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Relationships between Bird Assemblages and Habitat Variables in a Boreal Forest of the Khentii Mountain, Northern Mongolia

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Abstract: In order to determine the relationships between bird assemblages and forest habitat, we conducted surveys for bird assemblages in different forest habitats in the Khentii Mountain region, Northern Mongolia. A total of 1730 individuals belonging to 71 species from 23 families of 11 orders were recorded. Our findings revealed that passeriformes are the most species-rich order, accounting for 86.2% of the total species. The dominant species were *Anthus hodgsoni*, *Parus major*, *Poecile palustris*, and *Sitta europaea* in study area. Non-metric multidimensional scaling (NMDS) and permutation multivariate analysis of variance (PERMANOVA) showed that bird assemblages were affected by forest habitat types. Our findings also showed significant relationships between bird assemblages and canopy height and ground cover vegetation structure, whereas there were no relationships between altitude and other habitat variables. Thus, maintaining diverse forest habitats or restoring forest would play a key role in bird conservation and sustainable management of forest areas.

Keywords: bird assemblages; environmental variables; habitat; boreal forest

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1. Introduction

The boreal biome is located in the Northern Hemispheres, between 50° and 60° N latitudes [1]. The boreal forest covers northern Europe and Asia, and stretches from Far East Siberia to Scandinavia in the west [2]. Temperate conifers with varying proportions of deciduous trees dominate the boreal forest landscapes [2]. Mongolia is one of the world's least forested regions [3]. Forest covers approximately 12% of Mongolia; 84% of the forest is mostly coniferous and deciduous, but also 16% saxaul forest [4–6]. In Mongolia, boreal forests mostly exist in the northern parts, which form a transitional zone between the Siberian Boreal Taiga and the Central Asian steppe [6]. These forests have relatively few tree species and are composed mainly of Siberian larch (*Larix sibirica* Ledeb.), Scots pine (*Pinus sylvestris* L.), Siberian pine (*Pinus sibirica* Du Tour.), Siberian fir (*Abies sibirica* Ledeb.), and Birch (*Betula* spp.), along with some deciduous tree species [5]. Mongolian boreal forest is characterized by a low human population density and a relatively low level of anthropogenic impact compared to other countries with Boreal forest regions [5]. Nevertheless, human population increases have led to an ever-increasing demand for forest products, timber harvesting, forest fires, increases in livestock numbers, degradation, and pests progressively depleting the forest cover [7,8]. Forest depletion totaled four million hectares in the last three decades, and the rate of deforestation increased to approximately 60,000 ha per year [5]. Deforestation by legal and illegal logging for especially conifer trees—sawmilling targets the largest trees—increased from the beginning of the 1970s [9,10]. Studies in the Boreal biome and tropical deforestation show that global bird diversity is tending to go down [11–15], and reforestation is a key action for bird conservation [16]. The relationships between bird assemblages and forest habitat have been the focus of many studies worldwide, and it is evident that forest habitat is an important determinant of the condition of bird assemblages in the boreal forest biome [17]. Bird species diversity has been shown to increases as forest tree diversity increases [18,19]. In addition, environmental variables such as habitat heterogeneity, canopy cover, tree size, and seasonal and climate changes are important effects on the growth and reproduction of the forest bird assemblages [20].

Most of the research is bird composition on boreal forest has concentrated on countries with boreal biomes, such as those in Europe, North America, and several Russian regions [2]. In Mongolia, the study of forest habitat and its biological communities (especially birds) has just started, and a limited number of studies on forest birds and their habitats are available. Most studies on bird diversity and biological communities have focused on waterfowl and threatened bird species, but there are only a few studies on the relationship between forest habitat and bird assemblages [10,21]. Unfortunately, ecological studies of the forest bird in the area are rare or have been mostly published in the Russian or Mongolian journals in their native languages and thus are hardly accessible to other scientists. Moreover, as noted by Bold's (2003) [22], the early ecological finds from the forest bird assemblages of different habitats were reported based on bird species distribution as a result of a Russian–Mongolian joint expedition. His research focuses on bird species distribution and avifauna (Bold, 1973) [23]. In 1969, Bold [24] described some additional ecological and behavioral characteristics of some forest birds in different habitats of Mongolia. [25,26]. However, there are research gaps in Mongolia, especially regarding biological and ecological characteristics, such as forest bird species density, population dynamics, and the heterogeneity of micro habitat variables [10,21]. This his study aimed to quantify the forest structure, bird species composition, community assemblages, and occurrences of birds in different habitats of boreal forests, and to investigate the relationships between the avian community and forest conditions.

2. Materials and Methods

2.1. Study Sites

The research mainly focused on the surrounding regions of the Khentii Mountains (Figure 1). The Khentii Mountains are known as a forest region that is in northern Mongolia [27]. The annual average precipitation is 250–320 mm [3,28], and approximately 50–60% of precipitation is recorded in the summer [29]. The average annual temperature varies between −1.9 and −3.8 °C [30]. The forest of Khentii Mountains accounts for 33.5% (3755.2 ha, thousand) of the total forest area of Mongolia [24]. In the Khentii region, the western Siberian dark taiga forests with Spruce-*Picea obovata,* Fir-*Abies sibirica, Pinus sibirica*, and Siberian larch-*Larix sibirica* meet the eastern Siberian light taiga forests composed of species such as Birch-*Betula platyphylla* and related species, Larch-*Larix* sp. and Scotch pine-*Pinus sylvestris* [3,31–33]. Tree species of Khentii Mountain, especially mixed conifer and deciduous trees, and the plants, are relatively different in ecological regions from the other parts of Mongolia [34].

