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Breeding density and habitat preferences of the European Turtle Dove Streptopelia turtur Linnaeus, 1758 (Columbiformes: Columbidae) in Bulgaria: preliminary results

Gradimir Gruychev*, Stoyan Stoyanov, Evlogi Angelov, Hristo Mihaylov

University of Forestry, Faculty of Forestry, Department of Wildlife Management, 10 Kliment Ohridski Blvd. 1756, Sofia, BULGARIA
Corresponding author: gradi.val@gmail.com

Abstract. We conducted country-wide surveys from 15 May to 31 July 2022 to quantify singing males' population size and habitat-specific density of Turtle Dove (*Streptopelia turtur*). We applied point counts at survey stations situated in 11 plot locations systematically distributed across the country. The average Turtle Dove's density was estimated as 10.1 singing birds per 1 km² (λ = 10.084, SE = 0.674, 95% CI: 8.846 – 11.496). The mean detection probability (p) was 0.115 (95% CI: 0.105 – 0.126), and the scale parameter of half-normal detection function was 120 m (σ = 119.74 m, SE = 3.53, 95% CI: 113.03 – 126.86). The effective radius was 169.33 m (95% CI: 159.84 – 179.37). The Turtle Dove densities were influenced by altitude with lower densities in higher elevations. The number of singing males increased from May to July. The abundance was influenced by habitat type and land cover, and it was positively correlated with tree height and shrub height measured around sampling points. The highest densities were recorded around stubbles, sunflower crops, and in a mixture of agricultural land cover, although their importance was insignificant. The density of singing males was higher in open areas, in oak and mixed deciduous forests, and in *Paliurus* communities as well.

Key words: habitat associations, Turtle Dove monitoring, detection probability, AIC, model selection.

Introduction

The European Turtle Dove (*Streptopelia turtur*) is a migratory species that winters in the Sub-Saharan region but breeds from North Africa to Urals (Cramp, 1985). One of the largest breeding populations is in Mediterranean countries (Fisher et al., 2018). The Turtle Dove use western, central and eastern migratory flyways in Europe, depending of the breeding area (Marx et al., 2016). The species is classified as vulnerable, according to IUCN Red list criteria and have declined in many European countries (Birdlife International, 2019). Threats in Europe include fragmentation and reduction of breeding habitats (Browne et al., 2004; Dunn & Morris, 2012; Kleemann & Quillfeld, 2014), as well as changes in agricultural practices leading to a decrease in food availability (Browne & Aebisher, 2003, 2004; Baptista et al., 2015; Fisher et al., 2018; Bowler et al., 2019). Other factors that may worsen the condition of the population include agricultural intensification, and excessive hunting in the species' wintering habitats (Boutin & Lutz, 2007; Lormée et al., 2019).

In the middle of the 20th century Turtle Dove was a common and widespread species (Patev, 1950). Until the late 1980s, the population appears to have been stable (Simeonov, 1971; Simeonov & Petrov, 1978; Petrov, 1981; Nankinov, 1981, 1994). The size of the breeding population in Bulgaria was estimated to range between 100,000 and 1, 000,000 individuals (Kostadinova, 1997). In a later study, the population was estimated at 150,000-200,000 breeding pairs (Nankinov et al., 2004). Several ornithological studies indicate a decrease in the population trend indices in Bulgaria at the beginning of the new century (Hristov & Petkov, 2013; Spasov et al., 2017). Recent study reports a local decrease of breeding density in southeast Bulgaria (Gruychev & Mihaylov, 2019). Recent analyses of the species' status over a 20-year period, examining density indices, report a stable population trend in Bulgaria (Hristov et al., 2025).

The sustainability of Turtle Dove hunting in Europe has been discussed over the past few years, in a relation of decline of its population (Moreno-Zarate et al., 2021). The Turtle Dove is listed in the Annex II, part B of the Birds Directive and according to the Article 7(3) it may be hunted only in some Member States, including Bulgaria. In 2018 the European Commission approved the International Single Action Plan for the Turtle dove 2018-2028 (Fisher et al., 2018), which suggested a temporary hunting moratorium, until the adaptive harvest management modelling framework is being developed. Some Member States, such as Spain, France and Portugal, have provided for restrictions on Turtle Dove hunting (Moreno-Zarate et al., 2021).

