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Population recovery and spatial determinants of occupancy and breeding success in the Saker Falcon *(Falco cherrug)*: A study from Western Romania

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Abstract Despite the lowland area in Western Romania offering high-quality habitats for Saker Falcons, with abundant mammalian prey like the European Ground Squirrel (EGS), and proximity to the strong Hungarian population, Sakers mostly visited the region with few breeding attempts recorded before 2014. This changed after installing 83 aluminum nest boxes on high-voltage transmission line towers in a European Union funded conservation program, which encouraged settlement and led to a rapid growth in the Saker population. Our study, covering 2016–2023, analyzed population changes, focusing on nest box occupancy, nesting success, and brood size. Furthermore, we also investigated covariate effects by using generalized linear (mixed) models. By 2023, the population reached 43 pairs, with the nearest neighbor distance between occupied nest boxes decreasing from 9.9 km in the second year to 6.1 km in 2023. We evaluated 255 breeding attempts, 192 of which were successful, resulting in 794 young, while 63 attempts failed. The mean nesting success rate was 0.752±0.432 (n = 255), mean brood size per successful pair was 3.135±1.15 (n = 192), and mean brood size per all breeding attempts was 2.361±1.682 (n = 255). Evidence suggested that nest box occupancy positively correlated with the distance to nearest settlement, the cumulative grassland area within ten km, and the number of EGS colonies within 5 km of the nest boxes. The distance of nest boxes to the nearest EGS colony significantly and negatively impacted nesting success. Our results confirm that installing nest boxes can quickly establish a healthy population if nesting sites are the only limiting factor. These findings contribute to a more effective planning of future Saker conservation measures.

Keywords: Saker Falcon, Romania, nest box, occupancy, nesting success

Összefoglalás Annak ellenére, hogy Nyugat-Románia alföldi területei kiváló élőhelyet kínálnak a kerecsensólyom számára, gazdag emlős zsákmánnyal, például az európai ürgével, és e területek közel vannak az erős magyarországi populációhoz, a kerecsensólymok többnyire csak látogatóként jelentek meg a régióban, és kevés fészkelési kísérletet jegyeztek fel 2014 előtt. Ez megváltozott, miután 83 alumínium fészekládát telepítettek magasfeszültségű villanyoszlopokra egy Európai Unió által finanszírozott természetvédelmi program keretében, ami elősegítette a sólymok megtelepedését és gyors populációnövekedést eredményezett. Tanulmányunk, amely a 2016–2023 közötti időszakot öleli fel, a populáció változásait elemezte, különös tekintettel a fészekládák foglaltságára, a fészkelési sikerre és a fiókaszámra. Vizsgáltuk továbbá egyes magyarázó változók hatását általános lineáris (vegyes) modellek segítségével. 2023-ra a populáció 43 párra nőtt, a foglalt fészekládák közötti legközelebbi szomszéd távolság a második évi 9,9 km-ről 6,1 km-re csökkent 2023-ban. 255 költési kísérletet értékeltünk ki, amelyből 192 volt sikeres, 794 fiókát eredményezve, míg 63 kísérlet sikertelen volt. Az átlagos fészkelési siker 0,752±0,432 (n = 255), az átlagos fiókaszám sikeres páronként 3,135±1,15 (n = 192), az összes szaporodási kísérletre vonatkozó átlagos fiókaszám pedig 2,361±1,682 (n = 255) volt. Az eredmények arra utalnak, hogy a fészekládák foglaltsága pozitívan korrelált a legközelebbi település távolságával, a 10 km-en belüli összes füves terület nagyságával, továbbá az öt km-en belül található ürgekolóniák számával. A fészekládák távolsága a legközelebbi ürgekolóniáktól jelentősen és negatívan befolyásolta a fészkelési sikert. Eredményeink megerősítik, hogy ha az egyetlen korlátozó tényező a fészkelőhelyek hiánya, a fészkeládák telepítésével gyorsan létrehozható egy egészséges populáció. Ezek az eredmények hozzájárulnak a jövőbeli kerecsensólyom-védelmi beavatkozások hatékonyabb tervezéséhez.

Kulcsszavak: kerecsensólyom, Románia, fészekláda, foglaltság, fészkelési siker

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Introduction

In the turn of the 19th and 20th centuries, the Saker Falcon (*Falco cherrug,* hereinafter referred to as 'Saker') certainly occurred in the southeastern part of the Carpathian basin (Csörgey 1897, Chernel 1899), and it was common in the lowlands of Romania, particularly along the Danube, and in the Danube Delta (Linţia 1954). Over the past hundred years, however, extensive human-induced habitat changes and direct persecution have drastically reduced their numbers. Today, this falcon species is categorized as Endangered on the Red List of breeding birds of Romania (MEWF 2022). In recent times, there is a new, emerging population of Sakers in the western part of the country along the Hungarian border. Those pairs form the edge of the increasing Central European Saker population. Besides, there are a few pairs in Dobrudja, southeast Romania, which represent the remaining westernmost part of the rapidly decreasing Eastern European population (Ajder *et al.* 2025, Fântână *et al.* 2025, Prommer *et al.* 2025).

The Saker once bred in the lowlands of Western Romania, though historical data remains sparse to estimate the former population size. The last confirmed breeding in this area occurred during the 1970s in the Mureş River floodplain (Libus, A. *pers. comm*). This region remains a vital habitat for the European Ground Squirrel *(Spermophilus citellus)*, hereinafter referred to as 'EGS') in Central Europe, hosting about 280 colonies. The EGS, along with the Feral Pigeon *(Columba livia* f. *domestica)*, is a preferred prey of the Saker, a species specializing on small mammals of open areas (Baumgart 1991). Just like the Common Hamster *(Cricetus cricetus)*, which is also widespread in the region (Hegyeli *et al.* 2015), and can become a locally important prey for Sakers during population outbreaks. While EGS are now largely confined to the remaining shortgrass pastures, the Common Hamster predominantly inhabits agricultural areas, where it can become a pest during population outbreaks. Furthermore, the population of the Common Hamster exhibits larger fluctuations than that of the EGS, making it a less reliable food source on an annual basis.

Despite the favorable foraging situation, the largely treeless, agricultural landscape offers few natural nesting opportunities, particularly because nests of corvids were routinely removed from high-voltage transmission line towers during annual maintenance. Between 2001 and 2013, ten artificial nest platforms were erected in suitable tree habitats. In 2006, a pair of Sakers was seen using one of these platforms, although no breeding activity was documented (Hegyeli *et al.* 2019).

