EXPLORING AVIAN ECOLOGY, HABITAT ASSOCIATIONS, AND CORRELATIONS WITH VEGETATION STRUCTURE IN BADGOI CONIFEROUS FOREST, UPPER DIR, KHYBER PAKHTUNKHWA, PAKISTAN

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(Received 31st Jan 2024; accepted 3rd May 2024)

Abstract. In avian ecosystems, habitat dynamics significantly influence bird activities. This study was conducted from July to November 2019 in the Badgoi coniferous forest, Upper Dir, Khyber Pakhtunkhwa, Pakistan. Distance Sampling Point Count method was utilized in the study to quantify the correlation between bird abundance and habitat structure. Meticulously observing 485 birds spanning 28 species and 20 families, dominant species included the Common Raven (14.4%), Pine Siskin (11.30%), and House Sparrow (10.72%). Conversely, the Red Crossbill, Gray-back Shrike, and Yellow Tit emerged as the rarest inhabitants (0.4%, 0.2%, each). Blue Kail dominated the botanical landscape at 14.599%, while Chinar stood as the rarest species (7.299%). Shrubbery diversity showcased Simru as the most abundant (14.038%) and Kala Simlu as the rarest (6.836%). Correlational analyses highlighted the intimate association between bird species and ecological components, including vegetation structure and microclimate variables. Density analysis unveiled species-specific variations in populations, emphasizing diverse foraging guilds and nuanced resource utilization. The study sets the groundwork for future research, emphasizing genetics, advanced monitoring technologies, and collaborative conservation efforts, contributing to the long-term well-being of bird populations in the Badgoi forest.
Keywords: *avian dynamics, habitat correlation, flora composition, Badgoi ecosystem, Upper Dir biodiversity, avian population ecology*

Introduction

In the intricate tapestry of nature, habitats emerge as the lifelines for bird species, providing a crucial backdrop for their survival and varied activities. A habitat, often regarded as the cradle of life, serves as a haven where birds secure resources like food, cover, water, and space. This critical role underscores the essential interconnection between avian life and the specific environments they inhabit. Birds, being discerning dwellers, showcase a spectrum of habitat preferences. Some exhibit a penchant for unique habitats, while others navigate various landscapes for their survival needs. The specificity of a bird species' habitat is not arbitrary; it directly influences their ability to perform crucial activities and fulfil functional roles like seed dispersal, pest control, and pollination.

The selection of habitats among avian species, as illuminated by Bradstock et al. (2002), is a nuanced process influenced by factors such as the species' requirements,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32853301

vegetation cover percentage, food resource availability, and the severity of disturbances and surrounding landscapes. The diversity and richness of bird species may burgeon with habitat heterogeneity, rich food resources, and secure breeding sites, as articulated by Hino et al. (1985) emphasizing the importance of floristic diversity in harbouring avian diversity.

Birds, in their vibrancy and gregarious nature, act as bio-indicators of the health and productivity of coniferous habitats. Their close association with habitat characteristics, noted by Karr et al. (1990), renders them easily detectable and instrumental in understanding population structures. This understanding, as emphasized by Novell et al. (2003), forms a key tool for unravelling population trends and relationships, guiding future conservation and management efforts (Wiens, 1992; Caziani et al., 2000; Sauer et al., 2002). Rajpar et al. (2015) explored the correlation between bird abundance, microclimate, and habitat variables in open areas and shrublands, unveiling the significant impact of microclimate and vegetation structure on bird population structure. Similarly, Zakaria et al. (2011) delved into the correlation between bird abundance, microclimate, and habitat variables in Peninsular Malaysia’s wetlands, revealing the positive influence of habitat characteristics on bird distribution, diversity, and density. Examining the effects of vegetation structure in a tropical savannah woodland, Tassicker et al. (2006) demonstrated the intricate relationship between bird species composition, richness, and frequency with vegetation structure. They highlighted the potential advantage for some avian species with increasing floristic density, while mechanical modifications impacted flora and avian species richness.

The research by Shoji et al. (2002) delved into the impact of forest shape on the habitat selection of birds across seasons, emphasizing the negative effects on forest avian species during breeding seasons compared to migratory seasons. In a vegetation gradient study in the Andes of central Chile, Marfán (1997) explored bird habitat relationships, revealing that avian species diversity was less related to vegetation due to the unusual forest pattern. Vegetation height diversity emerged as a critical factor explaining avian species richness. Menaa et al. (2016) investigated the richness and habitat relationships of forest birds in the Zen oak woodland in northeastern Algeria, highlighting the importance of vegetation composition, including trees, shrubs, and herbs, for avifauna diversity.

Subalpine forests, characterized by diverse coniferous trees, shrubs, and ground vegetation, present a unique ecosystem in higher elevations. Despite their significance, these subalpine habitats have received less attention compared to wetlands (Hunter et al., 2001; Peterjohn, 2006). The conversion of large forest tracts into agricultural fields poses a threat to bird species, causing habitat loss and degradation (Wang et al., 2003; Peh et al., 2006), which ultimately reduced the shelter, breeding grounds and foraging sites (Harris and Pimm, 2004; Gray et al., 2007). This transformation endangers the survival of bird species, pushing some towards extinction (Azman et al., 2011). Our research aims to shed light on the critical importance of subalpine habitats and the urgent need for conservation efforts to protect the rich biodiversity they harbour.

Between alpine pastures and temperate coniferous forests, subalpine forests form a unique ecosystem characterized by a diverse array of plant species influenced by site quality and topography. This study holds paramount importance as it seeks to unravel the ecological intricacies of subalpine forests and assess their suitability as habitats for

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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avian species. The research objectives include a comprehensive examination of the distinctive features defining these ecosystems, particularly the distribution and characteristics of diverse plant species. Simultaneously, the study aims to evaluate the suitability of subalpine forests as homes for avian communities, shedding light on the intricate relationship between the environment and diverse bird life. This research contributes crucial insights for the conservation of subalpine ecosystems, emphasizing the need to preserve these delicate landscapes as vital habitats for both flora and vibrant feathered inhabitants.

