Assessing The Habitat Suitability of Six Coniferous Forests Using Avian Assemblages At High Altitude Ecosystem

M. N. Rajpar

Department of Forestry, Shaheed Benazir Bhutto University Sheringal Dir (Upper), Khyber Pakhtunkhwa, Pakistan

S. A. Khan

Department of Forestry, Shaheed Benazir Bhutto University Sheringal Dir (Upper), Khyber Pakhtunkhwa, Pakistan

S. Ullah

Department of Forestry, Shaheed Benazir Bhutto University Sheringal Dir (Upper), Khyber Pakhtunkhwa, Pakistan

A.H. Rajpar

Department of Mechanical Engineering, college of Engineering, Jouf University, Saudi Arabia

M. Zakaria (✉ mzakaria@upm.edu.my)

Department of Forest Science and Biodiversity, Faculty of Forestry and Environment, Universiti Putra Malaysia

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Abstract

Birds are habitat specialist, i.e. often selects habitat that offers ample services such as a variety of food resources, safe breeding and less disturb sites to satisfy their needs. We aimed to ascertain the conservation status of avian assemblages inhabited in six different coniferous forests. The study employed the point count method to determine the avian assemblages in each forest type. The surveys were conducted employing the distance sampling point count method and determining the floristic composition through direct visual estimation from January 2018 to March 2019. In total, 2465 bird individuals representing 57 species and 29 families were observed in six coniferous forests. Twelve tree species, nine shrub species, and 14 grass species were identified in the forests. Except for the *Streptopelia turtur* (vulnerable), all bird species are listed as “least concern” according to the IUCN Red List Category and Criteria 2019–2. Notably, the relative abundance of bird assemblages among six coniferous habitats was significantly different ($F_{5, 293} = 22.8, p < 0.05$). The CAP results reflected that bird diversity indices varied coniferous forests. Strikingly, dry–temperate coniferous forest (BG) was densely populated (5.831 ± 0.694 birds•ha⁻¹) as compared to other habitats. These findings suggested that subtropical coniferous forests are cradles of life for a wide array of avian assemblages and hence should be declared as protected forests to enhance avian assemblages in this region.

Introduction

Coniferous forests comprise the largest biome on earth, and approximately one-third of the world’s coniferous forest areas exist in the northern parts of North America, Europe, and Asia (Spurr and Barnes, 1080; Klappenbach, 2018). They are cradles of life for a wide array of wildlife species, especially birds and mammals (Langat et al., 2016; Duguma et al., 2019). Subtropical coniferous forests are more diverse in terms of their floristic composition (Behera et al., 2002; Bhattarai and Vetass, 2003; Acharya et al., 2011; Gaire et al., 2014) and richness in fauna (Gentili et al., 2015; Ahmed et al., 2018; Mannan et al., 2019). In addition, they provide countless ecosystem services for the livelihood of local communities, i.e., food, raw material for medicine, fuelwood, fodder, fruits, and economic benefits (Rasul, 2014; Maren et al., 2014; Sandhu and Sandhu, 2014; Dhyani and Dhyani, 2016). Pakistan is bestowed with 4.6 million ha of forest area, of which 1.96 million ha form Himalayan coniferous forests (Hasan et al., 2016).

Unfortunately, these unique habitats (coniferous forests) have been poorly protected and have experienced high–level losses and degradation due to human interaction (Wright, 2010). Human footprints, such as timber harvesting, intensive livestock grazing, agriculture expansion, and urbanization, are the most significant drivers of alteration in the habitat structure of the forest (Mahmood, 2003; Wright, 2010; Lawson et al., 2014; Elsen et al., 2017; Mannan et al., 2019). These factors alter the floristic composition and forest structure (Foley et al., 2005; Qasim et al., 2013; Ullah et al., 2016; Mukete et al., 2017), ultimately declining the population of wildlife fauna in subtropical coniferous forests. It has been estimated that, in the past two decades, around 14.0% of the subtropical forest in the mountains has been lost in low lying areas (Ahmad et al., 2018; Mannan et al., 2018).

Habitat loss and degradation due to human activities pose significant threats to the avian population structure and distribution (Appiah et al., 2009; Hersperger et al., 2010; Feyissa et al., 2014; Mukete et al., 2018). Some species have become threatened and endangered (e.g., rufous–vented prinia – *Laticilla burnesii*, western tragopan – *Tragopan melanocephalus*, long-billed warbler – *Locustella major*, Kashmir flycatcher – *Ficedula subrubra*, cheer pheasant – *Catreus wallichii*, and black–bellied tern – *Sterna acuticauda*) across different habitats (i.e., forests, wetlands, highland pastures, foothills, Indus plains, estuaries, deserts, reedbeds, and waterlogged areas) due to deforestation, habitat destruction, and degradation (Puyravaud et al., 2010).

Birds are the best bio–indicators of the coniferous forest ecosystem; i.e., the presence or absence of avian species may indicate the productivity of particular habitats (Waterhouse et al., 2002; Watson et al., 2004; Roberge and Angelstam, 2006). Birds are closely associated with the landscape mosaic, coniferous forest flora and food resources, and reflect the level of disturbance (Jokimaki and Solonen, 2011; Pakkala et al., 2014; Koli, 2014; Menna et al., 2016). The comparison of avian populations among different subtropical coniferous forests has previously been used to determine the conservation status, population trend, habitat preference, and productivity of different habitats (Kattan and Franco, 2004; Harisha and Hosetti, 2009; Khan et al., 2013; Khan and Pant, 2017).

Coniferous forests have been poorly surveyed due to their complex topography, difficult terrain, and harsh weather (Lomolino, 2001). Information about the avian assemblages inhabiting Himalayan subtropical coniferous forests and the detrimental effects on the habitat is scarce. More concrete information about the conservation status and avian assemblages is critically essential to protect and conserve avian species inhabiting the Himalayan subtropical coniferous forests and for better future management planning (Tomialojc and Wesolowski, 2004; Wesolowski et al., 2010). Hence, this study was conducted to examine the population structure of avian species in six subtropical coniferous forests of Pakistan and to identify the habitat suitability. The results will form a foundation for guiding future conservation and protection in the region.

Materials And Methods

Study Area: The coniferous forests, namely, sub–tropical coniferous forests (L; 34.89 ha), sub–tropical coniferous forests (S; 28.25 ha), dry–temperate coniferous forest (Z; 29.85 ha), dry–temperate coniferous forest (BG; 30.54 ha), mixed dry–temperate coniferous forest (G; 33.78 ha), and mixed dry–temperate coniferous forest (K; 33.77 ha), occurs in a narrow zone confined within approximately 900–2000 m elevation above sea level. The vegetation of coniferous forests consists mainly of evergreen cone–bearing and needle–leaved trees, while their multilayered canopy comprises conifers and broadleaved trees, shrubs, and grasses. Each habitat may vary in terms of vegetation species composition and structure. The characteristics of each particular habitat are given in Table 1.

