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The Relationship Between Bird Communities and Habitat

A Study Along a Trekking Corridor in the Sikkim Himalaya

To assess the impact of habitat disturbance on birds in the Yuksom–Dzongri trekking corridor in western Sikkim, India, the relationships between bird community attributes—including migratory groups and feeding guilds—and vegetation variables were examined. Birds were observed in 19 100-m-long transects, 3 times per season per transect, for 2 seasons from 1997 to 1998 and 1998 to 1999, in an area where forests are subject to various degrees of pressure from human disturbances. Closed canopy forests with relatively undisturbed habitat showed significant variation in habitat attributes, suggesting complexity of habitat structure. Bird species richness and diversity were significantly related to moderately disturbed habitats represented by Principal Component Analysis (PCA), where vegetation heterogeneity (vertical stratification and species composition) was greater. Analysis by migratory groups did not show an interpretable relationship with the habitats, except for the seasonal movements of migratory groups when correlated with altitudinal gradient along the corridor. However, feeding guilds showed significant relationships when correlated with different habitat types. Guilds such as insectivores showed a significant positive relationship with relatively undisturbed habitat, whereas nectarivores and granivores were associated with disturbed habitat. Such relationships have the potential to help assess bird communities and their habitat preferences. Long-term monitoring at landscape level is necessary to understand the dynamics of habitat use patterns by bird communities in relation to spatial and temporal changes.

Keywords: *Bird communities; habitat; vegetation; human disturbance; Principal Component Analysis (PCA); Khangchendzonga Biosphere Reserve; Sikkim; India.*

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Introduction

Human-induced disturbances such as firewood extraction, grazing, and logging may cause subtle to major landscape change. Identification of areas of significant conservation interest requires substantial time and effort for detailed inventories. Therefore, conservationists are generally interested in selecting a few taxa that are efficient indicators for measuring and monitoring biological diversity (Kremen 1992; Prendergast et al 1993; Faith and Walker 1996). Birds have been considered good predictors of habitat quality, as they relate to changes in their associated habitats in numerous ways (Shankar Raman et al 1998; Chettri et al 2001; Shankar Raman 2001) because they respond to habitat structure (MacArthur and MacArthur 1961) and represent several trophic groups or guilds (Steele et al 1984). The distribution of many bird communities is affected by habitat fragmentation or other habitat parameters and reflects inter-specific dynamics and population trends associated with the habitat (O'Connell et al 2000). This sensitivity suggests that bird communities have a high potential to act as a surrogate for their habitats at structural, regional, and landscape level management (Canterbury et al 2000; Lindenmayer et al 2000; O'Connell et al 2000).

Rapid deforestation of tropical forests and other large-scale human disturbances have increased concern about their effect on vegetation structure as well as on bird communities (Schulte and Niemi 1998). It is evident that harvesting resources for human use causes thinning of woodlands (Griffin and Muick 1990), affects vegetation structure and composition (Block and Brennan 1993; Chettri et al 2002), reduces canopy structure, and brings about changes in the age and size distribution of stands (Sundriyal and Sharma 1996; Aigner et al 1998). Such changes affect occupancy and resource use patterns of birds (Block and Brennan 1993; Chettri et al 2001). However, in order to understand bird community structures and their relationships with variations in vegetation types, it is important to relate them to changed habitats (Wiens and Rotenberry 1981). Therefore, it is vitally important to assess the relationship between birds and habitat changes (Canterbury et al 2000; Lindenmayer et al 2000; O'Connell et al 2000).

The Yuksom–Dzongri corridor has a very high bird diversity and the majority of species are local/altitudinal migrants that forage in a wide spectrum of the available habitats (Chettri et al 2001). Human disturbances such as firewood extraction, fodder lopping, and cattle grazing have increased manifold in the past two decades due to demographic growth and the increase of tourism (Sharma et al 2000, Chettri et al 2002), resulting in fragmentation and deterioration of wildlife habitat and the natural beauty of the area (Chettri 2000). An exploratory monitoring of bird–habitat relationships, as well as of species distribution patterns, is particularly important because of tourism disturbances along the corridor in recent years. In this paper, we emphasize bird–habitat relationships related to various disturbances caused in the available habitat due to the impact of tourism. The main objective of the study was to examine the relationships between bird community structure, migratory groups, seasonal patterns, and