Materials and methods

Study area

The research was conducted in the Badgoi Forest, a sprawling expanse covering 5,664 acres located in the Upper Dir district of Khyber Pakhtunkhwa Pakistan, approximately 7 km away from Thal at coordinates N: 35029.541' latitude and E: 072019.518' longitude (*Figs. 1* and *2*). This forested region falls within the administrative jurisdiction of the Dir Kohistan Forest Division. The study area consists of two distinct compartments. The subalpine coniferous forest is characterized by a diverse vegetation profile, including notable tree species such as Silver Fir (*Abies pindrow*), Spruce (*Picea smithiana*), and Kail (*Pinus wallichiana*). Additionally, the forest harbors various shrubs, such as Garden Sage (*Salvia officinalis*) and Rose Noble (*Scrophularia nodosa*), along with herbaceous plants like Mountain Balm (*Calamintha grandiflora*) and Pepperidge Bush (*Berberis vulgaris*), among others. The management and conservation of this ecologically significant area fall under the purview of the Dir Kohistan Forest Division.

Methods

Birds survey

Avian species within the study area were documented using the Distance Sample Point Count Method. A total of twenty-two-point count stations were strategically established at intervals of 250 m to prevent the duplication of bird observations. Bird surveys were conducted during the early morning hours, specifically from 7:00 AM to 10:00 AM, ensuring optimal observation conditions. Each point count station was observed for 15 min to record bird occurrences accurately. Species identification was facilitated through consultation with the field guide "The Birds of Indo Pak," following the methodology outlined by Thomas et al. (2010) and Gottschalk and Huettmann (2010).

Vegetation survey

The Quadrat Method, employing plots of 10 m x 10 m for trees, 5 m x 5 m for shrubs, and 1 m x 1 m for grasses, herbs, and bushes, was concurrently utilized with the bird point count stations. This widely recognized method is frequently employed for vegetation composition surveys across diverse habitats. A total of sixty-six quadrant plots were sampled, including 22 plots each for trees, shrubs, and herbs/bushes. The methodology for vegetation assessment adhered to the protocols outlined by Hudon et al. (1997), Fernandez et al. (2002), and Isacch et al. (2005).

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Site selection

The sampling sites within the Badgoi coniferous forest were carefully selected to ensure the representation of the diverse habitat features existing in the study area. The selection procedure elaborates the reflection of several criteria to capture the variability of habitats colonized by avian species. Firstly, vegetation density was considered a key factor in manipulating bird abundance and diversity. Sampling sites were chosen to include a range of vegetation densities, from densely forested areas to more open habitats, to capture the full spectrum of avian habitat preferences. Secondly, topography plays a crucial role in site selection, as it influences microclimate conditions and habitat structure. Sites were selected to represent different topographic features, comprising ridges, valleys, and slopes, to account for potential variances in bird species composition and distribution through different elevation gradients. Accessibility was also taken into account during site selection to ensure the viability of field surveys and data collection. Sites were chosen based on their accessibility via established trails or paths within the forest, facilitating efficient sampling efforts while reducing disturbance to the natural habitat.

