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Distribution, abundance and reproductive success of the Saker Falcon in Slovakia in 1976–2022

Jozef Chavko[1], Ján Lipták[1], Marek Gális[1], Roman Slobodník[1] & Mátyás Prommer[2]

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Abstract Between 1976 and 2022, we monitored the distribution of nest sites across two habitats of the Saker Falcon *(Falco cherrug)*, nesting in both the mountains and lowlands of Western and Eastern Slovakia. In Western Slovakia, we observed nesting in 79 known nest sites, accounting for 703 nesting attempts, while in Eastern Slovakia, we monitored 281 nesting attempts in 32 nest sites. The brood size varied between these regions; pairs in Western Slovakia produced an average of 3.0 nestlings, whereas those in Eastern Slovakia produced an average of 2.5 nestlings per successful nest. Throughout the period from 1976 to 2022, a total of 2,468 young Saker Falcons fledged in Slovakia. During this period, the range of breeding population gradually shifted to the lowland from the mountains. In the new, predominantly agricultural environment, the nesting success significantly increased from 57.1% in the mountains to 81.1% in the lowland. In Western Slovakia, the benefits of shift in habitat were further justified by the observation that the mean brood size per all breeding attempts in the lowlands was consistently above two young per brood most of the time. In contrast, pairs breeding in the mountains frequently produced two or fewer young per all breeding attempts. Additionally, our findings indicate that electrocution on mid-voltage (22 kV) power lines is the primary cause of mortality among Sakers in Slovakia, with collisions being the second leading cause.

Keywords: *Falco cherrug*, habitat, reproductive success, conservation management, aluminium nest box, power lines

Összefoglalás 1976 és 2022 között figyelemmel kísértük a kerecsensólyom *(Falco cherrug)* fészkelőhelyeinek eloszlását két élőhelyen, a hegyekben és az alföldön, Nyugat- és Kelet-Szlovákiában. Nyugat-Szlovákiában 79 fészkelőhelyen 703 fészkelést figyeltünk meg, Kelet-Szlovákiában pedig 281 fészkelést ellenőriztünk 32 ismert fészkelőhelyen. A két régióban eltérő volt az átlagos fiókaszám; a nyugat-szlovákiai párok átlagosan 3,0 fiókát, míg a kelet-szlovákiaiak átlagosan 2,5 fiókát neveltek fel sikeres költésenként. Az 1976–2022-es időszakban összesen 2468 fiatal kerecsensólyom repült ki Szlovákiában. Ugyanebben az időszakban az állomány fészkelőterülete fokozatosan a hegyvidékről az alföldi területekre tevődött át. Az új környezetben – elsősorban az agrárterületeken – jelentősen megnőtt a fészkelési siker aránya (81,1% a hegyekben mért 57,1%-kal szemben). Nyugat-Szlovákiában az új élőhely választásának előnyeit igazolta továbbá, hogy az alföldön az összes költési kísérletre vonatkoztatott fiókaszám jellemzően két fióka / fészek érték felett maradt. Ezzel szemben a hegyvidéki pároknál ez az érték kettő, vagy annál kevesebb fióka volt. Az eredményeink megmutatták azt is, hogy az elsődleges pusztulási ok a kerecsensólymoknál Szlovákiában a középfeszültségű oszlopokon elszenvedett áramütés. Ezt követte másik fő okként az ütközés.

Kulcsszavak: *Falco cherrug*, élőhely, költési siker, természetvédelmi kezelés, alumínium fészekláda, távvezetékek

[1] Raptor Protection of Slovakia (RPS), Trhová 54, SK-841 01 Bratislava, Slovakia
[2] University of Florida, 110 Newins-Ziegler Hall, Gainesville, FL 32611, U.S.A.
** corresponding author, e-mail: chavko@dravce.sk*