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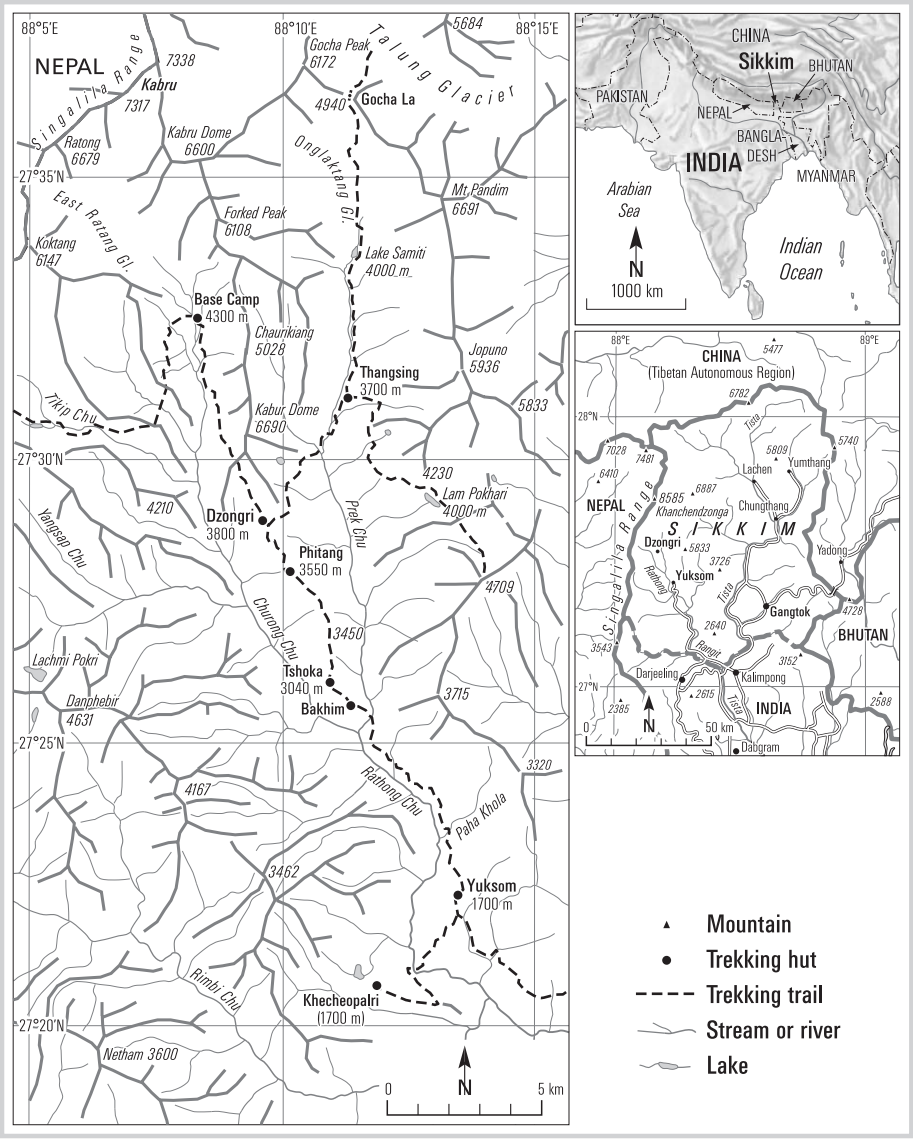


FIGURE 1 Location map showing Yuksom–Dzongri trekking corridor in West Sikkim. (Map by Andreas Brodbeck, based on map published in *MRD* vol 22 no 2, p 151)

feeding guilds on the one hand, and different habitat conditions on the other.

Study area

The Yuksom–Dzongri trekking corridor (26 km long) includes a range of elevations from 1780 m to 4000 m. A trekking trail passes through Sachen, Bakhim, and Tshoka in the southwestern part of Khangchendzonga Biosphere Reserve in Sikkim, India (Figure 1). Yuksom is a trailhead for this corridor and leads to the Base Camp, Dzongri, Thangsing, and Gocha La in West Sikkim. Yuksom (1780 m) has 11 settlements with 274 households and a total population of 1573 (at the time of data collection, ie 1997–1999). One settlement with 8 households is situated inside the reserve at Tshoka (3000 m), along the trail. The majority of residents are Subbas, followed by Bhutias, Lepchas, Nepalis, and Tibetan refugees. The primary occupation of the people living in this area is farming, while some derive an income from the tourism business as lodge operators, porters, pack animal operators, cooks, and trekking guides. Firewood and fodder collection, forest grazing, and leaf litter collection are common resource use practices among these different ethnic groups (Chettri 2000).