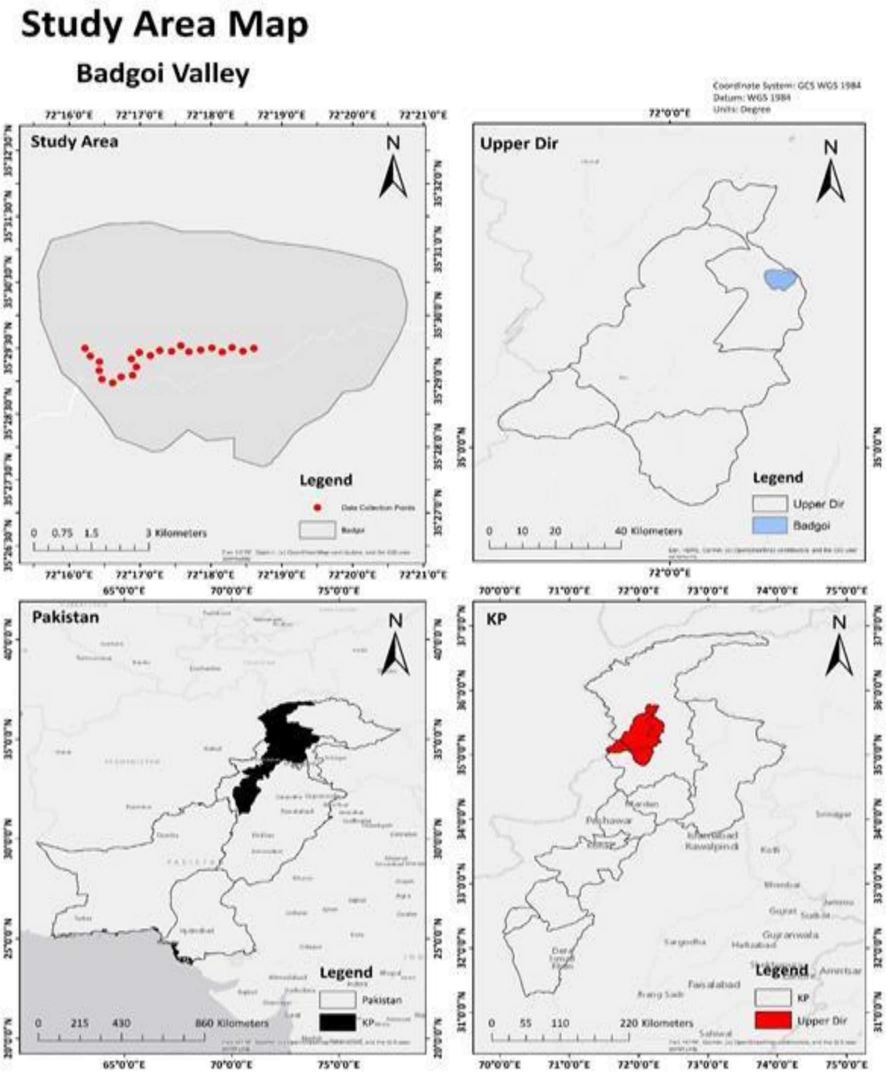

Figure 1. *Map of the study area (Badgoi coniferous forest)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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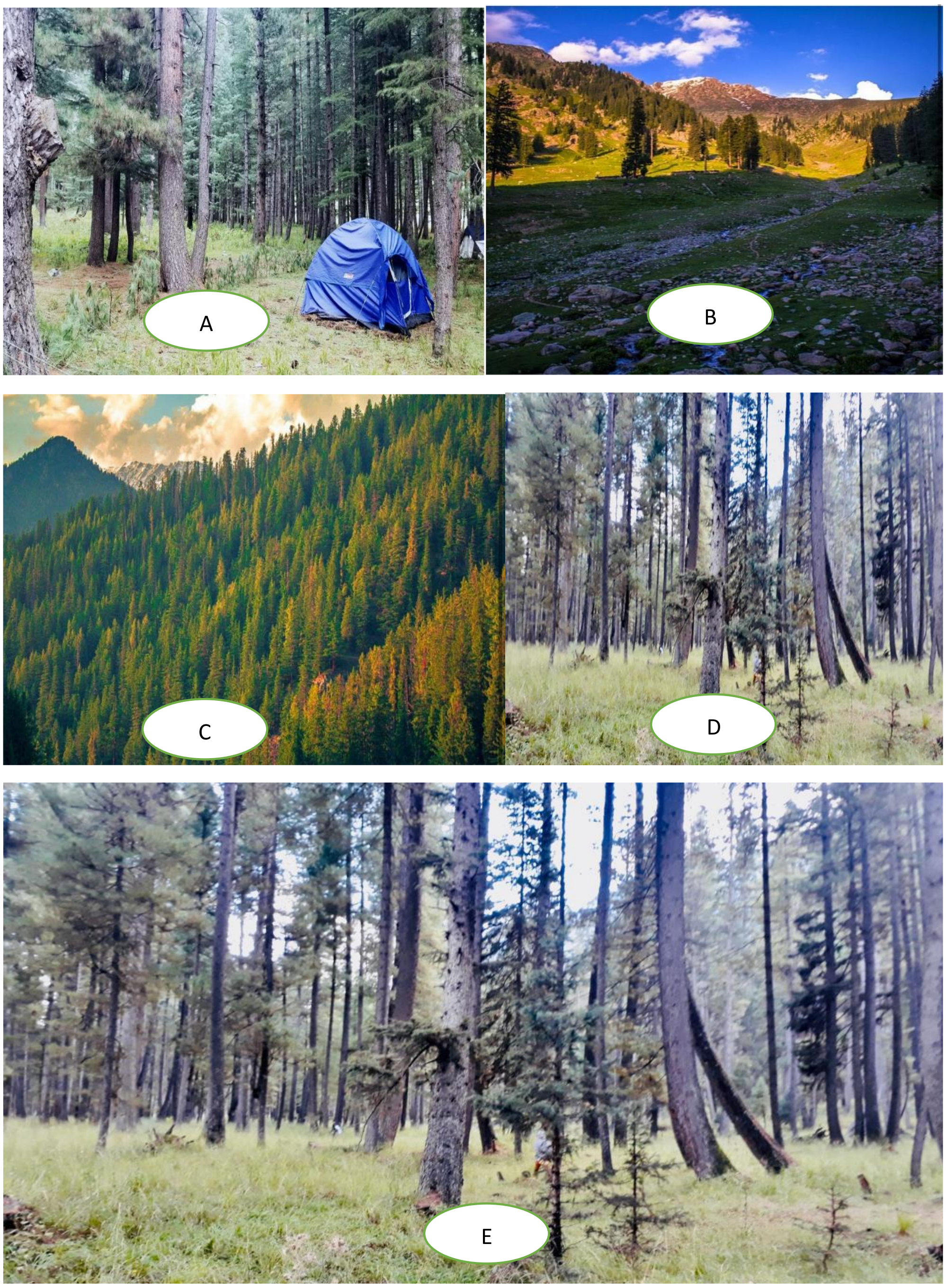

Figure 2. *Scenic view of Badgoi coniferous forest*

Timing of observations and surveys

The field observations and floristic surveys were conducted from July to November 2019. Bird counts were conducted regularly throughout this period to capture seasonal variations in bird abundance and behaviour. Additionally, the floristic surveys were carried out parallel with the bird surveys to calculate vegetation composition and structure. The surveys were not conducted only once but were repeated several times to ensure comprehensive coverage of the study area and to account for temporal variability in bird populations and vegetation dynamics.

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Methods of bird species determination

Bird species were determined through a combination of visual observation and sound detection methods. Visual identification was supplemented by the use of audio recordings to confirm the presence of certain species, especially those with distinct vocalizations. This approach ensured accurate species identification and increased the reliability of the data collected.

Recording of climatological parameters

The meteorological variables, including temperature and relative humidity, were recorded using data loggers strategically placed within the study area. These data loggers were programmed to capture environmental conditions at regular intervals throughout the study period, ensuring comprehensive coverage of climatic variations. Detailed information regarding the timing and methodology of data collection for climatological parameters will be explicitly outlined in the Materials and Methods section.

Recording of climatological parameters

In addition to temperature and relative humidity, wind speed was also recorded using data loggers strategically placed within the study area. These data loggers were programmed to capture wind speed measurements at regular intervals concurrent with the recording of temperature and humidity. The inclusion of wind speed data aims to provide a more comprehensive understanding of microclimate variability and its potential influence on bird species occurrence.

Statistical method

The data obtained from bird surveys and vegetation assessments were subjected to rigorous statistical analysis to elucidate key patterns and relationships. Descriptive statistics, including mean, standard deviation, and frequency distributions, were calculated to characterize bird abundance and vegetation composition. Additionally, inferential statistical methods such as correlation analysis and regression modelling were employed to investigate associations between bird occurrence and habitat characteristics. All statistical analyses were conducted using software R (version 4.3.2) with significance levels set at $\alpha = 0.05$ unless otherwise stated.

