POPULATION SURVEY AND HABITAT SELECTION OF THE EUROPEAN NIGHTJAR (*Caprimulgus europaeus* L.) IN THE GYŐR-GÖNYŰ SAND STEPPES

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ABSTRACT

BODOR, Á. & WINKLER, D. (2023): POPULATION SURVEY AND HABITAT SELECTION OF THE EUROPEAN NIGHTJAR (*Caprimulgus europaeus* L.) IN THE GYŐR-GÖNYŰ SAND STEPPES. *Hungarian Small Game Bulletin* **15**: 145–155. http://dx.doi.org/10.17243/mavk.2023.145
This study investigated the habitat selection of the European Nightjar (*Caprimulgus europaeus*) during the breeding seasons of 2017 and 2018 in the Győr-Gönyű calcareous sand steppe area. In order to assess the habitat preferences of the European Nightjar, habitat characteristics around occupied territories were compared with unoccupied control plots. To characterize the surveyed territories, a total of nine variables related to landscape characteristics, vegetation structure, and composition were quantified. Multivariate methods (PCA and GLMs) were used to distinguish the main factors influencing habitat selection and to model the presence of the European Nightjar. A total of 25 occupied territories were surveyed in the study area in 2017, while 21 in 2018, all of which were characterized by mosaic-structured habitats. Based on our results, in the Gönyű sand steppes, a high probability of European Nightjar presence can be predicted in plots with a sufficient proportion of bare ground patches, higher lengths of forest edges, and the presence of grasslands near the territories.

KEY WORDS: forest steppes, bare ground patches, forest edges, mosaic structure

KIVONAT

Kutatásunkban a lappantyú *(Caprimulgus europaeus)* élőhelyválasztását vizsgáltuk a Gönyűi-homokvidék erdőssztyepp élőhelyein, fészkelési időszakban, 2017-ben és 2018-ban. A felmért territóriumok jellemzéséhez a növényzet struktúrájára, faji összetételére és a tájszerkezetre vonatkozó változókat számszerűsítettünk. A lappantyú élőhely-preferenciáinak értékelésére a tényleges territóriumok mellett random kontroll pontok felmérését is elvégeztük, az esetleges elkülönülést és az elkülönülést okozó változókat többváltozós statisztikai módszerekkel (PCA, GLMs) elemeztük. A vizsgálati területen összesen 25 foglalt territóriumot sikerült felmérni 2017-ben, míg 2018-ban 21 revírt, amelyek mindegyikére a mozaikosság volt jellemző. Vizsgálataink alapján a nudum foltok jelenléte, a szegélyhossz és a revír távolsága a gyepektől, mint a mozaikosság mérőszámai, fontos szerepet játszanak a lappantyú habitatválasztásában.

KULCSZAVAK: erdősztyepp, nudum foltok, erdőszegélyek, mozaikosság

1. INTRODUCTION

The European Nightjar (*Caprimulgus europaeus* L.) is one of the most interesting protected migratory birds in Hungary. However, relatively little is known about this species because of its hidden nocturnal activity. The European Nightjar has a Palaearctic distribution, occurring in North Africa and Europe, and as far east as Lake Baikal, Outer and Inner Mongolia, and Northwest India (CLEERE 2001). The species is relatively thermophilic, so its main nesting sites are in lowlands and plains. Occasionally found in the mid-mountains and the high mountains in the south. However, broad areas are excluded for geographic, soil, vegetation structure, or local climatic reasons. Its distribution in Central Europe is concentrated in eastern Hungary. The largest gaps in its breeding range are in Austria and Switzerland. The upper limit of its range in the Carpathians and Alps is 7–800 m; in some places, it is 1000 m (GLUTZ VON BLOTZHEIM & BAUER 1980, SIERRO *et al.* 2001). It occurs in forests and open habitats. In Hungary, typical habitats are Poplar-juniper sand dune forests and thickets, karst scrub forests, sandy habitats with patches of shrubs and trees, abandoned vineyards, orchards, but it also occurs in planted pine or black locust stands (GYŐRY 1984, MÁRKUS 1998, WINKLER 2008, HARASZTHY 2019, GALLAI 2012, 2022). It avoids large, continuous closed forest stands but prefers more open forests and forest edges. It breeds in clear-cut areas and young afforestations but leaves the area after vegetation closure (WINKLER 2008).