In Greece, restrictions on the hunting of Turtle Doves also came into force after 2018 (Thomaidis et al., 2022). Hunting restrictions were introduced in Bulgaria, including a daily limit of hunting bags up to 8 birds per hunter and reduction in the number of hunting days after 2021. Despite the high importance of Turtle Dove as a game bird in Bulgaria, data on the breeding population is available only from a very few local studies (Gruychev & Mihaylov, 2019; Gruychev, 2020, 2021, 2022). A comprehensive assessment of the breeding density is lacking, as well as some population parameters, including the timing of breeding season and autumn migration to wintering grounds. A better understanding of vital parameters is crucial for applying adaptive management framework for Turtle Dove populations.

This study presents data from the first year of European Turtle dove monitoring in Bulgaria.

Materials and methods

Field methods

We conducted country-wide surveys from 15 May to 31 July 2022 to quantify singing males population size and habitat-specific density of Turtle Dove. The survey points from 11 plot locations across the country were selected (Fig. 1). All plots fell within the natural breeding range of the species in Bulgaria. The census protocol followed a predefined scheme of a systematic grid of points randomly distributed 1 km apart in each of the eleven plots. A total of 925 points were surveyed with a distance-sampling design (Buckland et al., 2001; Borchers et al., 2002). Each point was visited 3 times in the study period.

A key design constraint was to cover the sample plots once a month in the breeding period between May and July in which the population was both relatively conspicuous (singing males) and undisturbed.

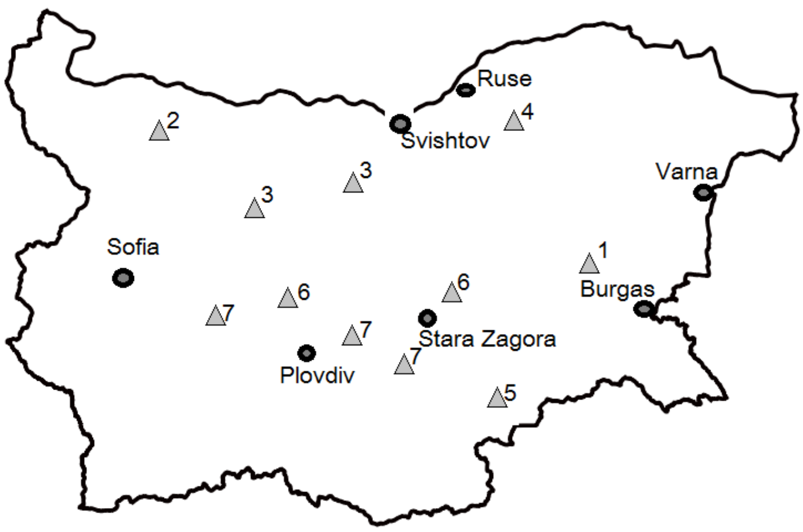

Fig. 1. Study area and distribution plots for breeding density estimation in gray triangle. (numbers are different plot area by figure 3: 1 – Aitos; 2 – Montana; 3 – Pleven; 4 – Razgrad; 5 – Sakar; 6 – Sr. gora; 7 – Trakia).

The number of singing Turtle Doves was estimated over the course of 5 minutes, after a 2-min wait on the part of the observer before the onset of the measurement of each point. Each survey was carried out in calm weather, without precipitation, between 4:30 and 8:30 am, and 5:30 and 7:30 pm. The distance to Turtle Doves seen or heard was measured with laser rangefinders or estimated by eye most of the time. Distance data were binned into two distance classes – inside 100 m and outside 100 m. We supposed that depending on weather conditions and terrain an observer could hear singing dove up to 500 m, so larger distances were impossible. However, the truncation did not affect the estimate of detection function model. Whenever possible, observers kept track of repeat detections of individual doves at each survey plot. Repeat detections were discarded for statistical analyses.