Results

Bird relative abundance

A total of 485 individual birds, representing 28 species and 20 families, were documented in the Badgoi coniferous forest. The study identified Common Raven (*Corvus corax*) as the most prevalent species, constituting 14.4% of the total bird population. Pine Siskin (*Spinus pinus*) and House Sparrow (*Passer domesticus*) were also prominent, comprising 11.30% and 10.72% of the observed individuals, respectively. Conversely, Red Crossbill (*Loxia curvirosta*), Gray-Back Shrike (*Lanius tephronotus*), and Yellow Tit (*Parus holsti*) were identified as the least common bird species in the Badgoi coniferous forest, each representing only 0.4%, 0.2%, and 0.2%, respectively (*Table 1*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Table 1. *Relative abundance of bird species detected in Badgoi coniferous forest*

Family	Scientific name	Common name	Detections	%
Corvidae	*Corvus corax*	Common raven	70	14.4
Fringillidae	*Spinus pinus*	Pine siskin	55	11.30
Passeridae	*Passer domesticus*	House sparrow	52	10.72
Prunellidae	*Prunella modularis*	Dunnock	36	7.42
Paridae	*Poecile gambeli*	Mountain chickadee	32	6.59
Columbidae	*Columba palumbus*	Common woodpigeon	30	6.18
Sturnidae	*Acridotheres tristis*	Common myna	24	4.94
Acrocephalidae	*Iduna caligata*	Booted Warbler	19	3.91
Picidae	*Colaptes auratus*	Northern flicker	19	3.91
Lybiidae	*Lybius undatus*	Banded barbet	18	3.71
Lybiidae	*Tricholaema melanocephala*	Black-throated barbet	18	3.71
Corvidae	*Perisoreus canadensis*	Gray jay	18	3.7
Passerellidae	*Passerella iliaca*	Fox sparrow	16	3.29
Locustellidae	*Locustella ochotensis*	Grasshopper warbler	13	2.68
Corvidae	*Nucifraga columbiana*	Clarks Nutcracker	11	2.26
Certhidae	*Certhia familiaris*	Eurasian treecreeper	10	2.06
Cinclidae	*Cinclus mexicanus*	American dipper	7	1.44
Upupidae	*Upupa epops*	Common hoopoe	7	1.44
Lybiidae	*Pogoniulus simplex*	Green tinkerbird	5	1.03
Cardinalidae	*Piranga ludoviciana*	Western tanager	5	1.03
Peucedramidae	*Peucedramus taeniatus*	Olive Warbler	4	0.8
Tyrannidae	*Empidonax traillii*	Willow Flycatcher	4	0.8
Prunellidae	*Prunella rubida*	Japanese accentor	3	0.6
Cuculidae	*Eudynamys scolopaceus*	Common Koel	3	0.6
Lybiidae	*Stactolaema olivacea*	Green barbet	2	0.4
Fringillidae	*Loxia curvirosta*	Red crossbill	2	0.4
Laniidae	*Lanius tephronotus*	Gray-backed shrike	1	0.2
Paridae	*Parus holsti*	Yellow tit	1	0.2
	Total		**485**	

Vegetation structure and composition

Utilizing the quadrant method, eight tree species belonging to five families were identified within the study area. Blue Kail (*Pinus wallichiana*) emerged as the most dominant tree species, constituting 14.599% of the total documented tree population, while Chinar (*Platanus orientalis*) stood out as the rarest, representing 7.299%. In the realm of shrubs, Simru (*Rhododendron campanulatum*) exhibited the highest abundance, comprising 14.038% of the shrub species observed, whereas Kala Simlu (*Berberis lyceum*) held the distinction of being the rarest, representing 6.836%. The herbaceous layer of the Badgoi coniferous forest showcased Calamint (*Calamintha grandiflora*) as the most prevalent species, accounting for 41.267% of the herb population, while Yarrow (*Achillea millefolium*) claimed the status of the rarest herb, representing 6.334% (*Table 2*).

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***Table 2.** Vegetation structure and composition of Badgoi coniferous forest*

Family	Scientific name	Common name	Total number	%
Tree species				
Pinaceae	*Pinus wallichiana*	Blue kail	120	14.599
Pinaceae	*Abies pindrow*	Silver fir	118	14.355
Oleaceae	*Fraxinus spp.*	Ash tree	117	14.234
Salicaceae	*Salix tetrasperma*	Indian willow	115	13.990
Pinaceae	*Cedrus deodara*	Deodar	109	13.260
Pinaceae	*Picea smithiana*	Spruce	100	12.165
Rosaceae	*Pyrus pashia*	Himalayan pear	83	10.097
Platanaceae	*Platanous orientalis*	Chinar	60	7.299
		Sub-total	**822**	
Shrub species				
Ericaceae	*Rhododendron campanulatum*	Simru	154	14.038
Ericaceae	*Uva ursi*	Bearberry	127	11.577
Caprifoliaceae	*Lonicera caucasica*	Trumpet honeysuckle	116	10.574
Lamiaceae	*Thymus vulgaris*	Garden thyme	115	10.483
Asteraceae	*Petasites frigidus*	Arctic butterbur	115	10.483
Cuperssaceae	*Juniperus macropoda*	Pashtun juniper	113	10.301
Adoxaceae	*Viburnum nervosum*	Cranberry bush	109	9.936
Rosaceae	*Crataegus monogyna*	May blossom	82	7.475
Rosaceae	*Cotoneaster spp.*	Cotoneaster	81	7.384
Berberidaceae	*Berberis lycium*	Kala simlu	75	6.836
		Sub-total	**1097**	
Herb species				
Lamiaceae	*Calamintha grandiflora*	Calamint	215	41.267
Brassicaceae	*Cardamine pratensis*	Mayflower	140	26.871
Lamiacea	*Nepeta cataria*	Catnip	133	25.527
Asparagaceae	*Scilla forbesii*	Glory of snow	87	16.699
Asteraceae	*Achillea millefolium*	Yarrow	33	6.334
		Sub-total	**521**	

Correlation between birds and trees

The correlation between birds and trees was assessed through Constrained Redundancy Ordination (RDA) in consideration of a small beta value (<3). The first two axes of the RDA yielded explanatory percentages of 88.0% and 85.0%. The RDA biplot diagram revealed a close correlation between birds and trees, as detailed in *Table 3*.

***Table 3.** Summary table of RDA coordination for birds and tree species in Badgoi coniferous forest*

Axes	1	2	3	4	Total inertia
Eigenvalues	0.121	0.086	0.062	0.040	1.000
Specie environment correlation	0.881	0.858	0.783	0.704	
Cumulative % variance of species data	12.1	20.7	26.9	31.0	
Cumulative % variance of specie-environment relation	30.6	52.1	67.9	78.0	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					0.397

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The RDA biplot diagram revealed distinctive associations between avian species and specific tree types. Booted Warblers, Japanese Accentors, and Green Thunderbirds exhibited close correlations with Indian Willow and Silver Fir trees. Grasshopper Warblers and Dunnocks displayed a strong association with Blue Kail, while Pine Siskin and Fox Sparrows were linked with Himalayan Pear. Northern Flickers demonstrated a pronounced relationship with Chinar, while Common Ravens indicated an association with Spruce, and Eurasian Tree creepers exhibited a connection with Ash Trees. Gray Jays, Common Koels, and Common Mynas displayed a robust association with Deodar trees. Clarks Nutcrackers and Mountain Chickadees showcased a close link with Silver Fir trees, as illustrated in *Figure 3*.

