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Bird Community Structure in Phakot and Pathri Rao Watershed Areas in Uttarakhand, India

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ABSTRACT

We sampled bird communities in two watershed areas namely Phakot and Pathri Rao, located in Garhwal Himalaya, using Point Count and Species Listing Method from 2005 to 2007. We sampled 109 and 116 bird species from Phakot and Pathri Rao Watersheds, respectively. Chao 1 overestimated species number for Phakot whereas all four estimators were within 95% confidence limits for Pathri Rao. In terms of bird diversity, Pathri Rao was more diverse as compared to Phakot. Bird density was highest in Phakot (30.48 individuals ha^{-1} ± 1.77) than in Pathri Rao (16.82 individuals ha^{-1} ± 1.60). Bird density varied significantly across different seasons ($F_{2,6}$ = 14.87, P<0.0005) but not across different habitats in Phakot watershed area whereas no significant difference was found across seasons ($F_{1,6}$ = 0.57, P>0.47) and across different habitat types in Pathri Rao. Bird density, diversity and richness showed U type pattern in Phakot whereas in Pathri Rao it showed steep decline along the altitudinal gradient. Based on guild structure, Phakot bird community was more complex as compared to Pathri Rao watershed area because of variation in altitude and complex vegetation structure.

Key Words: Bird Community, Richness, Diversity, Guild, Vegetation Structure.

INTRODUCTION

Watershed is a natural hydrological entity from which surface runoff flows to a defined drain channel, stream or river at a particular point (Vittal 2004). It also refers to a contiguous area draining into a water body and also to a topographical area having a common drainage. Watersheds play an important role in maintenance of ecological balance and life support system particularly in fragile and heterogeneous hilly ecosystems such as Himalayas (Sharma et al. 1992). The watershed areas act as conservation hotspots crucial for maintaining biodiversity at local level. The biodiversity values are affected by alteration of ecosystem (Diaz 2006), climate change and destruction of natural habitats and are considered greatest threats to terrestrial biodiversity (Parmesan 2003).

Birds are considered good indicator of environmental quality and are frequently being used to monitor environmental and ecosystem health (Jarvinen and Vsisaunen 1979, Canterbury et al. 2000). By virtue of conspicuous in nature and easily researched, particularly with agro issues, their pattern of behavior, distribution and demography track closely onto the spatial and temporal scales of agricultural changes (Bradbury et al. 2000, Ormerod and Watkinson 2000). Bird assemblages based on species composition, abundance, richness and diversity along with other attributes such as rarity and endemism are frequently used for ornithological evaluations and assignment of conservation value to sites (Fuller 1980, Daniels et al. 1991). The present study was aimed to compare the bird community structure of two watershed areas located in two different geographical zones.

STUDY AREA

The Phakot Watershed Area is part of Phakot beat of Saklana range of Garhwal Himalayas. It lies between 78° 19′53″ to 78° 22′16″ East and 30° 14′29″ to 30° 13′17″ North in the middle Himalayas. It is approximately 35 kilometers from Rishikesh town on either side of National Highway No. 94 in the Tehri district of Uttarakhand state. The study area is spread over 20 km^2. PWA is the catchment area of the *hemal* stream. The area is mountainous in nature and general elevation varies from 600 m to 2000 m. There are three distinct seasons. Summer starts in mid march and lasts till June. The average temperature varies from 25 to 35°C. Monsoon comes earlier than other north Indian towns. Starting from early June, there is heavy down pour. Monsoon lasts till the end of September. The days usually remain cool and foggy. Winter in Phakot is less harsh than expected, mainly due to its geographic position. The nights are cold but days are comparatively warm. There is however, no snowfall in the area.

The Pathri Rao Watershed is located between 77° 57′7″ to 78° 23′36″ East and 29° 51′7″ to 30° 15′50″ North in the districts of Haridwar, covering an area of 45 km^2. The Watershed is named after Pathri Rao, a seasonal river, originating from Shiwalik foothills and flow towards south-west direction. The area is hilly towards north-east and almost plain in the south-western part (Figure 1).

Half of the study area falls on the south-east of Rajaji National Park. The area lies between Ranipur and Beri Bara ranges and is comprised of three beats. Two hill streams or '*Rao*' namely Chirak Rao and Harnul Rao which receive the water from many small mountain streams pass respectively through the Chirak West and Harnul beats. These two streams meet at the boundary of the protected area forming a larger stream called as Pathri Rao. The rest of the area is mosaic of agriculture land under different crops, plantations, villages and wasteland. The temperature during summer varies from 25 to 45°C and during winter temperature varies from 10 to 20°C.

METHODOLOGY

Classification of Different Habitats

The habitats in Phakot were classified based on the dominant species present in the area. Oak, pine, sal and mixed bakli were dominated by *Quercus leucotrichophora* Linn., *Pinus roxburghii* Linn., *Shorea robusta* Roxb. and *Anogeissus latifolia* Wall, respectively. Miscellaneous forest consisted of *Quercus leucotrichophora* Linn., *Bauhinia retusa* Linn., *Eupatorium adenophorum* Linn. and *Rhus parviflora* Linn. In Pathri Rao dry deciduous forest was classified based on the tree cover density using IKONOS data. Deciduous forest (L) was defined as forest with a cover up to 40%.