Table 1: Descriptions of each coniferous habitat types

Description	Forest Types					
	Sub-tropical coniferous forests (L)	Sub-tropical coniferous forests (S)	Dry-temperate coniferous forest (Z)	Dry-temperate coniferous forest (BG)	Mixed dry-temperate coniferous forest (G)	Mixed dry-temperate coniferous forest (K)
Latitude	N 34° 47' 35"	N 34° 47' 35"	N 34° 45' 01"	N 34° 44' 06"	N 34° 42' 32"	N 34° 42' 32"
Longitude	E 72° 02' 14"	E 72° 02' 14"	E 72° 02' 56"	E 72° 06' 38"	E 72° 3' 27"	E 72° 3' 27"
Elevation (m asl)	788 to 1670	997 to 1065	965 to 1066	1065 to 1170	812 to 935	964 to 998
Vegetation Cover %	60.0%	65.0%	75.0%	80.0%	85.0%	80.0%
Most Dominant tree sp.	<i>Pinus roxburghii</i> , <i>Q. baloot</i> , <i>Mallotus philippensis</i> , <i>Punica granatum</i>	<i>P. roxburghii</i> , <i>Q. incana</i> , <i>Pyrus pashia</i>	<i>P. wallichiana</i> , <i>Pinus roxburghii</i> , <i>Ailanthus altissima</i> , <i>Ficus carica</i>	<i>Pi. wallichiana</i> , <i>Morus alba</i> , <i>Morus nigra</i> , <i>Acacia modesta</i>	<i>P. wallichiana</i> , <i>P. roxburghii</i> , <i>Q. delata</i> , <i>A. modesta</i>	<i>P. wallichiana</i> , <i>P. roxburghii</i> , <i>Q. baloot</i> , <i>Ailanthus altissima</i> , <i>F. carica</i>
Most Dominant Shrub sp.	<i>Indigofera gerardiana</i> , <i>Justicia adhatoda</i> , <i>Ephedra gerardiana</i>	<i>Reptonia muscatencesea</i> , <i>Berberis lyceum</i> , <i>Dodonaea viscosa</i>	<i>Solanum nigrum</i> , <i>Verbascum thapsus</i> , <i>Ranunculus muricatus</i>	<i>Berberis lyceum</i> , <i>Zanthoxylum alatum</i> , <i>Myrtus communis</i>	<i>Dodonaea viscosa</i> , <i>Berberis lyceum</i> , <i>Indigofera gerardiana</i>	<i>Crataegus oxyacantha</i> , <i>marijuar</i> , <i>Dysphania ambrosioides</i> , <i>Tribul terrestris</i>
Most Abundant Grass sp.	<i>Cannabis sativa</i> , <i>Cynodon dactylon</i>	<i>C. dactylon</i> , <i>Phalaris minor</i>	<i>Apluda mutica</i> , <i>Polygonum aviculare</i> , <i>Dichanthium annulatum</i>	<i>Chrysopogon montanus</i> , <i>Polygonum aviculare</i> , <i>Rumex dentatus</i>	<i>C. dactylon</i> , <i>Heteropogon contortus</i>	<i>Setaria glauca</i> , <i>Miscanthus nepalensis</i>
Most Common herbs	<i>Carthamus oxyacantha</i> , <i>Verbena officinalis</i>	<i>Chenopodium ambrosioides</i> , <i>Valeriana jatamansi</i>	<i>Taraxacum officinale</i> , <i>Urtica dioica</i>	<i>Solanum nigrum</i> , <i>Stellaria media</i>	<i>Mentha longifolia</i> , <i>Rumex histatus</i>	<i>Verbena officinalis</i> , <i>Rumex dentatus</i>
Surrounding habitat	Agricultural fields and human settlements	Agriculture fields and human settlement	Agriculture fields and human settlement	Agriculture fields	Agriculture fields and human settlement	Agriculture fields and orchards

(Note; L = Laram; S = Shengari, Z = Zarback, BG = Baber Gakhai, G = Gulabad and K = Khanpur)

Bird Survey: The distance sampling point count method is one of the most robust and preferred quantitative bird survey methods used for determining the population structure of bird species inhabiting forest habitat (DeSante et al., 2005; Buckland et al., 2008; Gale et al., 2009; Thomas et al., 2010; Ma, 2012). This method involves the visual and auditory detection of birds with fixed or variable radius plots in order to determine avian density (Kissling and Garton, 2006; Meadows et al., 2012). The detection of birds in coniferous forests varies depending on tree density, upper story layer, middle story layer, ground vegetation cover, visibility and sounds of avian species, and observer's skill (Gregory et al., 2007; Melles et al., 2011; Anderson et al., 2015).

Data collection for this study was designed on the basis of (i) habitat structure, i.e., landscape, vegetation richness and density, vegetation complexity, percentage vegetation cover, and vegetation composition (e.g., trees, shrubs, and grasses); (ii) occupancy of cryptic, shy, and skulking species, such as tits, tree creepers, babblers, warblers, and chiffchaffs; (iii) availability and richness of food resources; (iv) human intrusion; and (v) areas best fitted to attract bird species. This is because the vegetation composition and complexity affect the distribution and diversity of species (Souza et al., 2015). Likewise, the availability and distribution of food resources in a particular habitat influence the bird community structure and behavior (Levinton and Kelaher, 2004). Similarly, human encroachment cause alterations in habitat structure, which affects the distribution, diversity, and population of avian species in dwelling habitats (Capucchio et al., 2019).

Bird surveys were completed for selected months, i.e. January 2018 (winter), June and July 2018 (summer), November 2018 (autumn) and March 2019 (spring) across the six coniferous forests using the distance sampling point method. A total of 180 point counts (30 point counts in each habitat, i.e., sub-tropical coniferous forests (L), sub-tropical coniferous forests (S), dry-temperate coniferous forest (Z), dry-temperate coniferous forest (BG), mixed dry-temperate coniferous forest (G) and mixed dry-temperate coniferous forest (K) were collected. The sampling points were selected according to the topography of the study area, the ease of access in rolling terrain, the structure and composition of the vegetation, and the safety of the observer. Point counts within each habitat were separated by 250 m to minimize the risk of double-counting the same bird individuals (Antongiovanni and Metzer, 2005). Each point was visited at least four times during the 15 consecutive months of the study period. Normally, the bird surveys at the 30 points were completed within 1–5 days. Efforts were made to cover all six study areas within the same month. Whenever this was not possible, we ensured that the surveys were completed in the following month.

Only sighted bird species within each point count station sampled were considered. However, some bird species were identified through vocal sound, and their position was determined from where the sound was heard. The birds were surveyed at each point count station for 15 min and allowed a 1 min settling time (Gregory et al., 2004). The radial distance from the bird to the observer was recorded using visual estimation. The birds were surveyed between 7:30 and 11:00 a.m. This time was most suitable to conduct the survey because most of the birds were active in foraging, perching, leafing, and sallying activities. Moreover, to avoid the bias of weather, the survey was stopped immediately when the weather conditions were unfavorable (e.g., rain or thick mist). A radius of 30 meters around the point count was used for the bird survey. All surveys were conducted by the main author.

Vegetation Survey: Assessing the floristic composition (i.e. trees, shrubs, grasses and herbs) are key variables that reflect the territory efficiency, aesthetic beauty, and harbor the assorted bird fauna species meet their needs (Schulz et al., 2009). In each habitat, the assurance of vegetation assemblages, i.e. the percent vegetation cover was done to determine the habitat suitability (Dethier et al., 1993; Hees et al., 2000; Godinez–Alvarez et al., 2009). This is one of the foremost used and accepted methods to inventory the floristic composition in an assortment of forest ecosystems (Mumby et al., 1997; Hudon, 1997; Fernandez–Alaez et al., 2002). The vegetation was inventoried at the same points used for surveying birds. Trees, shrubs, grasses, and forbs were identified with the help of a plant taxonomist. Trees were categorized into coniferous and broadleaved. The methodology was followed as described by Yates et al., 2019 and Banag–Moran et al., 2020.