Habitat data

Doves are largely confined to woodlands and shrubs, surrounded by croplands of cereals, stubbles, and sunflowers. Therefore, we used habitat type, cropland adjacent to the fixed radius, tree and shrub height, and altitude as covariates in density modelling. The air temperature during each count was also recorded. Vegetation cover at the time of our country-wide surveys was represented by cereals, stubbles, sunflower crops, fodder crops, flax and technical fields, plowed fields, pastures, a mixture of above mentioned, vineyards, orchards, and others. For each 500 m radius point count circle, we used Google Earth, GPS data, and the habitat data to estimate average elevation and the percent cover of seven habitat categories: coniferous plantations (plantations of Scot Pine (*Pinus silvestris* L.), Austrian Pine (*Pinus nigra* Arnold) and *Cedrus*); Oak forests, represented by Hungarian Oak (*Quercus frainetto* Tenn.), Austrian Oak (*Quercus cerris* L.) and Downy Oak (*Quercus pubescens* Willd.); mixed deciduous forests with a mixed composition of Narrow-leafed Ash (*Fraxinus ornus* L.), Oriental Hornbeam (*Carpinus orientalis* Mill.), Downy Oak (characterized by a shrub floor of Common Hawthorn (*Crataegus monogina* Jacq.), Dog Rose (*Rosa canina* L.), Provence Rose (*Rosa gallica* L.), Jerusalem Thorn (*Paliurus spina-christi* Mill.) and Cornelian cherry (*Cornus mas* L.)); riparian wet forests of poplars, willows and ash trees; shrubs with a predominant presence of Jerusalem Thorn (3.2 m height) amid pastures and hay meadows, with single pears and oaks among the shrubs; strips of deciduous trees and shrubs amid open lands; forest belts amid vineyard and arable lands in northern Bulgaria, represented by oaks, pears and ash trees and having a shrub floor of Blackthorn (*Prunus spinosa* L.), Hawthorn (*Crataegus* sp.) and Jerusalem Thorn. These habitats are the most common and widespread and are indicated as frequently used by breeding Turtle Doves in Bulgaria (Simeonov, 1971; Simeonov & Petrov, 1978; Simeonov et al., 1990). We used systematic design, so the distribution of survey points corresponded with the percentage cover of the relevant breeding habitat type at the time of the survey (Table 1). The distribution of points across breeding habitat types was aligned with the proportional representation of these habitats within the respective plots. This approach aimed to avoid bias in the results that cloud arise if only sides where the species is concentrated or sites where it is absent were used.

Table 1. Number of points count by habitat type.

Habitat type	Number of points
Coniferous plantations	53
Oak forests	51
Mixed deciduous forests	214
Riparian wet forests	118
Shrubs of Jerusalem thorn	59
Strips of deciduous trees and shrubs amid open lands	125
Forest belts	305
Total	925

Statistical methods

We used the extended hierarchical distance-sampling model of Royle et al. (2004) to include submodels that describe how both the abundance process and the detection process vary as functions of environmental covariates, i.e., temperature, time of survey, elevation, land cover, tree and shrub height, and the habitat categories (Chandler et al., 2011; Sillette et al., 2012). In the abundance component of the model, spatial variation in the number of doves at each plot (N_i) was treated as a Poisson random variable with expectation $E[N_i] = \lambda_i$. The detection process is based upon the classical distance-sampling likelihood for point transect data (Buckland et al., 2001, 2008). We expected that detection probability would decrease monotonically with distance from the observer and modeled this process testing three different detection functions: half-normal, hazard and negative exponential. Environmental covariates of λ_i and σ_i (shape parameter of half-normal detection function) were accommodated using a log link function. Distances were recorded in two belts. We carried out exploratory analyses using two distance intervals up to 100 m and above 100 m, yielding two distance classes.