Introduction

The Saker Falcon *(Falco cherrug)* inhabits a vast steppe zone from the Pannonian lowlands to the east through Moldova, Southern Ukraine, Russia, and Kazakhstan to the Asian steppe zone in Southern Siberia, Central Asia, and Western China. In non-nesting times, it occurs in Western and Southern Europe, the Middle East, the Indian subcontinent and East China (Baumgart 1994). According to the Saker Falcon Global Action Plan (Saker GAP), the Asian population reaches the level of ~5,400–14,000 pairs, with nests in 13 countries, while the European population (~640–730 pairs) makes only 7% of the world's population (Kovács *et al.* 2014). Within Pannonia it nests in the north in Slovakia, in the west in Southern Moravia (Beran *et al.* 2012) and in Lower Austria (Frey & Senn 1980, Zink *et al.* 2012) and in the south in Vojvodina, Serbia (Puzović 2008). The centre of the European population is in Ukraine and Hungary (Kovács *et al.* 2014, Bagyura *et al.* 2025, Prommer *et al.* 2025).

The original habitats of the Saker Falcon were grassland biotopes that have been turned to agricultural land use and gradually more or less disappeared in Slovakia, except for small areas of pastures, at the end of the 1950s–1960s (Chavko 2002a). As a result of the post-war change of the political orientation, there were also significant changes in the strategy of agricultural use of the country. The merge of smaller agricultural tables into large blocks of arable land has caused unfavourable changes in natural habitats, the impact of which persists even today. Recently, Saker Falcons in Slovakia nest and forage only in such secondary biotopes.

The mountains of south-western and south-eastern Slovakia are parts of the historically known nesting areas of the Saker Falcon, where the first findings of nests are dated back to the second half of the 19th century. The first documented nest in Western Slovakia was reported in 1885 and 1886 (the rock of Devín Castle near Bratislava in Devín). Further nests were found in lowland forests along the Danube in 1928, 1933 and 1934 (Kunszt 1929, Matoušek 1933, Csiba 1959). Also, between 1951 and 1959 up to two pairs of Saker Falcons nested in the floodplain of Šúr nature reserve at Svätý Jur near Bratislava, where active nests were found (Brtek 1956, Hell 1958a, 1958b, Ferianc 1964). In Western Slovakia, the core area was the Little Carpathians, where nesting was confirmed in 1931 (Janda 1932), and further evidence of nesting (observations of fledged young) were reported in the period of 1946–1954 (Brtek 1956, Matoušek 1956). Ferianc (1964) estimated the population of the Saker Falcon in the Little Carpathians in the 1950s and 1960s to six pairs. Later, nesting was also confirmed in the Považský Inovec mountains (Hell 1958a, 1958b, Soviš & Šindár 1964, Varga 1969), Strážov Mountains, White Carpathians and Pohronský Inovec Mountain range (Soviš & Šindár 1964).

The first data on nesting Saker Falcons in Eastern Slovakia (Slovak Karst) were recorded between 1860 and 1870 (Tschusi 1887). Other known nesting data from this mountain range are from 1931 (Lokcsánský 1931), 1951 and 1958 (Mošanský 1974). Nesting in Eastern Slovakia was comprehensively processed by Mošanský (1974). Based on the results of his work, we know that Saker Falcons nested in the Slovak Karst (on cliffs), Slanské and Volovské Hills (on both cliffs and trees).

Our work follows the two published articles for the period 1976–2010 (Chavko *et al.* 2010) and for the period 1976–2016 (Chavko *et al.* 2019) concerning the development of

the Saker Falcon population in Slovakia. For this reason, the primary aim of this work is to add the population data for the period 2017–2022, which have not yet been published and report population changes in the period between 1976 and 2022.

Methods

Based on the distribution of breeding and wintering Saker Falcons in Slovakia, we can delineate a Western and an Eastern area for the species *(Figure 1)*. The distance between these two populations is approximately 150 kilometres. To date, nesting has not been recorded in the southern part of Central Slovakia. We adhered to these natural divisions during data collection and processing.