DATA ANALYSIS

Relative Species Abundance (%): Relative species plenitude is the number of bird individuals per species that occupied in a coniferous forest habitat. It may change from year, altitude, aspects, weather conditions, geographic range, and restoration endeavors (McGill et al., 2007; Verberk, 2011).

The relative abundance of bird species of coniferous forest was evaluated agreeing to the taking following equation:

$$\text{Relative Species Abundance (\%)} = \text{Isi} / \sum \text{Nsi} \times 100$$

Where, ISI = Total Number of Individual species, $\sum \text{Nsi}$ = Total Number of bird species (Anderson, 2017).

Bird Relative Abundance among Six Coniferous Forests: Bird relative abundance was compared using one-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD) test (Analytical Software, version 8.1) by McGraw–Hill (2008).

Diversity Indices: The diversity indices of bird species were analyzed through Community Analysis Package (PCA) Version 4.0 by Henderson and Seaby (2007). In this study, Shannon's diversity index, Margalef's Richness Index, and Pielou J Evenness Index were ascertained to compare the bird diversity indices among six coniferous habitats.

Species Diversity Index: The diversity is a varied and inconstant among the bird assemblages in coniferous forest. It accounts for plenitude by giving data on the irregularity and commonality of bird species. For example; Shannon's diversity index is calculated as follows:

$$H = - \sum [(p_i) \times \ln(p_i)],$$

Where, H' designates diversity, S indicates the number of species, i specifies the abundance of species, N is the total number of all individuals, p_i is the relative abundance of each species, and $\ln$ is the natural logarithm.

Species Richness Index: It is the number of diverse bird species in a given habitat. It moreover gives data on the homogeneity and irregularity of bird distribution and occurrence. For example; *Margalef's Richness Index*;

$$R = (S - 1) / \ln N,$$

Where, S is the total number of species and N is the total number of individuals in the sample.

Species Evenness Index: It is the degree of the relative plenitude of distinctive bird species in a specific range. For example; Pielou J Evenness Index;

$$J = H / \log(S)$$

Where, H = is the observed Shannon-Wiener index and S = is the total number of bird species in the coniferous forest.

The correlation between Bird Diversity and Vegetation Structure among Six Coniferous Forests: Pearson's correlation coefficient was applied in order to understand the effects of vegetation structure on bird diversity in the six coniferous forests.

Bird Density among Six Coniferous Forests: Determining an accurate population size is highly important to obtain the current population status of different bird species in a dwelling habitat. The bird population was determined through the DISTANCE Software (Version 7.1) by Buckland et al. (2004).

The key to distance sampling is to use the distribution of observed distances to determine the "detection function" $g(y)$, i.e., the probability of estimating a bird at distance y . This function can then be used to ascertain the mean probability of detecting a bird given that it is within w of the point, denoted P_a . Given an estimate of P_a , bird density can be determined using the following equation:

$$\hat{D} = \frac{1}{a} \sum_{i=1}^n \frac{1}{\hat{P}_a(z_i)}$$

where a is the size of the covered region, n is the number of birds detected, and $P^{\wedge}a(z_i)$ is the probability of detecting the i -th bird given that it is within w of the point and has the covariate values z_i (Buckland et al., 2006; Marques et al., 2007; Fewster et al., 2009).

Results

Bird Species Composition and Relative Abundance among Six Coniferous Forest: A total of 2465 bird individuals belonging to 53 species and 29 families in six coniferous habitats were identified as; (sub-tropical coniferous forests (L), 50 species, 439 birds, 17.809%; sub-tropical coniferous forests (S), 48 species, 405 birds, 16.430%; dry-temperate coniferous forest (BG), 51 species, 447 birds, 18.133%; dry-temperate coniferous forest (Z), 51 species, 401 birds, 16.267%; mixed dry-temperate coniferous forest (G), 44 species, 346 birds, 14.036%; mixed dry-temperate coniferous forest (K), 51 species, 427 birds, 17.322%. Notably, the *Turdus atrogularis* (sub-tropical coniferous forests (L), 1.623%; sub-tropical coniferous forests (S), 1.217%), *Acridotheres tristis* (dry-temperate coniferous forest (BG), 1.460%; mixed dry-temperate coniferous forest (Z), 1.217%), *Turdoides caudata* (dry-temperate coniferous forest (BG), 1.298%), and *Corvus splendens* (mixed dry-temperate coniferous forest (L), 2.840%) were the most dominant bird species on the basis of the number of detections in the six habitats. In contrast, the *Elanus caeruleus* (in sub-tropical coniferous forests (L) and dry-temperate coniferous forest (BG), *Upupa epops*, *Copsychus saularis*, *Accipiter badius* (in mixed dry-temperate coniferous forest (BG), *Accipiter virgatus* (in dry-temperate coniferous forest (Z), *Myophonus caeruleus*, *Columba hodgsonii*, *Motacilla cinerea*, *Halcyon smyrnensis* (in mixed dry-temperate coniferous forest (L), and *Falco tinnunculus* (in mixed dry-temperate coniferous forest (BG) were the rarest species in the study area (Table 2).

Table 2: Detection of bird species composition and relative abundance among six coniferous forest habitats