Between 2006 and 2014, during the first and second major Saker Falcon conservation programs in Central Europe funded by the European Union's LIFE Fund, 92 Sakers were equipped with satellite-receiving tracking devices (Prommer & Bagyura 2023). The data collected from these devices highlighted regions in Western Romania where the falcons spent extended periods. In addition, a survey took place in 2011 focusing on transmission lines using the experience from Hungary, where a high percent of the population breeds on such transmission line towers. One pair and another occupied territory were confirmed during the survey. In 2013, as part of the conservation work, the first young Saker was mounted with a tracker in Western Romania. Then, in the same year and in 2014, a total of 83 aluminum nest boxes were installed on transmission line towers within areas previously identified by the field survey and the movement patterns of the tracked Sakers. The locations (transmission line towers) were selected based on the tracks of satellite-tracked falcons, presence of favorable habitat, and the distance to settlements and asphalt roads. Our efforts were highly rewarded: as early as 2014, we identified six occupied territories from which 14 young successfully fledged (Hegyeli *et al.* 2019).

In this study, following our monitoring efforts, we aim to process the data gathered in the 2016–2023 period and to examine changes in the occupancy of nest boxes, as well as to explore demographic parameters (such as reproductive performance: nesting success and brood size) behind the population dynamics of the Saker in Western Romania. We also intend to identify potential factors impacting these parameters. Specifically, our hypotheses are as follows: (i) the distance to the nearest foraging area will have a negative effect on occupancy and reproductive parameters, with shorter distances associated with higher probabilities of occupancy, greater nesting success, and larger brood sizes; (ii) we assume that occupancy and reproductive performance positively correlate with the number of available EGS colonies and the cumulative areas of grassland; and (iii) we hypothesize that an increasing distance from the nearest settlement will positively influence both the probability of occupancy and reproductive performance.

Methods

Study site

The study site is in Western Romania, on the eastern edge of Central Europe. It is a 10–80 km wide strip running parallel to the Hungarian border, bordered by Serbia to the south and Ukraine to the north *(Figure 1)*. With its surface area of 17,100 km^2, it represents 7% of Romania's area (Grecu 2010). Geographically, it lies on the eastern edge of the Carpathian Basin lowlands. Accordingly, the climate and vegetation are similar to those of the Hungarian Great Plain and the Vojvodina province in Serbia, as these regions are part of the same lowland.

The average elevation of the study site is around 100 meters above sea level, with a minimum of 75 m and a maximum of 200 m. The terrain is mostly flat in the southern part, with elevation slightly rising towards the north and east. The average annual temperature is 11 °C in the Banat Plain, and decreases towards the north, with a value of 9.7 °C in

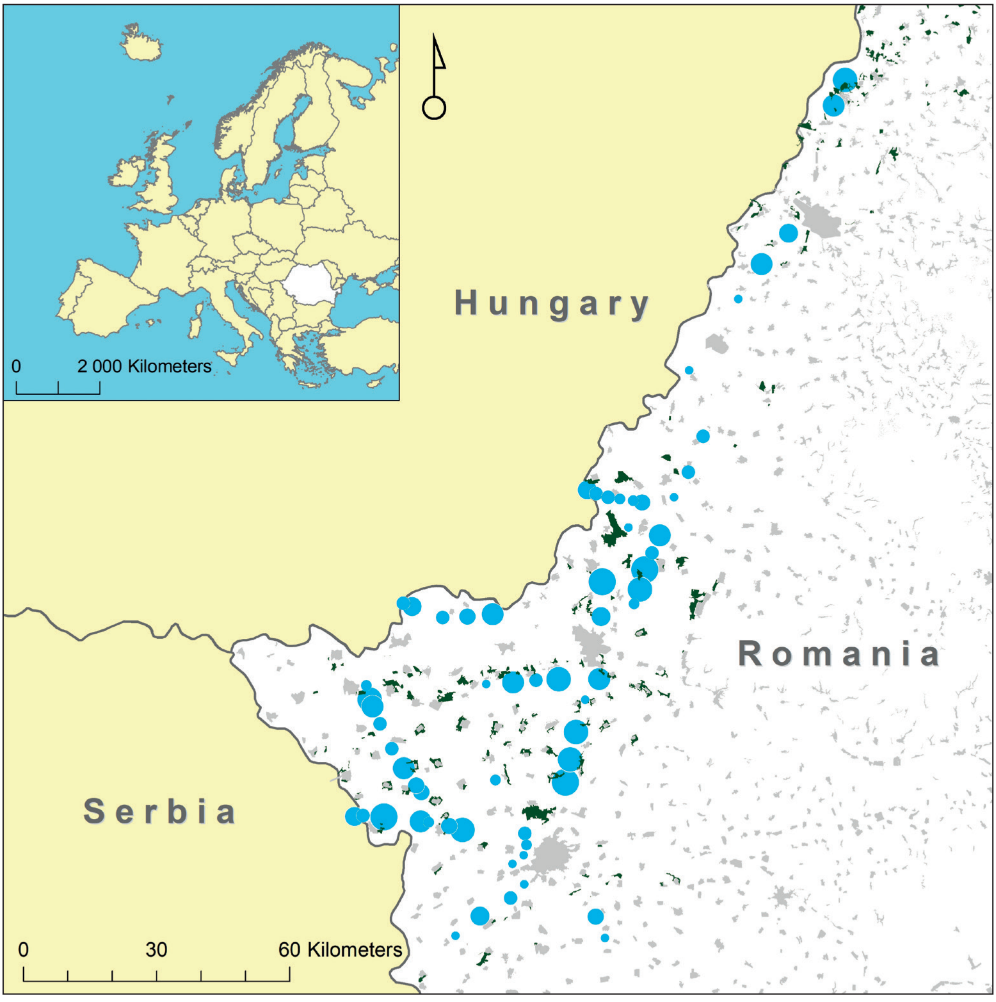

Figure 1. Romania in Europe (inlet) and the study area in Western Romania. Blue circles indicate the locations of the nest boxes; the size of each circle represents the number of years the given box was occupied. Dark green patches represent the grassland areas with colonies of the European Ground Squirrel *(Spermophilus citellus)*, and the settlements are shown in light grey (not all are shown to the east)

1. ábra Románia Európában (kis térkép) és a kutatási terület Nyugat-Romániában. A kék körök jelzik a fészekládák elhelyezkedését; minden kör mérete jelzi, hogy hány éven át volt lakott az adott fészekláda. A sötétzöld foltok az ürge *(Spermophilus citellus)* kolóniáknak otthont adó gyepeket jelölik, a településeket pedig világosszürke színnel ábrázoltuk (a keleti részen nincs minden település feltüntetve)

Satu Mare. Values of average January temperatures range from -1 °C to +3 °C, while July temperatures range from 20 to 22 °C. Average annual rainfall is 540–550 mm in the west and 700 mm in the east, with maximum amounts of 80-100 mm in June (in the Someș Plain). The annual number of snow days is 20. The prevailing winds are westerly, with an average annual speed of over 3 m/s, with a maximum of 23–27 m/s (Grecu 2010).

The area, once covered by riverine forest-steppe and steppe, is now predominantly used for agriculture. It encompasses four main cities – Satu Mare, Oradea, Arad, and Timișoara – which also serve as the administrative centers of Satu Mare, Bihor, Arad, and Timiș counties, respectively, as well as 14 smaller towns. These smaller settlements are characterized by their generally sizable populations (often over 3,000 people) and by the relatively large distances between them.