The latent transect-level abundance distribution is currently assumed to be:

$$N_i \sim \text{Poisson}(\lambda_i),\ i = 1, \ldots, \text{M}$$

The detection process is modeled as:

$$y_{ij} \sim \text{Multinomial}(N_i, \pi_{ij}),\ i = 1, \ldots, \text{M};\ j = 1, 2$$

where π_{ij} is the multinomial cell probability for transect i in distance class j, or π_{ij} is the product of the probability that an individual occurs in distance class j (ψ_j) and the detection probability (p_{ij}); M – number of survey points.

In distance-sampling models for point transect data, individuals are assumed to be uniformly distributed around a point. Therefore, ψ_j is simply the proportion of the plot area in distance class j (Sillette et al., 2012). The probabilities π_{ij} are computed by integrating a detection function such as the half-normal (with scale parameter σ) over each distance interval (Chandler et al., 2011; Sillette et al., 2012; Kéry & Royle, 2016). Parameters λ and σ are vectors affected by transect-specific covariates using the log link.

All calculations and statistical analyses were made by using package unmarked (Fiske & Chandler, 2011) and R software (R Core Team, 2022).

Model selection and evaluation

Given the known habitat associations of Turtle Dove, we considered a maximum model consisting of the following covariates of $\log(\lambda_i)$: elevation, habitat type, land cover, tree height and shrub height. We used generalized linear model with Poisson distributed errors, where one or more covariates (ν) may influence the expected abundance, λ_i, on a suitable scale:

$$\log(\lambda_i) = \beta_0 + \beta_1 \nu_i$$

Because temperature and time of the day could have influenced the ease with which singing birds were detected, we further considered these two variables as effects on the $\log(\sigma_i)$ parameter of the detection function (Marques et al., 2007). For example:

$$\log(\sigma_i) = a_0 + a_1 \nu_i$$

where ν_i is one or more covariates that may influence the detection probability and vary across sites.

The scale parameter (σ) is a continuous, non-negative number, hence, it is natural to apply a linear model of covariates on a transformed scale, typically the log, as for the expected count (λ) in a Poisson generalized linear model.

We tested the three detection functions and found which one best fits the data by using Akaike's information criterion (AIC). Then we fitted models in a stepwise fitting procedure starting with the null model, assuming no covariables influenced the abundance and detection function, and considering the full model as the upper limit. We included variables in succession in both directions by adding variables (i.e., forward) and removing variables (i.e., backwards), resulting in thirteen models, as indicated by Akaike's information criteria (AIC) to arrive at a final model set. AIC deals with the trade-off between the goodness of fit of the model and the simplicity of the model (i.e., the number of predictor variables). The fitting procedure followed the principle of parsimony by searching for a model with as few explanatory variables as possible that is still adequate regarding explained variation and model fit.

We used parametric bootstrapping to evaluate the goodness-of-fit of the best model (Fiske & Chandler, 2011). We simulated 1000 data sets from our model and each time refit the model to these data and computed a χ^2-statistic. We then compared the value of the fit statistic for the observed data set to the reference distribution obtained from the simulated data sets. For a model to fit, the observed value should not be too extreme, i.e., beyond the 0.05 percentile of the reference distribution (Sillette et al., 2012).

Results

Model selection

Applying the null model with no covariates included, we found that the half-normal detection function best fit the data (Table 2).

The best parsimonious model for the density included all tested covariates, while the detection probability was influenced only by the time of the day at which the survey was carried out (Table 3, Fig. 2).

Although the temperature was an important covariate, its influence on the detection function scale parameter (σ) was not significant and most probably was correlated with the time of the day, because in later morning surveys the temperature increased in the morning hours. The top model accounted for 69% of the AIC weight. Estimated model parameters for this model are given in Table 4.

Table 2. Akaike information criterion (AIC) values for three detection function models.

Model	nPars	AIC	ΔAIC	AICwt	cumltWt
Half-normal	2	3726.24	0.00	0.73	0.73
Hazard	3	3728.24	2.00	0.27	1.00
Negative exponential	2	4460.90	734.66	0	1.00

Table 3. Akaike information criterion (AIC) values for models of dove abundance (λ) and the shape parameter of a half-normal detection function (σ).