Tourism has been increasing at a rapid rate in the study area in recent years, and more people are engaged in this sector (Maharana et al 2000). Annually, about 2000 domestic and foreign tourists visit the area, accompanied by more than 150 support staff. Apart from these persons, this trekking trail is used by 140 *dzos* (cross between a cow and a yak) and a dozen horses 6 times per year on average. The Himalayan Mountaineering Institute (HMI) conducts training for about 500 trainees annually in the area. Communities living in the area, trekking tour staff members including porters hired by travel agents, and the HMI trainees on location collect a sizeable amount of firewood for cooking and heating along the entire length of the corridor. This has been one of the major factors of habitat destruction and forest fragmentation along the trail (Chettri et al 2002).

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Methods

Vegetation sampling

The trekking corridor was divided into 2 forest types differentiated according to patterns of forest utilization by settlements and tourism enterprises. Warm temperate broadleaf forest (1780–2350 m), designated as the "lower forest," is used by the Yuksom community for subsistence needs. Cool temperate subalpine forest (2350–3600 m), designated as the "upper forest," is where the Tshoka community, HMI trainees, and tourism-related enterprises depend on resources. Nineteen permanent plots measuring 30 m x 40 m were laid along the trekking corridor in the forest with >40% canopy cover, designated as "closed canopy," and forest with <40% canopy cover, designated as "open canopy."

Trees from each of the plots were identified according to species, and their diameter at breast height (dbh) was measured. Species composition and tree structure under closed canopy and open canopy conditions were sampled by measuring dbh, total height, and height of first branch (with clinometer) of each of the species, and crown diameter was estimated as the average distance in meters of extreme branch projection with two right angles. The standing woody biomass of trees was calculated on the basis of an allometric relationship between dbh, height, density and volume developed by Sundriyal et al (1994) and Sundriyal and Sharma (1996). Stems with diameters of >10 cm at a height of 1.3 m were considered trees, and stems with diameters of <10 cm but >2.5 cm as shrubs or saplings. To see the effects of habitat heterogeneity on birds, trees were categorized in different height and dbh classes.

A set of 5 x 5-m subplots was located within each corner and at the center of 30 x 40-m plots. The number of shrubs, lopped branches, chopped trees, and trampling was recorded from each of these subplots. The depths of sandy soil, dry leaf litter, clay, and humus were measured by digging 100 cm^2 pits to a depth of 50 cm at the center of each subplot. Herb status was estimated from 5 randomly placed 1 x 1-m subplots in each 30 x 40-m plot. Species diversity (Shannon-Weaver's index) and species richness (Margalef's species richness) of trees, herbs, and shrubs were calculated following Hayek and Buzas (1997).

Bird sampling

We conducted bird counts in 19 bird transects, each measuring 100 m x 40 m, crossing each of the permanent plots to cover the spatial representation of the stands, following Hawrot and Niemi (1996). Seven observations were made at each transect each year during two seasons, in 1997–1998 and 1998–1999. The surveys were made during the summer (May–August) and winter (October–February) by walking down along the center line for 100 m, recording all birds heard or seen within 20 m on each side of the line, following Hawrot and Niemi (1996) with necessary modifications (Chettri et al 2001). The total number of surveys made was 266 (56 each in the closed canopy stands of the lower forest and upper forest, 70 in the open canopy stands of the lower forest, and 84 in the open canopy stand of the upper forest). Bird surveys were made between 06.00 h–09.30 h in the mornings when wind was weak, to avoid tree branch movement that might affect the accuracy of bird spotting. Observation during heavy rainfall and foggy days was avoided because of lack of visibility. The Line Transect Method was selected because of its robustness, sampling efficiency (Burnham et al 1980), and ease of sampling compared to other methods (Verner 1985; Javed 1996).