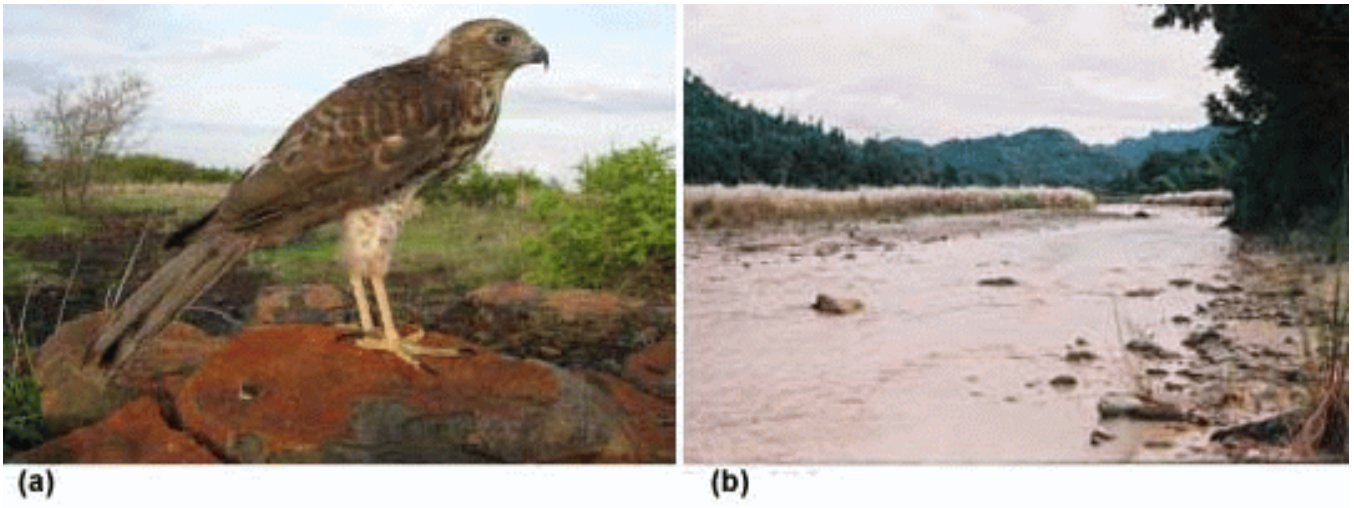

Figure 1. Shikra bird in Phakot Watershed area (a), a general view of Pathri Rao Watershed area (b).

Deciduous forest (M) had a cover density between 40 to 70% and deciduous forest (D) had forest cover density of more than 70%. Riverine habitat included forest along the river and sand and plantation habitat included mango orchards, and eucalyptus trees.

Species Listing Method

We used species listing method to compare the areas whether the sampling effort was enough to list the number of the bird species from the two watershed areas. We prepared species list, each of 15 different bird species following Poulsen et al. (1997a).

Distance Sampling for Comparing Bird Density

The bird communities were also sampled using the Point Count Method (Reynolds et al. 1980). The sampling points were taken randomly. A distance of approximately 250 m was maintained between two sampling points with fixed radii of 20 m. The duration on the point count is one of the most obvious factors influencing the detection probability of the bird species. Keeping the above-mentioned fact in mind, each point was monitored for 20 minutes. At each point station, data were recorded on the following variables: (a) species and number of individuals, (b) stratum and height of tree, (c) perch height and (d) activity. In total 110 and 125 permanent points were sampled in different seasons in Phakot Watershed Area and Pathri Rao Watershed, respectively from April 2005 to January 2007.

Guild Structure

Guild studies are particularly valuable since they determine the function of avian communities and also how these communities are structured in a resource hyperspace used by a set of species. Composition of species within a guild in any area depends on the habitat related attributes like the foraging substrate, vegetation structure, vertical heterogeneity and other aspects of physiognomy (Robinson and Holmes 1982, Holmes and Rechner 1986). Bird species have been observed to show preferences for perch height and food sites (Landres and MacMahon 1980). The data on such preferences were collected whenever a bird was encountered. The data on foraging height and horizontal distance from the tree trunk were collected following Kratter et al. (2001), whenever a bird was seen feeding on a substrate or making any attempt (e.g. canopy, tree trunk, branch or ground). The data for all the individuals across all the seasons were pooled on the assumption that there is very little or no change in the foraging behavior of the birds during different time of the year following Javed (1996). This pooling of data was done separately for two watershed Areas. 41 species from Phakot Watershed and 39 species from Pathri Rao Watershed were chosen for cluster analysis.

Statistical Analysis

Shannon-Weiner Index (H′) and Margalef's Index (RI) were used for computation of bird species diversity and richness, respectively. Pearson's product moment correlation coefficients were computed to find out relationship between bird community attributes (density, diversity, richness, evenness) and habitat parameters.

Each species list was treated as a separate sample for statistical analysis using computer program Biodiversity Pro (Neil 1997). Four non-parametric statistics Chao 1, Chao 2, Jacknife 1, Jacknife 2 (Chao 1: Chao 1984, Chao 2: Chao 1987, Jacknife 1: Smith and van Belle, 1984, Jacknife 2: Palmer 1991) were used to extrapolate species richness curves. Chao 1 is abundance based estimate whereas other three statistics are based on the incidence of species in samples. Rarefaction was used to compare the species diversity of two watershed areas. Rarefaction plots the expected number of species against number of individuals. It provides a measure of species diversity which is robust to sample size effect, permitting comparison between communities. Steeper curves indicate more diverse communities. The numbers of species were plotted against the number of individuals for comparing the diversity of the bird communities for both watershed areas.

The program DISTANCE Release 5.0 (Thomas et al. 2005) was used to compare three different models namely Uniform, Half-Normal and Hazard-Rate to assess the goodness-of-fit of underlying data and determine estimates of bird density for the study period, seasonally and across different habitats in both watersheds. The underlying models were compared using Akaike's Information Criteria (AIC; Burnham and Anderson 1998). By the definition the best model is the one with the least AIC value. When using AIC to select a particular model among alternative candidate models of the detection function, it is not unusual to find that more than one model have similar AIC scores (perhaps differing by AIC's of 2 or fewer). When this happens, more reliable inferences can be obtained

based on the final results on an AIC weighted average of these plausible alternative models (Buckland et al. 1997, Burnham and Anderson 2002). Variation in bird densities across different habitats and seasons was tested by using Two Way Analysis of Variance. A matrix consisting of bird species, mean perch height and horizontal distance from trunk for each species was prepared and subjected to single linkage cluster analysis using nearest neighbor method to generate guild. As no objective criteria is available to use Euclidian distance for separating groups, we considered midpoint of Euclidian distance as the separating point and clusters were groups separated by Euclidian distance greater than 0.25 or the mid point value for cluster interpretation. All the statistical tests were performed following Zar (1999).

