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Bird Composition in Forest Fragments Across the Western Upper Thracian Lowland, Bulgaria

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Abstract: Currently, the plain forests across the Upper Thracian lowland are the last remnants of once widely spread deciduous vegetation dominated by oak forests. The avifauna in the Upper Thracian lowland forests has been poorly studied over the years. Here, we present a large dataset on the composition, species richness, and distribution of bird species within 15 managed plain forest fragments. This study is the first comprehensive scientific research on the topic, revealing the importance of the last remaining plain forests in the country for bird conservation. In total, 95 avian species were registered during the survey. Seventy-eight were confirmed as breeders in the study area, and 17 were excluded from the analysis, as their presence was either related to specific non-forest microhabitats within the forest patches or stopover sites during migration. Species richness varied from 51 to 35 species per forest fragment. In total, 14 (18%) species occurred in all sites, and six (7.7%) species were present in a single locality. Shannon Diversity Index showed the highest species diversity in the Tyurkmen forest (H=3.33), where the greatest number of forest edge species was found. The index showed the lowest value in the Izbeglii forest (H=2.943). The evenness of the species distribution was lowest in Izbeglii (J=0.77) and highest in Novi Izvor (J=0.88).

Key words: forest fragments, forest birds, bird diversity, species richness

Introduction

Forests are the largest terrestrial ecosystem in the European Union (Forest Europe, 2015), and most plant and animal diversity is contained in forests. The spread of human settlement and increased agricultural land are the most important factors causing the loss, degradation, and fragmentation of natural vegetation, including forests, worldwide (Hanski et al. 1996, Jackson & Fahrig 2013; Yabuhara et al. 2019). In many parts of the world, agricultural landscapes dominate, and woods remain only as islands in the farmland matrix (Namkoong & Koshy 2008).

Similarly, forests in the Western Upper Thracian lowland are represented by separated and heavily transformed isolated forest patches, covering only about 4% of the area (Nam et al. 2022), distributed across an extensive farmland matrix. These patches of forests provide islands of habitats (Matthews & Triantis 2021) for many bird species in the heavily disturbed region of the Thracian lowland. Thus, these forest patches offer an excellent opportunity for studying the effects of forest fragmentation and how anthropogenic landscapes drive species composition, richness, and diversity (Fahrig 2003).

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Habitat loss and habitat fragmentation are the leading causes of adverse effects on biodiversity worldwide. While habitat loss is known to be the major threat to forest biodiversity, forest fragmentation can have both negative and positive impacts (Jackson & Fahrig 2013). Fragmentation is the transformation of "a large expanse of habitat into several fragments of smaller total area, separated from each other by a matrix of habitats unlike the original" (Fahrig 2003). Forest fragmentation results from a combination of forest removal and the creation of forest patches within a non-forest matrix (Stratford & Sekercioglu 2015) and has three major components: reduction in habitat patch size, increasing isolation of habitat patches (Andren 1994), and change in habitat configuration (Jackson & Fahrig 2013).

Changes in forest structure can negatively or positively affect forest bird species, depending on variable habitat preferences. Intensive forestry has created mosaics of mature and successional stands of various ages with an increased amount of forest edge (Hanski et al. 1996). Typically, the number of species associated with mature forest trees (e.g., flycatchers, treecreepers, etc.) is reduced in forest fragments (Stratford & Sekercioglu 2015), while species associated with early successional habitats and forest edges usually benefit from harvesting and fragmentation (Leso et al. 2019).

Forest size is generally correlated with the species richness and composition of breeding bird assemblages. Smaller forest fragments can hold more species, but many area-sensitive bird species are uncommon in smaller forests. Typically, dependent on forest area, species, breed only in interior habitats of the larger forests (Blake & Karr 1984, Freemark & Collins 1992).

Despite the historical changes and the intensive management practices, the last forest remnants of the Western Upper Thracian lowland hold a considerable number of bird species from different ecological groups and taxa, thus providing a good example of complex and dynamic landscapes. The avifauna in the Upper Thracian lowland forests is poorly studied. Faunal review and distribution depending on the habitat preferences of bird species is considered in Fauna of Thrace – Birds in Thrace (Boev et al. 1964). The bird composition of the lowland is reviewed in the popular science articles of Hristovich (1890, 1892) and the publications of Reiser (1894) and Balat (1962) (Boev et al. 1964). Patev (1950) presents data on the distribution of bird species in the lowlands, although without any specific surveys. Data on the avian distribution in the lowland is also found in the Fauna of Bulgaria (Simeonov et al. 1990, Nankinov et al. 1997, Ivanov 2011), as well as in the Atlas of the breeding birds in Bulgaria (Iankov 2007). However, currently, systematic or comparative studies of bird composition associated with the Western Thracian lowland mosaic landscape are not available.

Birds are best studied in relation to environmental changes and are viewed as one of the most important indicator groups (Balaz & Balazova 2012, Wesolowski et al. 2022). As major parts of European forests are managed for human purposes, investigating long-term population trends of birds is a way to understand the impacts of changes in the forest environment on biodiversity (Reif et al. 2022). One of the primary attributes of biodiversity, widely recognised as providing a framework for research on forest biodiversity, is assessing the species composition, including species lists and measures of species diversity (Gao et al. 2015).

The study aimed to provide detailed knowledge on bird composition and diversity and serve as a base for future understanding of the trends of avian communities in plain forest fragments. In this regard, we present the results of the analysis of a large dataset on the composition and diversity of bird assemblages within 15 plain forest fragments from the Western Upper Thracian lowland.