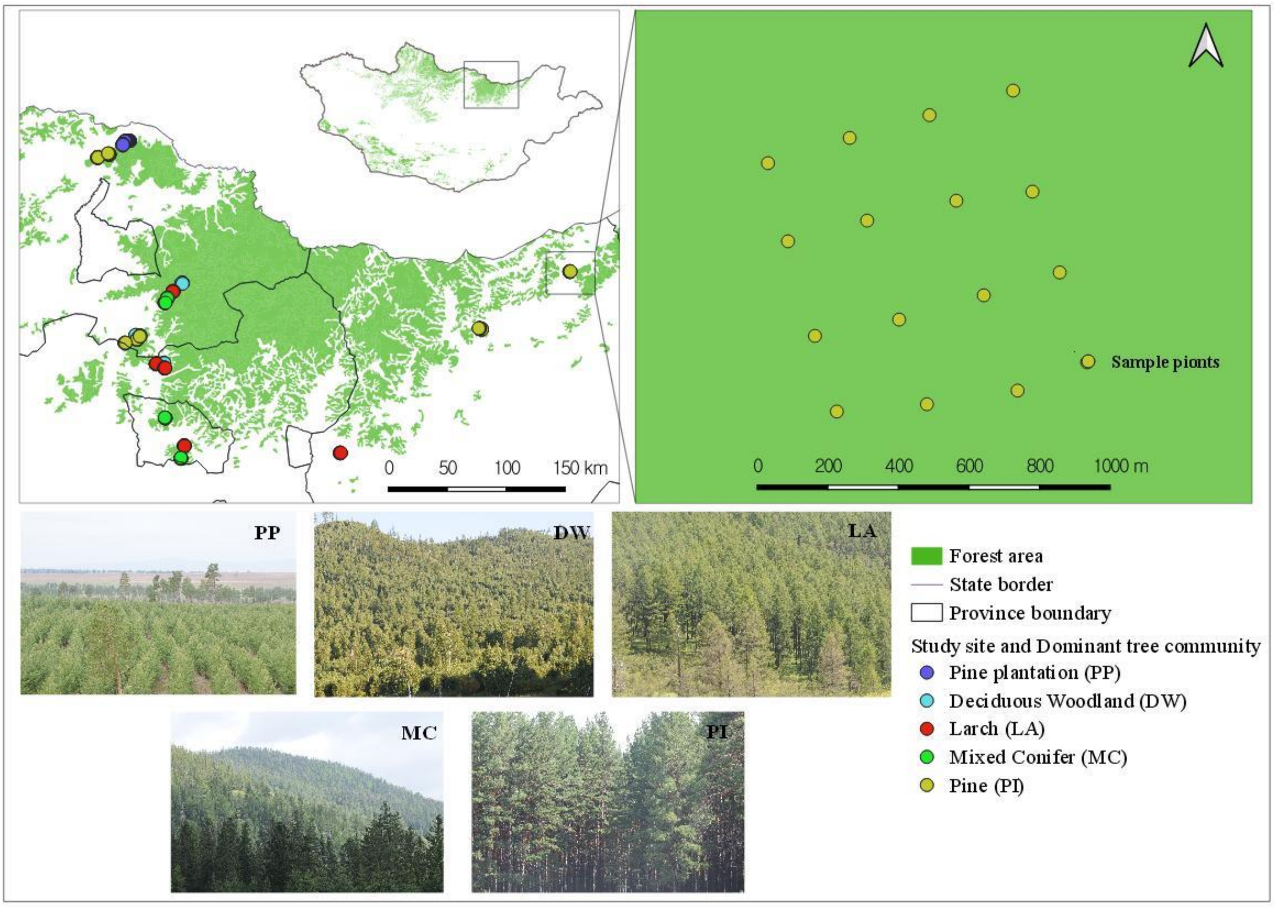

Figure 1. Study area location and sampling sites in a forested area of the Khentii Mountains.

2.2. Sample Collection and Analyses

The survey was carried out at twenty plot sites on Kentii Mountain for native forested areas and five plots within a pine plantation area (Tujiin Nars). Five plots at plantation areas were selected based on the restorative time period since reforestation [35]. Bird surveys were conducted from June to August in 2019, a period recognized as breeding season for most species in the region [24]. All birds were counted and recorded via visual observation [36,37]. Each species was assigned to several functional groups based on migrations and diet preferences (Table 1) [21]. Field surveys were carried out from 6:00 to 11:00 AM during suitable weather conditions (without rain and with wind less than 5 m/s) and birds were recorded in point-counts of 10 min with a 50 or 80 m radius [36,37]. Survey plots were 1 km^2 area with a 4 $\times$ 4 grid of 16 points, and a total of 400 point-counts were completed (Figure 1) [38,39]. The distance between points within plots was 250 m [37,38], and when we selected points at the forest's edge, the distance between a point and the interior of the forest was 50 m. The occurrences of bird species and study sites were recorded using a global positioning system (GPS; German map62), and these positions were used to map in QGIS version 3.22 [40].

Table 1. List of bird species and their abundances and occurrences in different habitat types in the forest of the Khentii Mountains.

Scientific Name	English Name	Diet	Status	Bird Individuals in Different Habitat Types DW	LA	PI	PP	MC	Frequency of Occurrence (%)	Relative Abundance (%)
Accipitriformes-Accipitridae										
Accipiter gentilis	Northern Goshawk	Carn	M		1				0.25	0.06
Aquila nepalensis	Steppe Eagle	Carn	M			1			0.25	0.06
Buteo buteo	Eurasian Buzzard	Carn	M	3	1		2		1.25	0.35
Hieraaetus pennatus	Booted Eagle	Carn	M	1	1				0.5	0.12
Milvus migrans	Black Kite	Carn	M	12	20	7	11	3	9	3.06
Aegypius monachus	Cinereous Vulture	Carn	R	1					0.25	0.06
Anseriformes-Anatidae										
Tadorna ferruginea	Ruddy Shelduck	Omni	M				9		1.5	0.52
Bucerotiformes-Upupidae										
Upupo epops	Eurasian Hoopoe	Inse	M		1	3	1		1	0.29
Caprimulgiformes-Apodidae										
Apus apus	Common Swift	Inse	M			5	21		1.25	1.50
Ciconiiformes-Ciconiidae										
Ciconia nigra	Black Stork	Carn	M			1		1	0.5	0.12
Columbiformes-Columbidae										
Streptopelia orientalis	Oriental Turtle Dove	Gran	M				15		2.5	0.87
Cuculiformes-Cuculidae										
Cuculus canorus	Common Cuckoo	Inse	M		5		26		6.75	1.79
Cuculus saturatus	Oriental Cuckoo	Inse	M		1				0.25	0.06
Falconiformes-Falconidae										
Falco cherrug	Saker Falcon	Carn	M			1	1		0.5	0.12
Falco tinnunculus	Common Kestrel	Carn	M	1	4				0.75	0.29
Falco amurensis	Amur Falcon	Carn	M		4				0.75	0.23
Falco columbarius	Merlin	Carn	M		3				0.5	0.17
Galliformes-Phasianidae										
Lyrurus tetrix	Black Grouse	Inse	R	12					1.5	0.69
Gruiformes-Gruidae										
Anthropoides virgo	Demoiselle Crane	Omni	M			2	5		1.25	0.40
Antigone vipio	White-naped Crane	Omni	M				3		0.25	0.17
Passeriformes-Aegithalidae										
Aegithalos caudatus	Long tailed Tit	Inse	R	14	1			2	1.75	0.98
Alaudidae										