Model	nPars	AIC	ΔAIC	AICwt	cumltWt
λ(alt+hab+land+tree.h+shrub.h) p(hour)	22	3617.40	0.00	0.69	0.69
λ(alt+hab+land+tree.h+shrub.h) p(temp+hour)	23	3618.99	1.59	0.31	1.00
λ(alt+hab+land+tree.h+shrub.h) p(temp)	22	3629.19	11.79	0.0019	1.00
λ(hab+land+tree.h+shrub.h) p(.)	20	3632.11	14.71	0.0044	1.00
λ(alt+hab+land+tree.h+shrub.h) p(.)	21	3633.20	15.80	0.0025	1.00
λ(alt+hab+land+tree.h) p(.)	20	3633.42	16.02	0.0023	1.00
λ(alt+hab+land+shrub.h) p(.)	20	3633.57	16.16	0.0021	1.00
λ(alt+hab+land) p(.)	19	3634.96	17.56	0.0011	1.00
λ(alt+land+tree.h+shrub.h) p(.)	15	3664.88	47.48	0.0000	1.00
λ(alt+hab+tree.h+shrub.h) p(.)	11	3678.52	61.12	0.0000	1.00
λ(alt+hab) p(.)	9	3688.88	71.48	0.0000	1.00
λ(.) p(.)	2	3726.24	108.84	0.0000	1.00
λ(alt) p(.)	3	3728.37	110.96	0.0000	1.00

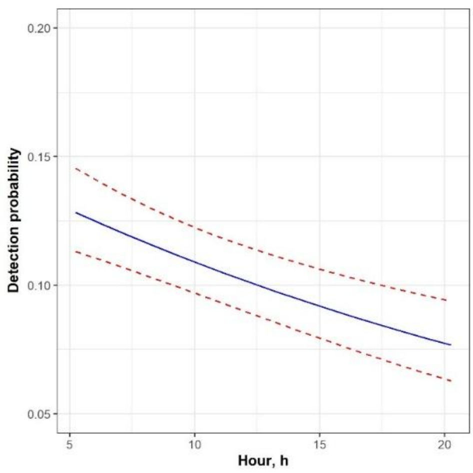

Fig. 2. Estimated detection probability predicted by the model depending on the time of the survey.

Table 4. Parameter estimates from the model with the lowest AIC values.

Variable	Estimate	SE	z	P(>|z|)
Density (λ) – log-scale				
Intercept	**2.383060**	**0.199754**	**11.930**	**<<0.000001*******
Altitude	**-0.000999**	**0.000424**	**-2.359**	**0.0183***
Deciduous belt	**-0.289686**	**0.146326**	**-1.980**	**0.0477***
Deciduous	0.051955	0.140808	0.369	0.712
Oak	**0.476531**	**0.185612**	**2.567**	**0.0102***
Paliurus	**0.349584**	**0.175917**	**1.987**	**0.0469***
Riparian	0.038705	0.160357	0.241	0.809
Trees and shrubs	-0.227101	0.155932	-1.456	0.145
Fodder	-0.126063	0.145091	-0.869	0.385
Mixture	**0.430227**	**0.183491**	**2.345**	**0.019***
Orchards	**-2.952604**	**1.009288**	**-2.925**	**0.00344****
Pastures	-0.195714	0.121021	-1.617	0.106
Plowed	-0.076677	0.423169	-0.181	0.856
Stubble	0.182135	0.118865	1.532	0.125
Sunflower	0.219089	0.115205	1.902	0.0572
Tissue	-0.425217	0.368843	-1.153	0.249
Vineyards	-0.285143	0.173839	-1.640	0.101
Others	-0.004982	0.196711	-0.0253	0.980
Tree height	0.009171	0.006714	1.366	0.172
Shrub height	0.053600	0.036459	1.470	0.142
Detection (*p*) – log-scale				
Intercept	**апр.63**	**0.04365**	**112.63**	**<<0.000001*******
Hour	**-0.0154**	**0.00369**	**-4.18**	**0.0000288*******

Note. Significance level: *p < 0.05, **p < 0.01, ***p < 0.001; **Mixture** – refers to the present of more than two crop types in the arable land surrounding each point, with relatively similar areal proportions; **Tissue** – industrial crops such as hemp, flax, cotton etc.; Others – combination of more than six crop types occuring in small areas around the sampling points that cannot be assigned to the other variables.