Materials and Methods

Study Area

The study was carried out in the forest landscape of the Western Upper Thracian lowland (Fig. 1). The forest patches are of broad-leaved vegetation, surrounded by intensive agricultural lands in a region with high population density and high level of infrastructure development. The forest landscape is mainly affected by human activities linked to silviculture and the creation of complex mosaic forest patches of different sizes (Kopralev 2002). The relief is plain with a mean elevation of 202 m (133-331 m a.s.l.). The climate is transitional continental. According to the origin, a major part of the forests is coppice stands (93.6%), with only a small portion of seed stands (6.07%). According to the species composition, the forest fragments consist predominantly of different oak species (*Quercus robur*, *Quercus patraea*, *Quercus frainetto, Quercus cerris*, *Quercus pubescens*), Field elm (*Ulmus minor*), Narrow-leaved ash (*Fraxinus anguistifolia*), Field maple (*Acer campestre*), False acacia (*Robinia pseudoacacia*), European hornbeam (*Carpinus betulus*), Silver poplar (*Populus alba*), White willow (*Salix*

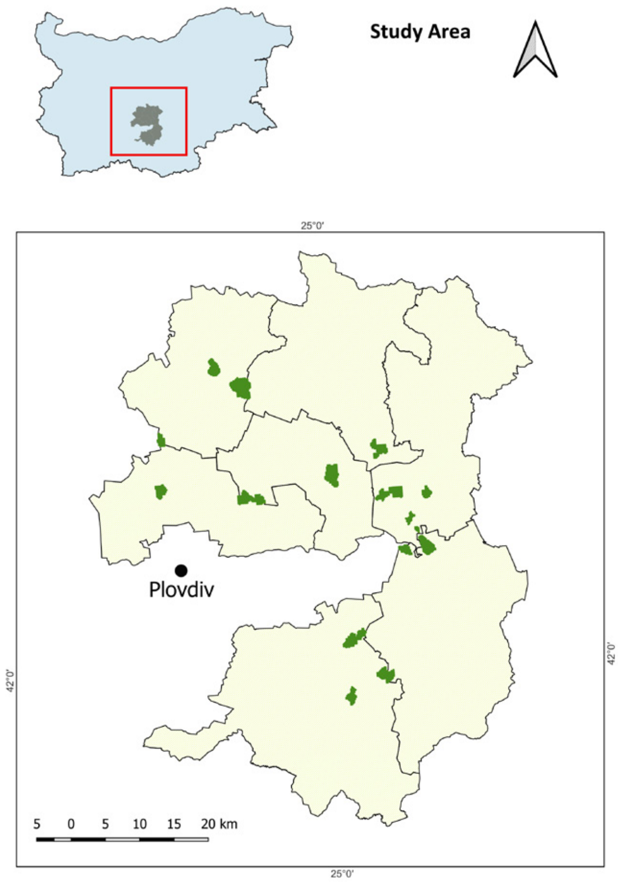

Fig. 1. Study area and sampling sites. Municipal districts are in yellow with black borders, and study forests are in green.

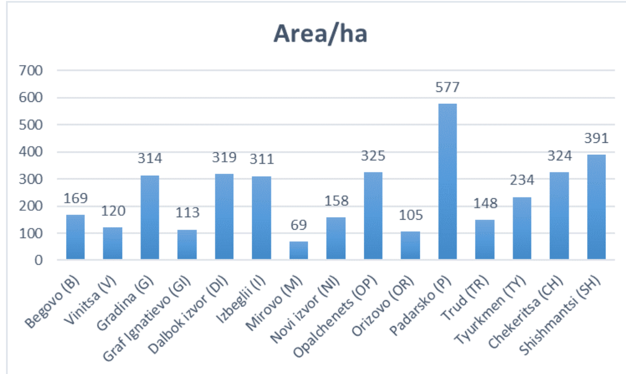

Fig. 2. Forest area in ha for the 15 study fragments with abbreviations in brackets.

alba) and Common alder (*Alnus glutinosa*) (Kopralev 2002).

The study covered 15 forest patches with size ranges from 68.8 ha to 577.4 ha and a total area of 3677.117 ha (Fig. 2). To study the composition and distribution of the breeding birds, we split the area into 1307 sample plots with grid size 150 x 150 m using QGIS 3.26.3 (2020). We used random selection to choose 71 study plots (≈ 5% of all plots) for our study, which is considered a sufficient sample size (Bibby et al. 1998).

Data was collected using Smart Birds Pro's electronic application, which allows for a standardised collection of biological information and summarisation for subsequent analysis (Popgeorgiev et al. 2015).

Birds Surveys

Diurnal Bird Species

A point count methodology for dense forests and inconspicuous birds was used to account for different species and their number (Bibby et al. 1998). Birds were also recorded during the transition between the census points, and data were used to complement the results on bird richness without applying line transect methodology (Fig. 3).

Bird surveys were performed between April and July for three consecutive years (2020–2022). Bird surveys in all selected study plots were performed from 5:30–11:00 am when birds are most active, displayed, and under good meteorological conditions (without strong wind, rain or fog). Each plot was visited twice per breeding season each year with 10–40 days (21 days on average) between the visits (Bibby et al. 1998). During each visit, every study plot was surveyed for approximately 15 minutes. Birds were identified based on both vocal (song/calls) registration and visual observation. Birds flying over the study plots were excluded from the count. For some individuals, calls and songs were recorded during the survey and identified in addition. We accounted for the number of breeding pairs whenever one of the following conditions was met: 1. Adult bird observed in a habitat suitable for breeding; 2. Singing male; 3. Male and female birds are located closely; 4. Flock of fledged young birds moving together with or without parents; 5. Occupied nest or hollow (Nikolov & Spasov 2005).

Nocturnal Raptor Species

The nocturnal raptor species were surveyed using vocal provocation at randomly selected points, depending on each species' territorial behaviour, at least 500 m apart (Shurulinkov et al. 2013). The survey was carried out between March and April 2020 and 2021. Species were recorded in 74 randomly selected points in all 15 forest fragments after sunset under good meteorological conditions. The survey targeted all nocturnal raptor species expected in the study area: Eurasian Scops owl (*Otus scops*), Little owl (*Athene noctua*), Long-eared owl (*Asio otus*), Barn owl (*Tyto alba*), Tawny owl (*Strix aluco*) and Short-eared owl (*Asio flammeus*). Bird calls

