PLOVDIV UNIVERSITY
„PAISII HILENDARSKI"

FACULTY OF BIOLOGY
ZOOLOGY DEPARTMENT

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BREEDING BIRD COMMUNITIES IN FOREST FRAGMENTS IN THE WESTERN THRACIAN LOWLAND

ABSTRACT

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and 178 are in Latin.

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The materials related to the defense are available to the interested parties at the Department of Zoology and in the library of PU "Paisii Hilendarski".

Introduction

The long history of exploitation of forest ecosystems in Europe has significantly changed their natural appearance (WELZHOLZ & JOHANN, 2007), with only about 2% of forest ecosystems considered primary forests (FOREST EUROPE, 2020). Present-day forests were formed under the influence of forestry practices (VACIK ET AL., 2009), the processes of settlement and agricultural expansion in which forest territories are exploited. These processes are at the root of the loss, degradation and fragmentation of natural ecosystems worldwide (HANSKI ET AL., 1996, JACKSON & FAHRIG, 2013, VIEIRA DE MATOS ET AL., 2018; YABUHARA ET AL., 2019). In many parts of the world, agricultural areas are dominant and forests represent island habitats in the agricultural matrix (NAMKOONG & KOSHY, 2008).

Intensive forestry has created habitats of different age and structure (HANSKI ET AL., 1996). Large part of the bird species inhabit the forest ecosystems and their communities are formed under the influence of anthropogenic activities. Changes in bird communities can be associated with both a decrease and an increase in species richness (CARNUS ET AL., 2006), depending on the vegetation structure.

A number of studies have focused on identifying the environmental factors associated with shaping the structures and numbers of bird populations in response to anthropogenic impact (PARKER ET AL., 2022). It is usually most pronounced in urbanized areas, where natural habitats are rapidly transformed for the needs of agriculture, forestry and other industries (FERNANDEZ-JURICIC, 2004). The density, diversity, abundance of birds in forest habitats are some of the most common research parameters to determine how changes in environmental conditions affect birds (BROWN, 1984; DIAZ, 2006; DOMOKOS & DOMOKOS, 2016; BERGNER ET AL., 2015; BERGNER ET AL., 2018).

The forest fragments in the Thracian Lowland represent island habitats and are a refuge for a wide variety of birds in the matrix of agricultural lands. The present study aims to expand the knowledge of the species composition and distribution of birds in the lowland forests of the Western Upper Thrace lowland, as well as to assess the environmental factors that impact the bird communities.

Literature Review

Approximately 75% of all bird species are associated with forest ecosystems (Stratford & Sekercioglu, 2015). Birds have diverse requirements regarding the structural characteristics of habitats in relation to finding nesting sites and food resources (Beason et al., 2023). Individual species and their populations have different roles in the functioning of forest ecosystems and are accepted as indicators of their quality (Sekercioglu et al., 2004; Sekercioglu, 2006; Balaz & Balazova, 2012; Wesolowski et al., 2022). Bird species diversity is most often used to assess the status of forests (Kraus & Krumm, 2013; Gao et al., 2015). The abundance of certain groups of birds is a criterion when comparing habitat quality and origin (Caro, 2010). Bird species diversity in deciduous lowland forests is of interest in terms of differences in the structures of communities in managed and unmanaged forests (Lopes et al., 2015; Bergner et al., 2018; Sommer & Fichtner, 2023), in forests with different tree composition (Domokos & Domokos, 2016), riparian forest habitats (Machar, 2012; Machar et al., 2019). The forests in the Western Upper Thracian Lowland are represented by isolated and highly transformed fragments located in a matrix of agricultural areas covering only about 4% of the territory (Nam et al., 2022). Similar island habitats are a refuge for a wide variety of birds (Matthews & Triantis, 2021). Despite historical changes and intensive farming practices, the species richness in the forests of the Western Upper Thracian lowland is significant and the communities are composed of different ecological groups of birds (Boev et al., 1964). The diversity of bird species shapes lowland forests as a complex and dynamic system and provides a good opportunity to study the effects of fragmentation and anthropogenic impact on the structure, diversity and distribution of birds (Fahrig, 2003). Detailed information about the forest species of birds in the Upper Thracian lowland, in relation to their habitat preferences, can be found in "Fauna of Thrace - The Birds of Thrace (Boev et al., 1964). An overview of the species composition can be found in the popular scientific articles of Hristovich (1890, 1892), Reiser (1894), Jordans (1940) and Balat (1962), and Patev (1950) provides data on the distribution of bird species in the lowland, although not based on specific surveys. Information about the species and their distribution can be found in all three volumes of the Fauna of Bulgaria (Simeonov et al. 1990, Nankinov et al. 1997, Ivanov, 2011), as well as in the Atlas of Breeding Birds in Bulgaria (Iankov, 2007). Data on the distribution of some of the studied species can be found in the studies of Demerdzhiev & Stoychev (2008) and Ignatov & Popgeorgiev (2021). A comprehensive study of the avifauna in different types of habitats in forest ecosystems can be found in the work of Petrov (1982).

Influence of forest structure and composition on species richness and abundance of birds

An important issue when studying the relationships between species and their environment is the quality of the available biological information, and in particular the description of the characteristics of the studied habitat (DIVISEK ET AL., 2014). Changes in forest structure can have both positive and negative effects on forest bird species, depending on their habitat preferences (STRATFORD & ŞEKERCIOGLU, 2015; LESO, 2019). Most of the forest bird species use a relatively small area during the breeding season, so studying the influence of the environment is also appropriate at the local level (MAG & ODOR, 2015).

In recent years, studies concerning the influence of habitat structural characteristics on birds and their communities in Europe have deepened. Tree species (ONODI ET AL., 2021; KEBRELE ET AL. 2021), forest age (PROBST ET AL., 1992) and heterogeneous vegetation structure (BERGNER ET AL., 2015; PIECHNIK ET AL., 2022; KAMENIAR ET AL., 2023) have been identified as important factors for forest bird species. The influence of the age of the forest on bird communities is mainly expressed as a positive relationship between the parameters characterizing the avifauna and the age class of the forest. It is known that old forests have a more complex structure than younger ones (SHOCHAT ET AL., 2001; LAIOLO, 2002) and the bird composition differs in this sense (PROBST, 1992). The preference of some bird species for older forests is a result of tree floor cover (KOIVULA ET AL., 2017), tree diameter (MAG & ODOR, 2015), number of old trees (SIKORA, 2021) and dead wood.

The presence of old trees and dead wood (standing and lying) provides abundant food resource and suitable nesting habitats for cavity-nesting species (DIAZ, 2006), and their presence affects many forest bird species (HEIDRICH ET AL., 2020). Recent studies on the species-specific responses to habitat characteristics show that forest vegetation structure and composition are equally important in assessing forest species distribution (SLATKI & KRALJ, 2020).

In Bulgaria, the studies concerning the influence of the structural characteristics of the habitats are mainly on individual species, such as the Semicollared Flycatcher (*Ficedula semitorquata*) (GEORGIEV ET AL., 2018) and upland nocturnal raptor bird species (NIKOLOV ET AL., 2022).

Influence of forest management

Forest management practices are important for species diversity (VACIK ET AL., 2009), and in recent years the area of forest plantations have increased. This leads to the need for more clarity on the extent to which they can support forest bird species (BESKARDES ET AL., 2017). Forestry practices have resulted in the creation of habitat mosaics with a significantly reduced proportion of mature forest in the landscape (BATTISTI, 2018). Bird diversity is usually directly related to the successional stages of forest ecosystems and differs between stages. Bird studies in secondary successional forests have shown overlapping replacement of bird species along breeding age gradients (MORGAN & FREEDMAN, 1986).

Population density and community composition vary with stand age, with forest species increasing with age (PROBST ET AL., 1992; CONNER & DICKSON, 1997; BESKARDES ET AL., 2017). However, the initial stages of forests may have a simplified plant structure, so bird diversity may temporarily decline or even peak in the earlier stages. This is a consequence of the change in the species composition, determined by the different conditions during the different ages of the forest. In younger stands, species have a more even distribution, and species richness is probably limited by the poorly represented stratification and simplified structure (PROBST ET AL., 1992). In the later stages of regeneration, the number of bird species increases with the vertical complexity of the vegetation and the unevenness or horizontal heterogeneity. Diversity in vertical structure and open areas in the forest can affect bird populations, creating a greater number of potential ecological niches and increasing species diversity (BESKARDES ET AL., 2017; SIKORA, 2021). The plantations, which are grown mainly for timber harvesting, have the structure of monocultures with uniform age, uniform distribution and high density. These characteristics result in a simplified vertical structure, reduced grass and shrub vegetation, which in turn limits food resources, nesting success, and the availability of nest sites and shelters from predators. As a result, bird communities become impoverished and less diverse (PEDLEY ET AL., 2019).