Although the IUCN Red List classifies the European Nightjar in the Least Concern category, the global population trend is declining (BIRDLIFE INTERNATIONAL 2023). The European Nightjar's Hungarian population was estimated at 5–10,000 pairs in the 1990s (MAGYAR *et al.* 1998), and 3.5–6,000 singing males were recorded between 1998–2001 (HADARICS & ZALAI 2008). The current estimated size of the domestic population is 3,700–9,500 pairs based on surveys in 2017–2018 (GALLAI 2022).

Data on the European Nightjar available in the national literature refer rather only to faunistic observations and population surveys (*e.g.,* RUZSIK 1957, MOSKÁT 1976, FENYŐSI 1993), while habitat selection of the species has been less studied (WINKLER 2008, GALLAI 2012). The international literature on European Nightjar, although not extensive, provides some interesting research on habitat selection (BERRY 1979, SIERRO *et al.* 2001, WICHMANN 2004, SHARPS *et al.* 2015, PEPŁOWSKA-MARCZAK *et al.* 2017, MITCHELL *et al.* 2020, POLAKOWSKI *et al.* 2020).

One of the main objectives of our research was to survey the population of European Nightjar in the Gönyű sand steppe area. In addition, another important objective was to study and evaluate the habitat selection of the species and to find out which parameters influence the habitat selection the most in this mosaic-structured sand steppe environment.