Grassland areas with EGS colonies

The study region supports a viable population of EGS. For processing spatial information about nest boxes in relation to spatial covariates, we utilized GIS layers of grasslands (primarily pastures) with known EGS colonies. Each grassland area was considered to host one EGS colony, thereby equating the number of colonies with the number of grassland areas, a method that closely approximates reality regardless of the areas' sizes. Our focus on EGS and grasslands is supported by literature (Bagyura *et al.* 1994, Nedyalkov *et al.* 2014, Chavko *et al.* 2019), and corroborated by unpublished local studies, which utilized nest cameras and analyzed prey remains, and demonstrated the high proportion of EGS in the Sakers' diet during the breeding period (Hegyeli *et al*. unpublished).

Nest boxes

A total of 83 nest boxes were installed on transmission line towers (ranging from 110 to 400 kV) managed by different electricity distribution companies (Electrica S.A., ENEL România, and C.N.T.E.E. Transelectrica S.A.). The towers range from 21 to 41 meters in height, with the nest boxes typically installed on the lower (cross) arms of the towers, at a minimum height of 17 meters from the ground. The 60 cm × 60 cm boxes are made of aluminum (Fidlóczky *et al.* 2014), and most of them are oriented with two open sides facing southeast to shield against the prevailing winds and precipitation. To encompass the entire population and all breeding attempts, we included a pair occupying a natural nest, bringing the total number of nesting sites to 84. No other pair in natural nest was known during the study period. For simplicity, we will refer to all these nesting sites as "nest boxes" throughout the rest of the article. We used the nest boxes' GPS coordinates for spatial analyses.

Data collection

The dataset for this study was compiled through annual monitoring by the NGO Milvus Group starting in 2016. During the monitoring, nest boxes were visited at least twice in the breeding season: first at the start of the season (March to early April) to check occupancy, and then during the pre-fledging period, when nesting success and brood size were recorded, and the young were ringed occasionally. All the observations were made from the ground with a telescope. While the population began to increase as early as 2014, there was no monitoring conducted in 2015 due to various reasons. Consequently, our analysis is based solely on the data collected from the period 2016 to 2023.

Raw data for calculating covariates were collected from the EGS monitoring program (location of EGS colonies and grasslands) and publicly available GIS data sources.

Data processing

We calculated basic demographic parameters such as occupancy rate, changes in occupancy status, mean nesting success, and brood size using standard statistical methods. We calculated covariates that were not readily available, such as distances, and used assumed ranges for other calculations, such as the number of available colonies and cumulative area of grassland within specific distances.

We employed QGIS ver. 3.22.3 (QGIS Development Team 2021) for processing the GIS data and performing calculations and analyses. Since the nesting locations were artificially created, we did not calculate the NNI for occupying pairs.

We employed generalized linear mixed models (GLMMs; Agresti 2015) using R (version 4.3.2) within the RStudio computing environment (version 2024.04.1; R Core Team 2023) to test the effects of covariates on both nest box occupancy and nesting success, with year included as a random effect. Occupancy, nesting success, and brood size were the response variables, and the predictors included nest box distances to the nearest EGS colony and nearest settlement, as well as the number of colonies, and the areas of grassland patches with colonies within two, five, and ten km of the nest boxes.

Both occupancy and nesting success are binary outcomes (occupied/unoccupied and successful/failed, respectively). Therefore, we used a binomial GLMM with a logit link function in the model:

$$\log\left(\frac{\mu}{1-\mu}\right) = X\beta + Zu$$

where

- μ is the probability of successful breeding (response variable);
- X is a vector of predictor variables (covariates);
- β is a vector of coefficients corresponding to each of the predictor variables in X;
- Zu represents the random effects structure, where Z is the design matrix for random effects, and u is the vector of random effects (e.g. for region or year), and
- $g(\mu) = \log\left(\frac{\mu}{1-\mu}\right)$ is the logit link function that connects the linear predictor $X\beta$ to the probability of successful breeding μ.

Brood size varied between 1 and 5 (positive integers), so we used a Poisson distribution in the GLMMs. In these models, the random effects term Zu accounted for variability among years, allowing us to model unobserved heterogeneity and improve the accuracy of estimated fixed effects.

However, the GLMM encountered convergence issues for nesting success due to a lack of variance in the random effect. Since the random effect showed minimal or no impact, we excluded it and opted for a simpler Generalized Linear Model (GLM), which proved to be stable.

The GLM was:

$$\log\left(\frac{\mu}{1-\mu}\right) = X\beta$$

where the components of the equation are as defined above.

We standardized continuous covariates by subtracting means and dividing by standard deviations. Subsequently, we used the models to test the level of significance with a predetermined significance level (α) of 0.05 (Sokal & Rohlf 2011) to test our hypotheses.

We further investigated the significant covariate effects by calculating the effect size, quantified using odds ratios. Odds ratios were obtained by exponentiating the regression coefficients from the GLM models, providing an interpretable measure of the change in odds of the outcome associated with a one-unit increase in each covariate (Cohen 1988, Nakagawa & Cuthill 2007). Odds ratios greater than one indicate a positive association with the outcome, while those less than one indicates a negative association. We calculated statistics and visualized results in the R computing environment (R Core Team 2023).

In certain figures, we applied locally weighted smoothers (LOESS) to enhance the interpretability of data patterns through locally weighted regression. This method captures trends in the data without imposing a specific parametric structure, enabling a clearer depiction of relationships within the observed data.

Results

Occupancy

During the study period, a total of 84 nest boxes were available for Sakers. The observed mean nearest neighbor distance between all installed boxes was 4,414 m, which remained constant during the study period as no boxes were added or removed. Given that the nest boxes were attached to the same transmission line towers, the nearest neighbor index (NNI) showed clustering (n = 84, NNI = 0.412, Z-Score: -10.304).

Out of all nest boxes 67 (equating to 79.76%) hosted at least one nesting event (breeding attempt or successful breeding) out of the recorded 255 events. The boxes were unoccupied (no nesting event was recorded) on 417 occasions. Only four boxes saw occupancy in all eight years. Seventeen boxes were never occupied by Sakers throughout the study period. The observed mean nearest neighbor distance was highest (9,924 m) in the second year, 2017, and then it gradually decreased to 6,114 m by 2023 *(Figure 2)*.

The occupancy status of the individual boxes changed from year to year; however, this variation was independent of the population's absolute size and the annual population growth rate *(Figure 3)*. The mean change rate (and standard error, SE) was 0.2551±0.00931 (n = 672), which varied moderately, ranging from 0.2262 (from 2018 to 2019 and from 2021 to 2022) to 0.2857 (from 2020 to 2021 and from 2022 to 2023).