Data analysis

Significantly correlated ($r < 0.05$) vegetation variables with 'case to variables' ratios >3:1 were considered for a GLM test (General Linear Model) following Williams and Titus (1988) and Schulte and Niemi (1998). Within the model, we treated habitat condition as the fixed effect and other attributes as the random effect to identify the difference between open and closed canopy forests (Schulte and Niemi 1998). Data were analyzed to describe bird habitats and determine whether birds exhibited discernible patterns of habitat use at temporal and spatial levels. Principal Component Analysis (PCA), a multivariate statistical technique, was used to reduce the dimensions of vegetation variables by deriving 3 uncorrelated principal components (PCs) from a set of 21 significantly correlated variables, following Javed (1996) and Schulte and Niemi (1998). The vegetation components derived from the PCAs were then used as the predictor (independent) variables and bird communities were used as response (dependent) variables.

Species diversity (Shannon-Weaver's index), species richness (Margalef's species richness), and evenness (Simpson's evenness index) of birds were calculated following Hayek and Buzas (1997). Bird species diversity and richness were estimated from only those species recorded at least 3 times in each transect during the study period. Bird species diversity and richness were tested for regression with tree species diversity and tree species richness, keeping bird species diversity and bird species richness as constants. Seasonal changes in these relationships were analyzed with a two-tailed *t*-test for different habitat types and seasons. Apart from community attributes, migratory groups and guild response to vegetation structure were also analyzed by correlating them with the represented PCs. All statistical tests were performed with SYSTAT, version 6 (SPSS Inc. 1996).

During the analysis, bird species were categorized as migratory groups such as breeding resident (species actu-

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TABLE 1 Mean (M) values and standard errors (SE) of structural variables of designated bird habitats, and results of ANOVA test within a general linear model (GLM) of habitat conditions from upper and lower forests along the Yuksom–Dzongri trekking corridor.

	Lower forest				Upper forest					
	Closed canopy		Open canopy		Closed canopy		Open canopy			
Vegetation variables	M	SE	M	SE	M	SE	M	SE	*F*	*P*
DBH: diameter at breast height (cm)	32.57	±1.2	42.88	±6.6	38.65	±3.8	44.20	±6.5	96.9	0.000
Basal area (m^2/ha)	57.26	±5.6	35.96	±7.1	51.80	±8.1	40.15	±8.1	35.1	0.000
Tree density (individuals/ha)	435	±11.4	208	±55.8	320	±40.6	228	±48.2	55.6	0.000
Woody biomass (Mg/ha)	704	±82	399	±98	382	±74	306	±67	22.9	0.000
Crown radius (m/tree)	6.04	±0.6	7.37	±0.8	6.12	±0.4	7.58	±0.9	98.4	0.000
Crown area (m^2/tree)	41.21	±6.0	54.89	±9.5	39.72	±6.3	59.53	±12.5	59.3	0.000
Height of first branch (m)	5.39	±0.5	5.86	±0.8	5.42	±0.1	6.34	±0.9	100.4	0.000
Dry litter depth (cm)	4.00	±0.5	1.80	±0.1	3.50	±0.6	0.65	±0.1	18.07	0.001
Humus depth (cm)	2.50	±0.8	1.20	±0.4	2.00	±0.4	0.33	±0.1	17.7	0.001
Trampling (number/25 m^2)	33.68	±1.4	55.80	±15	2.50	±0.1	85.00	±16	31.2	0.000
Clay depth (cm)	4.00	±1	1.80	±0.8	4.25	±0.7	2.17	±6	14.7	0.001
Lopped branches (number/ha)	260	±26	368	±28	0	0	214	±16	5.04	0.038
Herb species richness	1.59	±0.2	2.55	±0.4	2.37	±0.2	2.78	±0.3	134.9	0.000
Shrub density (individuals/ha)	2000	±68	1320	±55	1300	±57	1200	±40	29.6	0.000
Chopped trees (individuals/ha)	240	±31	294	±22	46	±9	255	±16	15.6	0.001
Tree height <10 m (individuals/ha)	237	±23	73	±20	181	±24	107	±37	46.7	0.000
Tree height 10–20 m (individuals/ha)	51	±11	69	±8	82	±12	77	±9	16.8	0.001
Tree DBH 10–20 cm (individuals/ha)	204	±59	178	±40	221	±49	144	±32	37.2	0.000
Tree DBH 21–30 cm (individuals/ha)	67	±13	47	±12	92	±14	58	±19	27.48	0.000
Tree DBH 31–40 cm (individuals/ha)	123	±31	88	±29	46	±20	39	±10	27.5	0.000
Tree DBH >40 cm (individuals/ha)	44	±9	12	±5	29	±4	24	±3	24.36	0.000