2. MATERIAL AND METHODS

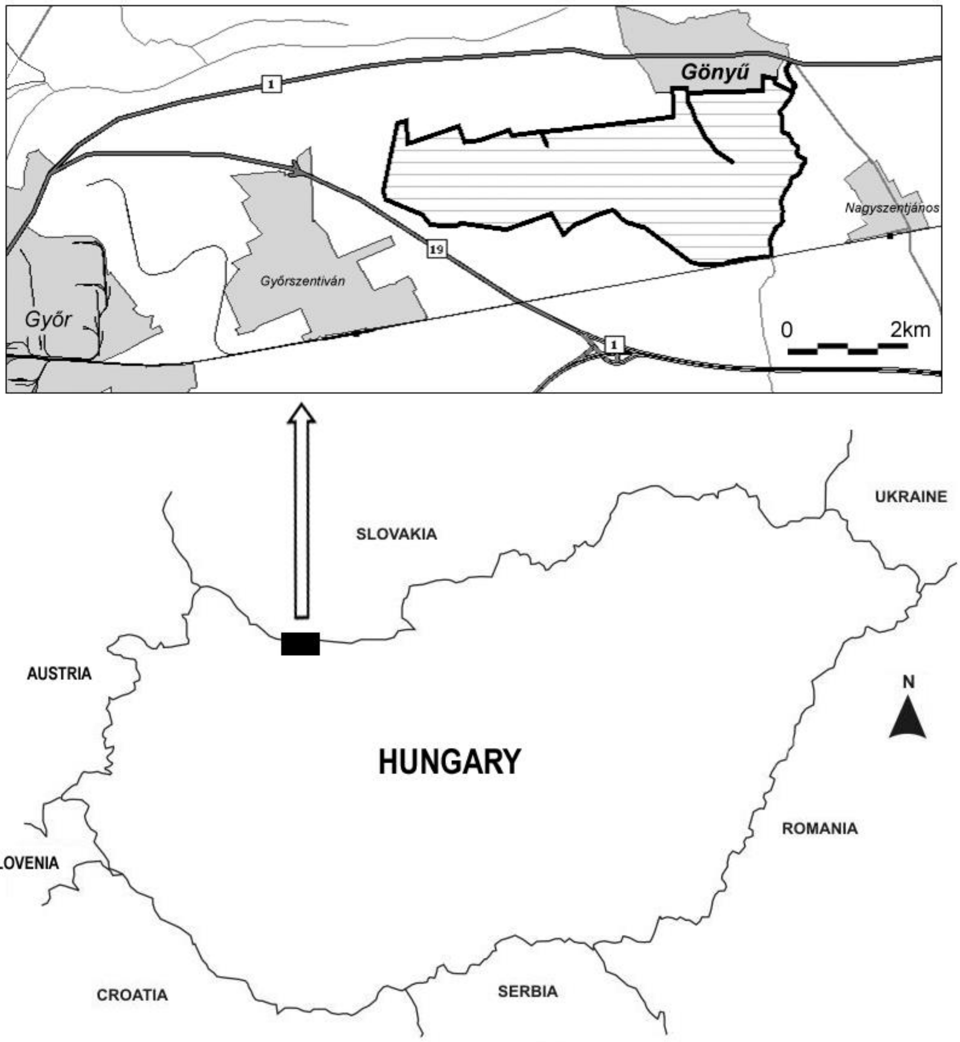
2.1. STUDY AREA

The study area is located in the eastern part of Győr-Moson-Sopron county, covering an area of 1307 ha. The Gönyűi-homokvidék, which is part of the Pannonhalmi Landscape Protection Area, is an area that preserves the remains of the Little Plain calcareous sandy steppes. Since 2004, it has been part of the Natura 2000 network (HUFH2009 – Gönyűi-homokvidék) (TAKÁCS & KIRÁLY 2015). The exact location of the research is the Gönyűi-forest and the area of the military shooting ground in Győrszentiván (**Map 1**).

Its climate is moderately warm to moderately dry (PÉCZELY 1979). The mean annual temperature is around 10ºC, with a multi-year average of 16ºC during the vegetation period. It is one of the most rainy regions in the country, with an annual rainfall of 580–620 mm.

The study area and its surroundings are covered with sandy soils, chernozemic sandy soils, and meadow soils (DÖVÉNYI 2010). The study area is characterised by flat, broad-backed, sandy hummocky ridges and wet flats at an altitude of 112–122 m above sea level.

The natural forest communities in the area are open steppe oak forests, poplar steppe woods, and lowland closed pedunculate oak forests. In addition, planted black locust, Scots pine, black pine, and turkey oak can be found in the area.



Map 1. Study area (Győr-Gönyű sand steppes)

2.2. FIELD SURVEYS

2.2.1. Survey of European Nightjar territories

The European Nightjar nesting population survey was carried out in 2017 and 2018 during the breeding season, between the end of May and the end of June. Nightjars started to churr at around 9 pm and sounded loudly for 1–2 hours. Based on the distinctive churring sound of the males, European Nightjar territories in the area were identified and recorded with GPS coordinates in the phone apps Epicollect+ and Epicollect 5.

2.2.2. Survey of habitat characteristics

In order to assess the habitat preferences of the European Nightjar, habitat composition for a total of 26 occupied territories was compared with 26 unoccupied control plots randomly selected in the study area using Hawth's Analysis Tools for ArcGIS (BEYER 2004). To characterize the habitat around territories, a total of nine variables related to landscape characteristics, vegetation structure, and composition were quantified (**Table 1**). Heights and distances were given in m, the other characteristics in % of the area. Following PEPLOWSKA-MARCZAK *et al.* (2017), a 50 m radius plot established around the central point of the territories was chosen for the determination of the habitat variables. For territories occupied in both study years (a total of 10 territories), habitat surveys were carried out in only one year.