Table 1. *Cont.*

Scientific Name	English Name	Diet	Status	DW	LA	PI	PP	MC	Frequency of Occurrence (%)	Relative Abundance (%)
			Bird Individuals in Different Habitat Types							
Alauda arvensis	Eurasian Skylark	Inse	M				28		1.75	1.62
Corvidae										
Corvus dauuricus	Daurian Jackdaw	Omni	M		6				1	0.35
Corvus corax	Northern Raven	Omni	R	4	5	5	14	2	4	1.73
Corvus corone	Carrion Crow	Omni	R	11	12	9	18	9	10	3.41
Cyanopica cyanus	Azure-winged Magpie	Omni	R				14		0.75	0.81
Garrulus glandarius	Eurasian Jay	Omni	R	9	3	5		10	3	1.56
Pica pica	Eurasian Magpie	Omni	R	3	9	15			2.5	1.56
Pyrrhocorax pyrrhocorax	Red-billed Chough	Omni	R			1			0.25	0.06
Emberizidae										
Emberiza cioides	Meadow Bunting	Inse	M		18	26	25		8.75	3.99
Emberiza leucocephalos	Pine Bunting	Inse	M		14	24	67		10.25	6.07
Emberiza pusilla	Little Bunting	Inse	M	7					0.75	0.40
Emberiza pallasi	Pallas's Bunting	Inse	M		2				0.5	0.12
Fringillidae										
Fringilla montifringilla	Brambling	Omni	M			1			0.25	0.06
Carpodacus erythrinus	Common Rosefinch	Gran	M		10				1	0.58
Carpodacus roseus	Pallas's Rosefinch	Gran	R	1					0.25	0.06
Coccothrraustes coccothrraustes	Hawfinch	Gran	R			6			1.25	0.35
Laniidae										
Lanius cristatus	Brown Shrike	Inse	M		12	2			2.5	0.81
Motacillidae										
Anthus hodgsoni	Olive Backed Pipit	Inse	M	15	62	41	94	8	26.25	12.72
Anthus richardi	Richard's Pipit	Inse	M				1		0.25	0.06
Anthus trivialis	Tree Pipit	Inse	M	10	1	27	28		8.5	3.82
Motacilla alba	White Wagtail	Inse	M	1	3				1	0.23
Muscicapidae										
Ficedula albicilla	Taiga Flycatcher	Inse	M	8	16	4			3.5	1.62
Muscicapa sibirica	Dark-sided Flycatcher	Inse	M			13			2	0.75
Oenanthe oenanthe	Northern Wheatear	Inse	M		7				1	0.40
Phoenicurus phoenicurus	Common Redstart	Inse	M	15	10	3		2	5	1.73
Saxicola torquatus	Common Stonechat	Inse	M	2	10	4	2		2	1.04
Muscicapa dauurica	Asian Brown Flycatcher	Inse	M		1	8			1	0.52

Table 1. *Cont.*

Scientific Name	English Name	Diet	Status	Bird Individuals in Different Habitat Types DW	LA	PI	PP	MC	Frequency of Occurrence (%)	Relative Abundance (%)
Oenanthe pleschanka		Inse	M				2		0.25	0.12
Oenanthe isabellina	Isabelline Wheatear	Inse	M	2	4		23		2.5	1.68
Phoenicurus auroreus	Daurian Redstart	Inse	M		9	1	6		2.5	0.92
Phoenicurus erythrogastrus	White winged Radstart	Inse	R		1				0.25	0.06
Paridae										
Cyanistes cyanus	Azure Tit	Inse	R		14				1.25	0.81
Parus major	Great Tit	Inse	R	50	27	32	4	31	16.75	8.32
Periparus ater	Coal Tit	Inse	R	26	9	1		7	6.75	2.49
Poecile montanus	Willow Tit	Gran	R	9	32	42	1	14	9.75	5.66
Poecile palustris	Marsh Tit	Gran	R	72	31	20		4	15.25	7.34
Passeridae										
Passer domesticus	House Sparrow	Inse	R		5				0.5	0.29
Passer montanus	Eurasian Tree Sparrow	Omni	R			9	8		1	0.98
Phylloscopidae										
Phylloscopus borealis	Arctic Warbler	Inse	M		1				0.25	0.06
Phylloscopus fuscatus	Dusky Warbler	Inse	M		5				0.75	0.29
Phylloscopus proregulus	Palla's leaf Warbler	Inse	M	26	5	5		1	4.5	2.14
Sittidae										
Sitta europaea	Wood Nuthach	Inse	R	11	31	66		11	13.25	6.88
Turdidae										
Turdus naumanni	Naumanns Thrush	Omni	M		5				0.5	0.29
Turdus ruficollis	Red Throated Trush	Omni	M	5					0.75	0.29
Piciformes-Picidae										
Dendrocopos leucotos	White backed Woodpecker	Inse	R	5	2				1.5	0.40
Dendrocopos major	Great spotted Woodpecker	Inse	R	5	3	2	11	3	4.75	1.39
Dryobates minor	Lesser spotted Woodpecker	Inse	R		7	7	2		3.25	0.92
Dryocopus martius	Black Woodpecker	Inse	R	1		1			0.5	0.12
Strigiformes-Strigidae										
Aegolius funereus	Boreal Owl	Carn	R	2					0.25	0.12
Bubo bubo	Eurasian Eagle Owl	Carn	R			1		1	0.5	0.12
	Abundance			344	434	401	442	109	-	-
	Species richness			31	46	36	28	16	-	-

Notes: Diet: Carn—carnivores, Omni—omnivores, Inse—insectivores, Gran—granivores. Migratory status: R—resident, M—migrant. Forest types are deciduous woodland (DW), larch (LA), pine (PI), pine plantation (PP), and mixed conifer (MC).

We estimated forest tree (height, diameter at breast height—dbh) cover, and ground-cover variables (percentage of vegetation cover, bare ground, and down wood) of each point in a 50 m radius [39], and snag samples were 20 m in radius. Tree height was measured at ≥10 dominant trees at each point (around the center points). These data were grouped as mean values at the point-count level. The forest vegetation was sampled immediately after the end of bird counts. Forest characteristics were described as forest pattern, average tree height, cover, and tree component in the study area, the habitat was classified into five groups: the forest patterns and structure variables of each habitat type are shown in Table 2.

The relative abundance (RA) of a bird species was determined using the following expression: (number of individuals for species n/N total number of individuals) × 100%. To find differences in environmental factors and bird community attributes (i.e., species richness, abundance, and forest structure variables) among different habitat types, we performed analysis of variance (ANOVA) and Tukey's post hoc test using the function aov in R software [41].

Differences in bird species richness among forest habitats were assessed through the rarefaction and extrapolation method based on sample coverage [42]. The species richness was calculated for each forest habitat based on the lowest sample coverage among the five habitats obtained within the 95% confidence intervals. This analysis was performed with the iNEXT and devtools package, using R [43,44].

To visualize the differences in bird assemblage composition between habitat types, we used permutational multivariate analysis of variance (PERMANOVA). Before performing PERMANOVA, the multivariate homogeneity of group dispersions was tested by the function betadisper, which indicated that there was a difference in dispersion between groups ($F = 4.95$, $p < 0.01$). The habitat type was used as an explanatory factor for PERMANOVA, which was tested using the function Adonis in the R package vegan [45]. The five forest types were considered a fixed effect in the analysis. Differences in species composition among samples collected in each site and forest type are presented in non-metric multidimensional scaling (NMDS) using the function metaMDS in the R package vegan 2.6-2 [46]. Moreover, similarity percentage (SIMPER) was also used to determine species that contributed most to the dissimilarities observed. All recorded species were included in the analysis. For SIMPER, we reported species that contributed to 83% of the bird community assemblages [45].