Impact of lowland forest fragments on birds

A leading cause of forest habitat fragmentation worldwide is agricultural expansion (JACKSON & FAHRIG, 2013), and this can have a mixed effect on biodiversity and birds in particular. Although the negative effect of fragmentation is well documented and studied, isolated forest fragments can be an important habitat in a heavily exploited and species-poor landscape (FISCHER ET AL., 2011; MUELLER, 2020). While the consequences of habitat loss have a negative effect (HANSKI, 2011), fragmentation can have both negative and positive effects (FAHRIG, 2003; JACKSON & FAHRIG, 2013). The term fragmentation is used in cases of "transformation of large habitats into separated fragments of smaller area, isolated from each other in a matrix of habitats other than natural". In general, the effect of fragmentation can be expressed in the degradation of habitat quality, the reduction of its total area, the separation of individual fragments by an anthropogenic matrix (e.g. pastures, agricultural areas, settlements) and the increased intensity of the edge effect (ANDREN, 1994; FAHRIG, 2003; STRATFORD & SEKERCIOGLU, 2015). Fragmentation and its impact on biodiversity have been the focus of a large number of studies (LYNCH & WHIGHAM, 1984; OPDAM ET AL., 1985; SHOCHAT ET AL., 2002; PRUGHA ET AL., 2008; HADDAD ET AL., 2015; DALE, 2019). The impact on birds and their communities is complex and species-specific (GEORGE & DAVID, 2002; VERGA ET AL., 2017; HOFMEISTER ET AL., 2017). A comprehensive and systematic study of birds in forests in relation to the fragmentation caused by natural processes and the influence of the structural characteristics of the habitat on bird communities can be found in the studies of

NIKOLOV (2007A, 2007B, 2009, 2013). Habitat fragmentation has a positive effect if adaptive species increase at higher rates than rare species disappear, leading to increased species richness (KOIVULA ET AL., 2017). Bird communities have been found to show greater species diversity in disturbed forest ecosystems at the landscape level, and conversely less species diversity in undisturbed forests at the local level (CARO, 2010). Habitat quality is considered a better indicator of species abundance and distribution (DE CAMARGO ET AL., 2018; KOIVULA ET AL., 2017), with heterogeneity having a positive influence for biodiversity, in cases where the area of the fragment remains sufficiently large in relation to the requirements of the individual species (OPDAM ET AL., 1985).

Goal and objectives

The main goal of the research is:

To assess the composition of the nesting bird species in fragments of lowland forests in the Western Upper Thracian lowland and to evaluate the influence of the structure and characteristics of the fragments on their populations and communities.

For the fulfillment of the set goal, we have defined the following objectives:

1. Study on the composition and distribution of the breeding birds in the forest fragments;

2. Assessing the number and density of the breeding birds;

3. Analysis of the impact of lowland forest fragments and habitat characteristics on bird species richness and abundance.

Study area

The present study covers the western part of the Upper Thracian Lowland. From a physical-geographical point of view, it is divided into two parts by the Chirpan highlands - Starozagorsko field and Pazardzhik-Plovdiv field. The study area falls entirely within the scope of the Pazardzhik-Plovdiv field (BOEV ET AL., 1964).

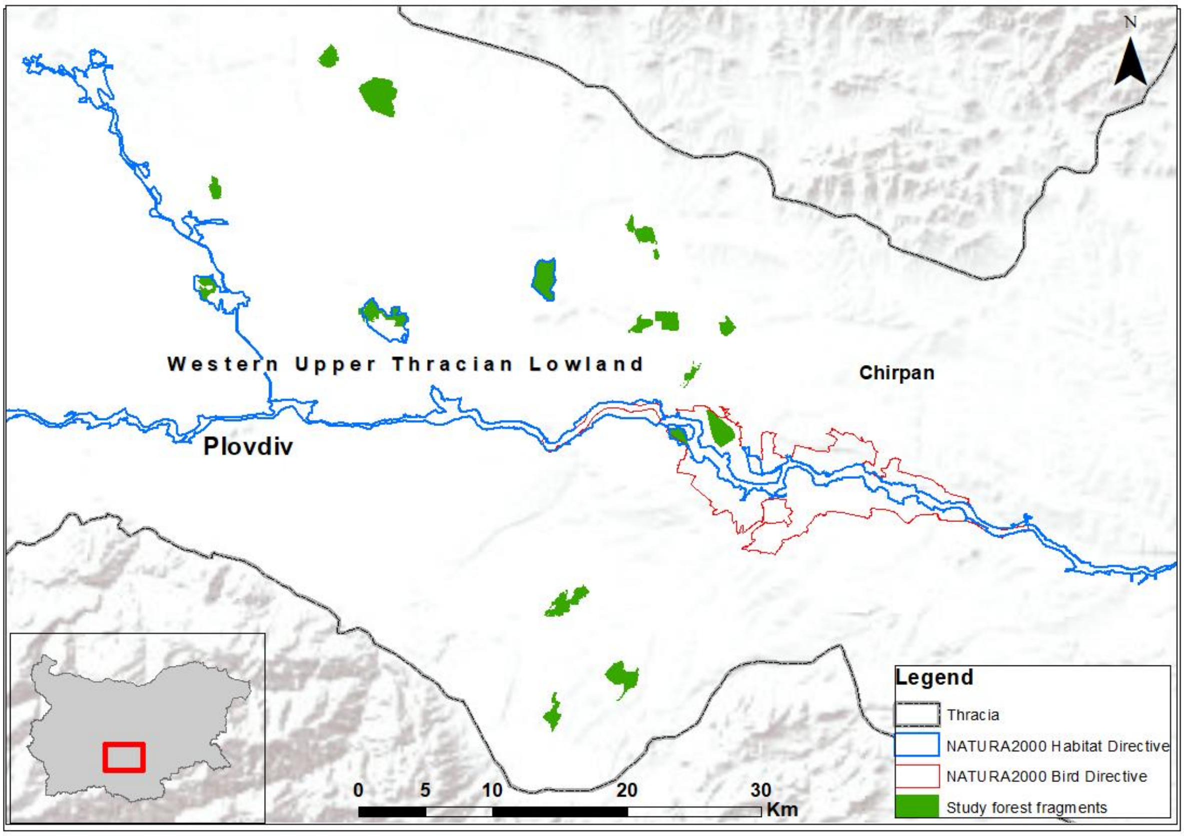

Fig. 1. Map of the study area

The study area is predominated by floodplain forests (39%), oak forests (26.7%) and Black Locust forests (*Robinia pseudoacacia*) (22%). The minimum age of the stand is in the fragment near the village of Graf Ignatievo, which is represented entirely by Black Locust. Maximum age and old-aged forests (80–120 years) are partially preserved in some of the forests included in the ecological network Natura 2000. From an ecological point of view, the study forest fragments are classified into three types: 1) riparian forests; 2) mesophytic and 3) xerothermic oak forests (GANCHEV, 1965A,B; BONDEV & NIKOLOV, 1983; FEA, 2021).

Material and methods
Choice of sampling plots

The present study was conducted in 15 fragments of lowland forests in the Western Upper Thracian Lowland. The entire area of the forest territories is divided into a grid of 150 x 150 m (n=1307) using the program QGIS (2020) (Fig. 2). The minimum recommended plot size was chosen, which is suitable for surveying dense forest habitats and songbird species (BIBBY ET AL., 1998). 5% of all generated plots were randomly selected in which the field studies were conducted (n=69) (Fig. 2).