Further investigating occupancy, we compared occupied and unoccupied nest boxes in relation to the covariates. We found strong evidence that occupied nest boxes were located farther from

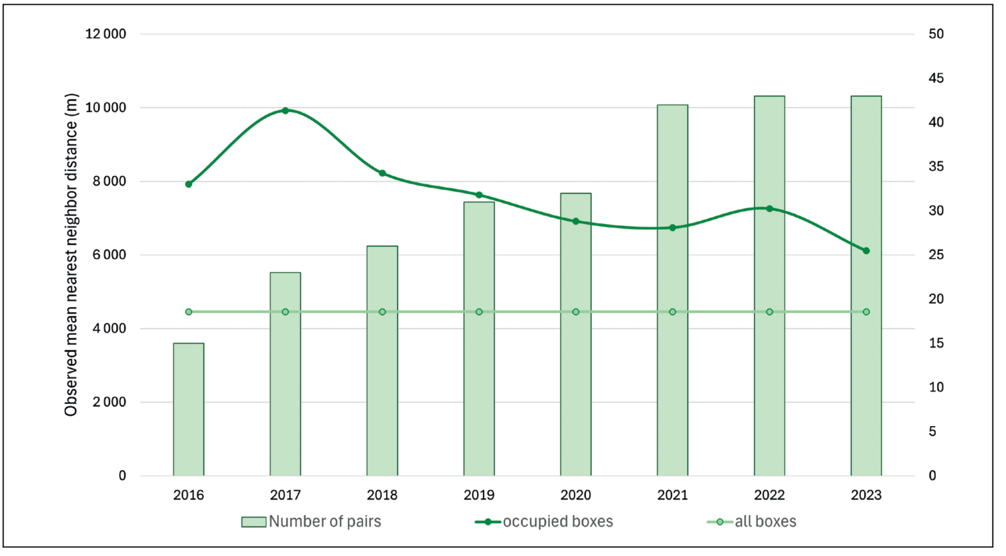

Figure 2. Population size, observed nearest neighbor distance between all the installed nest boxes (constant value) and occupied nest boxes (annually changing with the population change) in the period 2016–2023.

2. ábra Az állományméret és a legközelebbi szomszéd távolság az összes (állandó érték), valamint a foglalt (az állomány változásával évente változó érték) fészekládák között a 2016 és 2023 közötti időszakban

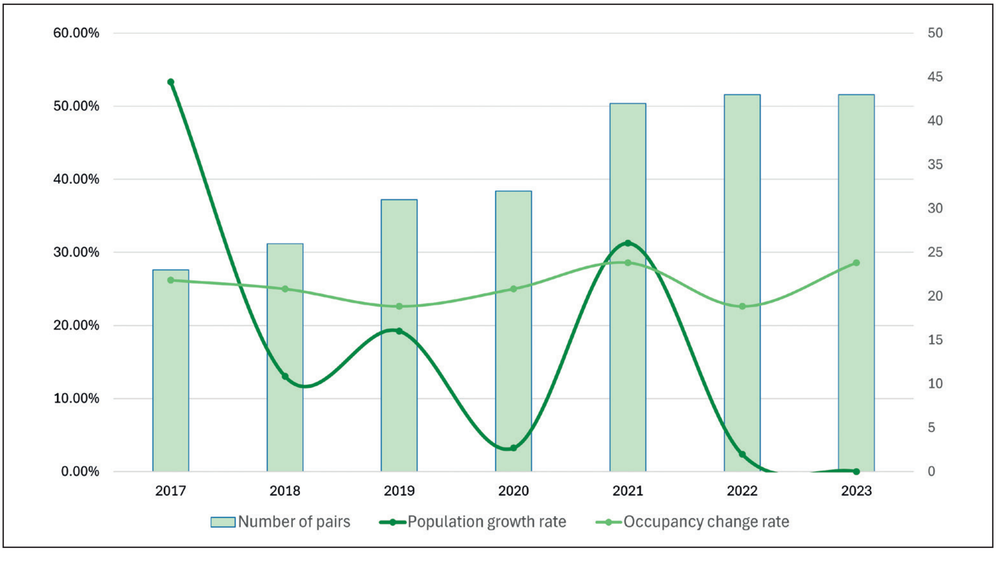

Figure 3. Changes in number of pairs, population growth rate, and nest box occupancy status. Latter means the rate at which status of nest boxes (occupied ⇆ unoccupied) changed from one year to another

3. ábra A párok számának, a növekedési rátának, valamint a fészekládák foglaltsági állapotának változása. Utóbbi azt fejezi ki, hogy a milyen arányban változott a fészekládák státusza (foglalt ⇆ üres) az egyes évek között