RESULTS

Accuracy of Sample Size

Chao 1 showed the highest accuracy (81.03%) followed by Jacknife 1, Chao 2 and Jacknife 2, respectively for Pathri Rao watershed area whereas Jacknife 2 showed the highest accuracy (74.29%) followed by Chao 2 and Jacknife 1 for Phakot watershed area. Table 1 gives the details of species recorded using species listing method during the study period along with the estimates predicted by different estimators. In case of Pathri Rao watershed area, Jacknife 2 showed the highest deviation with an accuracy value of 67.21% whereas in case of Phakot watershed area Chao 1 showed the highest deviation with least accuracy of 35.89%.

Figures 2 and 3 illustrate performance of four estimators for 15 species lists respectively for Phakot and Pathri Rao watershed areas. 89 species of birds were recorded in Pathri Rao and 96 species in Phakot using species richness method. The curves show the stabilization of the number of species observed in watershed areas with respect to different estimators. In Phakot Jacknife 1 and 2 flattened around 17th species list. Cho 2 flattened at about 9th list. However Cho 1 showed Phakot Watershed trend throughout. In Pathri Rao, Jacknife 1 and 2 showed asymptote around 18th and 12th list, respectively, and in Chao 1 at 19th list. Figure 4 shows the rarefaction curves for the two watershed areas. Pathri Rao showed a steeper curve than Phakot, and hence, it was more diverse than Phakot.

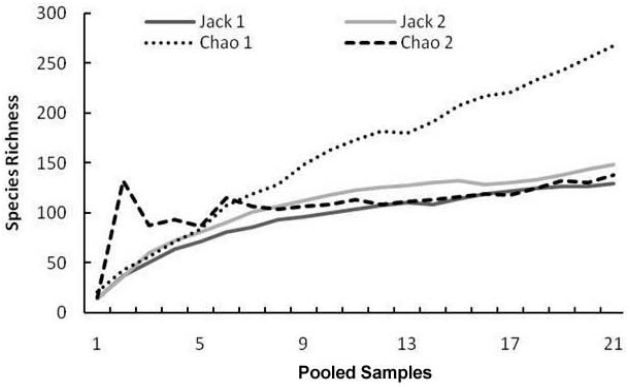

Figure 2. Performance of 4 estimators for Phakot Watershed area.

Comparison of Bird Density

Table 2 shows data on bird density, density of clusters, encounter rate and average cluster size across different seasons in Phakot watershed. A total of 96 species were encountered during the study period. Overall bird density (D) was 30.48±1.77 ha^{-1} and the density of clusters (DS) was 23.21±1.20 ha^{-1}. Encounter rate (n/K) was 2.92±0.12 and the average cluster size (A(S)) was 1.31±0.03. The bird density was highest in summer 43.13±2.76 ha^{-1} and lowest in winter 5.96±2.61 ha^{-1}.

Table 1. Observed S_{obs} and estimated species number calculated by 4 estimators.

	S_{obs}	Jacknife 1	Jacknife 2	Chao 1	Chao 2
Pathri Rao	89±1.76	117.26±6.43	132.42±7.77	109.84±6.14	118.03±6.12
Phakot	96±0.88	148.96±6.86	129.26±7.86	267.81±15.98	138.2±5.56

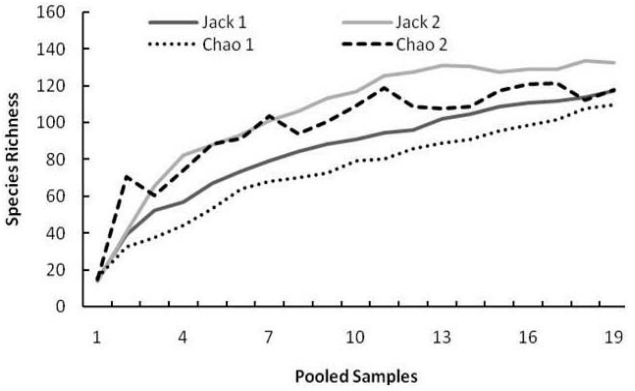

Figure 3. Performance of four estimators for Pathri Rao Watershed area.

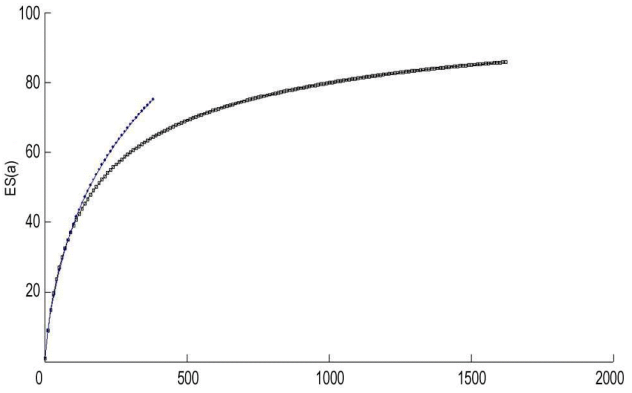

Figure 4. Rarefaction curves for Phakot and Pathri Rao Watershed areas.

Table 2. Variation of Bird Density (D), Density of Clusters (DS) Encounter Rate (n/K) and average Cluster Size across different seasons in Phakot Watershed Area.

Habitat	D±SE	95% CL	DS±SE	95% CL	n/K±SE	95% CL	A(S)±SE	95% CL
Overall	30.48±1.77	27.28-34.17	23.21±1.20	20.96-25.69	2.91±0.12	2.68-3.16	1.31±0.03	1.24-1.38
Winter	5.96±2.61	2.58-13.78	10.35±1.13	8.35-12.83	1.30±0.07	1.15-1.46	0.57±0.24	1.0-1.30
Summer	43.13±2.76	38.04-48.91	31.97±1.93	28.40-36.0	4.01±0.18	3.66-4.40	1.34±0.02	1.29-1.40
Monsoon	29.81±3.77	23.26-38.20	20.87±2.11	17.10-25.49	2.62±2.11	2.44-3.06	1.42±0.10	1.23-1.65

Table 3. Variation of Bird Density (D), Density of Clusters (DS) Encounter Rate (n/K) and average Cluster Size across different habitats in Phakot Watershed Area.