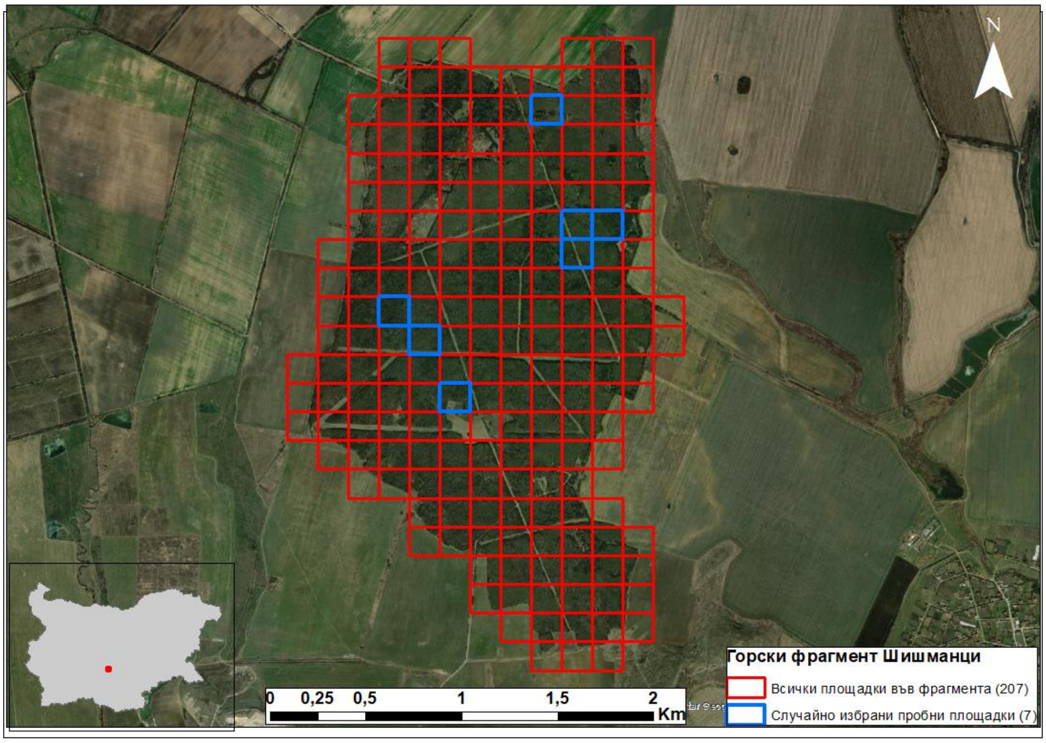

Fig. 2. Grid 150 x 150 m and randomly selected sample plots in the forest fragment of Shishmantsi.

Birds surveys
Diurnal Bird Species

Distance sampling method with point transects was used for surveying the diurnal bird species (Fig. 3). The point transect method is widely used in estimates of relative densities of songbirds, where individuals are recorded mostly by sound. It is based on the recording the distance from the observer to the studied object, and on randomly selected sample plots (BIBBY ET AL., 1998). Spatial analysis was implemented using QGIS (2020) software, and the precision of the distances from the observer to the registered object in the collected biological information was achieved through a connectivity operation. The biological information was collected using the mobile app. SmartBirds Pro (POPGEORGIEV ET AL., 2015).

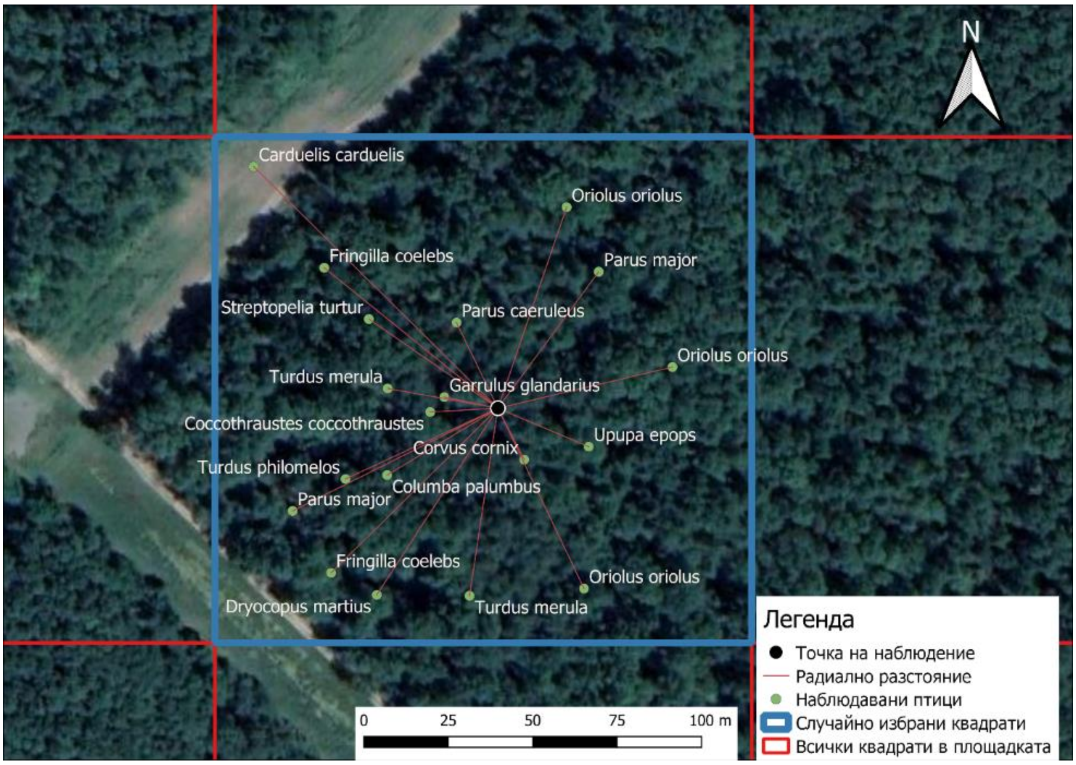

Fig. 3. Data on birds recorded in point transects during the second visit of the breeding season in 2022. The observation point with calculated radial distances and recorded individuals are visualized.

The surveys were carried out between April and July for three consecutive years from 2020 to 2022 (Fig. 4) and within 98 days. Bird surveys in all selected trial sites were carried out in the morning hours from 5:30 to 11:00, when bird activity is greatest. Each site was visited twice during the bird's breeding season for each field year with 10–40 days (mean 21 days) between visits (BIBBY ET AL., 1998). Each subsequent visit to the trial site was carried out in reverse order, with the aim of recording all species depending on the individual breeding period. The birds in the individual trial sites were counted for a duration of 5 to 10 min. (BIBBY ET AL., 1998; BUCKLAND ET AL., 2001). Bird registration is based on vocal (song/call) registration or visual observation. Individuals in flight are excluded from the count.

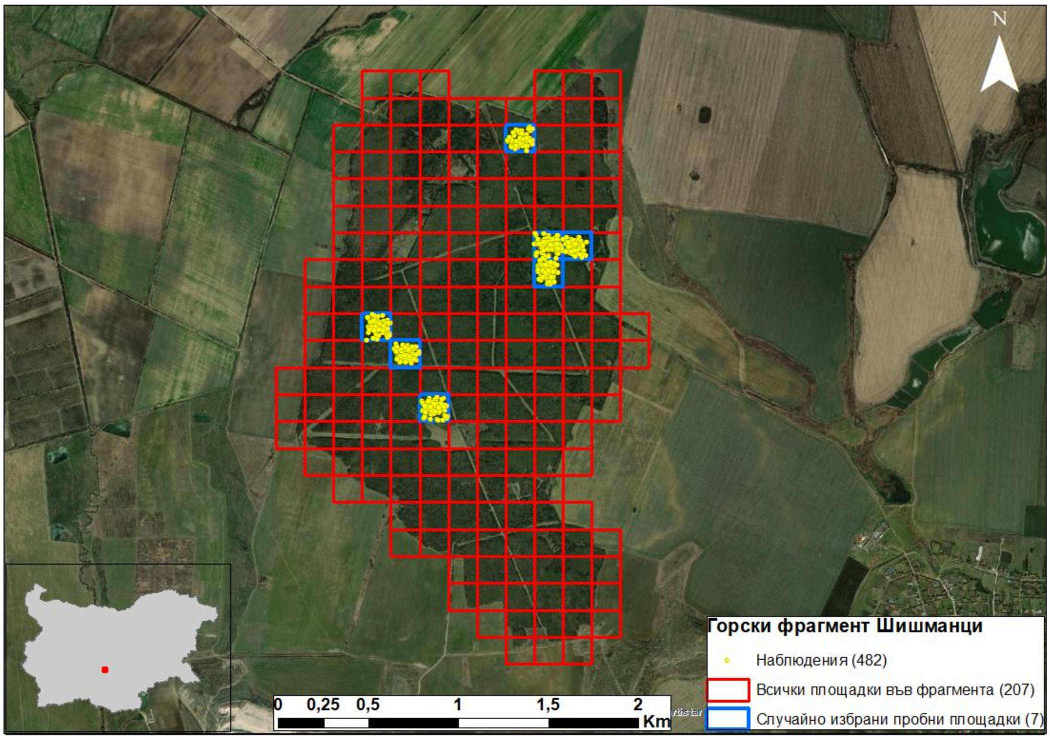

Fig. 4. Registered individuals within all field visits (n=6) of the study in the forest near Shishmantsi.