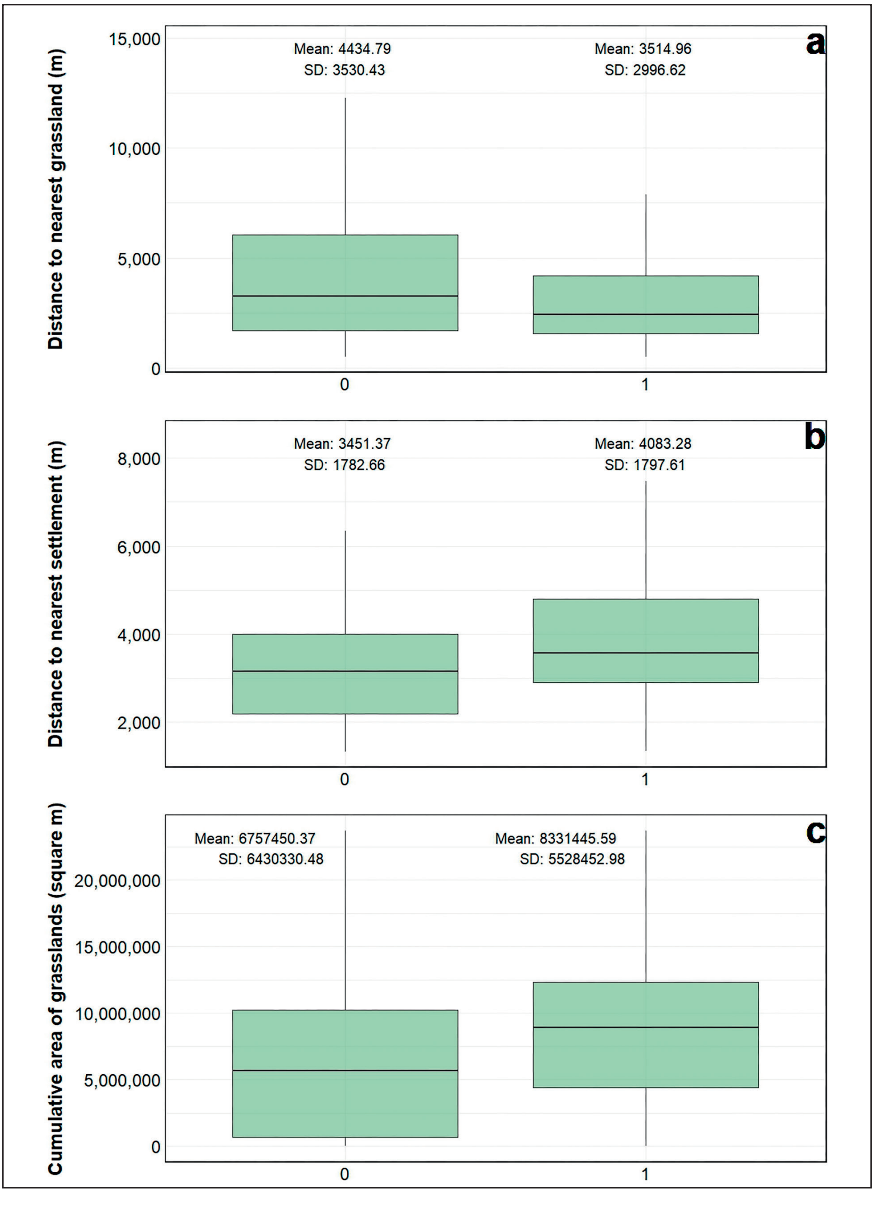

Figure 4. Differences between unoccupied (0) and occupied (1) nest boxes were analyzed with respect to various covariates. There is strong evidence for the effects of (a) the distance to the nearest settlements (estimate ± SE = 0.413±0.089, z = 4.633, p < 0.001) and (b) the cumulative area of grasslands within ten kilometers of the nest boxes (estimate ± SE = 0.251±0.121, z = 2.08, p = 0.038)

4. ábra Az üresen álló (0) és a lakott (1) költőládák közötti különbségeket különböző magyarázó változók tekintetében elemeztük. Erős bizonyítékot találtunk az alábbi tényezők hatására: (a) a legközelebbi települések távolsága (becslés ± SE = 0,413±0,089, z = 4,633, p < 0,001), valamint (b) a költőládáktól számított tíz kilométeres körzeten belüli gyepek együttes területe (becslés ± SE = 0,251±0,121, z = 2,08, p = 0,038)

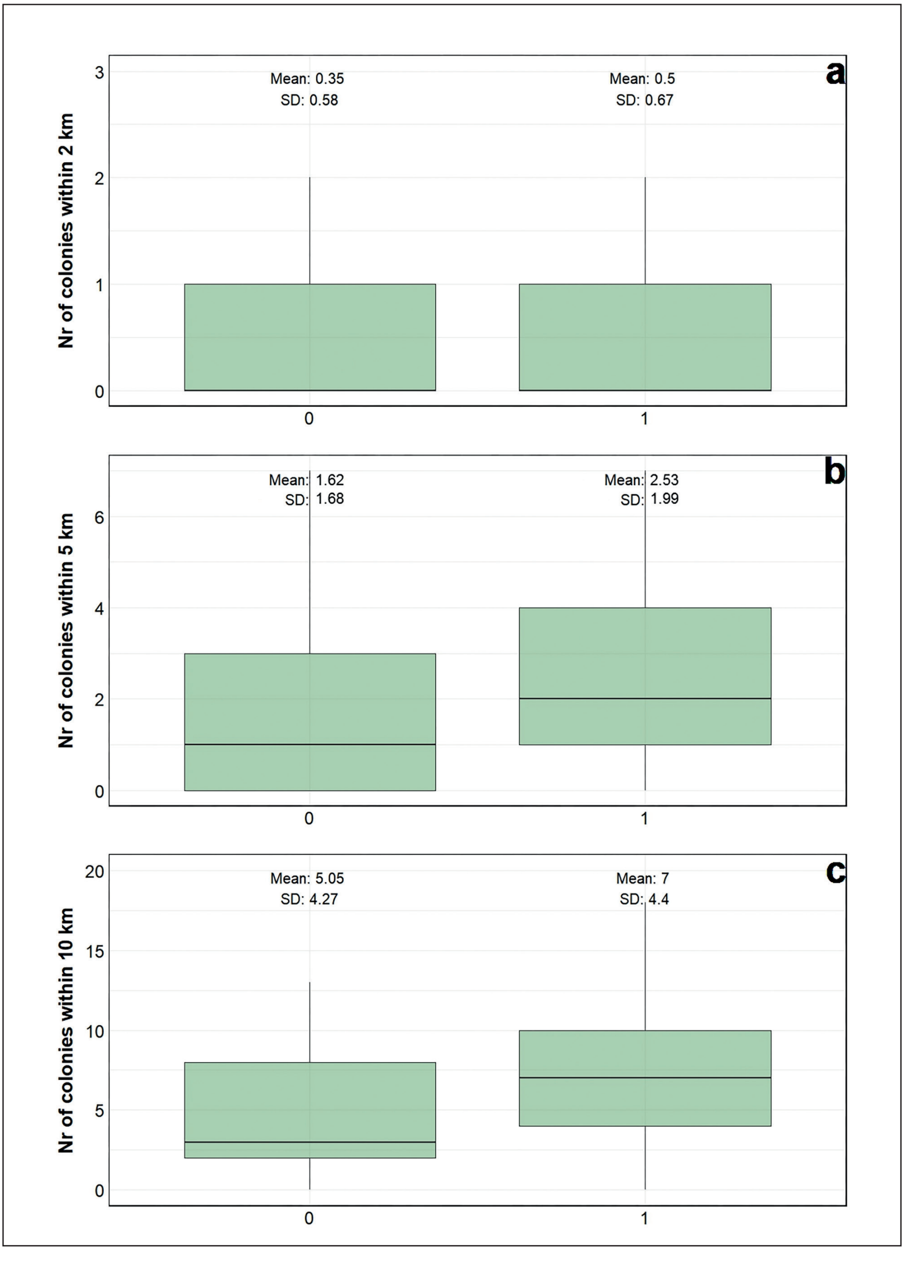

Figure 5. Differences between unoccupied (0) and occupied (1) nest boxes were analyzed with respect to the number of available EGS colonies within specific distances. We found strong evidence for an effect of the number of colonies within five kilometers of the nest boxes on occupancy (estimate ± SE = 0.385±0.158, z = 2.441, p = 0.015)

5. ábra Az üres (0) és a foglalt (1) költőládák közötti különbségeket elemeztük az elérhető ürgekolóniák számának függvényében, meghatározott távolságokon belül. Erős bizonyítékot találtunk arra, hogy a költőládától számított öt kilométeres körzetben lévő kolóniák száma hatással van a költőládák foglaltságára (becslés ± SE = 0,385±0,158, z = 2,441, p = 0,015)