The model showed that Turtle Dove densities were influenced by altitude with lower densities in higher elevations. The number of singing males increased from May to July (Fig. 3A). Breeding density also varied among the different study areas (Fig. 3B).

The abundance was influenced by habitat type and land cover, and it was positively correlated with tree height and shrub height measured around sampling points. The magnitude of the abundance in different habitats and land cover is shown in Fig. 4 A and B. The highest densities were recorded around stubbles, sunflower crops, and in a mixture of agricultural land cover, although their importance was insignificant. The density of singing males was higher in open areas, in oak and mixed deciduous forests, and in *Paliurus* communities as well. According to the best model, the influence of Oak forests and *Paliurus* communities was significant (Table 4).

The goodness-of-fit test based on the χ^2-statistic (χ^2 = 2051.994, n = 1000, p = 0.927) suggested that the selected model with half-normal detection function provided adequate fit to the data.

Density estimates

The detection probability decreased with the time of the day at which the survey was carried out (Fig. 2). Based on the best model, the average Turtle Dove's density was estimated as 10.1 singing birds per 1 km^2 (λ = 10.084, SE = 0.674, 95% CI: 8.846 – 11.496). The mean detection probability (p) was 0.115 (95% CI: 0.105 – 0.126), and the scale parameter of half-normal detection function was 120 m (σ = 119.74 m, SE = 3.53, 95% CI: 113.03 – 126.86). The effective radius was 169.33 m (95% CI: 159.84 – 179.37). Abundance estimates per plot or predictions for any arbitrary region can be obtained from the hierarchical distance-sampling model. The density of singing males varied between regions (Fig. 3), habitats and land cover (Fig. 4).

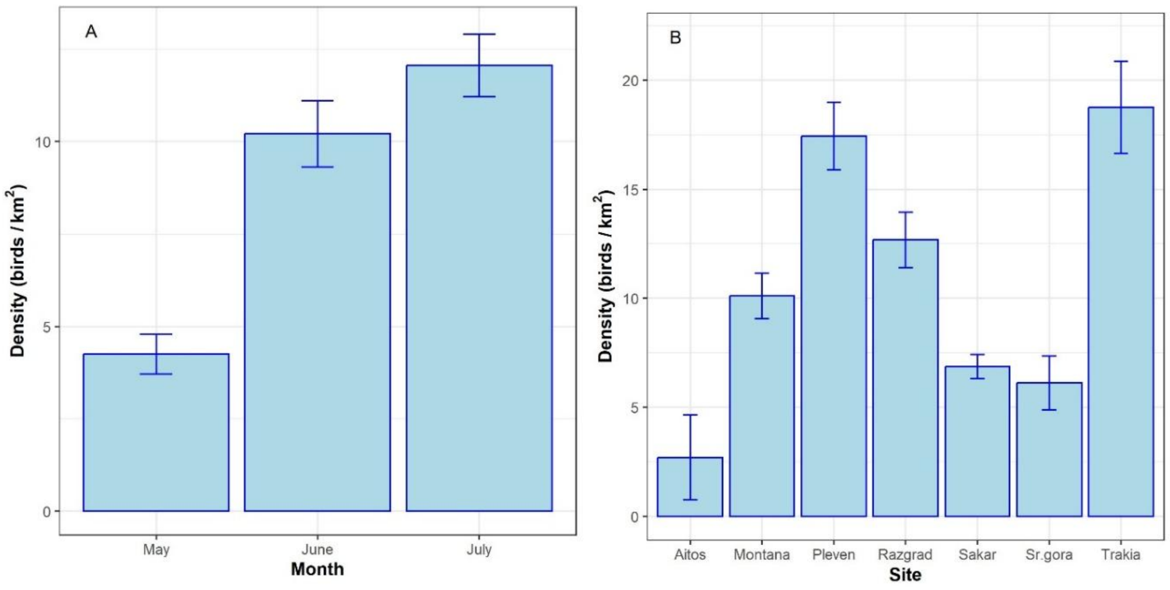

Fig. 3. Density of singing males by months (A) and regions (B).