Nocturnal Species

Nocturnal raptor species were surveyed by vocal provocation at randomly selected points other than the distance point transects. According to the features of the habitat, random points at a distance of at least 500 m were chosen, considering the territorial behaviour of the individual species (SHURULINKOV ET AL., 2013). The survey was carried out between March and April in 2020 and 2021 over a period of 28 days. Species were counted in total of 74 randomly selected sampling points in all forest fragments after sunset, under suitable weather conditions. The survey was carried out in suitable habitats for the following species: 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*). The different species were provoked through a sound reproduction device with an imitation of the breeding song of the target species. Species were stimulated in sequential order, starting with the smallest representative. The playback lasted for at least three consecutive minutes, followed by a minute of active listening and looking around the area for a response to the evoked species.

Grouping of species according to ecological requirements

All recorded breeding species were grouped according to Blake & Karr (1984), depending on their preferences in relation to habitat type for the species diversity assessment.

For analyzes related to the influence of habitat characteristics, nesting species found in the studied point transects were also grouped into guilds according to 1) food base during the breeding period and 2) breeding sites.

The grouping of species by guilds is according to CRAMP (1977–1994), SIMEONOV ET AL. (1990), NANKINOV ET AL. (1997) and IVANOV (2011).

Habitat characteristics

Sampling plot characteristics

The structural characteristics at each sample plot are described in relation with the analysis of the influence of habitat characteristics on the species composition and abundance of birds. The parameters were evaluated within a radius of 25 m from the bird observation point. The following characteristics are described: percentage cover of the vegetation floors, distinguishing six vegetation floors: 1) low grass vegetation floor (0.1–0.4 m); 2) tall grass vegetation (0.4–1 m); 3) low shrub vegetation floor (0.4–1 m); 4) high shrub vegetation floor (1.6–4 m); 5); low tree floor (4–7 m); 6) high tree floor (9–30 m); species composition of the trees in the high and low tree layers, percentage of canopy cover, fullness of the stand and diameter of the trees.

Habitat characteristics at the fragment level

For each of the study fragments, information was extracted based on a forest database, up-to-date as of 2021 (IAG). Based on the extracted information, the following are described: 1) forest type; 2) percentage share of dominant tree species in each fragment; 3) age of the forest.The variables fragment size (CA) and edge length (TE) were used to assess the impact of the forest fragments on species richness (SLATTERY & FENNER, 2021). The characteristics are described based on a spatial analysis of the study forest fragments using the Patch Analyst application of the ArcGIS 10.4.1 software (ESRI 2014).

Analysis of the species composition of breeding birds

The taxonomy and Latin names of the birds are according to HBW and BIRDLIFE INTERNATIONAL (2024), and the Bulgarian names of the birds are according to IANKOV (2007). Breeding status is according to HAGEMEJER & BLAIR (1997).

Species richness is represented as the total number of species for each forest fragment (n) (KREBS, 2014).

The index for the frequency of occurrence of the species was calculated according to the formula: $Fi = (m / n) * 100$, where: m – the number of point transects in which the species was registered; n – total number of point transects (ONODI ET AL., 2021).

The relative abundance of species is represented as the proportion of the number of observed individuals of a given species to the total number of all observed individuals and has been used to determine rare and widespread species (PRESTON, 1948; KREBS, 2014).The species diversity of birds in the individual fragments and in each sample plot is represented by the Shannon–Wiener index [H'] and the evenness index [J] (SHANNON & WIEVER, 1949). Analysis was performed in PAST ver. 4.3 (HAMMER ET AL., 2001).

Numbers and density of breeding birds

The software DISTANCE 7.3 Release 2 (THOMAS ET AL., 2005) was used for the analysis of the number and density of species. For greater precision of the detection function (df) and reliability of the results, multiple covariate distance sampling (MCDS) was applied (MARQUES & THOMAS, 2007). Species with fewer observations were excluded from the analysis. The choice of model is based on the Akaike information criterion (AIC), using the half-normal and hazard-rate functions with cosine and simple polynomial adjustment terms. Models with the lowest AIC were selected as appropriate (BURNHAM & ANDERSON, 2002). We used two approaches: 1) to estimate the densities of individual species for the area of all study forest fragments, we used a model with a detection function for the individual species based on species-specific stratification; and 2) to estimate individual species for the area of each fragment, we used the area of the individual fragment as the variable. The detection probabilities are based on the values of the observation variable of the individual species in each of the fragments (MARQUES & THOMAS, 2007). For the latter analysis, fragments with fewer than four observation plots were excluded from the analysis ($n \leq 4$). Mean densities are presented with 95 % confidence interval (CI).

Effect of habitat characteristics and fragmentation on the breeding birds

Multiple regression analysis was used for the models of influence on individual species. Species recorded in > 50 sample areas were selected. For species found in fewer sample areas, models were not reliable ($p > 0.5$). Percentage variables were square-root-transformed, and numerical variables were log-transformed. The coefficient of determination R was used as an indicator of the influence of the study variables explaining the variation in the sample. The closer the correlation coefficient value is to +1 or -1, the stronger the correlation is. The strength of the coefficient is determined at the following values: $R > 0.7$ – strong correlation; $0.5 < R > 0.7$ – average correlation; $0.3 < R > 0.5$ – weak correlation; $R < 0.3$ – no correlation (Popov, 2013). GLMM (generalized linear mixed models), multinomial logit model was used to assess the effect of the structural characteristics of the habitat on the abundance of guilds. Before running the models, all variables were tested for correlations with Spearman's rank correlation (rho). Values with > 0.6 of the dependent variable pair, the variable with greater weight was retained (Green, 1979). The weights of the variables were assessed with a subsequent Principal Component Analysis (PCA). The parameters of the structural characteristics for each sampling plot were used. As dependent variable was used guild type, with a categorical fragment. The explanatory variables used were: average tree height, % canopy cover, % cover of the high tree floor, % cover of the low tree floor, % cover of the high shrub floor, % cover of the low shrub floor, % stand fullness, average age of the tree stand. Basal area index (IBAT) was removed as the dependent variable, and % cover of low shrub floor and % cover of low tree floor were excluded from the model, as in a large part of the studied sites were present with a value of 0. All calculations were made with the program Statistica for Windows, 12 (Statsoft Inc., 2012), R v.2.15.2 (R Core Team, 2012) and MuMin v.1.47 package. 5 (Barton, 2020).

Results and Discussion

Species composition, number and density of breeding birds

Species composition

A total of 6,814 observations of 95 species, representatives of 17 orders and 38 families were registered during the study. The species were counted by the distance sampling method of the point transects, during the transition between the study plots and within the surveys for the nocturnal bird species. A total of 81 species were confirmed as breeding with different breeding status (Table 1), and the remaining 14 species were associated with microhabitats in the forest fragments or as a stop-over sites during migration and were excluded from further analyzes (Table 2).

The distribution of species according to their preference for habitat type showed the highest number of species breeding both on the edge of fragments and in their interior (IE) (n=39). Species that prefer forest edge (FE) were 24, and species of the open areas (OP) were 11. The species found in the forest interior (FI) were least (n=7) (Fig. 5)

Sixteen (20%) of the species were recorded in all forest fragments: Corn Bunting (*Emberiza calandra*), Hawfinch (*Coccothraustes coccothraustes*), Eurasian chafinch (*Fringilla coelebs*), Red-backed Shrike (*Lanius collurio*), European Robin (*Erithacus rubecula*), Common Nightingale (*Luscinia megarhynchos*), Golden Oriole (*Oriolus oriolus*), Great tit (*Parus major*), Eurasian Blackcap (*Sylvia atricapilla*), Blackbird (*Turdus merula*), Song Thrush (*Turdus philomelos*), Eurasian Hoopoe (*Upupa epops*), Common Wood-Pigeon (*Columba palumbus*), European Turtle-Dove (*Streptopelia turtur*), Eurasian Jay (*Garrulus glandarius*), Green Woodpecker (*Picus viridis*). Species with one observation were Short-toed Treecreeper (*Certhia brachydactyla*), a Common Kestrel (*Falco tinnunculus*), Lesser Grey Shrike (*Lanius minor*) and Woodlark (*Lullula arborea*).

The greatest species richness was found in the forest fragments Chekeritsa (n=51) and Tyurkmen (n=51), and lower in Begovo (n=35), Orizovo (n=36) and Novi Izvor (n=36). Species that prefer forest interior are least presented and range from zero to five species for forest fragment. Interior-edge species (IE) were numerous in all forest fragments (Table 5). Species diversity index has highest value for the forest of of Tyurkmen (H=3.33), and lowest value for the forest of Izbeglii (H=2.94) (Fig. 6). The evenness was lowest the forest of Izbeglii (J=0.77) and highest for the forest of Novi Izvor (J=0.88) (Fig. 7).