Redundancy analysis (RDA) was used as a direct gradient approach in order to determine how much variation in bird assemblages could be explained by environmental variables. Then, bird abundance data with total species were Hellinger transformed [47] using the function decosdtand in the R package vegan, in order to reduce the weights of abundant species while preserving the BrayCurtis index between samples in multidimensional space [45]. We performed RDA using the function RDA and tested the significance using the function ANOVA. In order to reduce the number of environmental variables entering the RDA, we used forward selection to get a parsimonious model. The forward selection was performed using the function ordiR2step with a permutation test (999 permutations) via the R package vegan [45]. The level of significance for all results was set to $p < 0.05$. All statistical analyses were performed using R version 3.5.1 [41].

Table 2. Structural variables were used to characterize the forest habitats of sampling sites where bird assemblages were described.

Structural Variables	Code	Description
Altitude (m)	Alt	Point elevation (m.a.s.l)
Number of snags	Sna	Counted the numbers of snags (≥15 cm dbh, trees that are completely dead) and stems those are ≥3 m high and within a 20 m radius of the center survey point.
Number of stem	Ste	
Dbh (cm)	Dbh	Measured the dominant tree's average diameter at breast height (dbh) of overstore trees within a number of ≥10 stem.
Over story cover (%)	Osc	Estimated the total percent coverage and dominant tree's average height of all overstore trees within a 50 m radius.
Over story height (m)	Osh	
Understory cover (%)	Usc	Estimated the percent cover and species makeup of any woody vegetation (including seedling trees) that is ≥0.5 m high and <3.0 m high of the understory layer.
Understory height (m)	Ush	
Bare/Litter cover (%)	Bal	The percentage of the ground surface covered by shrubs 0–0.5 m high, litter, down wood, forbs, grasses, and moss was estimated visually within 50 m radius plots (total 100%).
Dead and down (%)	Dad	
Dead standing grass cover (%)	Dsg	
Herbaceous cover (%)	Her	
Live grass cover (%)	Lig	
Moss cover (%)	Mos	
Dead standing grass height (cm)	Dsh	
Live grass&herb. height (cm)	Lgh	
Deciduous Woodland	DW	Forested habitat type of dominant tree species with ≥50% present in the overstore. The overstore cover should be ≥10% trees within a 50 m radius.
Larch	LA	
Pine	PI	
Plantation Pine	PP	
Mixed Conifer	MC	

3. Results

3.1. Bird Assemblage Composition

A total of 1730 birds were recorded during this study, belonging to 71 species from 23 families and 11 orders (Table 2). Of these, Passeriformes was the most species-rich order, accounting for 89% of the total species. The dominant species were *Anthus hodgsoni*—olive backed pipit (12.72%), *Parus major*—great tit (8.32%), *Poecile palustris*—marsh tit (7.34%), *Sitta europaea*—wood nuthatch (6.88%), *Emberiza leucocephalos*—pine bunting (6.07%), and *Poecile montanus*—willow tit (5.66%) which comprised 46.99% of the total bird count in this study. The dominant species varied among habitat types. For instance, *A. hodgsoni*, *P. major*, and *P. montanus* were generalists, which were dominant species in the most habitats. Moreover, *E. leucocephalos* was dominant in larix, pine, and pine plantation habitats, whereas *P. palusris* and *S. europaea* were dominant species in most habitats, but these species were not recorded in habitats with pine plantations. The high values of estimated sample coverage (ranges from 0.97 in LA and MC to 0.99 in PP) indicate that the sampling was sufficient to detect most species (Figure 2 and Table 3). In the forest habitats, species richness was higher in the larch (46 species) and pine-dominated habitats (31 species), compared to the pine plantation (28 species) and mixed conifer (16 species). We grouped the 71 species into four guilds: insectivores (38 species), omnivores (14), carnivores (13), and granivores (6) (Table 3). Insectivores were the most abundant group (68.09%), followed by granivores (14.85%), omnivores (12.2%), and carnivores (4.86%).