Table 1. Data system of habitat structure characteristics

Habitat characteristic	Abbreviation during analysis
average tree height	ATH
tree layer cover	TLC
proportion of conifers in the tree layer	CONTL
proportion of birch in the tree layer	BIRTL
shrub layer cover	SLC
average shrub height	ASH
bare ground patches proportion	BGP
forest edge length	FEDG
distance of territory from the nearest grassland	DISTGR

2.3. DATA ANALYSIS

Principal Component Analysis (PCA) was used to describe the habitat structure based on data from European Nightjar occupied and non-occupied control plots and to distinguish the main factors influencing habitat selection. Only PCA factors with eigenvalues over 1.0 were selected (Kaiser Criterion). Factor loadings were rotated with a varimax raw transformation. Mean factor scores between the occupied and control plots were compared by using a *t*-test. Normality and homogeneity of variances were tested for all parameters and, in case of necessity, transformed to fit the assumptions of parametric tests.

Generalized linear models (GLMs) were used to evaluate the presence of European Nightjar based on the principal components (PCs) obtained. Since territory occupation by the nightjars was considered a binary response variable (presence – 1, absence – 0), the logistic link functions were applied with a binomial error structure. The forward stepwise (likelihood ratio) method was applied to select the final variable in the model. Each variable was tested for significance, and only those contributing significantly ($p<0.05$) to the model were retained. The performance of the GLMs was assessed using Cohen's Kappa statistics, describing the proportion of the correctly classified predictions after the probability of chance agreement has been removed (Cohen 1960). According to LANDIS & KOCH (1977), the strength of agreement can be considered slight to fair for κ values 0–0.4, moderate for 0.4–0.6, substantial for 0.6–0.8, and almost perfect for 0.8–1.0, respectively. Statistical analyses were computed using SPSS vs20 (IBM Corp. Released, 2011) and SAS statistical package ver. 9.1 (SAS INSTITUTE INC. 2012).

3. RESULTS

The European Nightjar territories found and surveyed during the study period are illustrated in **Map 2**. In 2017, a total of 25 territories were found. Of these, 10 territories were located in the area of the military shooting ground due to its mosaic habitat structure. A further 15 territories were mapped in the Gönyűi Forest, primarily located in the vicinity of the grasslands between the forests (**Figure 1**). The exception is a territory located in a collapsed forest pine forest, which, unlike the others, is much further away from open habitats

(**Figure 2**). In 2018, a total of 21 territories were found, 10 of which were the same as in the previous year, and, in addition, 11 new territories were also detected (**Map 2**).

Map 2. European Nightjar territories in 2017 and 2018

Figure 1. Typical habitat of European Nightjar from the sandy wasteland (forest-steppe mosaic with grassland and forest patches) (Photo: Á. BODOR)

Figure 1. Female European Nightjar with the two fledglings (Photo: D. WINKLER)

The principal component analysis (PCA) performed on the surveyed habitat variables yielded three variables with eigenvalues greater than 1.00. The three components explain 70.6% of the total variance, which is appropriate for the study (**Table 2**).

Table 2. Eigenvalues for components and shares of total variance explained by components

Comp	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.959	43.990	43.990	3.959	43.990	43.990	3.208	35.644	35.644
2	1.256	13.951	57.941	1.256	13.951	57.941	1.832	20.354	55.998
3	1.138	12.642	70.584	1.138	12.642	70.584	1.313	14.586	70.584
4	0.883	9.812	80.396						
5	0.672	7.461	87.857						
6	0.534	5.929	93.787						
7	0.274	3.048	96.835						
8	0.195	2.167	99.002						
9	0.036	1.000	100.000						

The coefficients of the selected three components obtained by varimax orthogonal rotation are given in **Table 3**. The principal component coefficients can also be interpreted as correlation coefficients between the measured variables and the principal components.