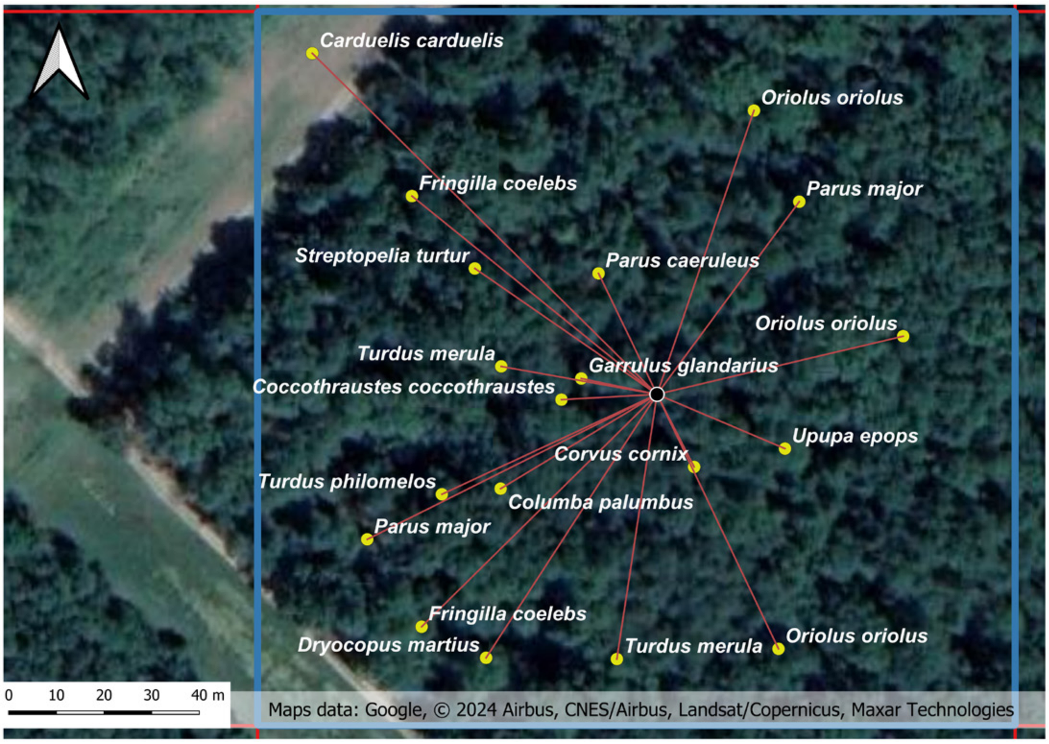

Fig. 3. Observed bird species (yellow dots) with radial distances (red lines) from observation point (black dot) in randomly selected sample plots (blue borders) within the forest of Chekeritsa during the breeding season of 2022 (Google Maps 2024).

were acoustically simulated with a sound-producing device and loudspeaker. The different species were vocally simulated with the specific breeding call in each study point. Each call of every species, starting with the smallest size, was played for at least three minutes, followed by a one-minute break for active listening for any vocal reactions.

Each bird species was classified by breeding habitat preferences as follows: 1) forest-interior species, which restrict their activity to interior parts of the forests and rarely occur near the edge; 2) forest-edge species, typically found around forest perimeters or in large clearings within a forest; 3) interior-edge species, found both on the edge and in the interior of the forests; 4) species of the open habitat, found in nearby fields or fields within the forests. Preferred breeding habitat classification was based on Blake & Karr (1984). The allocation of the species depending on the habitat preferences was based on Simeonov et al. (1990), Nankinov et al. (1997), Ivanov (2011) and our own field experience with the majority of species recorded.

A total of 69 species were registered during point count surveys and 26 species during the transition between the study plots (random observations). Seventeen species were excluded from the analysis, as their presence was related to specific non-forest microhabitats within the forests (e.g. small ponds, buildings, etc.), feeding sites or stopover sites during migration. Species richness includes all species with at least one observation within the study area. Breeding bird status is according to Hagemeijer & Blair (1997).

We used the Shannon-Wiener Diversity Index to derive Species Diversity and Species Evenness values. Only species with confirmed breeding status and species consistent with the breeding habitat groups were analysed. Strigiformes species were excluded from the diversity measure analysis, as the data was collected only for the period 2020–2021.

All statistical analyses were performed using Past v. 4.3 (Hammer et al. 2001), and maps were generated using QGIS 3.26.3 (2020).

Results

In total, 95 species from 17 Orders and 38 Families were recorded during the survey with different breeding status (Table 1). We confirmed 78 of them as breeders in the study area.

Forest-interior species formed a minor component of bird composition – 9% (n=7), followed by open habitat birds, represented by 10 species (13%). The best presented were the interior-edge species – 50% (n=39) and the forest-edge species – 28% (n=22). Fourteen species (18%) occurred in all sites,

Table 1. Complete list of all registered species within the study sites and their preferred breeding habitat (+) (FI – forest-interior; FE – forest-edge; IE – interior-edge; OH – open habitat). Species, excluded from the analysis (Other) are marked with * (waterfowls), ** (open habitats without relation to forests), *** (buildings or other infrastructure), **** (stopover sites during migration).

Order	Family	Species	FI	FE	IE	OH	Other
Accipitriformes	Accipitridae	*Accipiter gentilis*			+		
Accipitriformes	Accipitridae	*Accipiter nisus*			+		
Accipitriformes	Accipitridae	*Clanga pomarina*			+		
Accipitriformes	Accipitridae	*Buteo buteo*			+		
Accipitriformes	Accipitridae	*Circaetus gallicus*			+		
Accipitriformes	Accipitridae	*Haliaeetus albicilla*			+		
Accipitriformes	Accipitridae	*Hieraaetus pennatus*			+		
Accipitriformes	Accipitridae	Milvus migrans			+		
Accipitriformes	Accipitridae	*Pernis apivorus*			+		
Anseriformes	Anatidae	*Anas platyrhynchos* *					+
Anseriformes	Anatidae	*Tadorna ferruginea* *					+
Bucerotiformes	Upupidae	*Upupa epops*			+		
Caprimulgiformes	Caprimulgidae	*Caprimulgus europaeus*			+		
Charadriiformes	Charadriidae	*Charadrius dubius* *					+
Ciconiiformes	Ciconiidae	*Ciconia ciconia* **					+
Ciconiiformes	Ciconiidae	*Ciconia nigra*			+		
Columbiformes	Columbidae	*Columba palumbus*			+		
Columbiformes	Columbidae	*Streptopelia decaocto*		+			
Columbiformes	Columbidae	*Streptopelia turtur*			+		
Coraciiformes	Coraciidae	*Coracias garrulus*			+		
Cuculiformes	Cuculidae	*Cuculus canorus*			+		
Falconiformes	Falconidae	Falco subbuteo			+		
Falconiformes	Falconidae	*Falco tinnunculus* ***					+
Galliformes	Phasianidae	*Coturnix coturnix*				+	
Galliformes	Phasianidae	*Perdix perdix*				+	
Galliformes	Phasianidae	*Phasianus colchicus*			+		
Gruiformes	Rallidae	*Crex crex*		+			
Passeriformes	Acrocephalidae	*Acrocephalus palustris*		+			
Passeriformes	Acrocephalidae	*Hippolais pallida*		+			
Passeriformes	Aegithalidae	*Aegithalos caudatus*			+		
Passeriformes	Alaudidae	*Alauda arvensis*				+	
Passeriformes	Alaudidae	*Galerida cristata*				+	
Passeriformes	Alaudidae	*Lullula arborea*		+			
Passeriformes	Certhiidae	*Certhia brachydactyla*	+				
Passeriformes	Corvidae	*Corvus corax*		+			
Passeriformes	Corvidae	*Corvus cornix*		+			
Passeriformes	Corvidae	*Corvus frugilegus*		+			
Passeriformes	Corvidae	*Garrulus glandarius*			+		
Passeriformes	Corvidae	Pica pica		+			
Passeriformes	Emberizidae	*Emberiza cirlus*				+	
Passeriformes	Emberizidae	*Emberiza hortulana*		+			
Passeriformes	Emberizidae	*Emberiza melanocephala*				+	
Passeriformes	Emberizidae	*Emberiza calandra*		+			