ally breeding, or within the breeding range), summer migrant (species *en route* to breeding or wintering grounds), winter migrant (species that winters on the site but does not breed there) and incidental species (rarely detected and not regarded as regular species in the area). These categorizations were made following Ali and Ripley (1983), Ali (1989), and personal observations. Classification of birds into categories based on migratory status could only be arbitrary; therefore, feeding guilds were also considered, following Sauer et al (1996) and O'Connell et al (2000). Feeding guilds, which are the groups of species that require similar habitat, food, or other elements for survival, were manifested as populations of species dependent on a particular resource (O'Connell et al 2000). Bird species were categorized into insectivore, nectarivore, granivore, carnivore, frugivore and omnivore feeding guilds based on their major food habits, following Ali and Ripley (1983) and field observations.

Results

Vegetation

Vegetation variables differing significantly between the closed and open canopy conditions are presented in Table 1. Among 21 such variables, herb species richness was significantly higher under open canopy conditions

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TABLE 2 Sample size, composition, and structure of bird communities in different habitats along the Yuksom–Dzongri trekking corridor. SE = standard error; CC = closed canopy; OC = open canopy.

Bird variables	Lower forest		Upper forest	
	CC	OC	CC	OC
Sample size (per 100-m transect)	56	70	56	84
Number of species recorded	82	86	64	77
Number of species specific to habitat	15	23	4	8
Number of species per transect (mean±SE)	7±0.53	8±0.44	6±0.43	5±0.32
Density per ha (mean±SE)	28±2.7	30±2.4	27±3.5	24±1.9

compared to closed canopy. First branch height, mean diameter at breast height, mean crown radius, and mean height were significantly higher under open canopy compared to closed canopy conditions (Table 1). The least difference between open and closed canopy was recorded in the number of lopped branches. The basal area of trees and woody biomass were also significantly higher under closed canopy conditions compared to open canopy conditions. Disturbance factors such as the number of lopped branches, chopped trees, and trampling were also significantly higher under the open canopy, while humus, dry litter, and clay depths were greater under closed canopy conditions (Table 1).

Bird community–habitat relationship

Over the 2-year period, 7149 birds (individuals) representing 143 species were recorded. Of these 143 detected species, 40% (= 57) were common under all 4 habitat conditions. The white-throated laughingthrush (*Garrulax albogularis*), grey-winged blackbird (*Turdus boulboul*), grey-headed canary flycatcher (*Culicicapa ceylonensis*), and black-faced laughingthrush (*Garrulax affinis*) were more abundant under the open canopy condition. On the other hand, the rufous-bellied niltava (*Niltava sundara*), white-tailed nuthatch (*Sitta himalayensis*), Mrs Gould's sunbird (*Aethopyga gouldiae*), whiskered or yellow-naped yuhina (*Yuhina flavicollis*) and rufous-winged fulvetta (*Alcippe castaneceps*) were more abundant under the closed canopy condition. There was a distinct difference in abundance of 32 species between the lower and the upper forests. Among the species noted, the grey-headed canary flycatcher, yellow-naped yuhina, white-throated fantail (*Rhipidura albicollis*), verditer flycatcher (*Eumyias thalassina*), rufous-bellied niltava, blue whistling thrush (*Myophonus caeruleus*), white-throated laughingthrush, Mrs Gould's sunbird, and grey-winged blackbird were more abundant in the lower forest. The black-faced laughingthrush, plain-backed thrush (*Zoothera mollissima*), spotted nutcracker (*Nucifraga caryocatactes*), yellow-billed blue-magpie (*Urocissa flavirostris*), Eurasian tree-creeper (*Certhia familiaris*) and rufous-vented yuhina (*Yuhina occipitalis*) were among the abundant species in the upper forest. The presence of the large hawk cuckoo (*Cuculus sparverioides*), grey-headed flycatcher, verditer flycatcher, rufous-bellied niltava, black-faced laughingthrush, and yellow-naped yuhina differed significantly between forest types and habitat conditions, showing greater abundance under closed canopy conditions (see Chettri et al 2001, Appendix pp 12–14). Of 143 recorded bird species, 10% were restricted to the closed canopy forest, in contrast to 16% in the open canopy forest in the lower forest. In the upper forest, only 3% of the total species were observed as unique to the closed canopy and 6% of the total species were recorded as specific to the open canopy (Chettri et al 2001, see Figure 4 page 8).