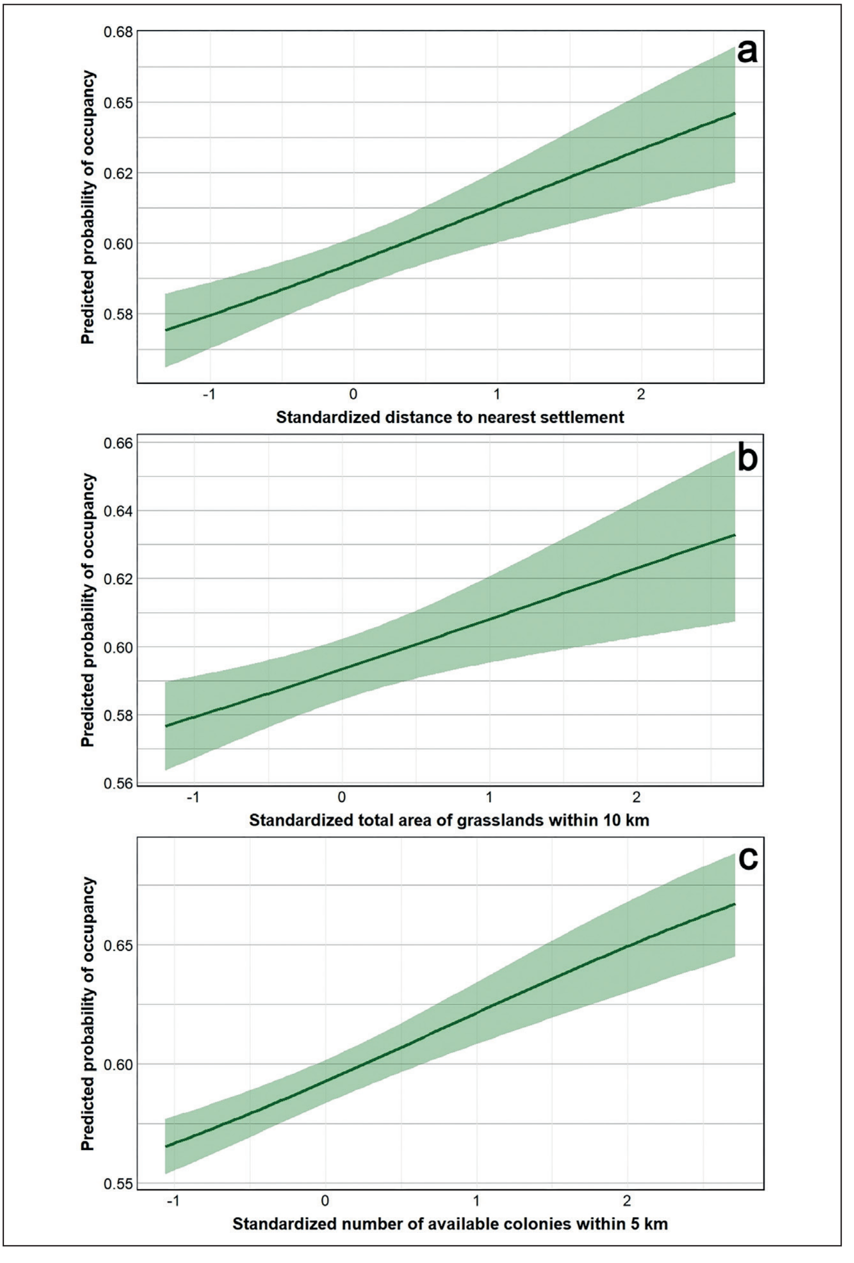

Figure 6. Covariates with a significant effect on nest box occupancy. Distance to the nearest settlement (a), cumulative area of grasslands within a ten km radius (b), and number of EGS colonies within five km (c) have a positive effect on occupancy rate. The light green area represents the 95% confidence interval

6. ábra A fészekládák foglaltságára jelentős hatással bíró magyarázó változók. A legközelebbi településtől való távolság (a), a tíz km-en belül található összes gyepterület nagysága (b), valamint az öt km-en belül található ürgekolóniák száma (c) pozitív hatással van a foglaltságra. A világoszöld sáv a 95%-os konfidencia intervallumot jelöli settlements (estimate ± SE = 0.413 ± 0.089, z = 4.633, p < 0.001) and were surrounded by a larger cumulative area of grasslands within a 10 km radius (estimate ± SE = 0.251±0.121, z = 2.08, p = 0.038) *(Figure 4)*. Additionally, occupied nest boxes had more EGS colonies within a 5 km radius (estimate ± SE = 0.385±0.158, z = 2.441, p = 0.015) *(Figure 5)*.

The effect size results, represented as odds ratios, indicated that for each additional EGS colony within five km, the odds of nest box occupancy increased by 47% (OR = 1.47). Distance from settlements showed an odds ratio of 1.51, and the cumulative grassland area within a ten km radius had an odds ratio of 1.29, indicating a 51% and 29% increase in the odds of occupancy, respectively. Significant effects on occupancy are visually represented in *Figures 6*, while detailed results of significance testing, and effect size calculations can be found in *Table 1*.

Reproductive success

During the study period from 2016 to 2023, the known population of pairs increased from 15 to 43. In total, 255 breeding attempts were recorded, with 192 being successful and 63 unsuccessful. The frequency of successful breeding attempts paralleled the growth in population size *(Figure 7a)*. The average nesting success rate for the period was 0.752±0.432 (n = 255), with a range from 0.677±0.475 in 2019 (n = 31) to 0.86±0.35 in 2022 (n = 43), as depicted in *Figure 7b*. No annual trend in nesting success was discernible. Strong evidence indicated that the distance to the nearest EGS colony had a significant reverse impact on nesting success (-0.6±0.236, z = -2.548; p = 0.011) *(Figure 8)* with substantial effect size *(Table 1)*.

We recorded a total of 794 young in the study period. The average number of fledglings per successful breeding attempt was 3.135±1.15 (n = 192), with yearly averages ranging from 2.545±1.128 in 2016 (n = 11) to 3.706±0.985 in 2017 (n = 17) *(Figure 7c)*. Across all breeding attempts, the mean brood size was 2.361±1.682 (n = 255), varying from 1.867±1.505 in 2016 (n = 15) to 2.739±1.864 in 2017 (n = 23). We found no evidence of covariate effects on brood size. The brood size distribution was normally distributed (Shapiro-Wilk normality test, W = 0.90361, p = 0.4302) *(Figure 9)*.

Table 1. Detailed results of significance testing and effect size calculations for covariates with significant effects

1. táblázat A szignifikáns hatást mutató magyarázó változók szignifikancia próbáinak és a hatások számított nagyságainak részletes eredményei

Model (response variable ~ covariate)	**Significance testing**				**Effect size**	**Comment**
	estimate	*SE*	*z value*	*p value*	*odds ratio*	
occupancy ~ distance to settlement	0.413	0.089	4.633	< 0.01	1.51	moderate effect
occupancy ~ cumulative grassland area within 10 km	0.251	0.121	2.080	0.038	1.29	moderate effect
occupancy ~ number of EGS colonies within 5 km	0.384	0.158	2.441	0.015	1.47	substantial effect
nesting success ~ distance to colony	-0.600	0.236	-2.548	0.011	0.55	substantial effect