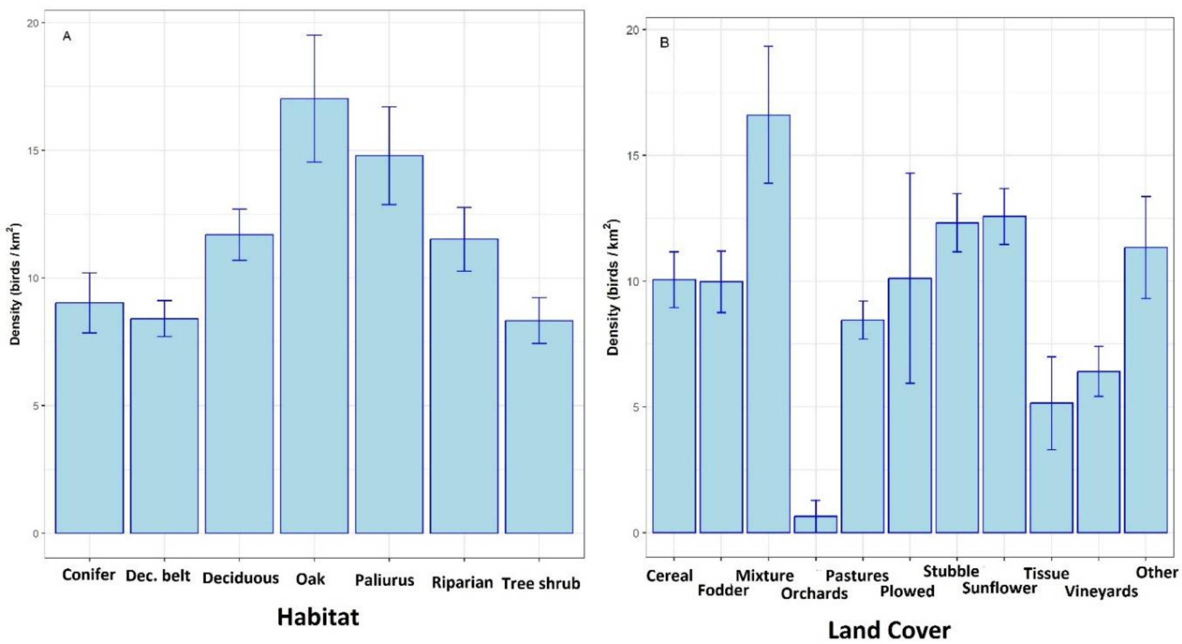

Fig. 4. Density of singing males by habitat type (A) and land cover (B).

Discussion

The Turtle Dove's breeding density in 2022, being the first monitoring year at a national scale, was higher than density reported in local surveys for the last years (Gruychev & Mihaylov, 2019). The densities reported since the beginning of the new century (Karaivanov, 2003, 2005; Nikolov & Spasov, 2005; Karaivanov et al., 2006), and in some studies in the 1960s and 1970s were higher (Simeonov, 1971; Simeonov & Petrov, 1978). In the period 1964-1978, densities of the Turtle Dove between 2 and 110 singing birds per square kilometer were found in different habitats (Simeonov, 1971; Simeonov & Petrov, 1978). Densities between 0 and 49 individuals were reported for Southeastern Bulgaria (Milchev, 1991), between 13 and 20 individuals for Northwestern Bulgaria (Karaivanov, 2003; Karaivanov et al., 2006), and 17.6 - 18.8 singing birds for Southwestern Bulgaria (Nikolov & Spasov, 2005; Karaivanov, 2005). In recent years, studies in Southeastern Bulgaria reported densities between 0 and 12.8 singing birds in different habitats