Family	Scientific Name	Common/English Name	Forest Type						Conservatio Status
			Sub- tropical coniferous forests (L)	Sub- tropical coniferous forests (S)	Dry- temperate coniferous forest (BG)	Dry- temperate coniferous forest (Z)	Mix Dry- temperate coniferous forest (G)	Mix Dry- temperate coniferous forest (K)	
Accipitridae	<i>Accipiter virgatus</i>	Besra	0.081	0.040	0.040	0.040	0	0	LC
Upupidae	<i>Upupa epops</i>	Common hoopoe	0.081	0	0.040	0.081	0.081	0.081	LC
Columbidae	<i>Streptopelia chinensis</i>	Spotted dove	0.325	0.406	0.325	0.243	0.121	0.365	LC
	<i>Streptopelia senegalensis</i>	Laughing dove	0.243	0.162	0.365	0.203	0.162	0.162	LC
	<i>Streptopelia turtur</i>	European turtle dove	0.284	0.162	0.121	0.081	0.162	0.121	VU
	<i>Streptopelia orientalis</i>	Oriental turtle dove	0.365	0.203	0.243	0.284	0.243	0.162	LC
	<i>Columba livia</i>	Rock dove	0.121	0.162	0.406	0.365	0.203	0.406	LC
	<i>Columba hodgsonii</i>	Speckled wood pigeon	0.081	0	0.081	0.162	0.040	0.081	LC
	<i>Treron phoenicoptera</i>	Yellow-footed green pigeon	0.081	0.081	0	0	0.081	0	LC
Alcedinidae	<i>Halcyon smyrnensis</i>	White-throated kingfisher	0	0.162	0.081	0.081	0.040	0.203	LC
Coraciidae	<i>Coracias benghalensis</i>	Indian roller	0.162	0.081	0.081	0.081	0	0.081	LC
Meropidae	<i>Merops orientalis</i>	Green bee-eater	0.081	0.040	0.162	0.121	0	0.081	LC
Falconidae	<i>Falco tinnunculus</i>	Common kestrel	0.162	0.081	0.121	0.081	0.081	0.040	LC
Phasianidae	<i>Francolinus francolinus</i>	Black francolin	0.487	0.081	0.325	0.406	0	0.325	LC
	<i>Coturnix coturnix</i>	Common quail	0.406	0.406	0.487	0.406	0.811	0.284	LC
Aegithalidae	<i>Aegithalos concinnus</i>	Black-throated tit	0.162	0	0.081	0.081	0	0.121	LC
Alaudidae	<i>Galerida cristata</i>	Crested lark	0.081	0.162	0.243	0.162	0.203	0.325	LC
Campephagidae	<i>Pericrocotus flammeus</i>	Scarlet minivet	0.325	0.811	0.325	0.203	0.081	0.325	LC
Certhiidae	<i>Certhia himalayana</i>	Bar-tailed tree creeper	0.243	0.081	0.081	0.162	0	0.081	LC
Corvidae	<i>Dendrocitta vagabunda</i>	Rufous treepie	0.081	0.162	0.243	0.325	0.081	0.081	LC
	<i>Garrulus lanceolatus</i>	Black-headed jay	0.203	0	0.081	0.081	0	0.081	LC
	<i>Corvus splendens</i>	House crow	0.284	0.730	0.487	0.568	2.840	0.121	LC
	<i>Corvus macrorhynchos</i>	Large-billed crow	0.406	0.081	0.162	0.243	0.081	0.162	LC
Dicruridae	<i>Dicrurus macrocercus</i>	Black drongo	0.487	0.811	0.690	0.406	0.325	0.487	LC
Emberizidae	<i>Emberiza cia</i>	Rock bunting	0.406	0.406	0.487	0.406	0.365	0.568	LC
Fringillidae	<i>Carpodacus erythrinus</i>	Common rosefinch	1.0142	0.527	0.811	0.406	0.487	0.811	LC
Hirundinidae	<i>Hirundo rustica</i>	Barn swallow	0.406	0.811	1.217	0.811	0.365	0.527	LC
Laniidae	<i>Lanius tephronotus</i>	Grey-backed shrike	0.406	0.487	0.730	0.325	0.284	0.568	LC

	<i>Lanius vittatus</i>	Bay-backed shrike	0.162	0.121	0.284	0.081	0.121	0.162	LC
Leiothrichidae	<i>Turdoides caudata</i>	Common babbler	0.811	0.609	1.258	1.298	0.406	0.690	LC
Leiothrichidae	<i>Trochalopteron lineatum</i>	Streaked laughing thrush	0.284	0.406	0.325	0.487	0.243	0.609	LC
Monarchidae	<i>Terpsiphone paradisi</i>	Indian paradise flycatcher	0.730	0.406	0.406	0.811	0.284	0.487	LC
Motacillidae	<i>Motacilla alba</i>	White wagtail	0.203	0.162	0.406	0.365	0.284	0.527	LC
	<i>Motacilla cinerea</i>	Grey wagtail	0.081	0.162	0.162	0.081	0.040	0.243	LC
Muscicapidae	<i>Myophonus caeruleus</i>	Blue whistling thrush	0.162	0.081	0.081	0.162	0.040	0.121	LC
	<i>Copsychus saularis</i>	Oriental magpie robin	0	0.081	0.040	0.040	0	0.121	LC
	<i>Saxicola caprata</i>	Pied bushchat	0.121	0.081	0.121	0.162	0.243	0.162	LC
Oriolidae	<i>Oriolus oriolus</i>	Eurasian golden oriole	0.406	0.365	0.609	0.487	0.284	0.730	LC
Paridae	<i>Parus cinereus</i>	Cinereous tit	0.771	0.446	0.365	0.406	0.162	0.487	LC
Passeridae	<i>Passer montanus</i>	Eurasian tree sparrow	0.609	0.811	0.406	0.527	0.487	0.730	LC
	<i>Passer domesticus</i>	House sparrow	0.811	0.892	0.730	0.487	0.406	1.0142	LC
Phylloscopidae	<i>Phylloscopus collybita</i>	Brown chiffchaff	0.203	0.284	0.162	0.325	0.121	0.203	LC
	<i>Phylloscopus chloronotus</i>	Lemon rumped warbler	0.243	0.162	0.121	0.203	0.162	0.081	LC
	<i>Phylloscopus trochiloides</i>	Greenish warbler	0.284	0.081	0.162	0.121	0.203	0.243	LC
Pycnonotidae	<i>Pycnonotus cafer</i>	Red-vented bulbul	0.609	0.811	0.690	0.568	0.406	0.771	LC
	<i>Pycnonotus leucotis</i>	White-eared bulbul	0.081	0.162	0.121	0.203	0.243	0.406	LC
	<i>Pycnonotus leucogenys</i>	Himalayan bulbul	0.487	0.284	0.162	0.121	0.203	0.325	LC
Sturnidae	<i>Acridotheres tristis</i>	Common myna	0.811	1.014	1.460	1.055	0.730	1.217	LC
	<i>Sturnia pagodarum</i>	Brahminy starling	0.325	0.162	0.284	0.203	0.121	0.243	LC
	<i>Sturnus vulgaris</i>	Common starling	0.487	0.406	0.609	0.568	0.811	0.568	LC
Turdidae	<i>Turdus atrogularis</i>	Dark-throated thrush	1.623	1.217	0.609	0.649	0.811	0.406	LC
	Sub Total		439	405	447	401	346	427	
	Overall % in each habitat		17.809	16.430	18.133	16.267	14.036	17.322	
	Grand Total					2465			

Note: Conservation status determined according to the IUCN Red List, 2019

Comparison of Bird Relative Abundance among Six Coniferous Forests:

One-way ANOVA and Tukey's HSD test revealed that the bird detections among the six different coniferous forests were significantly different ($F_{5, 293} = 22.8$, $p < 0.05$). In addition, the relative abundance of avian assemblages was compared through Species and Richness IV (Pisces Software) employing rank abundance curve to determine the species distribution among habitats. The results shown that bird species relative abundance among six coniferous habitats varied (Figure 2)

Comparison of Vegetation Structure and Composition among Six Coniferous Forests: The vegetation inventory results showed that dry-temperate coniferous forest (BG) was more diverse and richer in vegetation composition, i.e., trees (20.98%; 12 species), shrubs (88.88%; 8 species), grasses (92.0%; 3 species) and

herbs (98.0%; 7 species), compared to the other habitats. However, vegetation composition varied habitat to habitat depending on soil depth and fertility, intensity of grazing pressure, uncontrolled firewood collection, and land-use change pattern (Table 3).

Table 3. Comparison of vegetation structure and composition among six coniferous forest types.