Data collection

Primarily, we employed the method of direct search for nests, initially aimed at revising historical nesting data from literary sources. Later, we expanded our monitoring to all potential biotopes, especially those with recorded occurrences of the species. Additionally, we regularly monitored all locations where nest boxes had been installed on transmission line towers, checking their occupancy. Each occupied nest site was then regularly inspected in subsequent periods. To date, at least 450 nest boxes have been installed in the Saker Falcon's nesting territories in the lowlands of Slovakia. These nest boxes facilitate easier and more accurate population monitoring. The success rate was monitored through direct observations of the occupied natural nests and nest boxes, mostly during the fledgling

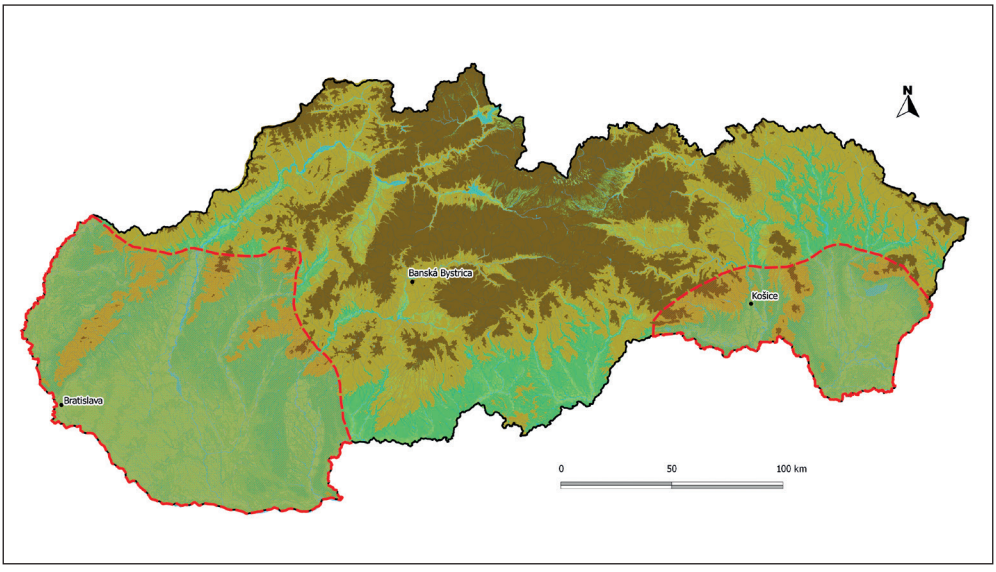

Figure 1. The distribution area of the Saker Falcon in Slovakia (1976–2022)
1. ábra A kerecsensólyom elterjedése Szlovákiában (1976–2022)

period. This monitoring included ringing the young and was supplemented by observations from a greater distance using telescopes and, as of 2020, drones.

Injuries and mortality events were recorded during monitoring; however, this study concentrates on population development. While we highlight the most significant mortality factors, a detailed analysis of these factors is not provided here.

Data processing and visualization

For data processing and visualization, we primarily used Office 365 MS Excel (ver. 2403). To analyse differences in reproductive performance, we applied a t-test using basic R (ver. 4.3.2) within the RStudio (ver. 2023.12.01) environment.

Results

Population development and nesting success rate

In the period 1976–2022, 117 nest sites were recorded in Slovakia, hosting in a total of 985 recorded nesting attempts, which resulted in 2,468 juveniles.

During the study period, the Saker Falcon population in Slovakia increased from one known pair to 46 pairs *(Figure 2)*. Between about the early 1990s and mid-2000s, a range shift was observed in both the Western and Eastern breeding pairs. Throughout this period, Saker territories gradually moved away from mountainous regions and expanded into lowland agricultural areas. However, differences in population size and dynamics were observed between the Eastern and Western regions.