Table 1. Continuation.

Order	Family	Species	FI	FE	IE	OH	Other
Passeriformes	Fringillidae	*Carduelis carduelis*		+			
Passeriformes	Fringillidae	*Chloris chloris*			+		
Passeriformes	Fringillidae	*Coccothraustes coccothraustes*			+		
Passeriformes	Fringillidae	*Fringilla coelebs*			+		
Passeriformes	Hirundinidae	*Delichon urbicum* ***					+
Passeriformes	Hirundinidae	*Cercopis daurica* ***					+
Passeriformes	Hirundinidae	*Hirundo rustica* ***					+
Passeriformes	Laniidae	*Lanius collurio*		+			
Passeriformes	Laniidae	*Lanius minor*		+			
Passeriformes	Laniidae	*Lanius nubicus*		+			
Passeriformes	Laniidae	*Lanius senator*		+			
Passeriformes	Motacillidae	*Motacilla flava*				+	
Passeriformes	Muscicapidae	*Erithacus rubecula*			+		
Passeriformes	Muscicapidae	*Ficedula semitorquata*	+				
Passeriformes	Muscicapidae	*Luscinia megarhynchos*			+		
Passeriformes	Muscicapidae	*Muscicapa striata*	+				
Passeriformes	Muscicapidae	*Saxicola rubetra*				+	
Passeriformes	Muscicapidae	*Saxicola torquata*				+	
Passeriformes	Oriolidae	*Oriolus oriolus*			+		
Passeriformes	Paridae	*Parus caeruleus*			+		
Passeriformes	Paridae	*Parus major*			+		
Passeriformes	Passeridae	*Passer domesticus*		+			
Passeriformes	Passeridae	*Passer hispaniolensis*		+			
Passeriformes	Passeridae	*Passer montanus*		+			
Passeriformes	Philloscopidae	*Phylloscopus collybita*			+		
Passeriformes	Philloscopidae	*Phylloscopus sibilatrix* ****					+
Passeriformes	Remizidae	Remiz pendulinus		+			
Passeriformes	Sittidae	*Sitta europaea*	+				
Passeriformes	Sturnidae	*Sturnus vulgaris*			+		
Passeriformes	Sylviidae	*Sylvia atricapilla*			+		
Passeriformes	Sylviidae	*Curruca communis*		+			
Passeriformes	Sylviidae	*Curruca curruca*		+			
Passeriformes	Sylviidae	*Curruca nisoria*		+			
Passeriformes	Troglodytidae	*Troglodytes troglodytes*	+				
Passeriformes	Turdidae	*Turdus merula*			+		
Passeriformes	Turdidae	*Turdus philomelos*			+		
Pelecaniformes	Ardeidae	*Ardea cinerea* *					+
Pelecaniformes	Ardeidae	*Ardeola ralloides* *					+
Pelecaniformes	Ardeidae	*Nycticorax nycticorax* *					+
Pelecaniformes	Ardeidae	*Egretta garzetta* *					+
Piciformes	Picidae	*Dendrocopos major*			+		
Piciformes	Picidae	*Dryobates minor*			+		
Piciformes	Picidae	*Dendrocopos syriacus*			+		
Piciformes	Picidae	*Dryocopus martius*	+				
Piciformes	Picidae	*Picus viridis*			+		

Table 1. Continuation.

Order	Family	Species	FI	FE	IE	OH	Other
Podicipediformes	Podicipedidae	*Podiceps cristatus* *					+
Strigiformes	Strigidae	*Asio flammeus* **					+
Strigiformes	Strigidae	*Asio otus*			+		
Strigiformes	Strigidae	*Athene noctua* ***					+
Strigiformes	Strigidae	*Otus scops*			+		
Strigiformes	Strigidae	*Strix aluco*	+				
Strigiformes	Tytonidae	*Tyto alba* ***					+

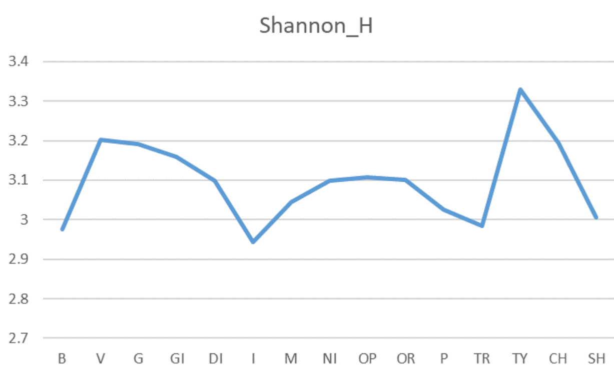

Fig. 4. Shannon Diversity Index of the species in the study forests.