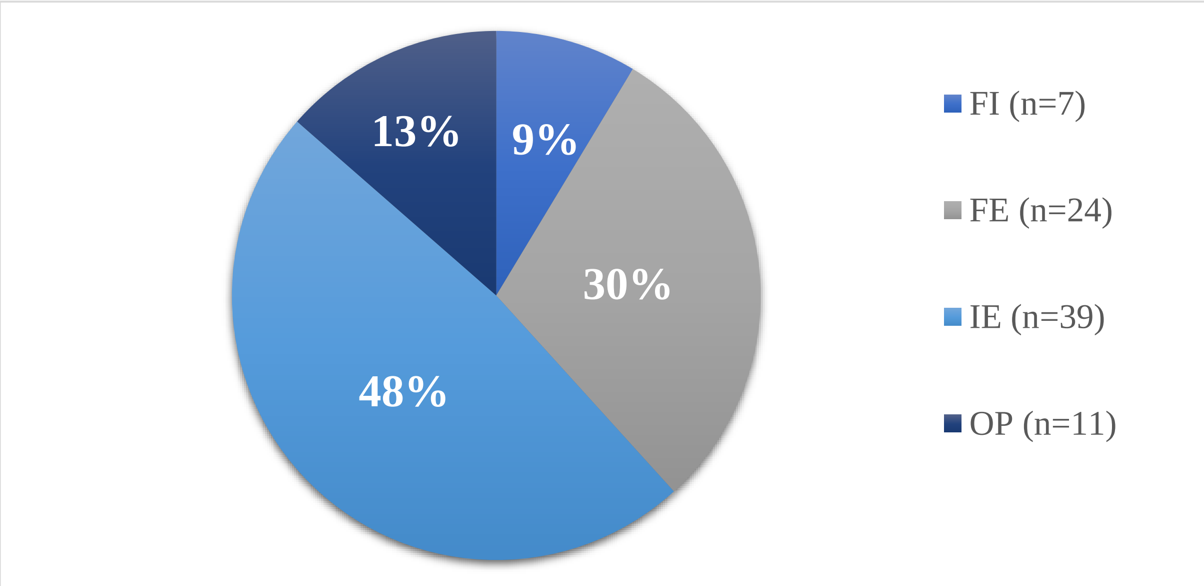

Fig. 5. Percentage distribution of breeding bird species by habitat type (FI – forest interior; FE – forest edge; IE – interior-edge; OP – open areas).

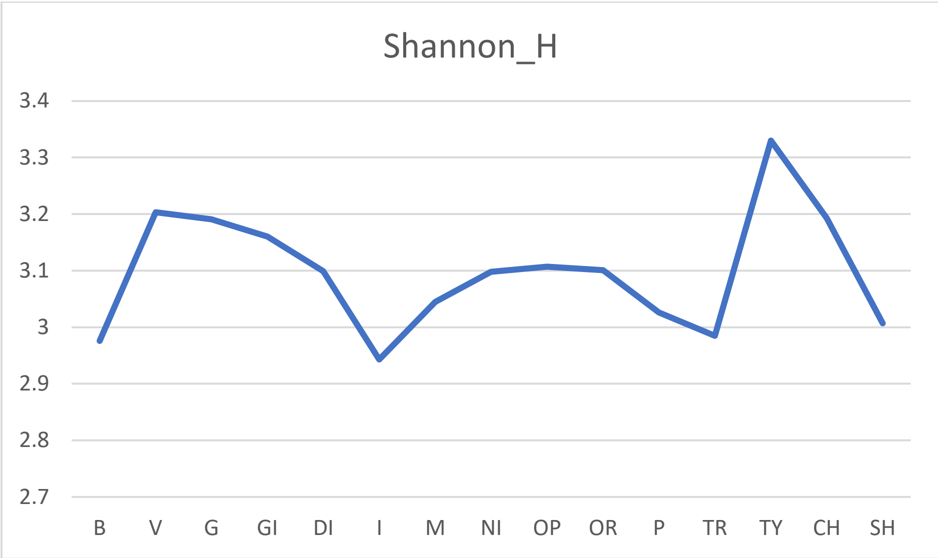

Fig. 6. Shannon Diversity Index of the species in the study forests.

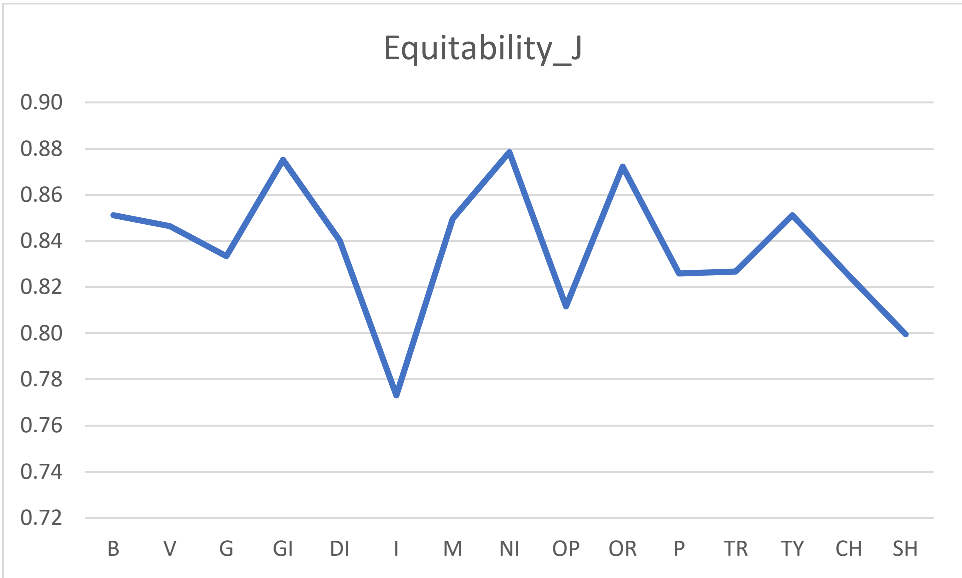

Fig. 7. Shannon Evenness Index (J) of the species in the study forests.

Table 1. List of breeding bird species, breeding status (PB – possible breeder; PRB – probable breeding; CB – confirmed breeding; NB – non-breeding) and grouping by breeding habitat type [HT]. Species recorded during the transition between plots are marked with *. Nocturnal bird species are marked with **.

Order	**Family**	**Species**	**№ ind.**	**Breeding code**	**HT**
Accipitriformes	Accipitridae	*Accipiter gentilis*, Linn. 1758	4	PRB	IE
Accipitriformes	Accipitridae	*Accipiter nisus*, Linn. 1758	10	PB	IE
Accipitriformes	Accipitridae	*Clanga pomarina**, Brehm 1831	10	PB	IE
Accipitriformes	Accipitridae	*Buteo buteo*, Linn. 1758	33	PRB	IE
Accipitriformes	Accipitridae	*Circaetus gallicus**, Gmelin 1788	3	PB	IE
Accipitriformes	Accipitridae	*Haliaeetus albicilla**, Linn. 1758	1	NB	IE
Accipitriformes	Accipitridae	*Hieraaetus pennatus**, Gmelin 1788	4	PB	IE
Accipitriformes	Accipitridae	*Milvus migrans**, Boddaert 1783	4	CB	IE
Accipitriformes	Accipitridae	*Pernis apivorus*, Linn. 1758	6	PB	IE
Bucerotiformes	Upupidae	*Upupa epops*, Linn. 1758	143	PB	IE
Caprimulgiformes	Caprimulgidae	*Caprimulgus europaeus**, Linn. 1758	11	PB	IE
Ciconiiformes	Ciconiidae	*Ciconia nigra**, Linn. 1758	30	CB	IE
Columbiformes	Columbidae	*Columba palumbus*, Linn. 1758	205	PRB	IE
Columbiformes	Columbidae	*Streptopelia decaocto*, Frivaldszky 1838	22	PB	FE
Columbiformes	Columbidae	*Streptopelia turtur*, Linn. 1758	522	PRB	IE
Coraciiformes	Coraciidae	*Coracias garrulus*, Linn. 1758	6	CB	IE
Cuculiformes	Cuculidae	*Cuculus canorus*, Linn. 1758	254	PB	IE
Falconiformes	Falconidae	*Falco subbuteo**, Linn. 1758	1	PB	IE
Galliformes	Phasianidae	*Coturnix coturni*x, Linn. 1758	6	PRB	OP
Galliformes	Phasianidae	*Perdix perdix*, Linn. 1758	26	PRB	OP
Galliformes	Phasianidae	*Phasianus colchicus*, Linn. 1758	115	PRB	IE
Gruiformes	Rallidae	*Crex crex**, Linn. 1758	1	PB	FE