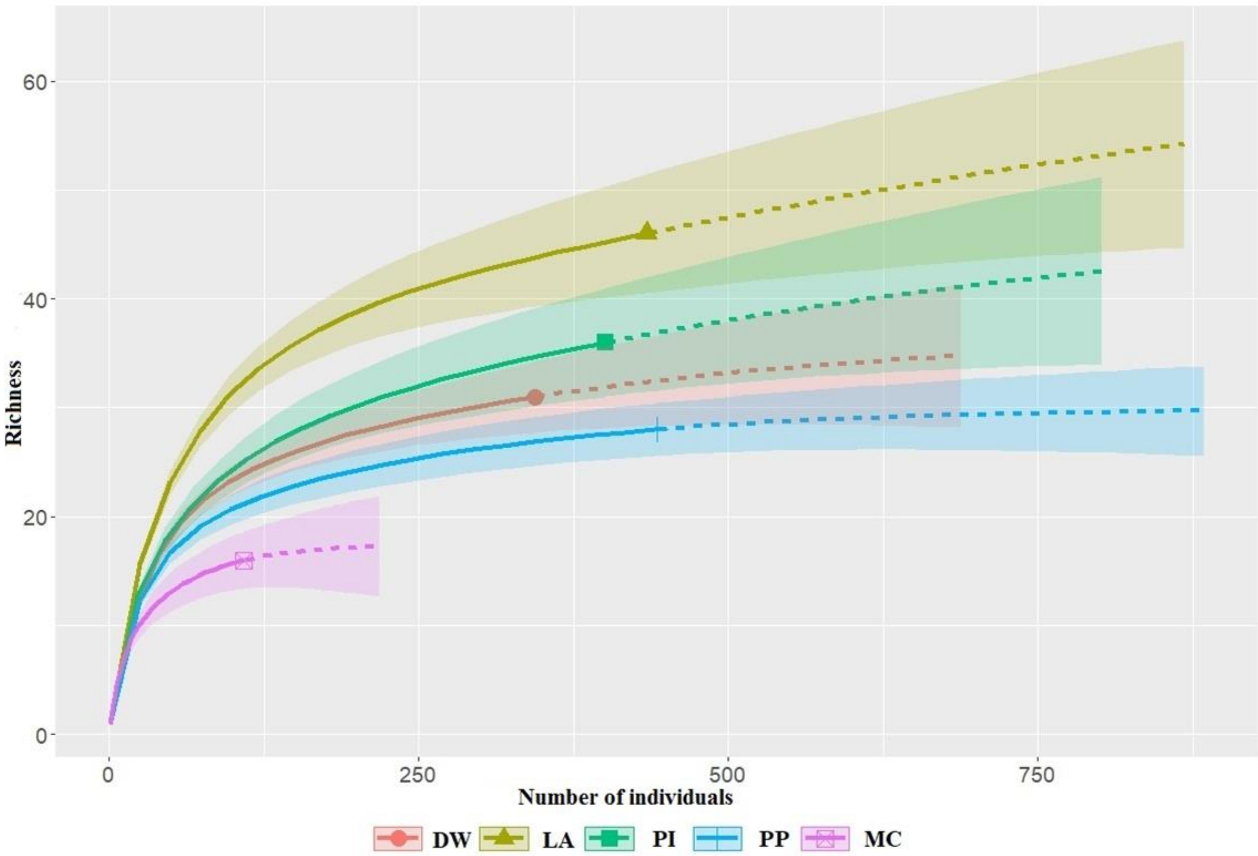

Figure 2. Species richness of birds was recorded during this survey in the Khentii Mountains. Habitat variables are deciduous woodland (DW), larch (LA), pine (PI), pine plantation (PP), and mixed conifer (MC). Solid and dashed lines are interpolated and extrapolated data, respectively, based on rarefaction and extrapolation methods, with their associated 95% confidence intervals.

Table 3. Bird richness in areas with different forest habitats in Khentii Mountains.

Habitat Type	Observed Richness	Sample Coverage	S.LCL	CI
Table 1 Deciduous Woodland	31	0.983	27.4	32–64.5
Larch	46	0.977	41.0	51–168.9
Pine	36	0.978	31.7	38.8–98.7
Pine Plantation	28	0.991	25.2	28.2–42.3
Mixed Conifer	16	0.973	13.4	16.1–28.7

Note: S.LCL = richness based on the lowest sample coverage for that forest habitat type; CI = 95% confidence interval. Differences between letters next to the CI indicate significant differences between forest types.

3.2. Correlations between Bird Assemblage and Habitat Types

Results of one-way ANOVA showed that the bird abundance per point for pine plantations was significantly higher than that for mixed conifer forest habitats (F (4, 395) = 3.14, $p < 0.05$). Bird species richness per point in the pine plantation habitat was significantly higher than for other habitat types (F (4, 395) = 3.97, $p < 0.05$) (Figure 3A,B). Permutation analysis of variance and NMDS (stress = 0.22) revealed bird assemblages were significantly affected by habitat type (PERMANOVA, pseudo-F = 2.59, $p < 0.001$) (Figure 4). In addition, SIMPER analysis confirmed these dissimilarities and revealed that *A. hodgsoni*, *P. major*, *P. palustris*, *E. leucocephalos*, *S. europaea*, and *P. montanus* are major contributors to dissimilarities between habitat types (Table 4).

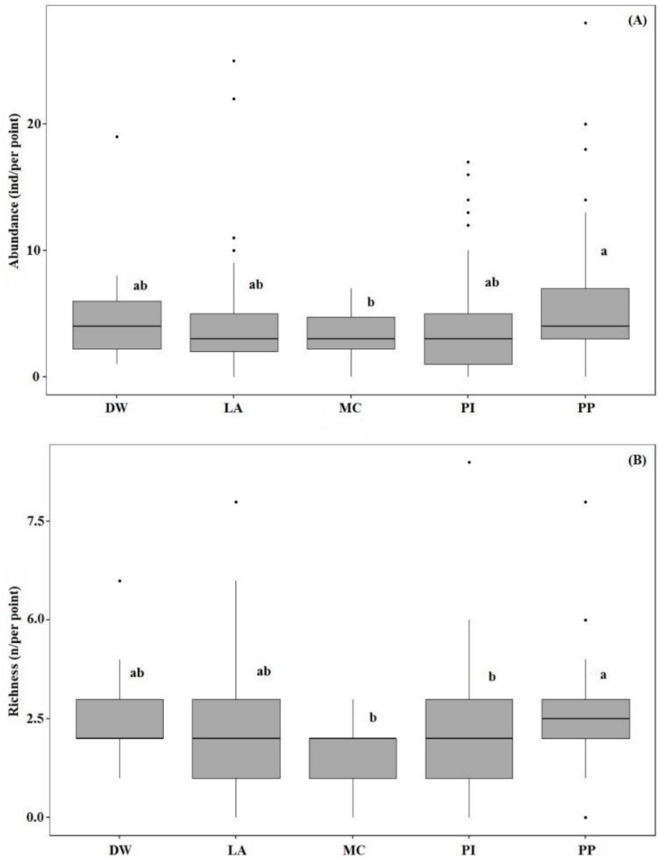

Figure 3. Analysis of variance (ANOVA) for abundance (**A**) and species richness (**B**) of birds in the number of birds per point among selected habitats. Forest types are deciduous woodland (DW), larch (LA), pine (PI), pine plantation (PP), and mixed conifer (MC).