Habitat	D±SE	95% CL	DS±SE	95% CL	n/K±SE	95% CL	A(S)±SE	95% CL
Agriculture	25.70±2.89	20.60-32.06	19.97±1.98	16.43-24.28	2.50±0.19	2.15-2.92	1.28±0.06	1.15-1.42
Fallow Land	38.57±6.70	27.37-54.34	27.96±4.50	20.31-38.50	3.51±0.46	2.68-4.60	1.37±0.08	1.21-1.56
Misc. Forest	32.82±4.42	25.17-42.80	26.07±3.31	20.28-33.52	3.27±0.32	2.68-3.99	1.25±0.05	1.15-1.37
Mixed Bakli	48.85±13.40	28.56-83.53	30.33±6.36	19.90-46.24	3.81±0.63	2.68-5.42	1.61±0.28	1.13-2.28
Oak	29.19±3.66	22.80-37.36	23.24±2.77	18.36-29.40	2.92±0.27	2.42-3.52	1.25±0.04	1.26-1.35
Pine	18.40±4.75	11.12-30.44	15.15±2.52	10.91-21.05	1.90±0.23	1.48-2.44	1.21±0.23	1.00-1.79
Sal	38.05±5.41	28.75-50.37	28.54±3.81	21.92-37.16	3.58±0.38	2.88-4.45	1.33±0.06	1.20-1.47

Table 3 gives the details of bird density, density of clusters, encounter rate and average cluster size across different habitats in Phakot watershed. Across different habitat in Phakot watershed density was highest in Mixed Bakli (48.85±13.40 ha^{-1}) and lowest in Pine forest (18.40±4.75 ha^{-1}). Two-way analysis of variance with seasons and habitat as a main effect showed that there was highly significant difference in bird density between seasons ($F_{2,6}$ = 14.87, P<0.0005) and there was no significant difference in bird density across different habitats ($F_{6,12}$ = 1.21, P<0.36).

Tables 4 and 5 give the details of bird density, density of clusters, encounter rate and average cluster size across different season and habitats in Pathri Rao watershed. A total of 89 species were encountered during the study period. Overall bird density (D) was

Table 4. Variation of Bird Density (D), Density of Clusters (DS) Encounter Rate (n/K) and average Cluster Size across different seasons in Pathri Rao Watershed Area.

Habitat	D±SE	95% CL	DS±SE	95% CL	n/K±SE	95% CL	A(S)±SE	95% CL
Overall	16.82±1.60	13.96-20.27	13.26±0.95	11.51-15.27	1.66±0.08	1.51-1.83	1.26±0.07	1.12-1.43
Winter	16.97±1.85	13.70-21.01	13.18±1.05	11.27-15.42	1.65±0.08	1.48-1.84	1.28±0.09	1.11-1.48
Summer	16.33±3.14	11.20-23.81	13.61±2.20	9.78-18.92	1.71±0.19	1.36-2.14	1.20±0.11	1.00-1.45

Table 5. Variation of Bird Density (D), Density of Clusters (DS) Encounter Rate (n/K) and Average Cluster Size across different habitats in Pathri Rao Watershed Area.

Habitat	D±SE	95% CL	DS±SE	95% CL	n/K±SE	95% CL	A(S)±SE	95% CL
Deciduous (L)	25.87±4.05	19.02-35.16	16.72±2.14	12.99-21.53	2.10±0.19	1.74-2.52	1.54±0.13	1.29-1.84
Deciduous (M)	12.60±1.94	9.31-17.05	11.85±1.29	9.55-14.69	1.48±0.10	1.30-1.70	1.06±0.11	1.00-1.31
Deciduous (D)	3.97±4.53	0.56-28.16	12.93±3.98	7.00-23.85	1.62±0.38	0.98-2.67	0.30±0.33	1.00-2.31
Agriculture	15.26±4.19	8.91-26.14	12.11±2.43	8.12-18.03	1.52±0.16	1.21-1.90	1.26±0.23	1.00-1.85
Riverine	16.97±7.26	7.23-39.84	10.61±2.88	6.08-18.51	1.33±0.14	1.05-1.68	1.60±0.52	1.00-3.31
Wasteland	2.23±7.98	0.01-357.0	8.95±3.14	4.17-19.19	1.12±0.12	0.86-1.46	0.25±0.85	1.00-41.91
Plantation	36.37±22.0	9.16-144.4	21.22±12.15	5.25-85.63	2.66±1.20	0.41-16.96	1.71±0.40	1.00-3.04

Table 6. Variation of Bird Diversity and Bird Richness across different habitats in Phakot and Pathri Rao Watershed Areas.

Phakot Watershed Area			Pathri Rao Watershed Area		
Habitat	Richness	Diversity	Habitat	Richness	Diversity
Agriculture	6.911	1.315	Deciduous(L)	9.811	1.458
Fallow land	9.92	1.406	Deciduous(M)	8.06	1.351
Miscellaneous forest	9.617	1.518	Deciduous(D)	3.53	0.954
Mixed bakli forest	8.628	1.438	Agriculture	4.847	1.147
Oak forest	9.779	1.533	Riverine	3.189	0.953
Pine forest	6.445	1.328	Wasteland	1.243	0.413
Sal forest	8.114	1.419	Plantation	1.949	0.743

16.82±1.60 ha^{-1} and density of clusters (DS) was 13.26±0.95 ha^{-1}. Encounter rate (n/K) was 1.66±0.08 and the average cluster size (A(S)) was 1.26±0.07. Bird density in winter and summer was marginally different.

Across different habitat in Pathri Rao watershed, bird density (number per ha) was highest in Plantation (36.37±22) and lowest in Deciduous (D) (3.97±4.53). Two-way analysis of variance with seasons (Winter and Summer) and Habitat as a main effect showed that there was no significant difference in bird density between seasons ($F_{1,6}$ = 0.57, P>0.47) and also no significant difference in bird density across different habitats ($F_{6,6}$ = 1.90, P>0.22).