Order	Family	Species	№ ind.	Breeding code	HT
Passeriformes	Acrocephalidae	*Acrocephalus palustris*, Bechstein 1798	8	PB	FE
Passeriformes	Acrocephalidae	*Iduna pallida*, Ehrenberg 1833	52	PB	FE
Passeriformes	Aegithalidae	*Aegithalos caudatus*, Linn. 1758	37	CB	IE
Passeriformes	Alaudidae	*Alauda arvensis*, Linn. 1758	39	PB	OP
Passeriformes	Alaudidae	*Galerida cristata*, Linn. 1758	19	PRB	OP
Passeriformes	Alaudidae	*Lullula arborea*, Linn. 1758	2	PB	FE
Passeriformes	Certhiidae	*Certhia brachydactyla*, Brehm 1820	1	PB	FI
Passeriformes	Corvidae	*Corvus corax*, Linn. 1758	29	CB	FE
Passeriformes	Corvidae	*Corvus corone*, Linn. 1758	13	CB	FE
Passeriformes	Corvidae	*Corvus frugilegus**, Linn. 1758	1	PB	FE
Passeriformes	Corvidae	*Garrulus glandarius*, Linn. 1758	134	PRB	IE
Passeriformes	Corvidae	*Pica pica*, Linn. 1758	7	PB	FE
Passeriformes	Emberizidae	*Emberiza cirlus**, Linn. 1758	2	PB	OP
Passeriformes	Emberizidae	*Emberiza hortulana*, Linn. 1758	96	PB	FE
Passeriformes	Emberizidae	*Emberiza melanocephala*, Scopoli 1769	17	PB	OP
Passeriformes	Emberizidae	*Emberiza calandra*, Linn. 1758	123	PRB	FE
Passeriformes	Fringillidae	*Carduelis carduelis*, Linn. 1758	11	PRB	FE
Passeriformes	Fringillidae	*Chloris chloris*, Linn. 1758	22	PRB	IE
Passeriformes	Fringillidae	*Coccothraustes coccothraustes*, Linn. 1758	112	CB	IE
Passeriformes	Fringillidae	*Fringilla coelebs*, Linn. 1758	589	CB	IE
Passeriformes	Laniidae	*Lanius collurio*, Linn. 1758	165	CB	FE
Passeriformes	Laniidae	*Lanius minor*, Gmelin 1788	5	PB	FE
Passeriformes	Laniidae	*Lanius nubicus*, Licht. 1823	22	PRB	FE
Passeriformes	Laniidae	*Lanius senator*, Linn. 1758	17	PRB	FE
Passeriformes	Motacillidae	*Motacilla flava*, Linn. 1758	21	PRB	OP

Order	**Family**	**Species**	**№ ind.**	**Breeding code**	**HT**
Passeriformes	Muscicapidae	*Erithacus rubecula*, Linn. 1758	225	CB	IE
Passeriformes	Muscicapidae	*Ficedula semitorquata*, Homeyer 1885	7	PB	FI
Passeriformes	Muscicapidae	*Luscinia megarhynchos*, Brehm 1831	700	PRB	IE
Passeriformes	Muscicapidae	*Muscicapa striata*, Pallas 1764	21	PB	FI
Passeriformes	Muscicapidae	*Saxicola rubetra**, Linn. 1758	2	PB	OP
Passeriformes	Muscicapidae	*Saxicola torquatus**, , Linn. 1758	6	PB	OP
Passeriformes	Oriolidae	*Oriolus oriolus*, Linn. 1758	496	CB	IE
Passeriformes	Paridae	*Cyanistes caeruleus*, Linn. 1758	60	CB	IE
Passeriformes	Paridae	*Parus major*, Linn. 1758	345	CB	IE
Passeriformes	Passeridae	*Passer domesticus**, Linn. 1758	2	PB	FE
Passeriformes	Passeridae	*Passer hispaniolensis*, Temminck 1820	115	CB	FE
Passeriformes	Passeridae	*Passer montanus*, Linn. 1758	15	PRB	FE
Passeriformes	Philloscopidae	*Phylloscopus collybita*, Vieillot 1817	84	PB	IE
Passeriformes	Remizidae	*Remiz pendulinus*, Linn. 1758	2	PB	FE
Passeriformes	Sittidae	*Sitta europaea*, Linn. 1758	50	PB	FI
Passeriformes	Sturnidae	*Sturnus vulgaris*, Linn. 1758	78	CB	IE
Passeriformes	Sylviidae	*Sylvia atricapilla*, Linn. 1758	418	PRB	IE
Passeriformes	Sylviidae	*Curruca communis*, Latham 1787	22	PB	FE
Passeriformes	Sylviidae	*Curruca curruca*, Linn. 1758	8	PB	FE
Passeriformes	Sylviidae	*Curruca nisoria*, Bechstein 1795	7	CB	FE
Passeriformes	Troglodytidae	*Troglodytes troglodytes*, Linn 1758	8	CB	FI
Passeriformes	Turdidae	*Turdus merula*, Linn. 1758	527	CB	IE
Passeriformes	Turdidae	*Turdus philomelos*, Brehm 1831	257	CB	IE
Piciformes	Picidae	*Dendrocopos major*, Linn. 1758	84	CB	IE
Piciformes	Picidae	*Dryobates minor*, Linn. 1758	10	PB	IE

Order	Family	Species	№ ind.	Breeding code	HT
Piciformes	Picidae	*Dendrocopos syriacus*, Ehrenberg 1833	8	PB	IE
Piciformes	Picidae	*Dryocopus martius*, Linn. 1758	25	PRB	FI
Piciformes	Picidae	*Picus viridis*, Linn. 1758	90	PB	IE
Strigiformes	Strigidae	*Asio otus**, Linn. 1758	18	PB	IE
Strigiformes	Strigidae	*Athene noctua**, Scopoli 1769	9	PRB	OP
Strigiformes	Strigidae	*Otus scops**, Linn. 1758	73	PB	IE
Strigiformes	Strigidae	*Strix aluco**, Linn. 1758	8	PRB	FI
Strigiformes	Strigidae	*Asio flammeus*, Pontoppidan 1763	1	PB	OP
Strigiformes	Tytonidae	*Tyto alba**, Scopoli 1769	8	PB	OP

Table 2. Species, associated with non-forest microhabitats or stop-over sites during migration.

№	Order	Family	Species
1	Anseriformes	Anatidae	*Anas platyrhyncho*, Linn. 1758
2	Anseriformes	Anatidae	*Tadorna ferruginea*, Pallas 1764
3	Charadriiformes	Charadriidae	*Charadrius dubius*, Scopoli 1786
4	Ciconiiformes	Ciconiidae	*Ciconia ciconia*, Linn. 1758
5	Falconiformes	Falconidae	*Falco tinnunculus*, Linn 1758
6	Passeriformes	Hirundinidae	*Delichon urbicum*, Linn. 1758
7	Passeriformes	Hirundinidae	*Cercopis daurica*, Linn. 1771
8	Passeriformes	Hirundinidae	*Hirundo rustica*, Linn. 1758
9	Passeriformes	Philloscopidae	*Phylloscopus sibilatrix*, Bechstein 1793
10	Pelecaniformes	Ardeidae	*Ardea cinerea*, Linn. 1758
11	Pelecaniformes	Ardeidae	*Ardeola ralloides*, Scopoli 1769
12	Pelecaniformes	Ardeidae	*Nycticorax nycticorax*, Linn. 1758
13	Pelecaniformes	Ardeidae	*Egretta garzetta*, Linn. 1766
14	Podicipediformes	Podicipedidae	*Podiceps cristatus*, Linn. 1758

Distribution of nocturnal breeding bird species

Seven nocturnal bird species have been registered: 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*) and Eurasian Nighjar (*Caprimulgus europaeus*) from the orders Strigiformes and Caprimulgiformes.

- Order Strigiformes

Best presented for the whole study area was found the Scops Owl with 70 observations in 11 of the forest fragments. The Long-eared Owl was found in 10 of the forests with 18 observation, and the Little Owl was found in seven of the study forests with nine observation. The Barn Owl was recorded in seven of the forests, and the Tawny Owl was found in fewer locations (n=5). One observation of Short-eared Owl was registered during the breeding season near the forest of Gradina.

- Order Caprimulgiformes

The European Nightjar was found in five of the forests. The species was confirmed as breeding for the forest of Novi Izvor. For the rest of the locations, individuals were recorded in April, when the species is still migrating. The forest of Shishmantsi (n=4) has the most observations per visit.