Family	Scientific Name	Forest Type					
		Sub-tropical coniferous forests (L)	Sub-tropical coniferous forests (S)	Dry-temperate coniferous forest (Z)	Dry-temperate coniferous forest (BG)	Mix Dry- temperate coniferous forest (G)	Mix Dry- temperate coniferous forest (K)
Tree Species							
Pinaceae	<i>Pinus roxburghii</i>	6.276%	7.221%	6.676%	8.856%	7.493%	8.651%
Pinaceae	<i>P. wallichiana</i>	2.520%	0	3.951	2.929%	1.499%	0
Fagaceae	<i>Quercus delatata</i>	4.223%	4.632%	5.177%	5.245%	4.837%	3.474%
Rosaceae	<i>Pyrus pashia</i>	0.136%	0.545%	0.272%	0.136%	0	0
Lythraceae	<i>Punica granatum</i>	0.068%	0.885%	0.204%	0.341%	0	0
Euphorbiaceae	<i>Mallotus phillippensis</i>	0.068%	0.613%	0.136%	0.545%	0.272%	0
Simaboubaceae	<i>Ailanthus altissima</i>	0	0	0.272%	0.341%	0.477%	0
Moraceae	<i>Ficus carica</i>	0.204%	0	0.545%	0.409%	0.204%	0.409%
Moraceae	<i>Morus alba</i>	0	0.545%	0.341%	0.204%	0	0
Moraceae	<i>Morus nigra</i>	0	0	0.204%	0.409%	0	0
Fabaceae	<i>Acacia modesta</i>	0	0	0.885%	1.090%	2.929%	0
Myrtaceae	<i>Eucalyptus camaldulensis</i>	0.613%	0.341%	0.341%	0.477%	0.204%	0.409%
Sub-Total		14.11%	14.78%	18.974%	20.98%	17.92%	12.94%
Shrub Species							
Fabaceae	<i>Indigofera gerardiana</i>	0	0	32%	18%	22%	0
Rhamnaceae	<i>Zizihpus nummularia</i>	0	0	0	0	0	10%
Acanthaceae	<i>Justicia adhatoda</i>	5%	18%	6%	28%	8%	15%
Sapotaceae	<i>Reptonia muscatencesea</i>	12%	12%	0	4%	0	0
Berberidaceae	<i>Berberis lyceum</i>	22%	0	0	31%	0	23%
sapindaceae	<i>Dodonaea viscosa</i>	52%	35%	48%	10%	68%	43%
Celastraceae	<i>Gymnosporia royleana</i>	0	30%	14%	3%	0	9%
Rutaceae	<i>Zanthoxylum alatum</i>	6%	5%	0	2%	2%	0
Myrtaceae	<i>Myrtus communis</i>	3%	0	0	4%	0	0
Sub-Total		66.66%	55.55%	44.44%	88.88%	44.44%	55.55%
Grass Species							
Poaceae	<i>Miscanthus nepalensis</i>	38%	0	0	0	0	0
Poaceae	<i>Cynodon dactylon</i>	24%	30%	28%	34%	14%	31%
Poaceae	<i>Heteropogon contortus</i>	3%	5%	6%	28%	10%	18%
Poaceae	<i>Chrysopogon fulvus</i>	9%	7%	12%	30%	8%	12%
Sub-Total		74.0%	42.0%	46.0%	92.0%	32.0%	61.0%

<i>Herbs Species</i>							
Asteraceae	<i>Carthamus oxyacantha</i>	0	28%	35%	22%	0	23%
Cannabaceae	<i>Cannabis sativa</i>	0	0	28%	25%	0	39%
Ephedraceae	<i>Ephedra gerardiana</i>	0	0	0	7%	0	0
Asteraceae	<i>Taraxacum officinale</i>	0	6%	0	7%	0	0
Lamiaceae	<i>Mentha longifolia</i>	0	9%	0	0	0	0
Amaranthaceae	<i>Chenopodium ambrosioides</i>	0	16%	18%	0	0	11%
Zygophyllaceae	<i>Tribulus terrestris</i>	0	0	9%	0	0	9%
Solanaceae	<i>Solanum nigrum</i>	0	0	0	8%	3%	0
Scrophulariaceae	<i>Verbascum thapsus</i>	0	0	0	5%	9%	0
Ranunculaceae	<i>Ranunculus muricatus</i>	0	0	0	13%	4%	0
Polygonaceae	<i>Rumex dentatus</i>	0	0	0	9%	6%	0
Polygonaceae	<i>Polygonum aviculare</i>	0	0	0	0	14%	0
<i>Sub-Total</i>		0	59.0%	90.0%	96.0%	36.0%	82.0%

Comparison of Bird Diversity among Six Coniferous Forests: CAP analysis demonstrated that avian diversity, varied among the six coniferous forests. The highest species diversity was documented in mixed dry–temperate coniferous forest (Z), $H' = 3.625 \pm 0.027$ while the lowest was documented in mixed dry–temperate coniferous forest (G), $H' = 3.261 \pm 0.027$. Likewise, dry–temperate coniferous forest (BG) was rich in avian species ($R_1 = 8.178 \pm 0.031$) and mixed dry-temperate coniferous forest (G) was the least preferred habitat ($R_1 = 7.191 \pm 0.031$). Similarly, bird species were evenly distributed in mixed dry–temperate coniferous forest (K), $E = 0.955 \pm 0.006$, and sparsely distributed in mixed dry–temperate coniferous forest (G), $E = 0.926 \pm 0.006$ (Table 4).

Table 4: Comparison of bird diversity indices among six coniferous forest habitats.

Habitat	Shannon's Index (H')	Margalef's Index (R ₁)	McIntosh's Index (E)
Mix Dry-temperate coniferous forest (K)	3.618	7.934	0.922
Dry-temperate coniferous forest (BG)	3.575	8.178	0.909
Sub-tropical coniferous forests (L)	3.612	7.892	0.919
Dry-temperate coniferous forest (Z)	3.625	8.032	0.920
Sub-tropical coniferous forests (S)	3.508	7.668	0.892
Mix Dry-temperate coniferous forest (G)	3.261	7.191	0.829
Overall	3.641	6.405	0.926
Standard Error	0.027	0.031	0.006

Correlation between Bird Diversity and Vegetation Structure among Six Coniferous Forests: Pearson's correlation coefficient (PCC) test revealed that bird diversity had a positive correlation with vegetation structure (trees; $r = 0.408$, $P > 0.05$, shrubs; $r = 0.138$, $P > 0.05$, and grasses; $r = 0.337$, $P > 0.05$). However, the level of correlation varied habitats (Table 5).

Table 5: Correlation between bird diversity and vegetation structure (among six coniferous forests).

Habitat Name	PCC between bird diversity and trees	PCC between bird diversity and shrubs	PCC between bird diversity and grasses & forbs
Sub-tropical coniferous forests (L)	$r = 0.271, P > 0.05$	$r = 0.024, P > 0.05$	$r = 0.210, P > 0.05$
Sub-tropical coniferous forests (S)	$r = 0.193, P > 0.05$	$r = 0.013, P > 0.05$	$r = 0.027, P > 0.05$
Dry-temperate coniferous forest (Z)	$r = 0.408, P > 0.05$	$r = 0.011, P > 0.05$	$r = 0.251, P > 0.05$
Dry-temperate coniferous forest (BG)	$r = 0.318, P > 0.05$	$r = 0.138, P > 0.05$	$r = 0.337, P > 0.05$
Mix dry-temperate coniferous forest (G)	$r = 0.355, P > 0.05$	$r = 0.006, P > 0.05$	$r = 0.081, P > 0.05$
Mix dry-temperate coniferous forest (K)	$r = 0.205, P > 0.05$	$r = 0.011, P > 0.05$	$r = 0.227, P > 0.05$

Comparison of Bird Density among Six Coniferous Forests: Density analysis highlighted that the dry-temperate coniferous forest (BG) was the most densely populated by avian species (5.831 ± 0.694 birds-ha⁻¹), while the mixed dry-temperate coniferous forest ((K) was the least populated (2.654 ± 0.627 birds-ha⁻¹) (Table 6).