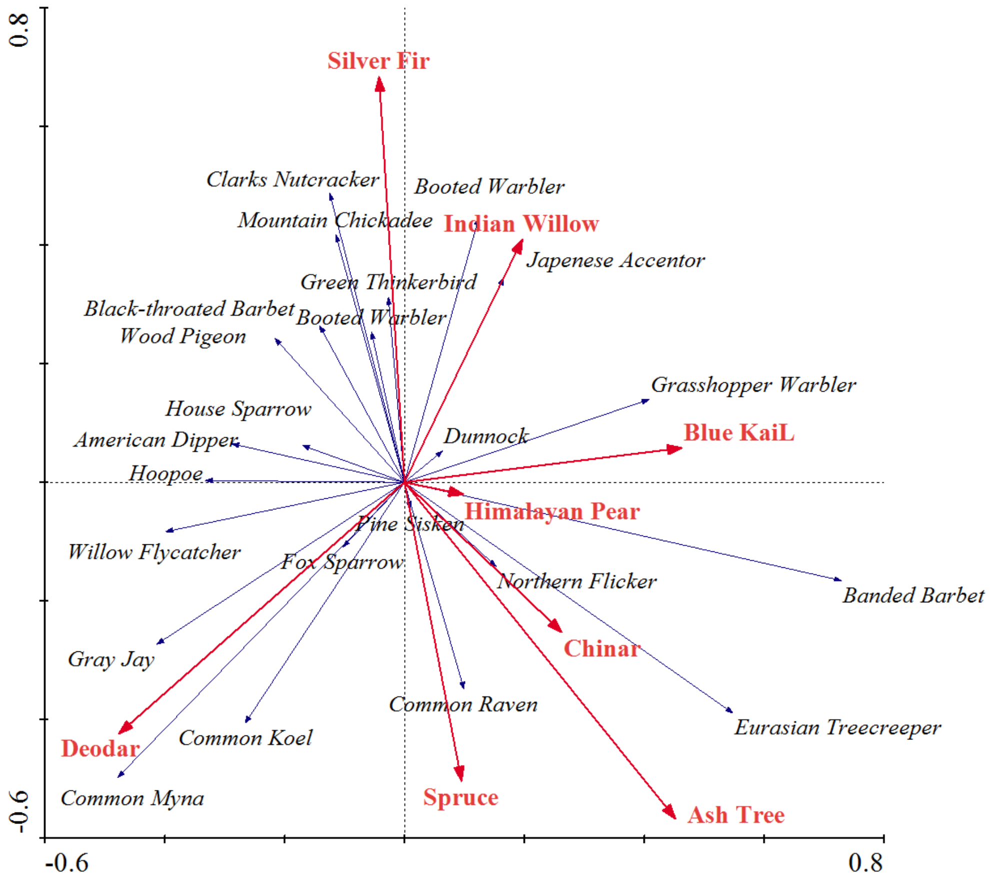

Figure 3. *Biplot of correspondence analysis, showing the association between Avian species and their preferred arboreal habitat*

Correlation ship between birds and shrubs

The analysis of the relationship between birds and shrubs within the Badgoi coniferous forest was conducted using Constrained Redundancy Ordination (RDA), a method chosen based on a beta level of less than 3. The explanatory power of the first two axes in the RDA biplot diagram was determined to be 93.0% and 90.0%, respectively. These axes provided insights into the association between birds and shrub species, as highlighted in the RDA biplot diagram. The results underscored that the distribution of bird species was significantly influenced by the presence and composition of shrub species, as detailed in *Table 4*.

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DOI: http://dx.doi.org/10.15666/aeer/2204_32853301

Table 4. *Summary table of RDA coordination for birds and shrub species in Badgoi coniferous forest*

Axes	1	2	3	4	Total inertia
Eigenvalues	0.154	0.105	0.075	0.057	1.000
Specie environment correlation	0.933	0.903	0.872	0.828	
Cumulative % variance of species data	15.4	25.9	33.4	39.1	
Cumulative % variance of species–environment relation	28.6	48.0	61.9	72.4	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					0.540

The RDA ordination biplot depicting the relationship between bird and shrub species in the Badgoi coniferous forest revealed distinctive associations. Notably, the Black-throated Barbet exhibited an association with the Pashtun Juniper, while the Mountain Chickadee, Dunnock, and Japanese Accentor demonstrated an affinity with Simru. Similarly, Gray Jay, Clarks Nutcracker, and Grasshopper Warbler displayed a connection with Kala Simlu and Bearberry shrubs. Positive relationships were identified between Green Thinker birds and House Sparrows with Cotoneaster shrubs, while Booted Warbler exhibited a strong association with Arctic Butterbur. Banded Babbler and Eurasian Tree creeper were correlated with Garden Thyme and Cranberry’s. American Dipper, Wood Pigeons, Northern Flicker, Common Raven, Pine Siskin, and Common Koels indicated a correlation ship with May Blossom. Additionally, Willow Flycatcher, Northern Flickers, and Fox Sparrows exhibited a strong correlation ship with honeysuckle shrubs, as illustrated in *Figure 4*.