General characteristics for birds in different stands are presented in Table 2. Higher bird species richness and diversity were observed under open canopy conditions in the lower forest. The density of birds was also higher under open canopy conditions in the lower forest, whereas it was higher under closed canopy conditions in the upper forest. Positive and linear relationships were observed between the overall bird species richness and diversity, and plant species richness and diversity when all the data were pooled together (Figure 2). But the relationships were not consistent when considered in terms of different habitat conditions, seasons, and forest areas.

Three principal components from PCA on vegetation variables had eigenvectors above 1; together they accounted for 83% of the total variance. Initially, the 3 PCs explained 64%, 15%, and 4% variance respectively. After varimax rotation, PC1 explained 33% of variance followed by PC2 = 30% and PC3 = 20%. The first principal component (PC1) was positively significant with total basal area, density, woody biomass, and crown cover, representing closed canopy forest. The second principal component (PC2) showed a negative correlation with clay depth, and a positive one with trampling, lopped branches, and chopped trees, representing habitat with a higher number of lopped branches and chopped trees with lower litter and humus depths, and higher trampling representing a high level of disturbance. PC3 was significantly and positively correlated with trees with a dbh >30 cm, herb species richness, and shrub density, representing diversified stands with complex vertical stratification.

Bird species richness and diversity were significantly and positively correlated with PC3 ($r = 0.622$, $P = 0.01$ and $r = 0.651$, $P = 0.01$ respectively), which represented the

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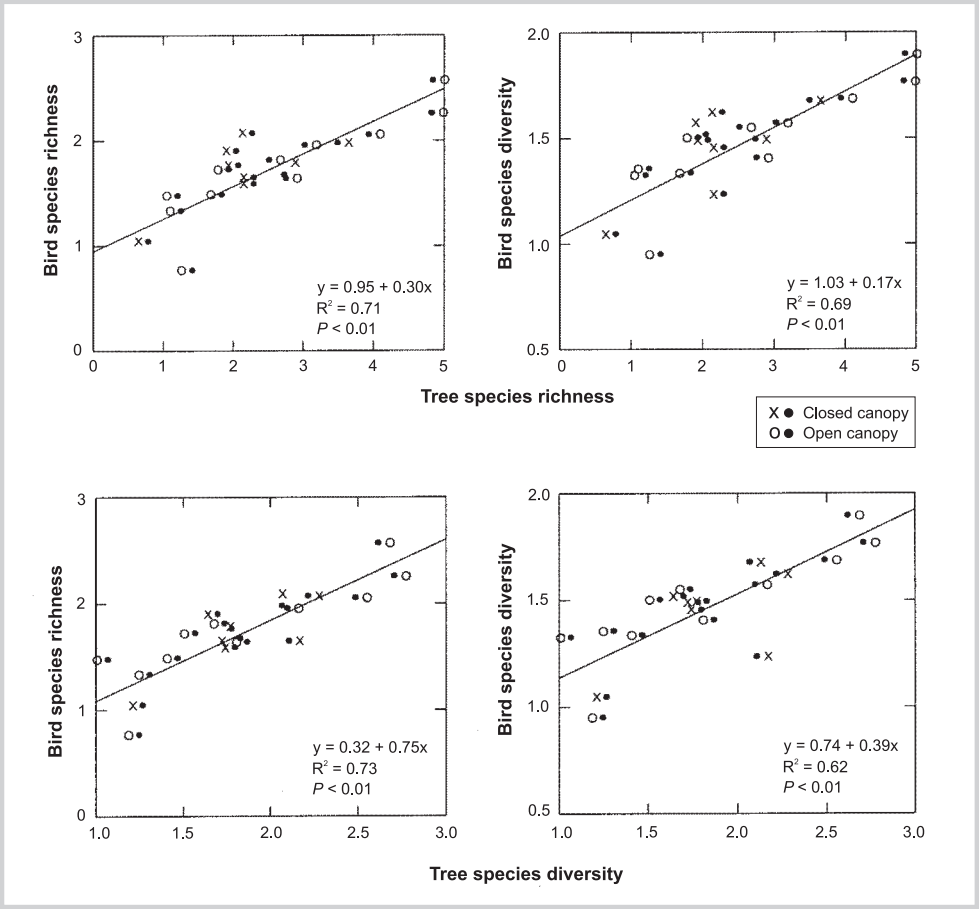


FIGURE 2 Tree and bird diversity indices in the forests showing significant relationships between tree species richness, tree species diversity, bird species diversity, and bird species richness in the Yuksom–Dzongri trekking corridor.

structurally 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), suggesting that the disturbed habitats with vertical heterogeneity have higher bird density (Table 3).