Table 6: Bird density among six coniferous forest habitats.

Habitat	Number of Species	Density (birds/ha)
Dry-temperate coniferous forest (Z)	51	4.077 ± 0.362
Dry-temperate coniferous forest (BG)	51	5.831 ± 0.694
Sub-tropical coniferous forests (L)	50	3.187 ± 0.769
Mix dry-temperate coniferous forest (G)	51	4.033 ± 0.987
Sub-tropical coniferous forests (S)	48	3.152 ± 0.658
Mix dry-temperate coniferous forest (K)	44	2.654 ± 0.627

Furthermore, the density test revealed that mixed dry-temperate coniferous forest (G) harbored the highest population of red-vented bulbul (0.952 ± 0.355 ha⁻¹), common starling (0.781 ± 0.261 ha⁻¹), and dark-throated thrush (0.589 ± 0.241 ha⁻¹), while mixed dry-temperate coniferous forest (K) featured the highest bird density of *Oriolus oriolus* (0.848 ± 0.284 ha⁻¹), *Dicrurus macrocercus* (0.790 ± 0.283 ha⁻¹), *Turdus atrogularis* (0.769 ± 0.249 ha⁻¹), *Stumus vulgaris* (0.724 ± 0.174 ha⁻¹), and *Acridotheres tristis* (0.712 ± 0.217 ha⁻¹). Likewise, mixed dry-temperate coniferous forest (K) attracted the higher bird density of *Emberiza cia* (0.965 ± 0.471 ha⁻¹), *Passer montanus* (0.842 ± 0.208 ha⁻¹), *O. oriolus* (0.790 ± 0.256 ha⁻¹), *Turdoides caudata* (0.750 ± 0.112 ha⁻¹), and *Pycnonotus cafer* (0.735 ± 0.689 ha⁻¹). The *P. leucogenys* (0.985 ± 0.362 ha⁻¹), *P. cafer* (0.966 ± 0.320 ha⁻¹), *Lanius tephronotus* (0.915 ± 0.288 ha⁻¹), *Parus cinereus* (0.796 ± 0.285 ha⁻¹), and *Francolinus francolinus* (0.793 ± 0.370 ha⁻¹) densely occupied the sub-tropical coniferous forests (L) habitat. Similarly, sub-tropical coniferous forests (S) was more populated by the Indian paradise flycatcher (0.992 ± 0.291 ha⁻¹), *O. oriolus* (0.926 ± 0.292 ha⁻¹), *P. cinereus* (0.844 ± 0.214 ha⁻¹), *Emberiza cia* (0.793 ± 0.224 ha⁻¹), and *D. macrocercus* (0.772 ± 0.276 ha⁻¹), while dry-temperate coniferous forest (Z) was more populated by the *Trochaloxyton lineatum* (0.896 ± 0.385 ha⁻¹), *P. cafer* (0.867 ± 0.295 ha⁻¹), *Terpsiphone paradisi* (0.841 ± 0.302 ha⁻¹), *Motacilla alba* (0.783 ± 0.125 ha⁻¹), and *F. francolinus* (0.726 ± 0.289 ha⁻¹). However, the densities of 19 species in mixed dry-temperate coniferous forest (Z), 20 species in dry-temperate coniferous forest (BG), 21 species in mixed dry-temperate coniferous forest (K), 17 species in sub-tropical coniferous forests (G), 25 species in sub-tropical coniferous forests (S), and two species in dry-temperate coniferous forest (L) were not determined due to a low number of bird detections, i.e., fewer than five detections (Table 7).

Table 7: Comparison of bird density (birds' ha⁻¹) among six coniferous forest habitats.

Family	Scientific Name	Name of Forest Type					
		Mixed dry-temperate coniferous forest (G)	Dry-temperate coniferous forest (BG)	Mixed dry-temperate coniferous forest (K)	Sub-tropical coniferous forests (L)	Sub-tropical coniferous forests (S)	Dry-temperate coniferous forest (Z)
		Density (birds/ha)					
Accipitridae	<i>Accipiter virgatus</i>	–	–	–	–	–	–
	<i>Elanus caeruleus</i>	–	–	–	–	–	–
	<i>Accipiter badius</i>	–	–	–	–	–	–
Upupidae	<i>Upupa epops</i>	–	–	–	–	–	–
Columbidae	<i>Streptopelia chinensis</i>	–	0.261 ± 0.102	0.622 ± 0.142	0.399 ± 0.210	–	0.677 ± 0.251
	<i>Streptopelia senegalensis</i>	–	0.246 ± 0.164	–	0.272 ± 0.104	–	0.318 ± 0.235
	<i>Streptopelia turtur</i>	–	–	–	0.328 ± 0.108	–	–
	<i>Streptopelia orientalis</i>	0.278 ± 0.144	0.285 ± 0.132	–	–	0.115 ± 0.082	0.274 ± 0.123
	<i>Columba livia</i>	0.234 ± 0.140	0.486 ± 0.252	0.313 ± 0.813	–	–	0.567 ± 0.234
	<i>Columba hodgsonii</i>	–	–	–	–	0.285 ± 0.124	–
	<i>Treron phoenicoptera</i>	–	–	–	–	–	–
Alcedinidae	<i>Halcyon smymensis</i>	–	–	0.142 ± 0.114	–	–	–
Coraciidae	<i>Coracias benghalensis</i>	–	–	–	–	–	–
Meropidae	<i>Merops orientalis</i>	–	–	–	–	–	–
Falconidae	<i>Falco tinnunculus</i>	–	–	–	–	–	–
Phasianidae	<i>Francolinus francolinus</i>	–	0.356 ± 0.274	0.244 ± 0.164	0.793 ± 0.370	–	0.726 ± 0.289
	<i>Coturnix coturnix</i>	0.204 ± 0.111	0.350 ± 0.189	0.326 ± 0.140	0.440 ± 0.174	0.136 ± 0.042	0.142 ± 0.484
Aegithalidae	<i>Aegithalos concinnus</i>	–	–	–	–	–	–
Alaudidae	<i>Galerida cristata</i>	0.216 ± 0.086	–	0.494 ± 0.126	–	–	0.198 ± 0.086
Campephagidae	<i>Pericrocotus flammeus</i>	–	0.225 ± 0.148	0.465 ± 0.146	0.410 ± 0.189	0.674 ± 0.231	0.257 ± 0.142
Certhiidae	<i>Certhia himalayana</i>	–	–	–	0.278 ± 0.144	–	–
Corvidae	<i>Dendrocitta vagabunda</i>	–	0.428 ± 0.248	–	–	–	0.145 ± 0.077
	<i>Garrulus lanceolatus</i>	–	–	–	–	–	–
	<i>Corvus splendens</i>	0.563 ± 0.445	0.263 ± 0.163	–	0.320 ± 0.210	0.379 ± 0.119	0.487 ± 0.213
	<i>Corvus macrorhynchos</i>	–	0.293 ± 0.180	–	0.721 ± 0.251	–	–
Dicruridae	<i>Dicrurus macrocercus</i>	0.399 ± 0.210	0.790 ± 0.283	0.315 ± 0.514	0.166 ± 0.552	0.772 ± 0.276	0.148 ± 0.548
Emberizidae	<i>Emberiza cia</i>	0.410 ± 0.189	0.663 ± 0.128	0.965 ± 0.471	0.490 ± 0.191	0.793 ± 0.224	0.205 ± 0.655
Fringillidae	<i>Carpodacus</i>	0.254 ± 0.106	0.252 ± 0.142	0.515 ± 0.703	0.607 ± 0.251	0.450 ± 0.231	0.174 ± 0.697