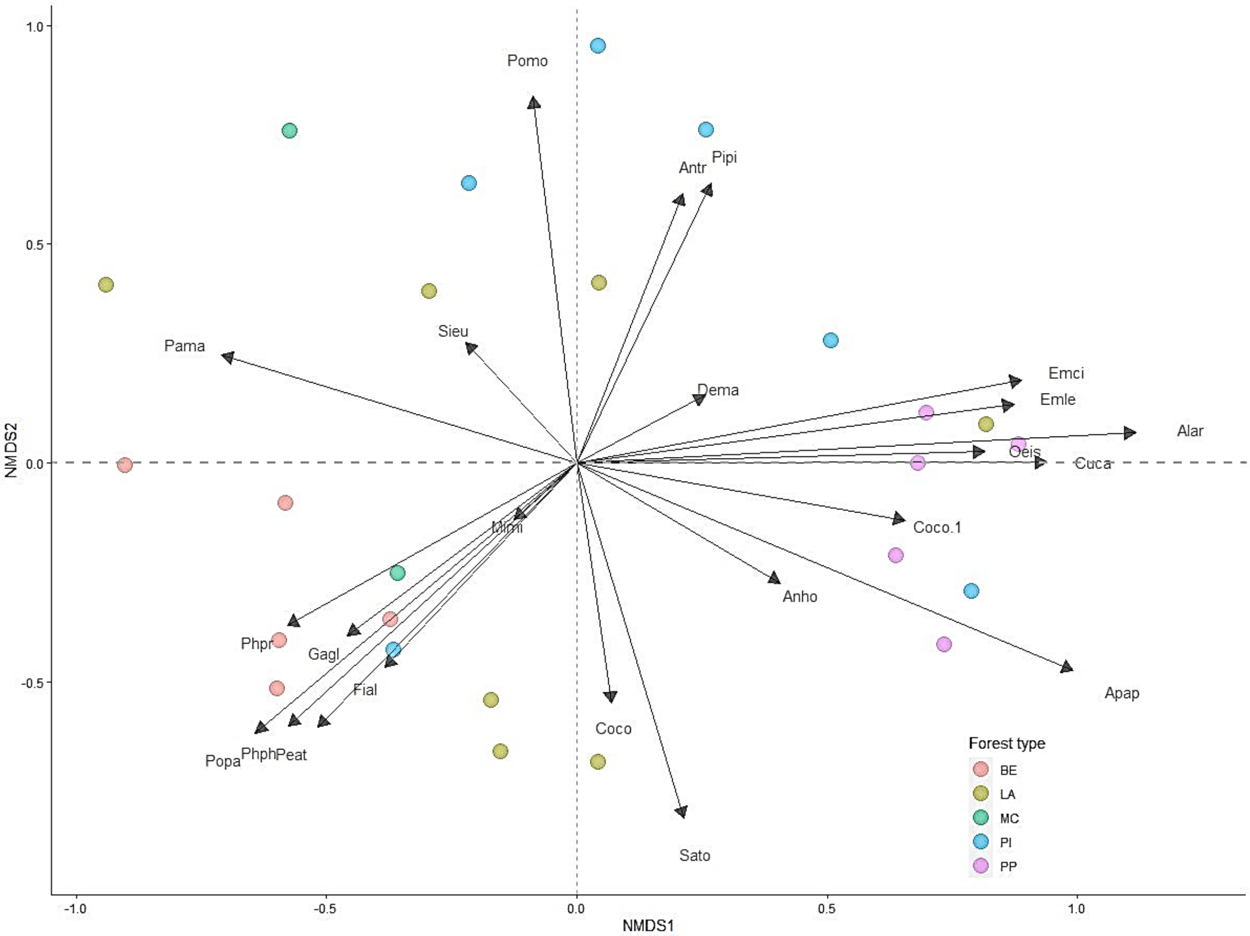

Figure 4. Non-metric multidimensional scaling (NMDS) ordination of selected bird assemblages in different habitat types in the forest of the Khentii Mountains. Forest types are deciduous woodland (DW), larch (LA), pine (PI), pine plantation (PP), and mixed conifer (MC). Note: Species names are generic acronyms or the four letters of the scientific names in Table 1.

Table 4. SIMPER analysis of dissimilarity among forest habitat types by most abundant species.

Species	Av. Dissim	Contrib. %	Cumulative %	Mean DW	Mean LA	Mean MC	Mean PI	Mean PP
Anthus hodgsoni	10.95	11.70	11.70	0.18	0.63	0.28	0.47	1.25
Parus major	8.28	8.85	20.55	0.61	0.28	1.07	0.36	0.05
Poecile palustris	7.32	7.82	28.37	0.88	0.32	0.14	0.23	-
Sitta europaea	5.65	6.04	34.41	0.13	0.32	0.38	0.75	-
Emberiza leucocephalos	5.23	5.59	40.00	-	0.14	-	0.27	0.89
Poecile montanus	5.08	5.43	45.42	0.11	0.33	0.48	0.48	0.01
Emberiza cioides	3.96	4.23	49.66	-	0.18	-	0.30	0.33
Corvus corone	3.88	4.15	53.80	0.13	0.12	0.31	0.10	0.24
Anthus trivialis	3.45	3.69	57.49	0.12	0.01	-	0.31	0.37
Milvus migrans	2.80	2.99	60.49	0.15	0.20	0.10	0.08	0.15
Periparus ater	2.57	2.75	63.24	0.32	0.09	0.24	0.01	-
Phylloscopus proregulus	1.98	2.12	65.35	0.32	0.05	0.03	0.06	-
Phoenicurus phoenicurus	1.97	2.10	67.46	0.18	0.10	0.07	0.03	-
Cuculus canorus	1.91	2.04	69.49	-	0.05	-	-	0.35
Ficedula albicilla	1.71	1.82	71.32	0.10	0.16	-	0.05	-
Dendrocopos major	1.66	1.77	73.09	0.06	0.03	0.10	0.02	0.15
Garrulus glandarius	1.60	1.71	74.80	0.11	0.03	0.35	0.06	-
Corvus corax	1.42	1.51	76.32	0.05	0.05	0.07	0.06	0.19

Table 4. *Cont.*

Species	Av. Dissim	Contrib. %	Cumulative %	Mean DW	Mean LA	Mean MC	Mean PI	Mean PP
Pica pica	1.16	1.24	77.56	0.04	0.09	-	0.17	-
Apus apus	1.12	1.19	78.75	-	-	-	0.06	0.28
Alauda arvensis	1.04	1.11	79.87	-	-	-	-	0.37
Oenanthe isabellina	1.04	1.11	80.97	0.02	0.04	-	-	0.31
Phoenicurus auroreus	1.03	1.11	82.08	-	0.09	-	0.01	0.08
Saxicola torquatus	1.01	1.08	83.15	0.02	0.10	-	0.05	0.03

3.3. Relationships between Bird Assemblages and Environmental Variables

One-way ANOVA revealed that mixed conifer had the highest average altitude (1688.6 ± 204.6 m), followed by larch-dominant habitats (1374.7 ± 267.9 m), and the pine plantation habitat altitude was lower still (701.7 ± 18.3 m). The forest habitat types were significantly different at different altitudes ($F_{4,\ 395}$ = 240.1, $p < 0.01$). The average numbers of snags of deciduous woodland and larch habitats were significantly higher than other habitat types ($F_{4,\ 395}$ = 10.95, $p < 0.05$). The dbh sizes in deciduous woodland, larch, and mixed conifer habitats were significantly larger than in other habitat types ($F_{4,\ 395}$ = 4.71, $p < 0.05$). The overstory, understory, and ground-level were significantly different in habitat structural variables (Table 5).

Table 5. Results of one-way analysis of variance (ANOVA) with Tukey's HSD test for environmental variables (mean ± SD) among different forest habitat types in the Khentii Mountains.

Habitat Types	Overstory Level						Understory Level	
	Alt (m)	Sna (n)	Dbh (cm)	Ste (n)	Osh (m)	Osc (%)	Usc (%)	Ush (m)
DW	1139.4 ± 119.9 [c]	4.6 ± 4.3 [a]	15.4 ± 6.9 [a]	46.8 ± 46.2 [b]	7.7 ± 3.4 [b]	25.8 ± 20.7 [c]	32.5 ± 15.5 [a]	2.3 ± 1 [a]
LA	1374.7 ± 267.9 [b]	3.8 ± 3.8 [a]	20.5 ± 8.7 [a]	66.5 ± 69.4 [ab]	10.8 ± 4 [a]	32.5 ± 25.5 [bc]	12.4 ± 10.5 [b]	1.4 ± 0.8 [bc]
MC	1688.6 ± 204.6 [a]	3.3 ± 3.1 [ab]	20.5 ± 8 [a]	86.2 ± 52.3 [a]	12.0 ± 4.8 [a]	53.1 ± 28.1 [a]	9.8 ± 7 [b]	1.8 ± 0.6 [ab]
PI	956.7 ± 205.29 [d]	2.4 ± 2.8 [b]	18.7 ± 8.7 [b]	63.5 ± 62.6 [ab]	10.5 ± 4.3 [a]	39.7 ± 29 [ab]	13.4 ± 12.7 [b]	1.8 ± 1.1 [c]
PP	701.7 ± 18.3 [e]	1.6 ± 1.6 [b]	13.0 ± 4.6 [b]	88.1 ± 85.9 [a]	7.2 ± 2.6 [b]	36.9 ± 31.1 [bc]	16.7 ± 16.9 [b]	2.2 ± 0.6 [a]