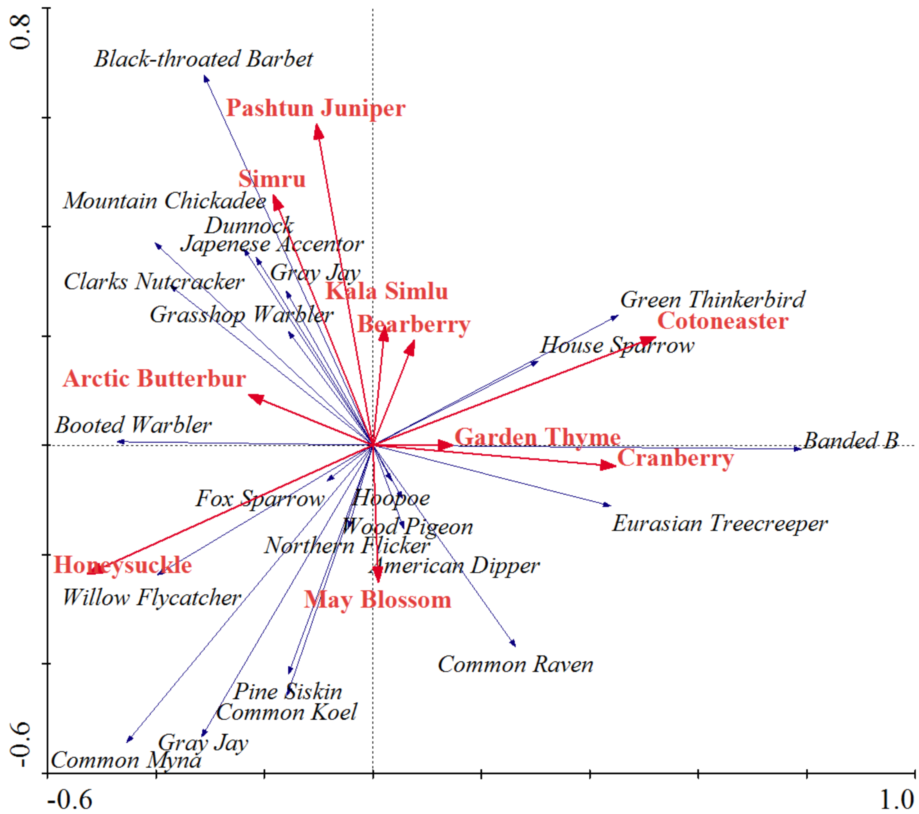

Figure 4. *Biplot of the correspondence analysis, showing the association between avian species and shrub*

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Correlation ship between birds and herbs

The effects of herbs on bird distribution were determined by using Constrained Redundancy Ordination (RDA). RDA was applied due to a beta level of less than three. The first two axes indicated that all variables could be explained by utilizing the RDA biplot diagram. Results show that birds were influenced by herb species from 74.0 to 87.0% respectively (*Table 5*).

Table 5. *Summary table of RDA coordination for birds and herb species in Badgoi coniferous forest*

Axes	1	2	3	4	Total inertia
Eigenvalues	0.119	0.059	0.51	0.039	1.000
Specie environment correlation	0.878	0.741	0.855	0.704	
Cumulative % variance of species data	11.9	17.7	22.8	26.7	
Cumulative % variance of specie-environment relation	40.5	60.6	78.1	91.3	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					0.293

The ordination biplot depicting the relationship between birds and herbs in the Badgoi coniferous forest revealed distinct associations. Eurasian Tree creepers and Banded Barbet were strongly associated with Catnip and Calamint herb species. House Sparrows indicated a correlation ship with the Mayflower. Moreover, Wood Pigeons, Hoopoes, and Black-throated Barbets showed a strong correlation ship with Glory of Snow herbs. American Dippers and Green Thinker birds demonstrated a close relationship with Yarrow herbs, as illustrated in *Figure 5*.

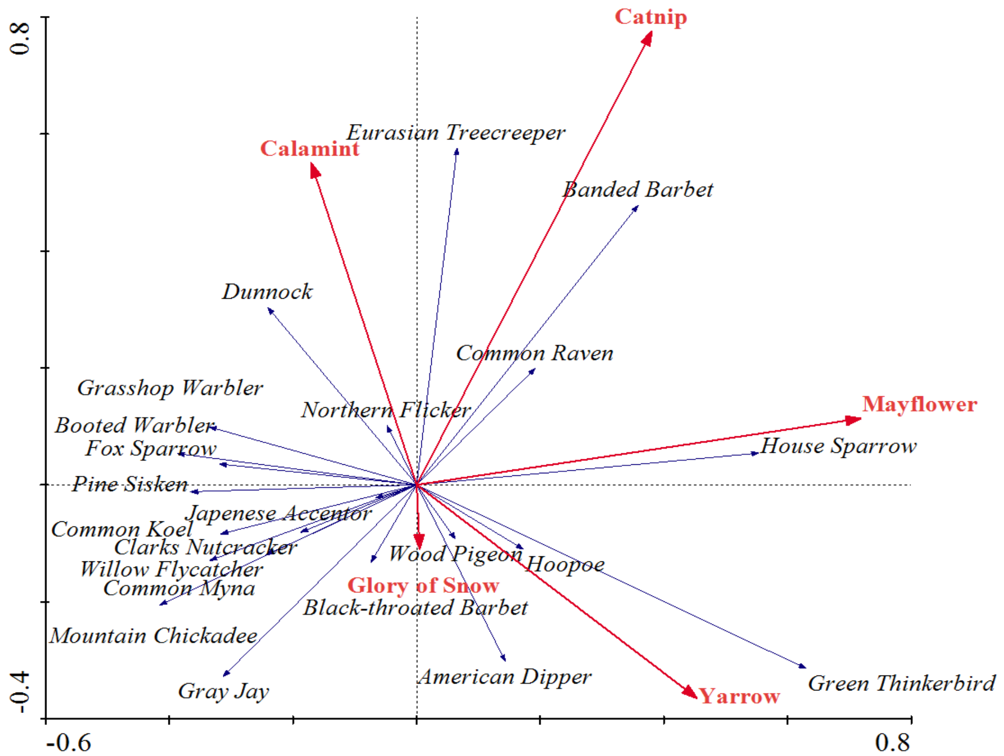

Figure 5. *Biplot of the correspondence analysis, showing the association between avian species and herb*

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http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Correlation ship between birds and microclimate

Significantly, the Badgoi coniferous forest habitat registered a mean temperature of 22.44°C (ranging between 20–23°C) and a mean relative humidity of 59.06% (varying from 52–63%). The relationship between birds and microclimate variables was explored through Constrained Redundancy Ordination (RDA). The correlation between bird and microclimate variables on the first two axes was determined to be 89.5% and 75.0%, suggesting that the RDA biplot diagram could effectively elucidate the impact of microclimate variables on bird species. The correlation analysis underscored a positive association between bird species and microclimatic factors, specifically temperature and relative humidity, as detailed in *Table 6*.