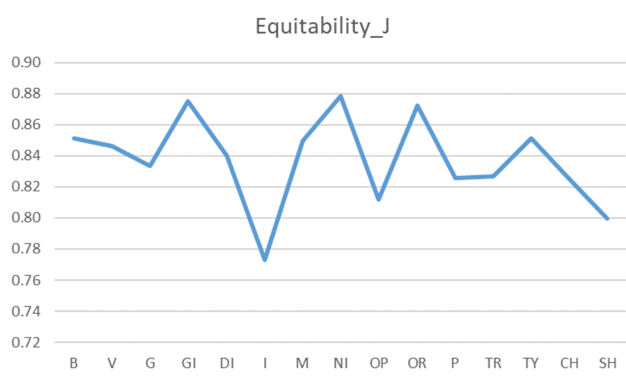

Fig. 5. Shannon Evenness Index (J) of the species in the study forests.

and six species (7.7%) at a single locality each (Table 2.). The best-presented order in all forest patches was Passeriformes, with a total of 48 species from 20 families.

Chekeritsa forest (n=51) and Tyurkmen forest (n=51) were found to be the richest in species, whereas the fewest species were registered in Begovo forest (n=35). The forest-interior species ranged from none to five per study site. The number of forest-edge species varied from two at Begovo forest to 15 at Tyurkmen forest. Interior-edge species varied from 21 to 33 per locality, with the highest number found in Gradina forest (n=33) and the smallest in Novi Izvor forest (n=21).

Shannon Diversity index showed the highest values in the Turkmen forest (H=3.33) and the lowest in Izbeglii (H=2.94) (Fig. 4). The Evenness of the species distribution (heterogeneity) was lowest in Izbeglii (J=0.77) and highest in Novi Izvor (J=0.88) (Fig. 5).

Discussion

During the current study, a great diversity of species was identified – in total, 95 species from 17 orders and 38 families. The study area encompassed different sizes and structures of forest fragments, with stand age predominantly between 20 and 80 years (65% of the total area), that differed in management interventions. Distribution and species diversity of birds in the patchy environment was determined primarily by the presence of suitable habitats (Opdam et al. 1985), heterogeneity (Boecklen 1986), forest structure (Hofmeister et al. 2017) and forest size (Freemark & Collins 1992). The study forests were highly fragmented; some of them consisted of different tree species of different ages and a large part of an ecotone area. Together with the combination of various waterbodies and arable lands, the lowland landscape presented a complex mosaic of habitats with a high level of heterogeneity (Nam et al. 2022). This diversity of habitats can explain the presence of large numbers of bird species from different communities.

The highest species richness was found in forests with high levels of heterogeneity, consisting of rich forest structure, diverse surrounding habitats and forest openings, providing foraging habitats. Both the forests of Tyurkmen and Chekeritsa were comprised of 51 species. The high species richness in the forest of Tyurkmen is due to increased heterogeneity with different stand stages despite

Table 2. Species (+) registered in the study forest fragments (Begovo [B]; Vinitsa [V]; Gradina [G]; Graf Ignatievo [GI]; Dalbok Izvor [DI]; Izbeglii [I]; Mirovo [M]; Novi izvor [NI]; Opalchenets [OP]; Orizovo [OR]; Padarsko [P]; Trud [TR]; Tyurkmen [TY]; Chekeritsa [CH]; Shishmantsi [SH]), and their breeding status (PB – possible breeder; PRB – probable breeding; CB – confirmed breeding; NB – non-breeding).

Species	B	V	G	GI	DI	I	M	NI	OP	OR	P	TR	TY	CH	SH	Counted forests	Breeding code
Accipiter gentilis	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	3	PRB
Accipiter nisus	-	+	-	+	+	-	-	-	-	-	+	-	+	+	+	7	PB
Acrocephalus palustris	-	-	-	-	+	+	+	-	-	-	-	-	-	+	-	4	PB
Aegithalos caudatus	+	+	+	-	+	+	-	-	+	+	+	+	+	+	+	12	CB
Alauda arvensis	-	+	-	+	+	+	+	+	+	-	-	+	+	+	+	11	PB
Clanga pomarina	-	-	-	-	+	+	-	-	+	-	-	-	-	+	+	5	PB
Asio otus	+	+	+	+	+	+	+	-	-	-	+	-	+	+	-	10	PB
Buteo buteo	+	+	+	+	-	+	+	-	+	-	+	+	+	+	+	12	PRB
Caprimulgus europaeus	-	-	+	-	-	+	-	+	+	-	-	-	-	-	+	5	PB
Carduelis carduelis	-	+	+	-	+	-	-	-	+	-	-	-	+	+	-	6	PRB
Chloris chloris	+	+	+	+	-	+	+	+	-	+	-	+	-	+	+	11	PRB
Certhia brachydactyla	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	1	PB
Ciconia nigra	-	+	+	-	+	+	-	-	+	-	+	-	+	+	+	9	CB
Circaetus gallicus	-	-	+	-	-	-	-	-	-	-	-	+	-	+	-	3	PB
Coccothraustes coccothraustes	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Columba palumbus	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	14	PRB
Coracias garrulus	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	4	CB
Corvus corax	-	+	+	+	-	+	+	+	-	-	+	-	+	+	+	10	CB
Corvus cornix	-	-	+	+	-	-	-	+	+	-	-	-	+	+	-	6	CB
Corvus frugilegus	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1	PB
Coturnix coturnix	-	-	-	+	+	+	-	+	+	-	-	-	-	-	-	5	PRB
Crex crex	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	1	PB
Cuculus canorus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	PB
Dendrocopos major	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	14	CB
Dryobates minor	-	-	+	-	-	-	-	+	-	-	+	-	-	+	+	5	PB
Dendrocopos syriacus	+	+	+	+	+	-	-	-	-	-	-	+	-	+	-	7	PB
Dryocopus martius	+	+	+	-	+	+	-	-	+	-	+	-	+	+	-	9	PRB
Emberiza cirlus	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	2	PB
Emberiza hortulana	-	-	-	-	+	+	+	+	+	-	+	-	+	-	+	8	PB
Emberiza melanocephala	-	-	+	-	-	+	+	-	+	+	-	+	+	+	-	8	PB
Erithacus rubecula	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Falco subbuteo	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	PB
Ficedula semitorquata	-	+	+	-	-	-	-	-	-	-	-	-	+	+	+	5	PB
Fringilla coelebs	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Galerida cristata	-	-	-	-	-	+	+	-	+	+	-	+	+	-	-	6	PRB
Garrulus glandarius	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	PRB
Haliaeetus albicilla	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1	NB
Hieraaetus pennatus	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	2	PB
Hippolais pallida	-	-	+	+	-	+	+	-	+	+	+	+	+	+	-	10	PB
Lanius collurio	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Lanius minor	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	2	PB
Lanius nubicus	-	+	+	-	-	-	-	+	+	-	-	-	+	-	-	5	PRB

Table 2. Continuation.