	Ground level					
	DaD (%)	Her (%)	Bal (%)	Lig (%)	Mos (%)	Lgh (cm)
DW	7.8 ± 6 [a]	31.7 ± 11.3 [a]	19.9 ± 13 [a]	32.1 ± 14.2 [bc]	1.3 ± 2.3 [c]	27.8 ± 8.9 [a]
LA	5.5 ± 6 [b]	31.3 ± 16.8 [a]	14.0 ± 10.6 [a]	38.220.5 [b]	3.8 ± 9.8 [bc]	21.0 ± 8.3 [b]
MC	8.6 ± 7.3 [a]	23.3 ± 17.7 [b]	12.9 ± 8.5 [b]	26.1 ± 16.2 [c]	26.6 ± 28.2 [a]	16.0 ± 7.5 [c]
PI	5.5 ± 6.5 [b]	16.8 ± 12.7 [b]	19.3 ± 13.5 [b]	39.0 ± 21.1 [b]	7.0 ± 11.3 [b]	16.3 ± 9.8 [c]
PP	0.5 ± 1.1 [c]	6.9 ± 6 [c]	5.4 ± 2.9 [c]	63.5 ± 5.8 [a]	0.0 [c]	28.2 ± 10 [a]

Notes: Different habitat types with different letters (a, b, c, d, e) in the same column indicate significant differences ($p < 0.05$). Forest types are deciduous woodland (DW), larch (LA), pine (PI), pine plantation (PP), and mixed conifer (MC). Habitat structural variable names were used by generic acronyms letters of the names in Table 2.

A total of 23 bird species were selected for redundancy analysis (RDA) with frequency of occurrence, and seven environmental variables were selected after a forward stepwise selection, including overstory, live grass, and dead grass height; and herbaceous, dead grass, live grass, and dead down wood cover. The first two axes (RDA1 and RDA2) accounted for 22.75% and 15.14% of the variation of 23 bird species, respectively (Figure 5). Different bird species preferred different environmental variables, which supports hypothesis ii. For instance, *Sitta europaea*, *Parus major*, and *Pica pica* were positively correlated with overstory height and dead wood, but negatively related to ground cover grass and height. *Ficedula albicilla* was positively related to herbaceous cover, but negatively related to dead standing grass cover. Moreover, *Emberiza cioides*, *Emberiza leucocephalos*, and *Anthus hodgsoni* also were positively correlated with grass cover dominant and pine plantation habitats, and negatively correlated with overstory height and dead down wood habitats.

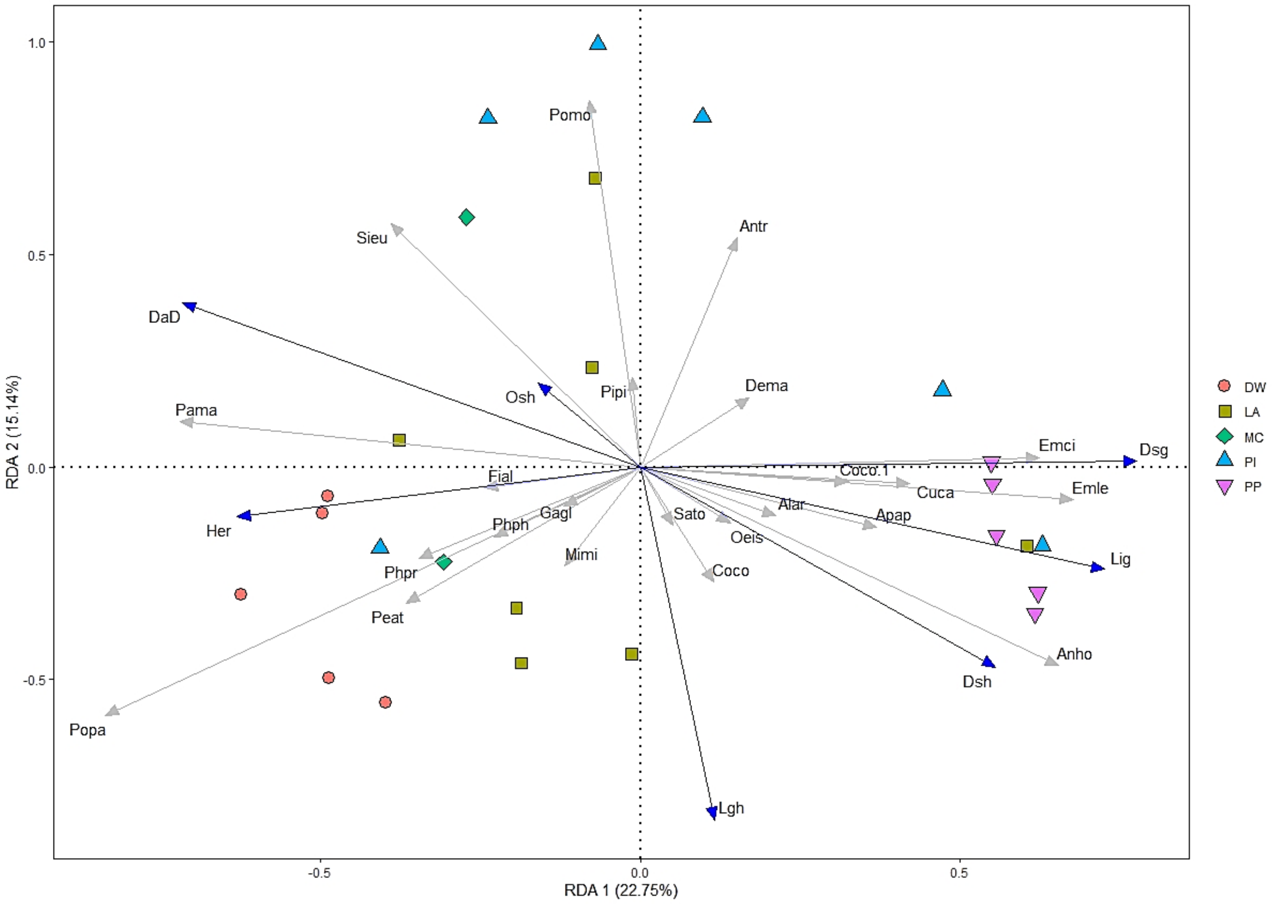

Figure 5. Redundancy analysis (RDA) ordination among bird assemblage and habitat types and environmental variables in the forest of the Khentii Mountains. Forest types are deciduous woodland (DW), larch (LA), pine (PI), pine plantation (PP), and mixed conifer (MC). Note: Species and habitat structural variable names are generic acronyms or the four or three letters of the names in Tables 1 and 2.