Density, numbers and frequency of occurrence of breeding bird species

Point transect surveys were conducted in a total of 73 sampling plots during 424 visits. 4922 individuals of 62 species of birds were registered, belonging to nine orders and 28 families (Table 2).

The most common species for the whole area (n=6) made up 61% of all records: Common Nightingale, Common Chafinch, European Turtle-Dove, Blackbird, Golden Oriole and Eurasian Blackcap (Table 3). The most common species (found in all plots) were Common Nightingale and European Turtle-Dove, followed by Blackbird, Common Chafinch, Great Tit and Eurasian Blackcap. The species with the lowest frequency are Short-toed Treecreeper, Common Kestrel, Lesser Grey Shrike and Eurasian Penduline-Tit (*Remiz pendulinus*) (Table 3).

Table 3. Frequency of occurrence [Fi] and relative abundance of species recorded during the point transects.

Species	Frequency [%]	Relative abundance [%]
Luscinia megarhynchos	**100.00**	**11.36**
Fringilla coelebs	**95.95**	**10.55**
Turdus merula	**98.65**	**8.90**
Streptopelia turtur	**100.00**	**8.76**
Oriolus oriolus	**97.30**	**8.13**
Sylvia atricapilla	**93.24**	**7.17**
Parus major	**95.95**	**6.10**

Species	Frequency [%]	Relative abundance [%]
Turdus philomelos	79.73	4.45
Cuculus canorus	**89.19**	4.02
Erithacus rubecula	70.27	3.98
Columba palumbus	**83.78**	3.58
Garrulus glandarius	70.27	2.28
Upupa epops	58.11	2.17
Phasianus colchicus	55.41	1.71
Coccothraustes coccothraustes	60.81	1.59
Picus viridis	51.35	1.34
Lanius collurio	39.19	1.30
Phylloscopus collybita	41.89	1.22
Sturnus vulgaris	44.59	1.12
Dendrocopos major	41.89	1.04
Sitta europaea	39.19	0.98
Parus caeruleus	41.89	0.91
Emberiza hortulana	18.92	0.73
Emberiza calandra	18.92	0.71
Hippolais pallida	20.27	0.69
Aegithalos caudatus	22.97	0.51
Alauda arvensis	17.57	0.43
Carduelis chloris	16.22	0.37
Dryocopus martius	17.57	0.37
Muscicapa striata	20.27	0.37
Streptopelia decaocto	14.86	0.37
Buteo buteo	16.22	0.26
Curruca communis	9.46	0.26
Corvus corax	10.81	0.22
Corvus cornix	9.46	0.16
Dryobates minor	9.46	0.14
Accipiter nisus	8.11	0.12
Motacilla flava	2.70	0.12
Perdix perdix	6.76	0.12
Troglodytes troglodytes	8.11	0.12
Acrocephalus palustris	5.41	0.10
Carduelis carduelis	6.76	0.10
Pica pica	2.70	0.10
Coracias garrulus	5.41	0.08
Dendrocopos syriacus	5.41	0.08
Lanius nubicus	5.41	0.08
Lanius senator	5.41	0.08

Species	Frequency [%]	Relative abundance [%]
Curruca curruca	5.41	0.08
Accipiter gentilis	4.05	0.06
Coturnix coturnix	2.70	0.06
Ficedula semitorquata	4.05	0.06
Passer montanus	2.70	0.06
Emberiza melanocephala	2.70	0.04
Galerida cristata	2.70	0.04
Passer hispaniolensis	2.70	0.04
Pernis apivorus	2.70	0.04
Remiz pendulinus	1.35	0.04
Curruca nisoria	2.70	0.04
Certhia brachydactyla	1.35	0.02
Falco tinnunculus	1.35	0.02
Lanius minor	1.35	0.02
Lullula arborea	1.35	0.02

Densities for 19 of the recorded species were estimated for the whole study area (Table 4). For the remaining 43 species, data was insufficient for analysis (n=39 of the total number of species) or unsuitable for reliable estimates (Common Cuckoo (*Cuculus canorus*), Common Pheasant (*Phasianus colchicus*), Eurasian Jay (*Garrulus glandarius*), Common Starling (*Sturnus vulgaris*)). Species with density > 1 pair/ha are Great Tit, Hawfinch, Eurasian Turtle-Dove, Common Chafinch, European Robin and Blackbird. Species with medium density values (0.5 > 1 pair/ha) are nine, and species with low density (< 0.5 pairs/ha) are the Golden Oriole, Green Woodpecker, Ortolan Bunting and Eurasian Hoopoe (n=4).

Densities for the nine of the forests were estimated for species with a sufficient number of records (Song Thrush, Blackbird, Eurasian Blackcap, Eurasian Turtle-Dove, Great Tit, Golden Oriole, Common Chafinch, European Robin and Common Nightingale). European Robin D=2.28 (1.36–3.85) and Eurasian Turtle-Dove D=1.8 (1.07–3.11) were found with highest densities for the forests of Begovo. Golden Oriole has a relatively low density for all forests (0.3 < 0.6 pairs/ha). We found that all analyzed species breed with lower densities in the forest at Dalbok Izvor (0.24 > 0.97 pairs/ha), compared to the rest of the studied forests.

Table 4. Density [D] and numbers [N] of 19 of the most abundant breeding bird species (pairs/ha), with coefficient of variation (CV) and 95% confidence interval (95% CI).

Species	pair/ha	CV	95% CI	N	95% CI
Parus major	1.29	6.31	1.14–1.46	4731	4179–5355
Coccothraustes coccothraustes	1.19	10.78	0.97–1.48	4391	3549–5431

Species	pair/ha	CV	95% CI	N	95% CI
Streptopelia turtur	1.14	6.17	1.01–1.28	4180	3703–4717
Fringilla coelebs	1.1	5.49	0.99–1.23	4055	3641–4516
Erithacus rubecula	1.08	9.74	0.90–1.31	3988	3293–4828
Turdus merula	1.04	5.49	0.93–1.16	3813	3424–4247
Luscinia megarhynchos	0.99	4.51	0.91–1.08	3642	3334–3979
Columba palumbus	0.91	8.99	0.82–1.16	3583	3003–4276
Hippolais pallida	0.88	22.32	0.56–1.37	3228	2073–5026
Lanius collurio	0.83	15.75	0.61–1.13	3050	2235–4164
Sylvia atricapilla	0.75	5.84	0.67–0.84	2757	2458–3091
Phylloscopus collybita	0.66	15.76	0.48–0.90	2410	1764–3294
Turdus philomelos	0.65	7.05	0.56–0.74	2380	2072–2733
Sitta europaea	0.62	15.84	0.45–0.85	2292	1673–3141
Emberiza calandra	0.59	22.55	0.38–0.93	2184	1397–3417
Oriolus oriolus	0.44	4.45	0.40–0.48	1601	1467–1747
Picus viridis	0.39	11.57	0.31–0.50	1452	1154–1825
Emberiza hortulana	0.32	11.05	0.26–0.40	1181	947–1472
Upupa epops	0.27	7.66	0.23–0.31	984	848–1142

Effect of habitat characteristics on the bird species composition and abundance

A generalized linear mixed model (GLMM) was used to assess the effect of the vegetation characteristics of the habitat on the species composition. Variable effect on the abundance of breeding bird species in each guilds was assessed. We found a positive relationship with the age of the stands for the species that breed in the interior-edge of the forests (Wald. Stat. = 13.53, P < 0.05), the high tree cover (Wald. Stat. = 10.22, P < 0.05) and canopy closure (Wald. Stat. = 6.27, P < 0.05). A negative influence was found with the density of the stands (Wald. Stat. = 10.43, P < 0.05). Species with specific requirements for the forest interior were positively affected by mean stand height (Wald. Stat. = 8.66, P < 0.05) and stand age (Wald. Stat. = 14.38, P < 0.05).

A negative correlation was found for the edge species with the percentage of canopy closure (Wald. Stat. = 6.91, P < 0.05). The analysis of the species in relation to the breeding sites showed a significant dependence of the species breeding in the canopy of the trees with the tree height cover (Wald. Stat. = 4.53, P < 0.05), and the cavity nesters with the canopy closure (Wald. Stat. = 5.06, P < 0.05), high tree cover (Wald. Stat. = 5.72, P < 0.05) and stand age (Wald. Stat. = 8.38, P < 0.05). Species breeding in the shrub layer were dependent on the cover of the high tree layer (Wald. Stat. = 4.14, P < 0.05) (Table 5). Of the species in the guild according to the preferred food type during the breeding season, carnivorous species had a negative relationship with stand density (Wald. Stat. =

4.45, P < 0.05), and granivores had a positive relationship with the shrub layer (Wald. Stat. = 4.9, P < 0.05). Insectivores showed a weak positive relationship with the cover of the shrub layer (Wald. Stat. = 3.5, P = 0.06) and a negative relationship with stand density (Wald. Stat. = 3.35, P = 0.06).