Species	B	V	G	GI	DI	I	M	NI	OP	OR	P	TR	TY	CH	SH	Counted forests	Breeding code
Lanius senator	-	+	+	-	-	+	-	-	-	-	-	+	+	-	-	5	PRB
Lullula arborea	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	2	PB
Luscinia megarhynchos	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	PRB
Emberiza calandra	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	PRB
Milvus migrans	-	+	+	-	-	-	-	-	+	-	-	-	-	-	+	4	CB
Motacilla flava	-	-	-	-	-	+	+	-	-	+	-	+	+	-	-	5	PRB
Muscicapa striata	+	-	+	+	+	-	-	+	+	+	+	-	+	+	+	11	PB
Oriolus oriolus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Otus scops	+	+	+	+	-	+	+	+	-	+	+	-	-	+	+	11	PB
Parus caeruleus	+	+	+	-	+	-	-	+	+	+	+	+	+	+	+	12	CB
Parus major	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Passer domesticus	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	1	PB
Passer hispaniolensis	-	+	-	-	-	+	+	-	+	+	-	-	+	-	-	6	CB
Passer montanus	-	+	+	+	-	-	-	-	-	-	+	-	+	-	+	6	PRB
Perdix perdix	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	11	PRB
Pernis apivorus	+	-	-	-	+	-	-	-	+	-	-	-	+	-	-	4	PB
Phasianus colchicus	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	14	PRB
Phylloscopus collybita	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	13	PB
Pica pica	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	2	PB
Picus viridis	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	14	PB
Remiz pendulinus	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	1	PB
Saxicola rubetra	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	2	PB
Saxicola torquata	-	-	-	+	-	+	-	-	-	+	-	-	-	-	-	3	PB
Sitta europaea	+	-	+	-	+	-	-	+	+	+	+	+	+	+	+	11	PB
Streptopelia decaocto	-	+	+	+	-	-	-	-	-	+	+	+	+	+	+	9	PB
Streptopelia turtur	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	PRB
Strix aluco	-	-	+	-	-	-	-	+	+	-	-	+	-	+	-	5	PRB
Sturnus vulgaris	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	14	CB
Sylvia atricapilla	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	PRB
Curruca communis	-	-	-	+	+	+	-	-	+	-	+	+	+	+	+	9	PB
Curruca curruca	-	+	-	+	+	-	-	-	-	+	-	+	-	-	+	6	PB
Curruca nisoria	-	-	-	+	+	+	-	-	-	-	+	-	+	-	-	5	CB
Troglodytes troglodytes	-	+	-	-	-	-	-	-	-	-	+	-	-	-	+	3	CB
Turdus merula	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Turdus philomelos	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15	CB
Upupa epops	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	14	PB

the intensive human disturbance. On the contrary, management activities in the forest of Chekeritsa are limited, as it is a game breeding station. Another beneficial feature of the Chekeritsa forest is the presence of the Stryama River in the periphery, with well-preserved riparian vegetation. On the other hand, the forest of Begovo, where fewer species were registered, mainly consists of one tree species, and human disturbance is minimal. There is a lack of forest openings and no differentiation of ecotone area, which can explain the low number of forest edge species (n=2) and the absence of species in the open habitats.

Bird composition consisted of species from four groups based on their breeding habitat preferences: 1) forest-interior species; 2) forest-edge species; 3) interior-edge species; 4) species of the open habitat (Blake & Karr 1984). Our results showed that the species inhabiting both the interior and edge of the forests are the most diverse – 39 (50%). Typically, the high number of bird species in fragmented forests is linked with the larger amount of edge area, as well as forest openings and early-successional stage habitats (Haulton 2008). We found that some generalist species were abundant closer to the forest edge (e.g., *Luscinia megarhynchos, Sylvia atricapilla, Turdus merula, and Fringilla coelebs*). At the same time, typical forest-dependent birds were well presented also in the core area of the forest fragments (e.g., *Erithacus rubecula, Columba palumbus, Turdus philomelos, Coccothraustes coccothraustes*). Many species benefit from the mosaic landscapes, as they provide suitable breeding sites and foraging areas with abundant prey in the open spaces. The presence of forest patches with different stand ages in the agricultural landscape fulfils the minimal habitat requirements for a number of species dependent on mature trees for breeding sites (Mirski & Vali 2021). This makes the lowland an attractive environment for the birds of prey. Although we didn't apply a specific methodology for diurnal raptor species, during the study, we registered 10 species from the order Accipitriformes and Falconiformes, demonstrating breeding or territorial behaviour.

The best presented was the Common Buzzard (*Buteo buteo*) found in 12 of the study sites, while the other species had occasional and local observations. Given that all registered species are common breeders in the Thracian lowland (Iankov 2007), the only exception for the vicinity of the Maritsa River was the observation of a White-tailed Eagle (*Haliaeetus albicilla*) pair with occupied territory, but unsuccessful breeding (Demerdzhiev, pers. comm.). Other interior-edge species, such as the woodpeckers (e.g. *Dendrocopos major, Dendrocopos syriacus, Dryobates minor, Picus viridis*) and some secondary cavity-nesters (*Parus major, Upupa epops*) are dependent on specific forest features, such as the presence of large, old-aged trees and deadwood (Basile 2019).

Forest-interior species formed a minor component of the bird composition – 7 (9%) in our study. Typically, the number of forest-interior and sensitive species is reduced in forest fragments (Banks-Leite et al. 2010), as these birds can be found in greater numbers in unmanaged forests (Leso et al. 2019). The low numbers of interior species in forest segments are mainly due to the high level of fragmentation, leading to multiple edges and lack of true interior (Banks-Leite et al. 2010) in most of the fragments. Forest-interior species varied from none to five per site and were best presented in the forest fragments with larger size and heterogeneous structure (forests of Opalchenets, Tyurkmen, Shishmantsi and Padarsko), forests with limited management activities (forest of Chekeritsa and Gradina) and riverine forests (Vinitsa and Gradina forests).