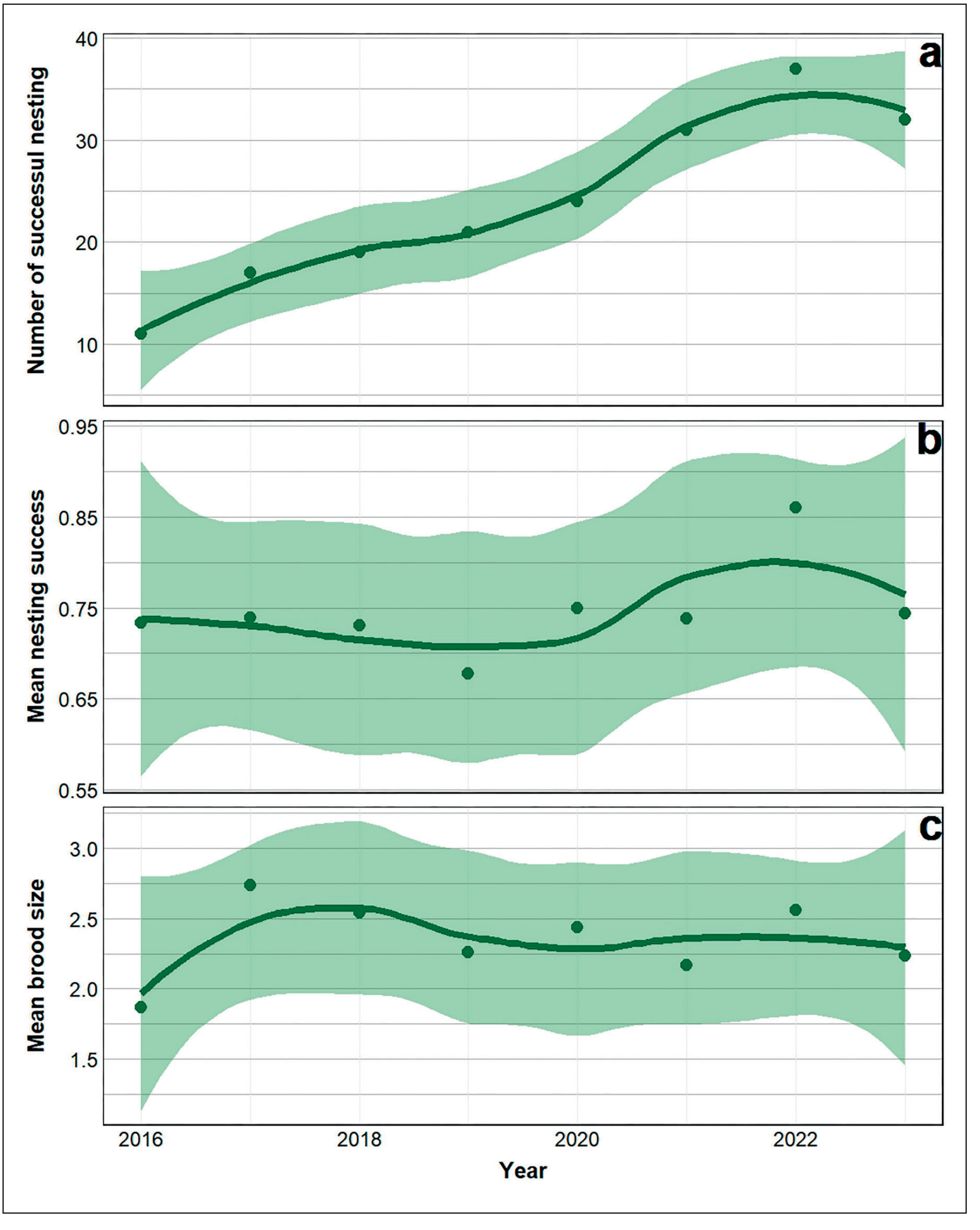

Figure 7. Demographic parameters of the Saker population in Western Romania in the period 2016–2023 a) number of successful breeding; b) mean breeding success; c) mean brood size per successful breeding. Lines are fitted using LOESS; the light green area highlights the 95% confidence interval

7. ábra A nyugat-romániai kerecsensólyom állomány demográfiai paraméterei 2016 és 2023 között: a) a sikeres költések száma; b) átlagos költési siker; c) sikeres költésenkénti átlagos fiókaszám. A vonalak LOESS módszerrel illesztettek, a világoszöld terület a 95%-os konfidencia intervallumot jelöli

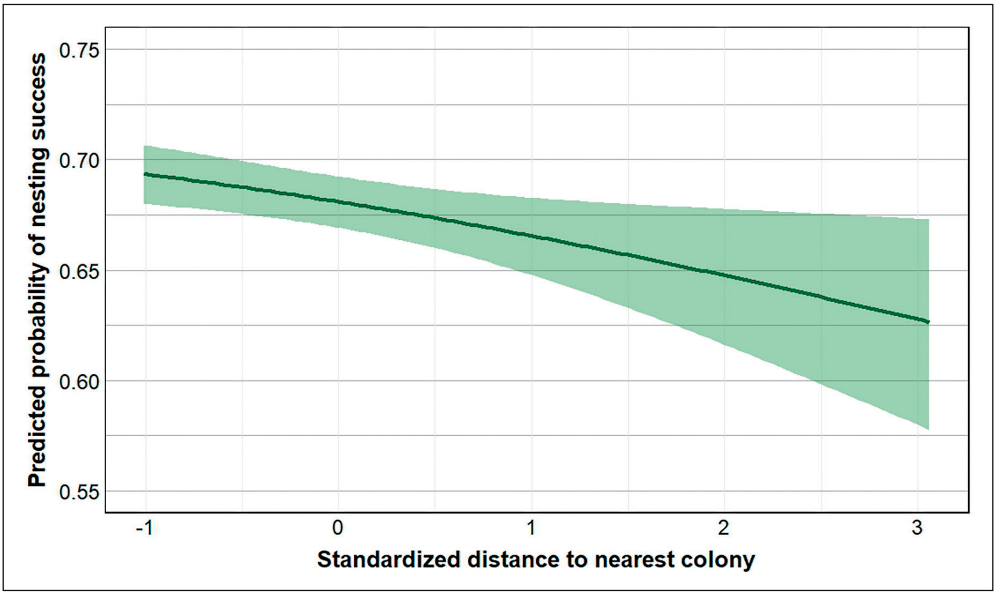

Figure 8. The significant effect of distance to nearest EGS colony on the probability of nesting success. The light green area shows a 95% confidence interval

8. ábra A legközelebbi ürgekolóniától való távolság szignifikáns hatása a fészkelési siker valószínűségére. A világoszöld sáv a 95%-os konfidencia intervallumot jelöli