	<i>erythrinus</i>						
Hirundinidae	<i>Hirundo rustica</i>	0.431 ± 0.112	0.260 ± 0.180	0.373 ± 0.210	0.158 ± 0.466	0.333 ± 0.118	0.219 ± 0.109
Laniidae	<i>Lanius tephronotus</i>	0.296 ± 0.049	0.464 ± 0.198	0.480 ± 0.566	0.915 ± 0.288	0.295 ± 0.137	0.106 ± 0.085
	<i>Lanius vittatus</i>	–	–	–	–	–	0.260 ± 0.129
Leiothrichidae	<i>Turdoides caudata</i>	0.264 ± 0.103	0.574 ± 0.139	0.750 ± 0.112	0.507 ± 0.234	0.714 ± 0.241	0.229 ± 0.876
Leiothrichidae	<i>Trochalopteron lineatum</i>	0.282 ± 0.120	0.413 ± 0.136	0.415 ± 0.584	0.296 ± 0.149	0.672 ± 0.291	0.896 ± 0.385
Monarchidae	<i>Terpsiphone paradisi</i>	0.346 ± 0.142	0.680 ± 0.126	0.283 ± 0.110	0.145 ± 0.536	0.992 ± 0.291	0.841 ± 0.302
Motacillidae	<i>Motacilla alba</i>	0.320 ± 0.210	0.572 ± 0.272	0.685 ± 0.642	–	–	0.783 ± 0.125
	<i>Motacilla cinerea</i>	–	–	0.168 ± 0.102	–	–	–
Muscicapidae	<i>Myophonus caeruleus</i>	–	–	–	0.346 ± 0.142	–	–
	<i>Copsychus saularis</i>	–	–	–	0.431 ± 0.112	–	–
	<i>Saxicola caprata</i>	0.245 ± 0.129	–	–	0.966 ± 0.320	–	–
Oriolidae	<i>Oriolus oriolus</i>	0.328 ± 0.108	0.848 ± 0.284	0.790 ± 0.256	0.651 ± 0.217	0.926 ± 0.292	0.246 ± 0.182
Paridae	<i>Parus cinereus</i>	–	0.574 ± 0.214	0.366 ± 0.384	–	0.844 ± 0.214	0.133 ± 0.411
Passeridae	<i>Passer montanus</i>	0.291 ± 0.124	0.210 ± 0.168	0.842 ± 0.208	0.267 ± 0.100	0.460 ± 0.094	0.243 ± 0.116
	<i>Passer domesticus</i>	0.231 ± 0.115	0.341 ± 0.149	0.608 ± 0.101	0.648 ± 0.226	0.587 ± 0.149	0.119 ± 0.404
Phylloscopidae	<i>Phylloscopus collybita</i>	–	0.396 ± 0.264	0.261 ± 0.122	0.796 ± 0.285	0.129 ± 0.094	–
	<i>Phylloscopus chloronotus</i>	–	0.192 ± 0.104	–	0.245 ± 0.12	–	–
	<i>Phylloscopus trochiloides</i>	0.131 ± 0.112	–	0.282 ± 0.124	0.282 ± 0.120	–	–
Pycnonotidae	<i>Pycnonotus cafer</i>	0.952 ± 0.355	0.219 ± 0.128	0.735 ± 0.689	0.245 ± 0.129	0.694 ± 0.210	0.867 ± 0.295
	<i>Pycnonotus leucotis</i>	0.272 ± 0.104	0.135 ± 0.147	0.585 ± 0.597	–	–	–
	<i>Pycnonotus leucogenys</i>	0.167 ± 0.134	–	0.386 ± 0.136	0.985 ± 0.362	0.128 ± 0.102	–
Sturnidae	<i>Acridotheres tristis</i>	0.170 ± 0.987	0.712 ± 0.217	0.658 ± 0.108	0.463 ± 0.159	0.716 ± 0.185	0.178 ± 0.723
	<i>Sturnia pagodarum</i>	–	0.206 ± 0.121	0.296 ± 0.148	0.167 ± 0.134	–	0.234 ± 0.096
	<i>Sturnus vulgaris</i>	0.781 ± 0.261	0.724 ± 0.174	0.415 ± 0.719	0.632 ± 0.193	0.476 ± 0.270	0.173 ± 0.572
Turdidae	<i>Turdus atrogularis</i>	0.589 ± 0.241	0.769 ± 0.249	0.254 ± 0.113	0.462 ± 0.110	0.582 ± 0.283	0.232 ± 0.916

Discussions

Subtropical, dry–temperate and mixed dry–temperate coniferous forests are known as the most productive habitats harboring a higher avian assemblage of endemic and threatened species (Joshi et al., 2012). They are diverse in a topography supporting luxuriant (thick and healthy) vegetation that forms mosaics and provides vital resources for a wide array of avian species (Myers et al., 2000; Elsen, et al., 2017; Elsen et al., 2018). Ascertaining the bird population parameters, vegetation structure, and food resources is crucial for indicating the habitat suitability and productivity of a forest ecosystem (Karubian et al., 2005; Cassey et al., 2007; Amar et al., 2008; IUCN, 2011). Furthermore, the vegetation structure and composition could help our understanding the bird species diversity pattern (Vetaas and Grytnes, 2002; Rahbek, 2005; Grytnes and McCain, 2007).

Most bird species are habitat specialists, i.e., they utilize different layers of vegetation for foraging, shelter, and breeding purposes. Some avian species prefer the forest floor (e.g., common babblers, common quails, common hoopoe, magpie robins, blue whistling thrush, and pied bushchat), while others utilize the

tree canopy, i.e., Indian paradise flycatchers, scarlet minivets, golden orioles, cinereous tits, yellow-footed green pigeon, speckled wood pigeon, streaked laughing thrush, and common rosefinch (Gardner et al., 2009; Malhi et al., 2014).

Notably, the food resources among the six coniferous forests are not distributed uniformly and may vary from area to area, depending on topography, microclimate, altitude, and vegetation structure and composition. Likewise, the bird relative abundance among these six forests also varies. The highest relative abundance was detected in dry-temperate coniferous forest (BG) and the lowest was detected in mix dry-temperate coniferous forest (G). This result indicated that the birds often select an area on the basis of proximate factors, i.e., landscape, terrain, substrate, microclimate, characteristics, extent of the disturbance, predation, and occurrence of food resources. These factors determine avian community parameters such as diversity, density, and distribution. Another reason could be that the floristic diversity shaping the forest structure influenced the bird population structure. Blake (2007) reported that the bird relative abundance and species composition might vary due to vegetation structure and complexity.