Twenty-two of all species were dependent on the forest edge. These species were mainly related to the presence of shrubs and open patches (e.g., Sylvidae, Lanidae, Passeridae), as well as with the adjacent habitat type (e.g., *Crex crex*) and farmlands (e.g., *Streptopelia turtur, Emberiza hortulana, Lanius collurio*). According to Leso et al. (2019), species related to edges might benefit in forests with altered habitats and usually benefit from harvesting and fragmentation. However, the number of forest edge species was not occasional and can be explained by the mosaic landscape, high level of fragmentation and a large amount of ecotone area, both in the periphery and in gaps within the forests.

We registered 12 species related to open habitats for breeding, which were recorded on the edge or in arable lands and openings within the forests. These species are not dependent on forests and tree stands, but according to Berg & Part (1994), their abundance is linked to the structure and quality of the field-forest ecotone. The registered species in the current study are mainly related to the presence of bushes within the pastures and meadows (*Emberiza cirlus, Emberiza melanocephala, Saxicola rubetra, Saxicola torquata*), quality of the habitat and foraging resource (*Alauda arvensis, Galerida cristata*), as well as ploughing of pastures and meadows. The common farmland species, which are presented in this group, are one of the most rapidly declining avian groups, mainly due to the intensification of agriculture and the decrease in pastures and meadows. Best presented in our study were the Corn bunting (*Emberiza calandra*) and the Skylark (*Alauda arvensis*), both showing a decrease in population trends according to the assessment of the common bird species in Bulgaria (Hristov 2022).

Bird species diversity was highest in Tyurkmen forest (H=3.33) and lowest in Izbeglii (H=2.94) (Fig. 4). The forest of Tyurkmen is highly fragmented, as patches are relatively separated from each other and surrounded by various mosaic habitats. A major part of the surrounding area is farmland, while meadows, pastures, shrubs, and grasslands have a small share. Intensive management activities are taking place in the forest, and almost half of it is a Black locust plantation (46% of the total forest area), with 67% of the trees under the age of 20 years. This shows that a large part of the forest is in the early successional stage, which is known to support higher bird richness, providing breeding and foraging habitats for field and shrub-nesting species (Berg & Part 1994). Turkey oak is the second tree species in the forest with 42% of the total area and with age between 20 and 80 years old. We can conclude that the forest of Tyurkmen continues to support a variety of bird communities despite human disturbance and landscape changes. The results show that the forest habitat is hostile for various bird communities with diverse and equally abundant taxa.

Controversially, the lowest value was found in the forest of Izbeglii (H=2.94). The forest consists entirely of two oak species – Hungarian oak and Pubescent oak, with a small portion of Black locust. The trees are relatively uniform in age, with a poorly presented shrub layer. We found a larger number of farmland species (n = 8), which can be explained by the presence of a considerable number of arable lands within the forest. Only one interior species was found to breed in the forest – the Black woodpecker (*Dryocopus martius*), probably due to the exceptional appearance of single large and old-aged trees. The results showed the lowest evenness for the forest of Izbeglii (J=0.77). The low heterogeneity index is likely based on the homogeneous vegetation structure with uniform stands and the surrounding habitat mosaics, providing various habitats but with small areas. Thus, the study site provides a suitable habitat for various bird communities, yet with low numbers and uneven distribution across the area.

The highest evenness was found to be in the forest of Novi Izvor (J=0.88), as well as relatively lower species richness (n=36). This result could be explained by the uniform forest structure, dominated by Hungarian oak (76% of the total area) and a small amount of Black locust (8% of the total area), with an almost complete absence of a shrub layer. The homogeneous forest structure and the small total area of the forest offer suitable habitat features for fewer bird species. Yet, the common and abundant species for the plain forests as a whole (e.g., *Luscinia megarhynchos, Turdus merula, Fringilla coelebs* etc.) are presented with low numbers, with the majority of the species presented having less than 10 observations. Both the poor species richness and higher value of the evenness index can be explained by the homogeneous forest structure, resulting in limited suitable breeding and foraging sites, thus supporting fewer bird taxa but an equally presented number of individuals among the communities.

The current study provides new data on the poorly studied avifauna of the forest patches of the largest lowland in Bulgaria. These forests harbour numerous bird species in the heavily disturbed agricultural region of the Western Upper Thracian lowland. Our results could serve as a guideline for the development of future management practices and benefit the preservation of vulnerable bird species and their habitat in the changing environment due to anthropogenic activities and climate change.

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References

Andren H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71: 355-366.

Balat F. 1962. Contribution to the knowledge of the avifauna of Bulgaria. Prace Brn. Zan CAV 34: 445-492.

Balaz M. & Balazova M. 2012. Diversity and abundance of bird communities in three mountain forest stands: Effect of the habitat heterogeneity. Polish Journal of Ecology 60 (3): 629-634.

Banks-Leite C., Ewers R.& Metzger J. 2010. Edge effects as the principal cause of area effects on birds in fragmented secondary forest. Oikos 119: 918-926.

Basile M. 2019. The influence of retention forestry on the occurrence and abundance of forest birds across the landscape. Thesis. Faculty of Environment and Natural Resources, Albert-Ludwigs-Universität. Freiburg im Breisgau, Germany. 169 p.

Berg A. & Part T. 1994. Abundance of breeding farmland birds on arable and set-aside fields at forest edges. Ecography 17: 147-152.

Bibby C., Jones M. & Marsden S. 1998. Expedition Field Techniques. Bird Surveys. − Royal Geographical Society, London. 143 p.

Blake G.J. & Karr J.R. 1984. Species composition of bird communities and the conservation benefit of large versus small forests. Biological Conservation 30: 173-187.

Boecklen W.J. 1986. Effects of habitat heterogeneity on the species-area relationships of forest birds. Journal of Biogeography 13: 59-68.

Boev N., Georgiev J. & Donchev S. 1964. Birds of Thracia. In: Fauna of Thracia. Volume 1. Zoologicheski Institut s Museum BAS, 55-105. (In Bulgarian).

Fahrig L. 2003. Effects of habitat fragmentation on biodiversity. Annual Review of Ecology Evolution and Systematics 34: 487-515.

Forest Europe, 2015: State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe Forest Europe, Liaison Unit Madrid. 312 p.