Table 5. Results of the GLMM analysis of the influence of the variables on the bird guilds. Statistically significant values are marked in bold.

Variable	*Guild*	*Estimate*	*SE*	*Wald stat*	*Lower CL*	*Upper CL*	*p*
Stand density [%]	A	-0.06	0.03	4.45	-0.11	0.00	**0.03**
High shrub layer [%]	B	0.01	0.01	3.50	0.00	0.02	0.06
Stand density %	B	-0.02	0.01	3.35	-0.03	0.00	0.07
High shrub layer [%]	C	0.01	0.01	4.90	0.00	0.02	**0.03**
High tree layer [%]	TRN	0.01	0.00	4.53	0.00	0.02	**0.03**
Canopy closure [%]	HN	0.01	0.00	5.06	0.00	0.01	**0.02**
High tree layer [%]	HN	0.01	0.01	5.72	0.00	0.02	**0.02**
Stand age	HN	0.02	0.01	8.38	0.00	0.03	**0.00**
High tree layer [%]	UN	0.01	0.00	4.14	0.00	0.02	**0.04**
Canopy closure [%]	IE	0.01	0.00	6.27	0.00	0.01	**0.01**
High tree layer [%]	IE	0.01	0.00	10.22	0.00	0.02	**0.00**
Stand density [%]	IE	-0.02	0.01	10.43	-0.03	-0.01	**0.00**
Stand age	IE	0.02	0.01	13.53	0.01	0.03	**0.00**
Mean tree height	FI	0.16	0.06	8.66	0.05	0.27	**0.00**
Stand age	FI	0.04	0.01	14.38	0.02	0.06	**0.00**
Canopy closure [%]	FE	-0.01	0.01	6.91	-0.02	0.00	**0.01**

Multiple linear regression was used to analyze the influence of habitat characteristics on the abundance of individual species. The results show mostly weak correlation (0.3 < R > 0.5) in five of the analyzed species and medium in two (0.5 < R > 0.7).We found a positive correlation of the cover of the high shrub layer with the abundance of the Common Nightingale (F=10.02, p < 0.001; R=0.49; p < 0.5), Common Chafinch (F=3.88, p < 0.05; R=0.45; p=0.5) , European Turtle-Dove (F = 4.13, p < 0.001; R = 0.34; p = 0.3) and the Eurasian Blackcap (F = 4.10, p = 0.05; R = 0.61; p < 0.001) (Table 16). The abundance of the Eurasian Blackcap was found to be related with the average height of the stands (F = 5.15, p < 0.05). We found a significant correlation with the abundance of the Golden Oriole and the canopy closure (F = 6.20, p < 0.05; R = 0.41; p = 0.07), and the European Robin with the average height of the stands (F = 4.25, p

< 0.05; R = 0.49; p = 0.05). The abundance of the Blackbird was related with the stand age (F = 6.34, p < 0.05) and canopy closure (F = 4.09, p < 0.05).

Effect of the forest fragments on the bird richness

Multiple linear regression was used for assessing the effect of the fragmentation on the bird richness. Forest fragment size and edge length of each fragments were used as variables. The results showed a strong correlation of the fragment size (F = 1071.110; p < 0.0001), explaining 55 % (R = 0.74; p < 0.001) of the species richness (Table 6). Edge length had no statistically significant relationship with species richness (F = 0.012; p = 0.9).

Table 6. Results of the regression analysis, assessing the effect of the variables fragment size (Area) and edge length (TE) on the species richness.

Regression analysis estimates: R=0.74, R2=0.55, adjusted R=0.55, F=729.08, p<0.0001

	SS	df	MS	F	p
Intercept	7.86	1	7.86	643.60	0.00
Area	**13.09**	**1**	**13.09**	**1071.11**	**0.00**
TE	0.00	1	0.00	0.01	0.91

Conclusions

1. The lowland forests of the Western Upper Thracian lowland show high species richness. 95 bird species were registered, with 81 confirmed as breeding in the study forest fragments.

2. Forest fragments with a heterogeneous vegetation structure show greatest species richness and diversity.

3. The forest fragments support a low number of species with specific requirements for the forest interior, such as the presence of dead wood, old cavity trees, dense undergrowth.

4. Highest relative abundance was found for the common forest species. Six species made over 60 % of all registered individuals: Common Nightingale (*Luscinia megarhynchos*), Common Chafinch (*Fringilla coelebs*), European Turtle-Dove (*Streptopelia turtur*), Blackbird (*Turdus merula*), Golden Oriole (*Oriolus oriolus*) and Eurasian Blackcap (*Sylvia atricapilla*).

5. Species with highest density for the whole territory are Great Tit (*Parus major*), Hawfinch (*Coccothrausthes coccothraustes*), European Turtle-Dove (*Streptopelia turtur*), Common Chafinch (*Fringilla coelebs*), European Robin (*Erithacus rubecula*) and Blackbird (*Turdus merula*), and with the lowest density are the Eurasian Hoopoe (*Upupa epops*) and the Ortolan Bunting (*Emberiza hortulana*).

7. Higher density estimates were found for the European Robin and the Eurasian Turtle-Dove in the forest of Begovo. The Golden Oriole is with lower density for all study forests. All analyzed species have low density estimates for the forest of Dalbok Izvor, compared to the rest of the studied forests.

8. The size of the fragment has a positive influence on the species richness in fragmented forests, while the length of the edge has no statistically significant relationship.

9. The abundance of species is correlated with the forest vegetation structure. A positive correlation was found for the variables: forest age, cover of high shrub layer, cover of high tree layer, canopy closure, average height of the tree stand. A negative correlation with the species abundance was found with increasing stand density.

Contributions

1. Contributions of an original scientific nature

1.1. The composition and species diversity of fragmented lowland forests in Bulgaria were assessed.

1.2. Density and abundance of songbird species in the lowland forests of the Western Upper Thracian lowland were estimated.

1.3. The effect of the forest structure on the abundance and species richness of the breeding birds in the lowland forest fragments was studied.

1.4. The distribution of nocturnal bird species in lowland forest fragments was studied.

2. Affirmative Contributions

2.1. The size of the fragments is important for supporting a high bird species richness, in cases of high level of habitat heterogeneity.

2.2. The structural characteristics of forests have a strong impact in relation to the species diversity and abundance of birds.

2.3. Species with specific preferences for the forest interior have lower frequency of occurrence and relative abundance in the forest fragments.

2.4. The composition of the avifauna of broad-leaved lowland forests is dominated by several widespread forest bird species with high abundance.

2.5. Forests with conservation status and preserved old stands have greater species diversity with more forest specialists.

3. Contributions of an original scientific and applied nature

3.1. A list of the breeding bird species in the lowland forests of the Western Upper Thracian Lowland has been prepared.

3.2. The main factors influencing the bird species have been identified.

3.3. The obtained results can be used for comparative analyzes and assessment of changes in the breeding bird communities in relation to management practices.

Publications on the subject of the dissertation

1. **Hristova, P.**, Popgeorgiev, G., Dobrev, V., Dimitrov, H. Plachyiski, D. 2024. Birds composition in forest fragments across the Western Upper Thracian lowland. Acta Zoologica Bulgarica. In press.
2. **Hristova, P**., Popgeorgiev, G., Dobrev, V., Dobrev, D., Dimitrov, H. & Plachiyski, D. 2024. Density and composition of breeding bird communities in lowland forests. Ecologia Balkanica. In press.
3. **Hristova, P**., Popgeorgiev, G., Dobrev, D., Plachyiski, D., Stoychev, S., Nedyalkov, N., Dobrev, V. 2024. Spatial distribution of nocturnal raptor species (Aves: Strigiformes) in the Upper Thracian lowland. Ecologia Balkanica. In press.

Participation in scientific conferences:

1. **Hristova, P.,** Popgeorgiev, G., Dobrev, V., Dimitrov, H. Plachyiski, D. 2022. Preliminary results of the composition, numbers and density of breeding birds in the Western Upper Thracian lowland. Third National Young Scientists Conference on Biology. Plovdiv. Poster Session
2. **Hristova, P.**, Popgeorgiev, G., Dobrev, V., Dimitrov, H. Plachyiski, D. 2024. Birds composition in forest fragments across the Western Upper Thracian lowland. International Conference One Health and Zoology 2023 Hisarya. Oral Presentation