4. Discussion and Conclusions

Our study demonstrates the species richness and composition of bird assemblages, and the relations of forest habitat patterns of the Khentii Mountain boreal forest. Other studies have provided overviews of the taxonomic richness and composition of the avifauna across the Northern Mongolia [24–26,48]. Nevertheless, these only focused on avifauna, which resulted in forest regions remaining understudied. In total, 71 species were seen by the end of the survey, which were recorded in 400 point-counts, and on average, 3.14 species were seen per point. Birds in the study area account for 36.4% of the total species richness in the Khentii Mountains region and contribute to bird diversity [24], suggesting that forest habitat variables play an important role in bird diversity in forest areas [10,25]. Of this total, fourteen bird species occurred in all habitat types. Bird assemblages in the Khentii forested area were dominated mainly by *Anthus hodgsoni*, *Parus major*, *Poecile palustris*, *Sitta europaea*, *Emberiza leucocephalos*, and *Poecile montanus*. These species had relative abundance values of 5 to 12%, thereby contributing a lot to bird diversity in this area, accounting for 45% of total species richness. The bird species richness increased from the taiga zone to the forest-steppe zone. More specifically, our study found that bird richness was higher in larch dominated forests. Light mixed deciduous and larch forest communities have highly diverse bird assemblages, more so than taiga forest communities [24]. Larch forests, especially those burned by wildfires, change their landscapes and increase the forest layers of young birch, shrubs, and grasses [3]. The presence of deciduous trees in conifer-dominated forests generally allows for higher bird diversity compared to pure conifer stands [49,50].

In this study, forest habitat variables (altitude, overstory, understory, and ground composition) changed markedly by forest type. Different habitats are essential for bird assemblages in this forested area. The total species richness in the Khentii forested area was found to play an important role in the breeding and growth of the bird community, and a refuge for bird assemblages in the breeding season, for 57.3% of Mongolian bird species [25,26]. Among all types of habitats, the avifauna abundances were similar: the resident and migrant species accounted for 47.2% and 52.8%, respectively. The guild types also have a certain impact on the habitat selection of birds [25]; thus, insectivores (DW, LA, PI, PP, MC) were the dominant guild within each habitat type, and in our study area, there were 38 (53.5%) insectivores out of the 71 species sampled. The researchers have mentioned that insectivores are commonly observed to dominate forest habitats in terms of species richness and abundance; they are very important to forest regeneration [25,26,51].

Moreover, the present study showed bird assemblages in forest habitats of the Khentii Mountains were structured by a combination of overstory height and ground-layer features (e.g., dead down wood, herbaceous, and grass). Among these, ground layer-factors acted as the most important contributors to forest habitat types. The importance of forest habitat heterogeneity to the compositions of bird assemblages has been demonstrated by numerous studies [51–55]. The habitat variability and the diversity of the bird community are strongly influenced by the structure of the vegetation heterogeneity [56,57]. Our study found a significant difference in the tree and vegetation cover between forest type and canopy layer-based forested areas. Thus, in our study areas, ground-nesting bird species associated with grass (e.g., *Anthus hodgsoni*, *Emberiza leucocephalos*, *Anthus trivialis*, *Alauda arvensis*, and *Emberiza cioides*) tended to occupy areas with tall grass, such as pine plantations, and pines were often high in these habitats. The species that prefer an open forest canopy structure often tend to dominate the assemblages of dry Scots pine stands with sparse crown cover [20,58]. The high canopy-dominated conifer tree sites (LA, PI, MC) provide habitats for secondary cavity-nester bird species associated with low grasses and herbaceous cover (e.g., *Sitta europaea*, *Parus major*, and *Poecile montanus*). Those habitats are the most abundant in dead and down trees. Moreover, these species did not occur in pine plantation sites, and some secondary cavity-nester species were less abundant. Natural mature forests are highly suitable for cavity nesters or bark feeding species [59,60] and the abundance of the insectivores responds positively to an increase in basal area or dead wood volume [11]. On the other hand, the *Phylloscopus proregulus*, *Poecile palustris*, and *Periparus ater* have been recorded in high-herbaceous-cover areas dominated by deciduous woodland and some conifer habitats. As well, four species (*Poecile palustris*, *Periparus ater*, *Phoenicurus phoenicurus*, and *Ficedula albicilla*) are hole-nesters, and two species are low canopy nesters (*Phylloscopus proregulus*, and *Garrulus glandarius*), suggesting that the presence of deciduous trees is suitable for nesting for these species. Especially, species that generally require the presence of deciduous trees within stands are woodpeckers, tits, some nuthatches, and songbirds [54,61,62]. In deciduous woodland and deciduous mixed conifer forests, tits and warblers represented by far the most abundant portions of the community, and in pine and pine plantations, Emberiza species were more abundant than tits. However, woodpeckers were often the smallest fraction of the community. Our results showed that some species are more associated with sites with taller vegetation, whereas other species occupy sites with shorter vegetation and diverse herbaceous cover.

This study was the first to describe the forest-type variations of bird assemblages in the Khentii Mountains forest in Northern Mongolia. Identifying the assemblage pattern is useful for the conservation of not only birds but also biodiversity in general. In the course of the investigation, 71 bird species from 23 families and 11 orders were registered in the forest habitats of the Khentii partially of the forest area, and the Passeriformes order dominated; this result is the most up-to-date and systematically collected baseline data for future forest bird research. Information obtained from this study will enhance our understanding of the variation in bird assemblages, and then help to develop strategies for future forest bird conservation in such areas. Among these, insectivore birds dominate in all forest habitats. Many studies have also shown that insectivorous birds are more sensitive to habitat disturbance and loss than other feeding guilds [51,55,62–64]. From 2004 to 2014, the burned forest in the area increased by 1.4 million hectares, and the logging and insect-affected forest area increased by 340 thousand hectares [6]. Unfortunately, at the same time, the reforestation area increased by 2 thousand hectares [6], which shows a lack of reforestation. The bird community structure was affected by many factors, such as vegetation, the size and structure of the forest, and forest type.

In conclusion, according to our findings, Khentii forest areas are outstanding sites for migratory and resident birds. The results from this study show the importance of forest habitat structure for the abundance and diversity of birds in mixed tree and conifer forests. The bird species diversity and distribution of Khentii region can be currently regarded as moderately well studied. However, considering the bird assemblages of forested regions in Mongolia, further study is needed to fine-tune the species population estimates. In the future, we aim to study the co-effects of habitat disturbance and temporal variation on bird communities and bird density in different forest habitats. Thus, further studies on the relationship between temporal variation and bird density are important not only for ecological theory, but also for the scientific fundamentals of forest management and environmental protection in Mongolia.

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