The “highest” bird density was estimated in the dry-temperate coniferous forest (BG) as compared to the other habitats. The higher bird density in dry-temperate coniferous forest (BG) was due to the occurrence of fruiting trees (e.g., *Ficus carica*, *Morus alba*, and *M. nigra*), shrubs (i.e., *Ziziphus nummularia*, *Reptonia muscatencesea*, *Berberis lyceum*, *Gymnosporia royleana*, *Zanthoxylum alatum*, and *Myrtus communis*), grasses, *Solanum nigrum*, and flowering trees (i.e., *Acacia modesta* and *Ailanthus altissima*) that provide adequate food sources to harbor the denser avian population. The dark-throated thrush, blue whistling thrush, and streaked laughing thrush prefer shrubs in their search for insects, arachnids, and berries. Likewise, the red-vented bulbul, Himalayan bulbul, and white-eared bulbul often utilizes fruiting trees and shrubs for berries and grasses for insects (Brooks, 2013; Old et al., 2014; Barnagaud et al., 2014; Thibault et al., 2018).

As well, the dry-temperate coniferous forest (BG) was rich in bird species. The richness was due to the complex structure and composition of the vegetation, which attracted the greatest richness of the avian species. For instance, trees that carry nuts (*P. wallichiana*), juicy and fleshy fruits (*M. alba*, *M. nigra*, *A. modesta*), shrubs that carries the berries (*Z. alatum*, *S. nigrum*), plums (*B. lyceum* and *M. communis*), grasses bears flowers (*Verbascum thapsus*, *Ranunculus acris*, *S. media*) and herbs that carry cereals (*P. aviculare*, *R. dentatus*, *C. montanus*, and *Heteropogon contortus*). It was previously reported that bird species often prefer to use a complex habitat that is more diverse in vegetation composition and rich in food resources (Wu et al., 2013; Joshi and Bhatt, 2015; Saha et al., 2016). Likewise, Casas et al. (2016) stated that the vegetation structure and composition offer ideal weather conditions, adequate food resources (fruits and insects), and suitable breeding sites to harbor a wide array of avian populations to perform multiple activities.

Foraging guild results demonstrated that Indian paradise flycatchers selected pine trees for perching after sallying. During sallying, they catch insects while flying (Gokula and Vijayan, 2003; Rassussen and Anderton, 2012; Das and Adhikari, 2019), such as flies, bugs, beetles, spiders, moths, butterflies, and damselflies. The scarlet minivet prefers the tree crown for foraging and perching. It was observed that minivets flushed insects such as flies, moths, grasshoppers, crickets, cicadas, and caterpillars in foliage through gleaning in the crown and caught them on while flying. Likewise, the Eurasian golden oriole and common starlings used common fig, wax apple, and barberry to consume a wide array of fruits and berries, and prey on insects, especially caterpillars. The wax apple populated degraded habitats such as forest edges and mixed vegetation for foraging, particularly on insects (including dragonflies, honeybees, grasshoppers, moths, beetles, and crickets), through sallying, gleaning, and hovering (Somasundaram and Vjayan, 2008). They mainly utilized forest edges and cultivated areas to forage on a variety of food items, i.e., fruits, lizards, rodents, and large insects.

Notably, the black francolin, common quail, and bay-backed shrike were confined to forest edges, shrubs, and grasses, as these are a shy species with secretive behavior. Another reason may be that the forest edges provide cover from predators (Fuisz and Yosef, 1998; Pande et al., 2004; Antczak et al., 2005). Furthermore, the white-throated kingfisher selected riparian habitats and forest edges for perching and foraging (Asokan and Ali, 2010; Coulombe et al., 2011; Kesler, 2012). Moreover, other birds, for instance, the greenish warbler, preferred to use conifer trees for foraging. During foraging, they glean in the crown to prey on midges, caterpillars, beetles, leafhoppers, bugs, wasps, moths, and spiders. However, sometimes, these birds sail in dense shrubs to catch insects on their wing (Johnson and Sherry, 2001). Likewise, the bar-tailed tree creeper also selected coniferous trees for foraging. Upon reaching the top of the conifer through progressive hops, they then fly down to the base of the next tree trunk and start climbing again in a spiral fashion in their search for food (i.e., insects, caterpillars, and spiders).

Apparently, the speckled wood pigeon and rock pigeon were concentrated in fruiting trees and shrubs (i.e., common fig, wind prickly ash, yellow Himalayan raspberry, and barberry) to forage for berries and fleshy fruits. Likewise, the European turtle dove, oriental turtle dove, and spotted dove preferred grounds to feed on grains and seeds of grasses (e.g., pine woods drop seed, beard grass, milkweed, and wild sunflower). The variation in habitat selection and food utilization showed that habitat structure, land-use pattern, and food resources are the major driving factors that significantly influence the habitat use and distribution of avian species (Casas et al., 2016). It could be that the heterogeneity in vegetation composition enables the formation of complex habitats (Hu et al., 2018), which harbor a higher avian diversity (Jankowski et al., 2009; Kissling et al., 2010; Paudel and Vetaas, 2014).

Conclusions

Based on the findings of this study, dry-temperate coniferous forest (BG) is rich in vegetation species composition and represents a highly productive habitat for a variety of avian species, compared to the other coniferous forests. The occurrence of birds reflects the forest stand structure, site productivity (food resources), vegetation composition, and distribution pattern. Furthermore, it was observed that the vegetation composition and food resources are the major driving factors affecting the habitat selection and home range of avian species. Hence, special attention should be given to the dry-temperate coniferous forest (BG) in order to maintain its high quality and productivity, which are essential for future conservation efforts aimed at harboring a high avian population. This could be that, it is dominated by broadleaf tree species; *Ficus carica*, *Morus Alba*, *M. nigra*, *Acacia modesta* and *Eucalyptus camaldulensis* and shrub vegetation, i.e., *Reptonia muscatencesea*, *Berberis lyceum*, *Dodonaea viscosa*, *Zanthoxylum alatum* and *Myrtus communis* that offer suitable foraging and safe hideout for avian species. Furthermore, the understorey vegetation is comprised of *Solanum nigrum*, *Verbascum thapsus*, *Ranunculus*

muricatus, *Polygonum aviculare* *Rumex dentatus* and grasses like *Cynodon dactylon*, *Heteropogon contortus*, *Chrysopogon fulvus* and *Miscanthus nepalensis* that bear a variety of grains and attracted a variety of insects that is a staple diet of avian species. Furthermore, going forward, the remaining coniferous forests can be declared as protected habitats to enhance their healthy avian population.

Abbreviations

IUCN = International Union for Conservation of Nature, CAP = Community Analysis Package, BG = Baber Gakhai, L = Laram, S = Shengari, Z = Zarback, G = Gulabad, K = Khanpur, LC = Least Concern, VU = Vulnerable, N = North, E = East, m = Meter, asl = Above sea level and ANOVA = Analysis of Variance

Declarations

Consent for Publication: We are agreed to publish entitle “Assessing the habitat suitability of six coniferous forests using avian assemblages at high altitude ecosystem” manuscript under BMC Ecology and Evolution.

Availability of data and material: All data and material is available

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Authors' Contribution:

- a) Rajpar, M.N.: Designed the study and wrote the manuscript
- b) Khan, S.A.: Collected and analyzed the data
- c) Ullah, S. Prepared the map and help in data analysis
- d) Rajpar, A.H.: help in data analysis and English editing
- e) Zakaria, M.: Reviewed and edited the manuscript

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Figures

Figure 1

Map of the study area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Rank relative abundance curve indicating difference in bird assemblages among habitats