Comparison of diversity and richness

Species diversity is the number of different species in a particular area weighted by some measure of abundance such as number of individuals or biomass where as species richness is the number of different species in a particular area (Ian et al. 2004). Table 6 gives the details of overall diversity and richness values across different habitats in Phakot and Pathri Rao watershed. Overall bird diversity in Phakot watershed was 1.618 and richness was 13.869. Bird species diversity and richness was almost uniform in all the 7 habitats in Phakot watershed. Richness was highest in Fallow land (9.92) followed by Oak (9.779) and Miscellaneous forest (9.617). Bird diversity across habitats varied from 1.315 to 1.533. Oak forest was most diverse (1.533) followed by Miscellaneous forest (1.518) and Mixed Bakli (1.438) and agriculture was least diverse (1.315) among all the habitats.

Two-way analysis of variance with seasons (Winter, Summer and Monsoon) and habitat as a main effect showed that there was significant difference in bird diversity between seasons ($F_{2,6}$ = 6.84, P<0.01) and there was no significant difference in bird diversity across different habitats ($F_{6,12}$ = 1.42, P>0.28). However, bird richness varied significantly across season ($F_{2,6}$ = 43.86, P<0.001) but did not show any significant difference across habitats ($F_{6,12}$ = 2.31, P>0.10).

Bird diversity was 1.682 and richness was 15.349 in Pathri Rao watershed. Richness was highest in deciduous forest (L) (9.811) followed by deciduous forest (M) (8.6). Wasteland had lowest richness (1.243). Similarly diversity was highest in deciduous forest (L) (1.458). However wasteland was least diverse of all habitats (0.413).

Two-way analysis of variance with seasons (Winter and Summer) and habitat as a main effect showed that there was highly significant difference in bird diversity between seasons ($F_{1,6}$ = 22.25, P<0.003) and different habitats ($F_{6,6}$ = 6.28, P<0.02). Bird richness also varied significantly across season ($F_{1,6}$ = 19.44, P<0.004) and across different habitat types ($F_{6,6}$ = 7.78, P<0.01).

Other Aspects of Comparison

In both the study areas bird richness and diversity did not seem to prefer any particular aspect. Species richness and diversity values were highest on eastern aspect but that was slightly higher than western aspect. Bird density in both watersheds on the other hand was more on eastern aspect, mainly because the sampling was carried out in morning sessions showing sampling bias.

Figures 5, 6 and 7 show the variation of density, diversity and richness with altitudinal gradient in Phakot watershed and Figures 8, 9 and 10 show variation of density, diversity and richness with altitudinal gradient in Pathri Rao watershed, respectively. Bird density showed a regular decline along the altitudinal gradient in Phakot watershed. Bird Richness and diversity showed decline with an increase in altitude, though decline in richness was more than in diversity. Bird density, diversity and richness increased along the altitudinal gradient from 200 to 400 m and then declined steeply in Pathri Rao watershed.

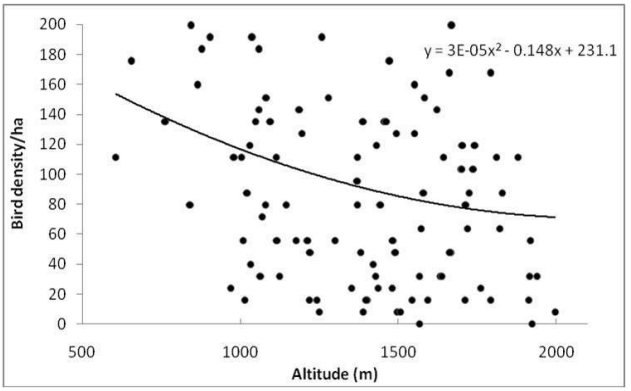

Figure 5. Variation of bird density with altitude in Phakot Watershed.

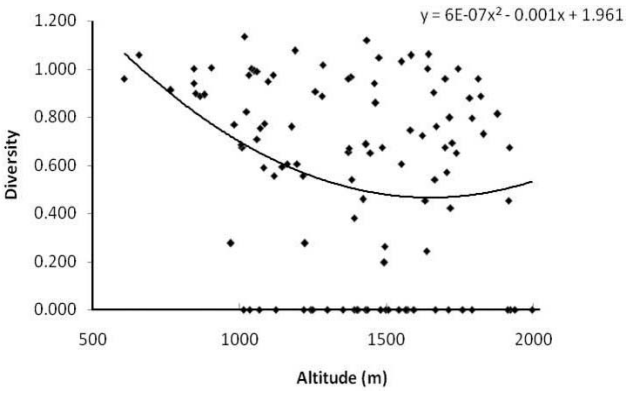

Figure 6. Variation of bird diversity with altitude in Phakot Watershed.

Correlation of bird diversity with tree and shrub diversity in different habitats in Pathri Rao watershed showed decline in bird diversity as one moved from low

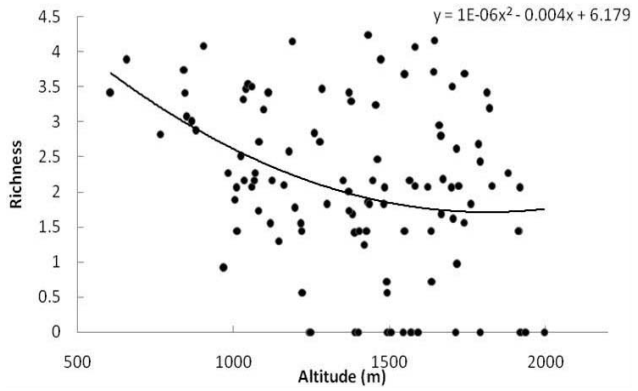

Figure 7. Variation of bird richness with altitude in Phakot Watershed.

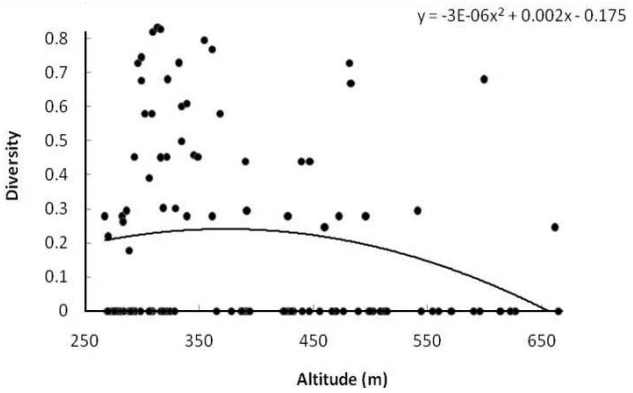

Figure 9. Variation of bird diversity with altitude in Pathri Rao Watershed.