Freemark K. & Collins B. 1992. Landscape ecology of birds breeding in temperate forest fragments. In: Hagan J. M. & Johnston D.W. (Eds.): Ecology and conservation of neotropical migrant land birds. Washington and London: Smithsonian Institution Press, 443-454.

Gao T., Nielsen A.B. & Hedblom M. 2015. Reviewing the strength of evidence of biodiversity indicators for forest ecosystems in Europe. Ecological Indicators 57: 420-434.

Google maps. 2024. Game breeding station Chekeritsa (Hybrid Image). Retrieved from https://www.google.com/maps/@42.2267043,24.8721272,4178m/data=!3m1!1e3?entry=ttu

Hagemeijer E. & Blair J. 1997. The EBCC Atlas of European breeding birds: their distribution and abundance. London: T & A D Poyser. 479 p.

Hammer Ø., Harper D.A. T. & Ryan P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9.

Hanski I.K., Fenske T.J. & Gerald J.N. 1996. Lack of edge effect in nesting success of breeding birds in managed forest landscapes. The Auk 113(3): 578-585.

Haulton S. 2008. Effects of silvicultural practices on bird communities of Eastern and Central North America. IDNR Division of Forestry. 22 p.

Hofmeister J., Hosek J., Brabec M. & Kocvara R. 2017. Spatial distribution of bird communities in small forest fragments in central Europe in relation to distance to the forest edge, fragment size and type of forest. Forest Ecology and Management 401: 255-263.

Hristov Y. 2022. State of common birds in Bulgaria. BSPB. Nature Conservation Series 38: 1-32. (In Bulgarian).

Hristovich G. 1890. Materials for studying the Bulgarian fauna. In: Collection of folklore 2: 185-225. (In Bulgarian).

Hristovich G. 1892. Materials for studying the Bulgarian fauna. In: Collection of folklore 7: 419-424. (In Bulgarian).

Ivanov B. 2011. Fauna of Bulgaria. vol. 30 Aves, Part. III. Sofia, Bulgaria: Academic Publishing House "Professor Marin Drinov". 410p. (In Bulgarian).

Jackson H. & Fahrig S. 2013. Habitat loss and fragmentation. In: Levin S.A. (Ed.): Encyclopaedia of Biodiversity. Amsterdam, Netherlands: Elsevier Inc., 50-58.

Kopralev I. 2002. Geography of Bulgaria. Sofia, Bulgaria: ForKom Press. 760 p. (In Bulgarian).

Lešo P., Kropil R. & Kajtoch Ł. 2019. Effects of forest management on bird assemblages in oak-dominated stands of the Western Carpathians-Refuges for rare species. Forest Ecology and Management 453: 117620.

Matthews T. & Triantis K. 2021. Island biogeography. Current Biology 31(19): 1201-1207.

Mirski P. & Vali U. 2021. Movements of birds of prey reveal the importance of tree lines, small woods and forest edges in agricultural landscapes. Landscape Ecology 36: 1409-1421.

Nam K., Tamburadzhiev I., Assenov A. & Bozhkov P. 2022. Investigation of ecosystems in the Pazardzhik-Plovdiv lowland area. Annual of Sofia University "St. Kliment Ohridski". Faculty of Geology and Geography. Book 2. Geography 114: 201-209.

Namkoong G. & Koshy M. 2008. Genetics and Speciation in the World's Forests. In: Evans J. (Ed.): The Forests Handbook, Volume 1: An Overview of Forest Science. Hoboken, USA: Blackwell science ltd., 67-80.

Nankinov D., Simeonov S.D., Michev T.M. & Ivanov B.E. 1997. Fauna of Bulgaria, 26, Aves, part II. Sofia, Bulgaria: Academic Publishing House "Professor Marin Drinov". 427 p. (In Bulgarian).

Nikolov S. & Spasov S. 2005. Frequency, density and number of some breeding birds of the south part of Kresna Gorge (SW Bulgaria). Acrocephalus 26: 23-31.

Opdam P., Rijsdijk G. & Hustings F. 1985. Bird communities in small woods in an agricultural landscape: Effects of area and isolation. Biological Conservation 34: 333-352.

Patev P. 1950. Birds in Bulgaria. Sofia, Bulgaria: Academic Publishing House BAS. 364 p. (In Bulgarian).

Popgeorgiev G., Spasov S. & Korniliev Y.V. 2015. SmartBirds: Information system with biological information of the BSPB. Available at https://smartbirds.org

QGIS.org. 2020. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.org.

Reif J., Skalova A. J., Vermouzek Z. & Vorisek P. 2022. Long-term trends in forest bird populations reflect management changes in Central European forests. Ecological Indicators 141: 109-137.

Reiser O. 1984. Materialien zur einer Ornis Balcanica. II. Bulgarien. Wien: In Commission bei Carl Gerold's Sohn: 294 p.

Shurulinkov P., Daskalova G., Stoyanov G., Delov V., Dalakchieva S., Angelov I., Borisov B & Tsvetkov P. 2013. Methods for breeding birds census in selected UTM squares with the aim of subsequent monitoring of the nesting avifauna. NBMS. (In Bulgarian).

Simeonov S. Michev T. & Nankinov D. 1990. Fauna of Bulgaria. 20., Aves, part I. Sofia, Bulgaria: Academic Publishing House "Professor Marin Drinov", BAS. 349 p. (In Bulgarian).

Stratford J.A. & Sekercioglu C. 2015. Birds in forest ecosystems. In: Corlett R., Peh K. & Bergeron Y. (Eds.): Handbook of forest ecology. Lonon, UK: Routledge Press, 281-296.

Wesolowski T., Czeszczewik D., Hebda G., Maziarz M., Mitrus C., Rowinski P. & Neubauer G. 2022. Long-term changes in breeding bird community of a primaeval temperate forest: 45 years of censuses in the Bialowieza National Park (Poland). Acta Ornithologica 57(1): 71-100.

Yabuhara Y., Yamaura Y., Akasaka T., Yamanaka S. & Nakamura F. 2019. Seasonal variation in patch and landscape effects on forest bird communities in a lowland fragmented landscape. Forest Ecology and Management 454: 117140.

Yankov P. 2007. Atlas of Breeding Birds in Bulgaria. Bulgarian Society for the Protection of Birds. Conservation Series, Book 10. Sofia: BSPB. 679 p. (In Bulgarian).