Migratory groups/feeding guild–habitat relationships

Pearson's product moment correlations for the three PCs with overall guild and migratory composition (total number of species per feeding guild and migratory group) are presented in Table 4. Among the migratory groups, only winter visitors were found to have a significant relation to PC2 ($r = 0.398$, n = 38, $P < 0.05$) and PC3 ($r = 0.349$, n = 38, $P < 0.05$). Insectivores, omnivores, nectarivores, and carnivores were significantly correlated at least with one of the 3 PCs (Table 4). Insectivores were positively related to PC1 ($r = 0.411$, n = 38, $P < 0.05$), omnivores, were positively related to PC2 ($r = 0.445$, n = 38, $P < 0.01$) and PC3 ($r = 0.457$, n = 38, $P < 0.01$). Nectarivores were positively related to PC2 ($r = 0.679$, n = 38, $P < 0.01$) and carnivores to PC3 ($r = 0.462$, n = 38, $P < 0.01$).

Resident species were significantly influenced by season ($F_{1,30} = 121.9$, $P < 0.01$). There was a remarkable variation in summer visitors between the seasons ($F_{1,30} = 10.2$, $P < 0.01$) as well as in different habitat conditions ($F_{1,30} = 4.9$, $P < 0.02$). Summer visitors showed weak but significant difference in correlation with forest type, habitat condition, and season. The effect of interaction was significant only for forest types and seasons ($F_{1,30} = 5.9$, $P < 0.02$). Similarly, apart from the seasonal differences, winter visitors differed significantly in the lower and upper forests ($F_{1,30} = 8.11$, $P < 0.001$).

Among the different feeding guilds, insectivores differed significantly 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 ($F_{1,30} = 30.9$, $P < 0.001$) for insectivores indicates that the forest type influenced the variation in the number of species with change in season. Apart from insectivores, forest types ($F_{1,30} = 5.3$, $P < 0.05$), habitat conditions ($F_{1,30} = 6.8$, $P < 0.01$), and season ($F_{1,30} = 5.9$, $P < 0.01$) also influenced omnivores significantly. Similarly, species composition of frugivores, granivores, nectarivores, and general feeders were significantly influenced by seasons.

Discussion

Open conditions in both the lower and upper forests had greater woody tree diversity and richness, suggesting that the opening of the canopy brought about invasion by new species or domination by secondary species. The vegetation parameters suggest that human disturbance had opened the closed canopy forests and changed the forest structure and complexities under the

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TABLE 3 Relationships between bird community attributes and principal components (PCs) along the Yuksom–Dzongri trekking corridor (n=19).

Bird community attributes	PC1	PC2	PC3
Species richness	0.274	0.012	0.622[b)]
Species diversity	0.199	–0.012	0.651[b)]
Density (individuals per transect)	–0.060	0.459[a)]	0.515[a)]
Simpson's Evenness	0.001	–0.060	0.456[a)]

[a)] $P< 0.05$
[b)] $P< 0.01$

TABLE 4 Relationships between feeding guilds, migratory groups, and vegetation components (n = 38; PC = principal component).

Guild/migratory groups	PC1	PC2	PC3
Insectivores	0.411[a)]	0.136	–0.118
Frugivores	0.119	0.000	–0.179
Omnivores	0.218	–0.445[b)]	0.457[b)]
Nectarivores	0.233	–0.679[b)]	0.095
Carnivores	–0.094	0.070	0.462[b)]
Granivores	–0.058	0.381[a)]	0.027
Incidental species	–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[a)]	0.349[a)]

[a)] $P< 0.05$
[b)] $P< 0.01$

open conditions. It should be noted here that a sizable amount of firewood was extracted from open forest conditions, leading to loss of tree density and impeding regeneration (Chettri et al 2002). However, open conditions provided better foraging ground for various species, making this a better habitat for a wide range of species (Shankar Raman et al 1998; Chettri et al 2001).

A strong correlation between bird community and habitat diversity indices suggests that birds are dependent on the compositional complexity of trees, shrubs, and herbs. These observations suggest that a bird community is significantly associated with plant species diversity, confirming the findings of Winternitz (1976) and James and Wamer (1982). The relationships differed at the spatial and temporal scales, which made interpretation difficult, but the variations were possibly due to seasonality in migrants and phenological events of plant species (Shankar Raman 2001). However, our previous species-level analysis showed that some habitat-specific species are more prevalent only in the specific habitats (Chettri et al 2001).