Table 6. *Summary table of RDA coordination for birds and microclimate factors in Badgoi coniferous forest*

Axes	1	2	3	4	Total inertia
Eigenvalues	0.152	0.053	0.129	0.097	1.000
Specie environment correlation	0.895	0.752	0.000	0.000	
Cumulative % variance of species data	15.2	20.6	33.5	43.2	
Cumulative % variance of specie-environment relation	74.0	100.0	0.0	0.0	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					0.206

Furthermore, the ordination biplot diagram illustrating the relationship between birds and microclimate variables highlighted specific influences. Common Mynas, Common Ravens, Pine Siskins, and Hoopoes were notably influenced by temperature. Conversely, Japanese Accentors, Black-throated Barbets, Grasshopper Warblers, House Sparrows, Wood Pigeons, Booted Warblers, and Clarks Nutcrackers displayed a positive correlation ship with relative humidity, as depicted in *Figure 6*.

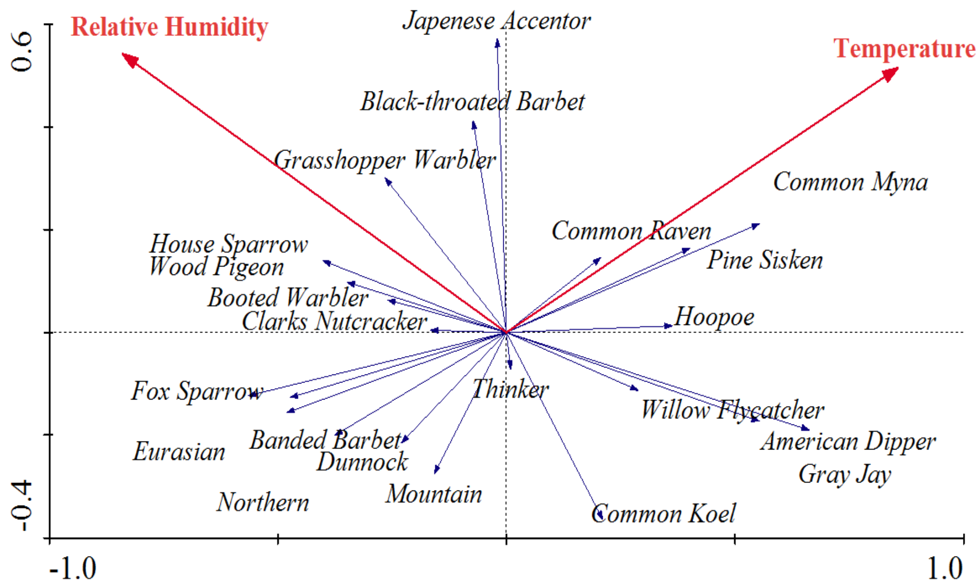

Figure 6. *Biplot of the correspondence analysis, showing the association between avian species and microclimate*

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DOI: http://dx.doi.org/10.15666/aeer/2204_32853301

Bird density/ha

The findings revealed that the Olive Warbler (*Peucedramus taeniatus*) exhibited a substantial population with a calculated abundance of 0.929 individuals per unit area and a density of 6.135 individuals per hectare. Additionally, *Passer domesticus* showed notable abundance with a population density of 1.23 individuals per unit area and 9.38 individuals per hectare. Pine Siskin (*Spinus pinus*) was also identified as an abundant species, with a calculated abundance of 0.83 individuals per unit area and a density of 10.02 individuals per hectare.

Conversely, the populations of *Empidonax traillii, Certhia familiaris,* and *Eudynamys scolopaceus* were observed to be less abundant in the study area. The calculated abundance for *Empidonax traillii* was 0.017 individuals per unit area, with a density of 53.19 individuals per hectare. *Certhia familiaris* exhibited a calculated abundance of 0.272 individuals per unit area and a density of 4.379 individuals per hectare. *Eudynamys scolopaceus* showed a calculated abundance of 0.023 individuals per unit area and a density of 12.08 individuals per hectare, as outlined in *Table 7*.

Table 7. *Bird density per hectare detected in Badgoi coniferous forest habitat*

Family	Scientific name	Common name	Density (birds/ha)	95% CFI
Peucedramidae	*Peucedramus taeniatus*	Olive Warbler	7.57	0.99 – 8.07
Passeridae	*passer domesticus*	Chanchara	3.04	1.23 – 9.38
Fringillidae	*spinus pinus*	Pine sisken	2.89	0.83 – 10.02
Prunellidae	*Prunella modularis*	Dunnock	2.54	0.96 – 9.96
Lybiidae	*Pogoniulus simplex*	Thunderbird	2.38	0.18 – 16.57
Columbidae	*Columba palumbus*	Woodpigeon	2.28	0.66 – 7.37
Locustellidae	*Locustella ochotensis*	Grasshopper warbler	2.26	0.38 – 11.08
Corvidae	*Corvus corax*	Common raven	2.12	0.929 – 6.13
Lybiidae	*Lybius undatus*	Banded barbet	1.91	0.59 – 6.17
Corvidae	*Perisoreus Canadensis*	Gray jay	1.89	0.29 – 12.22
Lybiidae	*Tricholaema melanocephala*	Throated barbet	1.87	0.43 – 7.73
Paridae	*Poecile gambeli*	Mountain chickadee	1.76	0.37 – 8.38
Passerellidae	*Passerella iliaca*	Fox sparrow	1.71	0.20 – 9.861
Sturnidae	*Acridotherestristis*	Common myna	1.64	0.43 – 6.31
Picidae	*Colaptes auratus*	Northern flicker	1.55	0.50 – 5.06
Corvidae	*Nucifraga columbiana*	Nutcracker	1.44	0.19 – 10.8
Cinclidae	*Cinclus mexicanus*	American dipper	1.22	0.05 – 28.71
Certhidae	*Certhia familiaris*	Eurasian treecreepers	1.09	0.27 – 4.379
Tyrannidae	*Empidonax traillii*	Willow Flycatcher	0.94	0.01 – 53.19
Cuculidae	*Eudynamys scolopaceus*	Common Koel	0.52	– 12.08

Foraging guild

The bird species were categorized into seven clusters according to their similar food consumption patterns. Among these, the Omnivore group stood out as the most dominant, constituting 35.052% of the total number of bird individual detections. In contrast, the Insectivore group emerged as the most abundant, representing 42.857% of the total bird species observed.