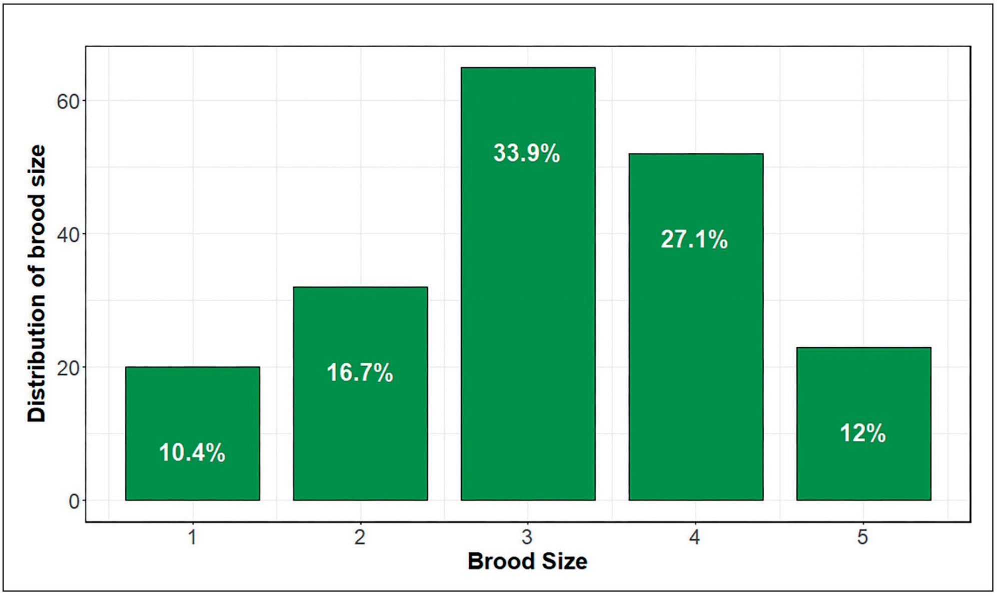

Figure 9. Distribution of brood sizes from 192 successful nesting attempts, resulting in 602 young

9. ábra A fészekaljankénti fiókaszámok eloszlása 192 sikeres fészkelésből, ami 602 fiókát eredményezett

Discussion

The effectiveness of artificial nesting sites such as nest platforms and nest boxes in facilitating the growth and expansion of Saker populations in otherwise suitable areas has been demonstrated in Austria, Hungary, Slovakia, and Mongolia (Chavko *et al.* 2014, 2019, Fidlóczky *et al.* 2014, Rahman *et al.* 2014, 2016, Zink *et al.* 2025). Falcons do not construct their own nests, hence in areas lacking pre-existing nests built by other species or natural cliffs to lay eggs, they do not breed. However, these regions are still utilized as indicated by satellite-tracking data, showing that falcons are quick to exploit new nesting opportunities when they become available. This approach has also been successful in Western Romania.

Historical data on the population size of Sakers in Western Romania are limited, making it difficult to establish a reliable baseline. The region's breeding population began to rapidly expand after 2014, following the implementation of active conservation measures under European Union-supported LIFE projects, which provided nesting sites for the species. This expansion coincided with the stabilization of the Hungarian population, which had by then seemingly saturated its available habitats (Bagyura *et al.* 2017). The rapid occupancy of the installed nest boxes suggests that the habitat and prey availability in the region were highly favorable for Sakers. Notably, (1) there was only three known breeding in the region prior to this in natural nests, (2) the sudden emergence of more than a dozen pairs shortly after the installation of the boxes, and (3) juvenile dispersal data from Hungary indicate that the initial breeders likely immigrated from neighboring countries, primarily Hungary, but possibly also from Serbia, Slovakia, Austria, or the Czech Republic. The observation of a female ringed in 2020 in Romania and found breeding in Hungary in 2022 (Hungarian Bird Ringing Centre 2024) lends further credence to this theory. Satellite-tracking data suggests, however, that it is less likely that Sakers immigrated from the declining populations in Eastern Romania or south-southwest Ukraine.

The connection between breeding success and the proportion of mammals in the diet of Sakers was established in a recent study in Mongolia (Zhang *et al.* 2024). In Central Europe, earlier studies (Bagyura *et al.* 1994, Chavko *et al.* 2019) and unpublished data (Hegyeli *et al*. unpublished) indicate that the EGS constitutes a significant part of the Sakers' diet. Thus, the abundance of EGS in Western Romania likely explains the population boom in Sakers once nest boxes were introduced in areas previously devoid of nests but otherwise suitable for habitation.

The number and proximity of foraging grounds to the nest implies a more favorable cost-benefit ratio in terms of energy expenditure. This may explain the higher occupancy rate of nesting boxes, where more colonies are within five km, and the greater nesting success in nest boxes nearer to grasslands that host EGS colonies. The importance of the number of available EGS colonies on occupancy may be related also to the annual fluctuations in population sizes of individual colonies. A higher number of colonies near the nest boxes may increase the likelihood that some colonies maintain sufficiently high EGS densities to support "economically viable" hunting, even if other colonies experience depletion. However, further studies are needed to confirm or refute this hypothesis. The larger cumulative area of grasslands within a ten km radius may also contribute positively, as more extensive grassland areas are likely to encompass more accessible EGS colonies. Additionally, greater distances from the nearest settlement may reduce disturbances during the breeding season, potentially enhancing breeding success.

Interestingly, while the proximity and number of hunting grounds appear to explain occupancy and, to some extent, nesting success, these covariates do not seem to influence brood size. We cannot exclude the possibility that brood size is more closely related to the population density of EGS colonies than to the proximity or number of available colonies; however, this hypothesis requires further investigation. Acquiring such data is particularly challenging due to the extensive time and effort involved, especially since, in addition to Saker reproductive success data, density data for all colonies in the area would need to be collected. Satellite-tracking of Sakers (Prommer & Bagyura 2023) has shown that breeding adults are willing to travel up to 25 km daily to visit specific EGS colonies, often bypassing other, presumably less favorable colonies along the way. This behavior likely indicates the importance of EGS density, and it aligns also with a study demonstrating the benefits of '*flying the extra mile*' when the distant foraging ground offers a more abundant or easily exploitable resource (Soriano-Redondo *et al.* 2021).

In summary, our results reaffirm that Sakers respond positively to conservation interventions under favorable habitat conditions. We demonstrated that the availability of prey, measured by the proximity, number, and size of grassland areas hosting EGS colonies, affects occupancy and, to some extent, nesting success, though not brood size. Furthermore, the findings suggest that Sakers are likely to compensate for annual fluctuations in prey availability by primarily occupying nest sites with the broadest access to potential foraging grounds with EGS colonies. Our results suggest the Sakers' strong preference for EGS when available. In Hungary and Slovakia, the dramatic decline in the EGS population (Cserkész 2018) has removed them from the Sakers' diet (Bagyura *et al.* 1994, 2017, Chavko *et al.* 2019), leading to a dietary shift towards domestic pigeons, which may increase conflicts with pigeon fanciers. Additionally, there are indications that a lower proportion of mammalian prey in the diet may be associated with reduced productivity (Karyakin *et al.* 2022). Therefore, it is of utmost importance that pastures hosting EGS colonies are conserved – not only for the benefit of these two species but also for other steppe-dwelling species. Additionally, these grasslands must be maintained on a scale large enough to allow ecological processes to function properly, such as accommodating spatio-temporal changes in prey-predator dynamics.

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