Table 3. Factor loadings after varimax rotation for the principal components in PCA on the habitat variables used

	Principal component		
	PC1	**PC2**	**PC3**
ATH	-0.152	0.219	**0.837**
TLC	0.273	**0.811**	0.322
CONTL	0.186	**0.671**	0.269
BIRTL	-0.012	**-0.640**	-0.114
SLC	0.389	-0.042	**0.794**
ASH	0.171	0.339	**0.581**
BGP	**0.803**	0.104	-0.089
FEDG	**-0.779**	-0.096	0.304
DISTGR	**-0.872**	0.082	0.141

The first component (PC1) accounted for 43.99% of the total variance, and it is principally governed by the proportion of bare ground patches (BGP), length of forest edges (FEDG), and distance of territory from the nearest grassland (DISTGR). Mean factor scores on this axis differ significantly between the Nightjar territories and the non-occupied control plots (*t*-test, $t = 2.742$, $p < 0.05$).

The second component (PC2) accounted for 13.95% of the total variance, with loadings large for tree layer cover (TLC) and the proportion of conifers (CONTL) and birch (BIRTL) in the tree layer. No significant difference has been observed on this axis between the mean factor scores of occupied and control plots (*t*-test, $t = 1.823$, NS).

The third component (PC3), accounting for an additional 12.64% of the total variance, is determined by the average tree height (ATH), the average height (ASH), and the cover of the shrub layer (SLC). No significant difference was observed among the Nightjar territories and control plots on this axis (*t*-test, $t = 1.179$, NS).

A summary of the final GLMs model is presented in **Table 4**. PC1 showed a positive influence ($\beta = 0.104$) on European Nightjar presence probability, and it was the most influential new variable ($\chi^2 = 41.254$) derived from the PCA. PC2 also showed a positive relationship with the presence probability of nightjars ($\beta = 0.589$) but was less influential ($\chi^2 = 4.312$) than PC1. The model performed better in correctly predicting European Nightjar habitat where presence occurred (67.4%) than in correctly classifying unoccupied habitat (59.9%). According to the κ statistic (0.404), the model had only moderate agreement with the testing dataset.

Table 4. Summary of GLMs for the probability of the presence of European Nightjar

Factors	**β**	**SE**	χ^2	**p**
(intercept)	3.477	0.986	10.326	0.006
PC1	0.104	0.014	41.254	0.000
PC2	0.589	0.178	4.312	0.041
Residual deviance	21.115			

4. DISCUSSION

There are only a few data on the domestic population density of the European Nightjar. It is probably best described by GYŐRY (1984) as a "widespread but a not very common bird in its suitable habitats". In our study area, 25 territories were found in 2017, corresponding to a density value of 0.19 pairs/10 ha, while in 2018, with 21 territories, this value decreased to 0.16 pairs/10 ha. On the other hand, if only the area of optimal habitat for the species (~600 ha) is taken into account, excluding completely closed forests, the density results in 0.42 pairs/10 ha (2017) and 0.35 pairs/10 ha (2018), respectively. FENYŐSI (1993) estimated the breeding population in the former Barcsi Landscape Protection Area, also in a sandy habitat with a mosaic structure, at 15–20 pairs. In its optimum habitat, 3 territories were found on about 100 ha, corresponding to a density of 0.3 pairs/10 ha. GALLAI (2012) recorded 31 singing nightjars on a 230 ha sample area in the Kolon Lake core area of the Kiskunság National Park Directorate, which is a markedly high density (1.35 pairs/10 ha) compared with the other occurrences and densities of the species in the country. Data for mid-mountain environment were provided by WINKLER (2008). In the southeastern part of the Sopron Mountains, he mapped a total of 7 European Nightjar territories on about 125 ha in the period 1990–1997, corresponding to a density of 0.6 pairs/10 ha. These data also confirm that based on the occurrence model map (SZÉP *et al.* 2022), the species is most likely to be present in the Sandridge of the Danube-Tisza Interfluve (GALLAI 2022).