The three PCs explain the distinct habitat conditions available to birds in the study area. Significant seasonal variations in the migratory groups reflected phenological variation and availability of resources. Relatively higher numbers of migrants under open conditions in both forest types suggest that human interference caused creation of a mid-successional stage by opening the area, which is beneficial to some common species. Hutto (1989) also made similar conclusions from disturbed vegetation in western Mexico. The variations between the season, forest type, and habitat conditions for summer visitors suggested behavioral sensitivity to spatial and temporal distributions. Habitat preference seems convincing for incidental species, which was greater under open conditions. Interestingly, winter visitors were strongly influenced by the forest types. In general, a significant decrease in the 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 in different habitats during winter. It is speculated that the decrease was a result of the wide range of habitat availability and the birds' altitudinal movements as they go lower than the designated sites (1780–3600 m) during winter. However, it is important to have detailed infor-

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mation regarding habitat and geographical distribution of migrants and landscape-level studies before drawing conclusions (Hutto 1989; Saab 1999).

The correlation of insectivores with the PCs showed a positive relationship under closed canopy, where the vegetation was dense, with higher tree density and higher basal area. This could be due to abundant insects as a result of moist conditions and dense foliage (Erwin 1982). On the other hand, nectarivores were related to habitat having more disturbances, which may be due to the higher number of flowering plants under open conditions, as suggested by Fraga (1989). Similar observations were also reported by Laiolo (2003). Carnivores were positively related to habitat with 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 a positive relationship to more disturbed and open habitats, which are especially prevalent and often restricted to early stages of ecological succession or open areas. This could be explained by the fact that forest openings generally have larger seed banks available to granivores (Diaz and Telleria 1996). This condition was prevalent in the study sites, as many small-seeded herbs such as *Viburnum cordifolia*, *Mahonia sikkimensis*, and fruiting herbs belonging to Graminae were abundant under open canopy conditions in the lower forest, and *Frageria nubicola*, *Rosa* spp., and many fruiting herbs were abundant in the open canopy condition of the upper forest. Omnivores were significantly related to open canopy habitat as well as habitat with better stratification where resource availability (insects, seed, fruits, and small mammals) was high (personal observation). In relative terms, the higher, though non-significant number of frugivores under open canopy conditions could be due to the visibility of fruit resulting from openness (Thompson and Willson 1978) and greater predictability over time in the case of the migrants (Denslow et al 1986). Among the migratory species, only winter visitors were positively related to PC2 and PC3, suggesting that they exploit the open areas as well as habitat with greater vertical complexity, irrespective of their guild.

Conclusion and management implications

Human factors such as firewood and fodder collection, timber extraction, and grazing bring about subtle changes in the habitats available to birds. The response of organisms to these changes provides information not only on the viability of life support systems but also on the efficacy of management of areas under pressure. The ordination technique helped indicate a predictive measure for monitoring of biological diversity. Our analysis succeeded in identifying explainable relationships between bird components and habitat types. Different guilds showed preferences for diverse habitats, suggesting that they are directly related to habitat conditions. Moreover, significant relationships between bird species diversity and richness and tree species diversity and richness added more convincing relationships with the overall biodiversity. Nevertheless, it is difficult to make specific recommendations for bird conservation features in the area because conservation benefits one guild at the expense of others.

The Yuksom–Dzongri trekking corridor, though subject to pronounced disturbances through firewood extraction and recreational activities, has developed a diversity of habitats where bird guilds have distinctly adapted in a set of these mosaic habitats. Therefore, conservation of habitats and birds where disturbances are pronounced will probably have to be achieved through an adaptation of management practices after assessing approximate natural disturbance events. As a lesson, the study revealed that dense and climax forest is not the ideal means to conserve bird diversity. There must be a variation in habitat types to accommodate different feeding guilds as well as species that are habitat specific. Conservation and management strategies should consider implications of measures for guild structure, keeping in mind that the entire guild should be accommodated in the management planning. Therefore, proper monitoring of resources and habitat conditions is recommended, since human disturbances in forests that continue beyond the replenishing capacity of forest ecosystems leads to non-linear or irreversible degradation.

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