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DOI: http://dx.doi.org/10.15666/aeer/2204_32853301

Conversely, the Frugivore/Insectivore group was identified as the rarest guild based on the number of bird individuals detected, accounting for 2.062%. Similarly, the Detrivore group was determined to be the rarest guild based on the number of species, with a representation of 3.571%, as outlined in *Table 8*.

Table 8. *List of birds foraging guilds detected in the Badgoi coniferous forest*

Guild name	**Total detections**	**%**	**Number of species**	
Omnivore	170	35.052	5	17.857
Insectivore	128	26.392	12	42.857
Granivore/insectivore	70	14.432	3	10.714
Granivore	33	6.804	2	7.143
Frugivore/insectivore	10	2.062	2	7.143
Frugivore	38	7.835	3	10.714
Detrivore	36	7.422	1	3.571
Total	**485**		**28**	

Discussion

The Badgoi coniferous forest, situated in the Upper Dir district, emerges as a crucial habitat for avian species, providing a rich and diverse ecosystem for their essential activities such as foraging and breeding. However, the study reveals a concerning threat to these bird populations—human-induced habitat loss and degradation. This aligns with broader concerns in conservation biology and emphasizes the urgency of addressing anthropogenic activities that jeopardize the delicate balance of ecosystems (Rajpar et al., 2015; Zakaria et al., 2011).

Employing the Distance Sampling Point Count method, our research documented 485 bird individuals from 28 species and 20 families within the Badgoi forest. This approach not only provides a quantitative assessment but also underscores the importance of understanding the intricate relationship between bird abundance and habitat characteristics. The study emphasizes the critical role of habitat structure, corroborating existing literature and reinforcing the idea that effective conservation strategies must consider the specific needs of avian communities (Rajpar et al., 2015; Zakaria et al., 2011).

The Badgoi forest, characterized by its dense vegetation, including trees, shrubs, herbs, and grasses, emerges as a vital habitat supporting a diverse array of avian species. The close associations observed between certain bird species and specific tree, or shrub species underline the significance of microhabitat preferences. Notably, the presence of species like Silver Fir, Indian Willow, and Blue Kail showcases the rich vegetation diversity that attracts birds for various activities, from nesting to foraging and breeding (Tassicker et al., 2006). Understanding these microhabitat associations is pivotal for tailoring conservation strategies that ensure the preservation of specific plant species critical for bird ecology.

Exploring foraging guilds sheds light on the ecological versatility of the Badgoi forest ecosystem. The dominance of omnivores highlights the adaptability of avian species to the abundant vegetation resources, supporting diverse foraging strategies. Additionally, the presence of Detrivores indicates a balanced ecosystem where decomposed vegetation contributes to nutrient cycling, supporting specialized feeding

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32853301

behaviours. This aligns with the broader ecological principles of maintaining a balanced and functional ecosystem (Chettri et al., 2005; Trzcinski et al., 1999; Menaa et al., 2016).

Microclimate variables, including temperature and relative humidity, are identified as significant drivers of bird distribution within the Badgoi forest. The positive correlations observed between certain bird species and these variables highlight the intricate relationship between environmental conditions and avian ecology. As climate change poses an increasing threat to global ecosystems, understanding these associations becomes crucial for predicting and mitigating potential impacts on bird populations (Chettri et al., 2005).

The findings of this study are consistent with previous research highlighting the importance of habitat structure and microclimate variables in influencing bird species distribution and abundance (Rajpar et al., 2015; Zakaria et al., 2011). However, it is important to note that the field of avian ecology is dynamic, with ongoing advancements in research and understanding. Therefore, updating the cited publications to include more recent studies would enhance the discussion and ensure that the findings are situated within the current context of avian ecology research

In conclusion, this comprehensive study provides crucial insights into the delicate balance between avian species and the unique subalpine ecosystem of the Badgoi coniferous forest. The identified threats, microhabitat preferences, foraging guilds, and the influence of microclimate variables collectively underscore the complexity of bird ecology in this habitat. These findings should guide holistic conservation approaches, addressing habitat loss, preserving key vegetation species, and considering microclimate variables. By integrating these insights into management plans, we can contribute to the resilience and ecological integrity of the Badgoi forest and similar habitats facing anthropogenic pressures.

Conclusion

This research underscores the critical role of the Badgoi coniferous forest in supporting avian life and the urgent need for conservation. Human-induced habitat threats put bird populations at risk, necessitating immediate action. Utilizing the Distance Sampling Point Count method, we identified 485 birds from 28 species. The study reveals the strong link between bird abundance and the forest’s vegetation structure, emphasizing the need for tailored conservation strategies. Specific associations between bird species and key plants like Silver Fir highlight the importance of preserving these microhabitats.

Foraging guild analysis highlights the adaptability of birds in the Badgoi forest, with omnivores dominating. The presence of Detrivores signifies a balanced ecosystem, supporting specialized feeding behaviours.

Microclimate variables, especially temperature and humidity, play a crucial role in bird distribution. Understanding these relationships is vital for predicting and mitigating climate change’s impacts on avian populations. In conclusion, this study provides essential insights for the conservation of subalpine ecosystems. Preserving key vegetation, addressing habitat threats, and considering microclimate variables are crucial for sustaining the Badgoi forest’s biodiversity. The urgency lies in finding a delicate balance between human activities and ecosystem preservation to ensure the continued coexistence of diverse avian species.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2204_32853301

Future recommendations

Looking ahead, it is important to dig deeper into how birds live in the Badgoi forest. We should focus on understanding specific bird behaviours to better protect them. Also, we need to be ready to adapt our conservation plans as the environment changes, especially with climate shifts. Studying the genetics of bird groups can help us know which ones can handle changes better. Using cool tech like remote sensing and sound monitoring can make our data collection even better. Teaming up with local communities, governments, and groups can make our efforts stronger. We should also think about programs that help birds deal with climate change, educate people, and connect with others doing research. It is crucial to get the Badgoi forest officially protected, and involving the public in watching over it will be a big help. These steps will keep the birds in the Badgoi forest safe and happy in the long run.

Author contribution. AUR and MOK conducted the field survey. MNR provided the idea and conceptualization for the current research work. AA performed the analysis and completed the writing of the paper. TA and IU contributed to the review process. DH reviewed and finalized the paper for publication

Funding. Bird Survey Project of Beijing Municipal Forestry and Parks Bureau, China (No. 661602039) Support this paper.

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