Aethopyga ignicauda*)	0.63	0.40	0.38	0.33	0.02	0.02	0.02
2410	Streaked Spiderhunter (*Aracnothera magma*)	0.50	1.00	–	–	0.13	0.16	0.09
2413	House Sparrow (*Parus domesticus*)	1.00	–	–	1.08	0.11	0.1	0.09
2416	Russet Sparrow (*Passer rutilans*)	1.25	0.60	–	–	0.02	0.04	0.02
2438	Blyth's Pipit (*Anthus godlewskii*)	0.13	0.03	0.22	1.94	0.12	0.11	0.07
2441	Olive-backed Pipit (*Anthus hodgsoni*)	0.25	–	1.00	1.42	0.09	0.08	0.07
2459	Marron-backed Accentor (*Prunella immaculate*)	–	–	0.83	0.61	0.09	0.09	0.08
2506	Black-headed Mountain-Finch (*Leucosticte brandti*)	–	–	0.21	0.52	0.09	0.09	0.06
2516	Dark-breasted Rosefinch (*Carpodacus nipalensis*)	–	–	0.50	1.06	0.14	0.12	0.09
2520	Pink-browed Rosefinch (*Carpodacus rhodochorus*)	–	–	0.50	0.39	0.05	0.06	0.04
2531	Redbreasted Rosefinch (*Carpodacus puniceus*)	–	–	–	0.83	0.35	0.31	0.26
2542	Red-headed Bullfinch (*Pyrrhula erythrocephala*)	–	–	1.35	1.47	0.05	0.06	0.03
2549	Collared Grossbeak (*Mycerobas affinis*)	–	–	0.35	0.87	0.18	0.16	0.12
2551	White-winged Grossbeak (*Mycerabas carnipes*)	–	–	0.25	0.67	0.16	0.14	0.11

[a] OBC codes (Inskipp et al., 1996).

[b] CC, closed canopy condition; OC, open canopy condition.

[c] FT, forest types; HC, habitat conditions.

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