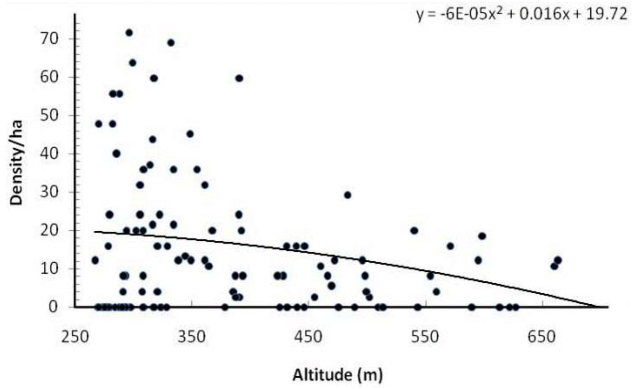

Figure 8. Variation of bird density with altitude in Pathri Rao Watershed.

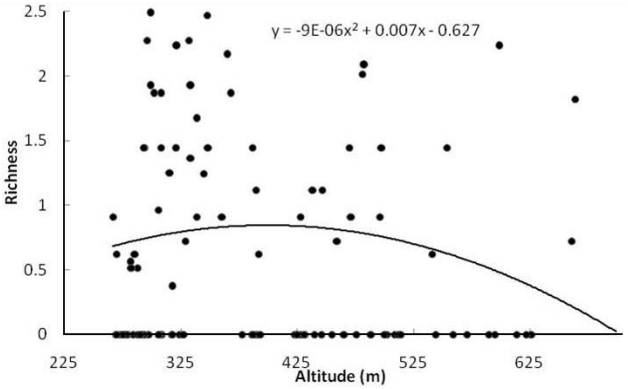

Figure 10. Variation of bird richness with altitude in Pathri Rao Watershed.

forest cover (deciduous forest (L)) to dense forest cover (deciduous forest (D)). However, bird diversity was relatively high in riverine, agriculture and wasteland despite their low tree and shrub density. It may be due to more abundance of species which prefer open habitats like chats, larks and mynas. In Phakot watershed, bird diversity showed positive relation with tree and shrub diversity. Bird diversity increased with increase in tree and shrub diversity across habitats.

Bird density, diversity and richness were negatively correlated with altitude in Phakot watershed. Bird diversity showed positive correlation with tree diversity ($r=0.164$ $P<0.01$), shrub diversity ($r=0.144$ $P<0.01$), herb density ($r=0.204$ $P<0.01$), lopping ($=0.257$ $P<0.01$) and grazing ($r=0.225$ $P=0.01$). Bird diversity was however negatively correlated with tree cover ($r=-0.189$ $P<0.01$). Bird richness showed similar pattern as diversity. Richness was positively correlated with shrub richness and negatively correlated with tree cover ($r=-0.186$ $P<0.01$).

Bird diversity showed strong negative correlation with altitude ($r=-0.255$ $P<0.01$), slope ($r=-0.258$ $P<0.01$) and tree cover ($r=-0.111$ $P<0.01$) in Pathri Rao watershed. Bird diversity showed positive correlation with tree diversity ($r=0.206$ $P<0.01$) and shrub cover ($r=0.266$ $P<0.01$). Bird species richness was negatively correlated with altitude and slope. Richness showed positive correlation with shrub cover ($r=0.206$ $P<0.01$), herb density ($r=0.221$ $P<0.01$) and herb richness ($r=0.198$ $P<0.01$).

Insectivore birds showed highest richness (10.942), diversity (1.534) in Pathri Rao watershed. This guild was followed by granivore (bird richness = 4.254, diversity = 1.055). Carnivore guild was least diverse. Guild diversity was highest for insectivore (1.59) followed by granivore (1.058) in Phakot watershed. Carnivore birds were found to be least diverse (0.579). Richness too followed the same pattern. However omnivore was least rich. Insectivore was almost 10 times richer than omnivore.