(Gruychev & Mihaylov, 2019). Previous studies are rather local in nature and cannot reflect the trend of the breeding density of the species. However, according to recent ornithological reports based mainly on "citizen science" data, the Turtle Dove has a stable trend (Hristov & Popgeorgiev, 2021; Hristov, 2022). In different parts of the European range of the species, the following breeding densities were reported: 5 pairs/km² (3.7-7.7) for intensive agroecosystem in Italy (Chiatane et al., 2021), 10-26 males/km² in Spain (Sáenz de Buruaga et al., 2012), 0.4-4.3 pairs/km² in English farmlands (Browne & Aebisher, 2004). The assessed breeding density in Bulgaria in our study is higher than in many European countries, but not as high as the maximum estimated densities.

Detection probability decreased from sunrise to sunset. On the other hand, this is one of the parameters that can significantly influence the results. Hence, the time of the day for conducting point surveys should be standardized because Turtle Doves' daily activity varies. Singing activity is higher near sunrise, lower in the middle of the day, and again higher near sunset (Bibby et al., 1992). Moreover, the number of birds reported decreases from sunrise to mid-morning (Lynch, 1997). Therefore, we recommend morning counts, and most of the survey point counts in the national monitoring scheme were made in the morning hours as described in the methods section.

The number of Turtle Doves is negatively related to altitude, according to our data. A similar dependence was established for Sarnena Sredna Gora Mountain in Bulgaria (Gruychev, 2022). The distribution of the species in Europe is mainly at low altitudes and in areas with high temperatures (Marx & Quillfeld, 2018; Keller et al., 2020). Furthermore, with the increase of altitude, the forest cover increases, and hence the share of open areas for feeding decreases. As it was shown by some other studies, Turtle Dove abundance is negatively correlated with increase of forest cover (Sáenz de Buruaga et al., 2012).

Following our preliminary results, the Oak Forest and Jerusalem Thorn communities should be considered as significant breeding habitats for Turtle Doves. Such results are confirmed from other studies in Bulgaria (Simeonov et al., 1990; Gruychev & Mihaylov, 2019; Gruychev 2020). Forest habitats can support 6.5 times higher densities of Turtle Dove than open areas (Browne et al., 2004), and in some parts of the Iberian Peninsula, the birds also prefer agricultural landscapes with single trees (Dias et al., 2013). According to our model, shrubs cover by Jerusalem Thorn was positively associated with Turtle Dove breeding densities. These communities are usually adjacent to various cultivated lands and the presence of single trees among them. Similar landscapes have been favored in some parts of Iberian Peninsula (Dias et al., 2013). High breeding densities of the species were reported in such areas in previous studies in Southern Bulgaria (Gruychev & Mihaylov, 2019), but only in certain years. Although Riparian forests are indicated in some studies as habitats with a high density of Turtle Dove (Sáenz de Buruaga et al., 2012; Gruychev & Mihaylov, 2019; Gruychev, 2020) according to our model, this variable was not significant (Table 3). Our study was too short to assure whether these are the most important habitats for the Turtle Doves in Bulgaria, but monitoring data in the coming years hopefully will answer to this question.

The mix of different crops near breeding sites was positively associated with the density of singing males. In Europe Turtle Doves feed mainly on seeds, most of which are naturally occurring in open areas around the breeding habitats (Dunn et al., 2018, 2021; Gutièrez-Galan & Alonso, 2016). In Sredna Gora Mountain, the singing birds' density was positively associated with cereals and various combinations between cereals and sunflower around the breeding habitats (Gruychev, 2022). The likely reason is that mixed open areas provide better food supply.

Conclusions

Our study presents the Turtle Dove breeding density for the first time at a national level. The average Turtle Dove's density was estimated as 10.1 singing birds per 1 km². The number of singing males increased from May to July. Turtle dove densities were influenced by altitude with lower densities in higher elevations. The highest densities were recorded around stubbles, sunflower crops, and in a mixture of agricultural land cover, although their importance was insignificant. The density of singing males was higher in open areas, in oak and mixed deciduous forests, and in *Paliurus* communities.

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