The European Nightjar is a highly territorial bird, and if the habitat does not change significantly, the same territories are used in consecutive years (LÖCHER 1992, CLEERE 2001, BULT 2002, PALMER 2003, WICHMANN 2004, REBBECK *et al.* 2001, WINKLER 2008). It is interesting to note that this phenomenon was already reported by CHERNEL (1899) more than a hundred years ago. During the two-year study period, we were able to prove this same phenomenon. More than half of the territories surveyed in the second year were found in precisely the same place. In many cases, even the tree used for churring was the same for the two consecutive years.

Based on our studies, the habitat selection of the European Nightjar in the Győr–Gönyű sand steppe area is mainly determined by the proportion of bare ground patches, the length of forest edges, and the distance of the territory from grassland. The greater length of forest edges and other edge ecotones and the proximity to grassland are good indicators of mosaic habitat structures. The presence of woody vegetation not only provides trees suitable for churring but their foliage shading and leaf litter falling also create nude ground patches that offer suitable nesting habitats for the species (VERSTRAETEN *et al.* 2011). In poplar-juniper sand dune forests of the Kolon Lake area in the Kiskunság, in a similar habitat to the one in our study area, GALLAI (2012) found that the proportion of patches of primarily common juniper (*Juniperus communis*) and the length of the edges were the determining factors in habitat selection of the European Nightjars. Nevertheless, while for the latter variable, nightjars showed avoidance at both the smallest and largest edge sizes, we found an apparent positive effect of larger edge sizes. It should be noted, however, that while juniper is markedly present in the Little Hungarian habitat, it is virtually absent from the sandy habitats of the Little Plain (KIRÁLY *et al.* 2015). KESZKENYŐS *et al.* (2013) found in the former Barcs Landscape Conservation Area that several vegetation structure elements play an important role in the habitat selection of the European Nightjar. Among others, the structure and cover of the canopy and shrub layer were detected as important parameters. There was also a significant difference in the proportion of birch, pine, and broadleaved species between occupied and unoccupied control plots. In a mid-mountain environment, WINKLER (2000) observed that, in addition to smaller (<2ha) clear-cutting areas and young afforestations, not only forest edges but also remnant trees play an important role in the habitat selection of the species. In black pine forests in Austria, WICHMANN (2004) found that territories are primarily located in the centre of more extended clearing areas, which may be related to better hunting opportunities. He also highlights the presence of suitable taller trees used for churring. However, no decisive effect was found between the proportion of bare ground patches and territory selection.

In relation to the European Nightjar, several authors mention forest management interventions, which are usually reported in a negative context for biodiversity. However, especially in large, continuous stands, small gap clearings and not extensive clearings have clearly had a positive effect on the European Nightjar (BERRY 1979, SCOTT *et al.* 1998, POLAKOWSKI *et al.* 2020), especially in forests where natural processes (*e.g.*, windthrow-induced gaps) are less prevalent.

The role of individual tree species is also worth mentioning. Several studies, both from Hungary and other European countries, highlight the role of coniferous woody vegetation in European Nightjar's habitat selection (e.g., WICHMANN 2004, WINKLER 2008, PEPŁOWSKA-MARCZAK *et al.* 2017), even in areas where the individual coniferous species are not native. Besides being suitable trees used for churring, they can provide bare patches on the ground through their needle litter, which are essential for nightjars. In some studies, birch appears as another seemingly favoured tree species (KESZKENYŐS *et al.* 2013, PEPŁOWSKA-MARCZAK *et al.* 2017). However, this may be more related to the fact that birch is often found as a pioneer tree species in some of the nightjars' typical habitats. In contrast to the preferences mentioned above, studies by VERSTRAETEN *et al.* (2011) showed that forest type and tree species appeared to be non-significant.

ACKNOWLEDGEMENT

We want to thank the staff of the Fertő-Hanság National Park Directorate, the Kisalföld Forestry Company, and the 12th AIR DEFENSE MISSILE REGIMENT "Arrabona" for their contribution to the successful field surveys in the areas under their use and management.

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