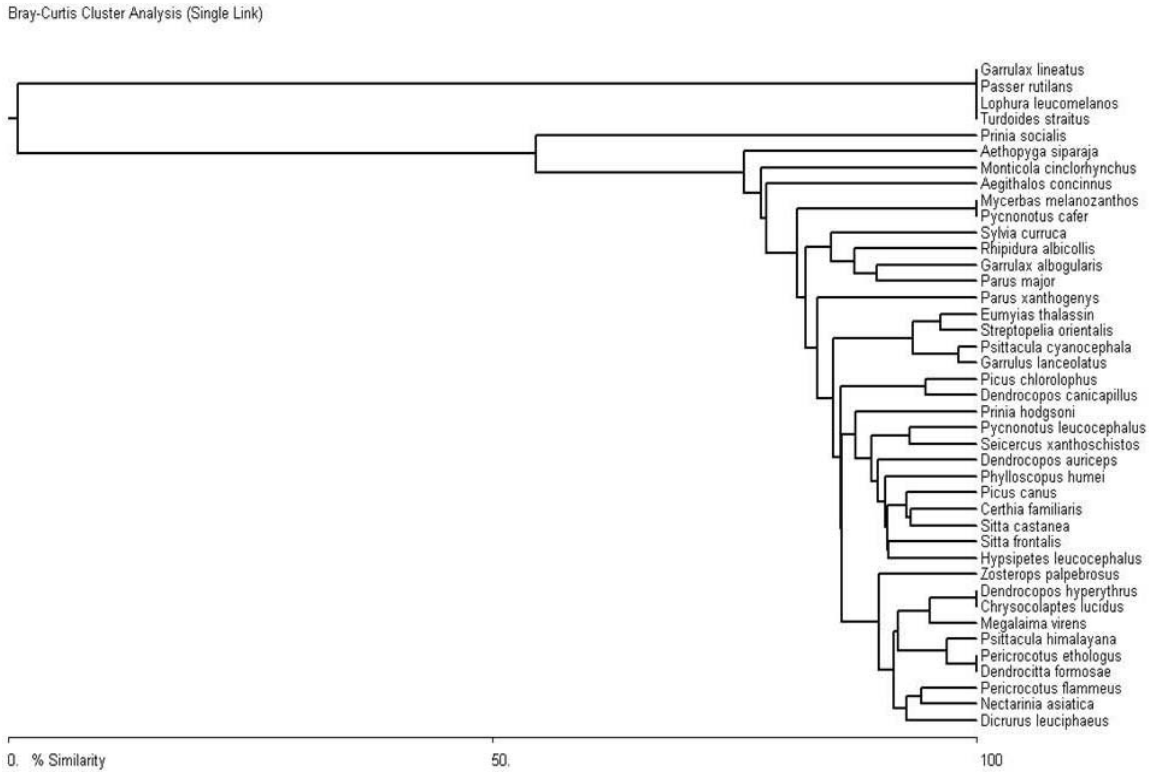

Figure 11. Cluster diagram of bird community based on feeding niche in Phakot Watershed area.

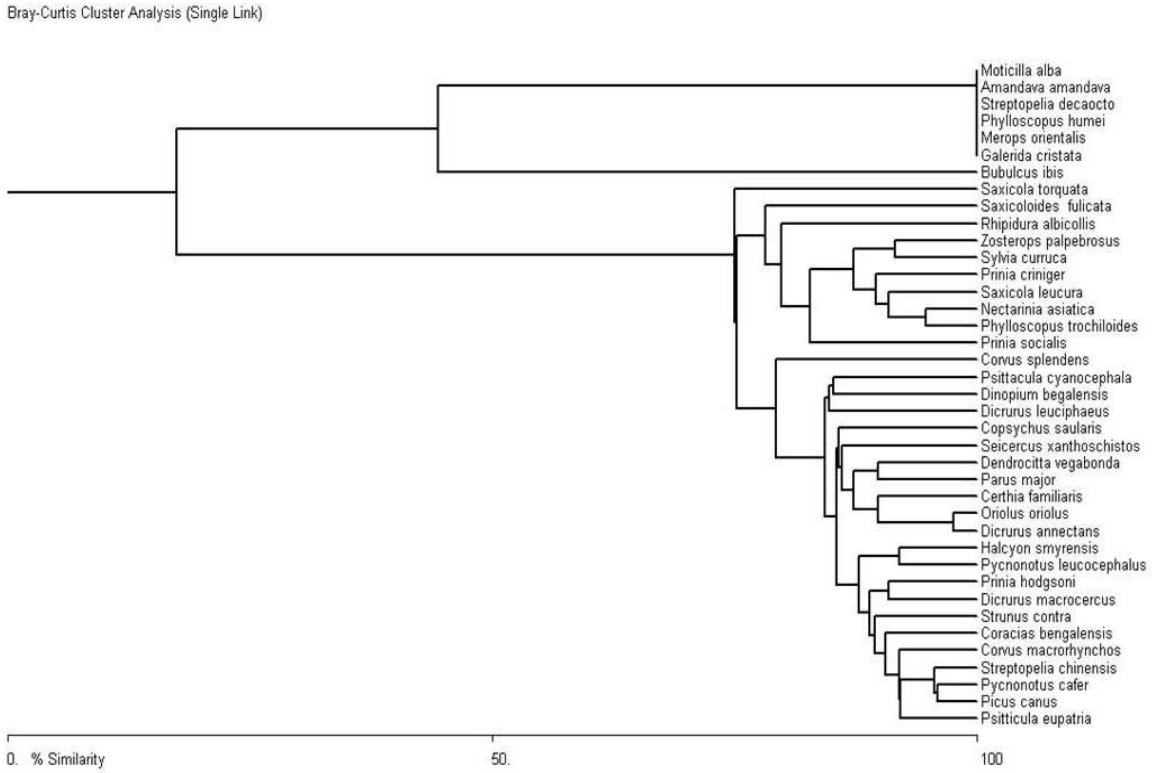

Figure 12. Cluster diagram of bird community based on feeding niche in Pathri Rao Watershed area.

Guild Structure Comparison

41 species from Phakot and 39 species from Pathri Rao watershed were used to generate guilds based on their similarities in exploiting certain sections of the vegetation for food. Figure 11 and 12 show the single linkage cluster diagram of birds in Phakot and Pathri Rao watersheds, respectively. Four different guilds were identified in Phakot and three in Pathri Rao watershed respectively.

Guild 1 consisted of species which forage on the ground. It included *Lophura leucomelanos, Turdoides straitus, Passer rutilans* and *Garrulax lineatus* in Phakot watershed and doves, wagtails, mynas and larks in Pathri Rao watershed. Guild 2 included species like *Aethopyga siparaga, Dicrurus leuciphaeus, Pycnonotus leucogenys, Pycnonotus cafer* in Phakot and *Pericrocotus ethologus* and parakeets in Pathri Rao. These guilds occupy the top canopy and include granivore, nectanivore and insectivorous birds. But this guild was dominated by insectivorous birds in both watersheds. Guild 3 consisted of bird species which exploited tree trunk for food. It included woodpeckers and nuthatches in both watershed areas but more prominent in Phakot watershed. Guild 4 contained birds which occupied middle and lower canopy. It includeed *Parus major* and *Aegithalos concinnus* in Phakot and *Eumyias thalassin, Rhipidura albicollis* and *Phylloscopus humei* and *Sylvia curruca* in Pathri Rao. This guild was more prominent in Phakot but could not be clearly distinguished in Pathri Rao.

Four guilds occupied different zones in vegetation hyperspace. In general insectivore species tended to occupy top canopy and outer canopy, their mean distance from tree truck was more than any other species. It allowed them maneuverability to catch insects. Species like drongos and bulbuls used perch height only to position themselves to catch insects, unlike woodpeckers and nuthatch which drill the tree trunk to look for their food. Species like *Phylloscopus humei, Zosterops palpebrosus* and *Sylvia curruca* occupied middle canopy and thrushes exploited the lower canopy. While *Parus major* tended to be near trunk, *Aegithalos concinnus* occupied the outer side, however, these species maneuvered within the canopy depending on the height of the tree. In general insectivore species mean distance from trunk was more because it will give them freedom to maneuver while catching insects. Specie like *Prinia socialis* preferred shrubs rather than tall trees. In general, community structure of both the sites seems to be consisting of insectivore, granivore and frugivore species, though insectivore species dominated in both the areas. The community structure of birds in Phakot is more complex than the Pathri Rao area. For example 50% of area in Pathri Rao watershed consisted of deciduous forest without structural difference and same is true for riverine and wasteland areas.

DISCUSSION

In terms of bird diversity Pathri Rao Watershed was more diverse as compared to Phakot Watershed. This is mainly due to location of Pathri Rao watershed area in tropic where as Phakot lies in temperate region of the middle Himalayas. Based on the unique geographical setting of the Pathri Rao Watershed, it has the avifaunal assemblages of both Himalayas and Gangetic Plains. The overall bird listing including the occasional records accounted for 116 species for Pathri Rao and 109 species for Phakot watershed. The estimate for Pathri Rao watershed area, based on four estimators, is within 95% confidence limits, whereas for Phakot watershed area Chao 1 overestimated the probable number of species within the watershed. The main reason behind this is that Chao 1 estimator is abundance based and bird densities were highest in Phakot watershed area in summer season. The location of Phakot is between the altitudinal gradient from 600-2000 meters and the area attracts most of the birds of the lower altitudes. The importance of this migration was confirmed by the sighting of *Pavo cristatus* in the Phakot watershed only during summer seasons.

The structure and functioning of a biological community are affected by the characteristics, life histories and interactions of its constituent species. Which species actually co-occur in a particular place at a given time is determined by a variety of historical and ecological factors (Holmes et al. 1979). Food is an important limiting resource (Lack 1954). Density, diversity and richness were highest in summer than winter. Anderson et al. (1982) and Rosenberg et al. (1982) have earlier shown that bird density and diversity depend on the availability of insect population in different seasons. Since winters are cold in both the areas, it is possible that insect population goes down subsequently reducing population of insectivorous bird species during winter.

Bird density of agriculture fields in Phakot watershed was more than agricultural fields in Pathri Rao watershed. Agriculture fields are present in mosaic with

surrounding woodlands in Phakot watershed. These woodlands provide breeding and feeding sites and allow colonization by individual and species (Woodhouse et al. 2005, Buckingham et al. 2006). These may also provide roosting sites for the birds. High density but lower diversity and richness of birds in agriculture fields in both areas may be due to the presence of granivore species like parakeets which forage in groups.

Oak and miscellaneous forest in Phakot showed higher diversity and richness of birds. Average tree height and GBH was also highest in these habitats. Older trees provided more food availability for foliage and trunk gleaner as well as more breeding sites for birds nesting in tree holes (Thomson et al. 1999, Keller et al. 2003). Avery and Charles van Riper III (1989) attributed the high relative density of birds in oak forests to greater complexity of habitats. Bird diversity and richness showed positive relation with tree and shrub diversity in all the habitats. Diaz (2006) found species richness increasing with shrub diversity in Oak forest. Bird species correlated with tree species was also demonstrated by Peck (1989) for British forest birds. Increase in structural complexity and floristic composition quite often are related to enrichment of associated bird communities since more heterogeneity allows more species to create niches (Poulsen 2002, Shochat et al. 2001, Laiola 2002, Machtans and Latour 2003).

Margalef (1958) suggested sigmoid relation between diversity and cover. Grass layer adds slightly to the avian diversity. With the addition of the first shrub cover, diversity increases more rapidly. As more cover is added, diversity decreases as it restricts the mobility of the avifauna in the very dense foliage. This might explain the decrease or negative correlation of bird density, diversity and richness with cover. These results were in conformity with Karr and Roth (1971). Blair (1996) and Henning's and Edge (2003) put similar argument that bird species richness and diversity peaked in areas with moderate canopy cover.

Decline of bird species richness and density with elevation has been attributed to decline in forest area at higher elevations, decline in abundance and size distribution of invertebrates, competition and changes in environmental conditions (Terborgh 1971), local migration of birds along gradient (Stiles 1978), spatial variation in resources (Blake and Loiselle 2002), reduced primary productivity (Lawton et al. 1987). Some studies emphasized that low bird density and diversity at higher elevations is due to the fact that such areas act as ecological islands (Prodon et al. 2002, Kattan and Franco 2004, Diaz 2006). We however believe that apart from these reasons the higher altitudes in both the areas had dense canopy cover which affected both bird density and diversity.

Bird diversity and richness were higher on eastern aspects than western aspects in both the watershed. Eastern aspects in hills get sunlight earlier than other aspects in morning and woodland birds are known to prefer hot sunny sites than cool shaded sites (Mitchell et al. 2006). Since sampling was carried out in morning hours only, therefore high bird density and diversity may be due to warmth on the eastern aspect in the morning. The results from the Pathri Rao watershed area were in contrast probably because half of the area had flat terrain with no marked aspects.

Bird density and richness in both the areas showed tolerance towards grazing and lopped areas. Laiolo et al. (2004) put forward the view that grazing is known to have little effect on typical open habitat bird species. This study confirms the above pattern. Daniels (1989) and Javed (1996) found an increase in bird species diversity when forests were disturbed. Secondary vegetation growth as a result of lopping or grazing provided more scope for forest generalist species to exploit for food and resting (Beehler et al. 1987, Terborgh and Weska 1969). Bock and Webb (1984) argued that birds generally responded to changes in vegetation structure as a consequence of grazing rather than to the presence of cattle per se but avian response vary from site to site (Wein and Dyer 1975). Urbanization is accompanied by changes in bird species richness but such changes whether positive or negative depend upon on the degree of urbanization.

Both watershed areas were disturbed due to human activities. However, disturbance in Phakot is more restricted to lopping and grass cutting whereas, in Pathri Rao more commercial activities were carried out as a result of establishment of industrial setups. Rural activities modify wildlife habitats and increase vegetation structure and variety (Crooks et al. 2004, Glennun and Porter 2005, Chapman and Reich 2007). Native habitats mixed with cropland create a landscape with habitat for a wide variety of species (Burke and Nol 2000, Soderstom and Part 2000).

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