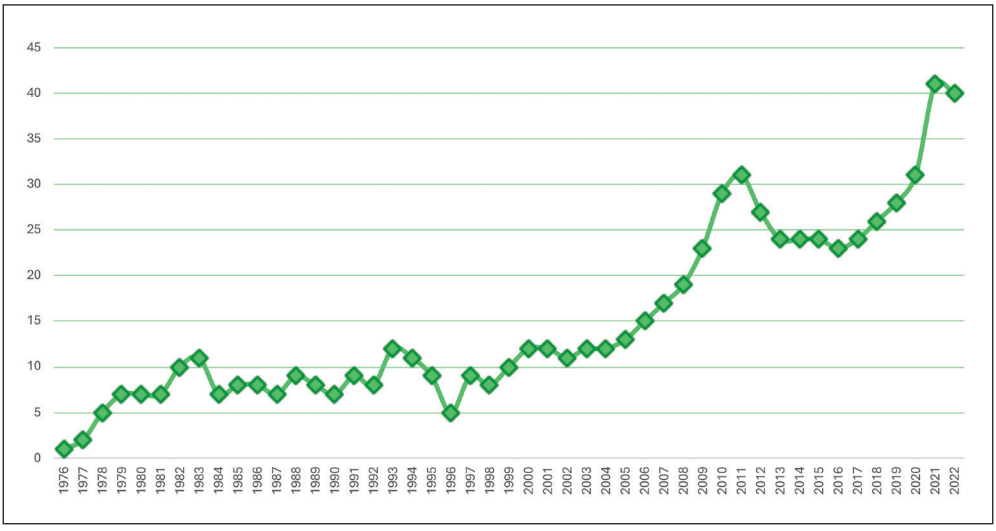

Figure 2. Development of Saker Falcon population in Slovakia (1976–2022)
2. ábra A kerecsensólyom állományának alakulása Szlovákiában (1976–2022)

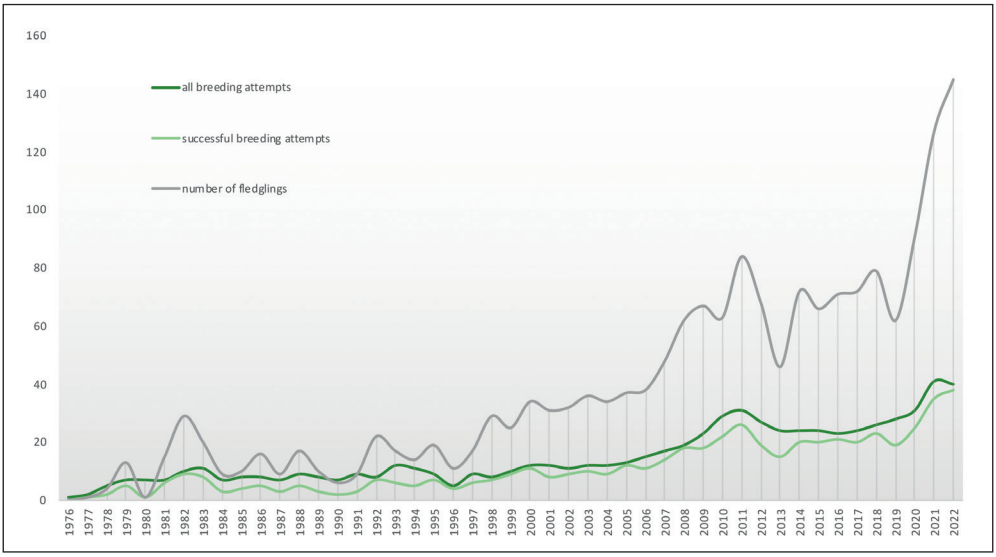

Figure 3. Development of the Saker Falcon population in Western Slovakia (1976–2022)
3. ábra A kerecsensólyom-állomány alakulása Nyugat-Szlovákiában (1976–2022)

Figure 4. Saker Falcon nest in tree on the floodplain of the Morava River, in May 1993. The female brought a European Hare *(Lepus europaeus)* to the nest killed by mower, when mowing meadows. Photo: J. Chavko
4. ábra Fán lévő kerecsensólyom-fészek a Morava folyó völgyében, 1993 májusában. A tojó egy kaszálógép által levágott mezei nyulat *(Lepus europaeus)* hozott. Fotó: J. Chavko

Western Slovakia

In Western Slovakia, we recorded 84 nest sites occupied by 79 pairs during the study period of 1976–2022. A total of 703 nesting attempts were made, out of which 534 were successful, resulting in the birth of 1,788 nestlings. We also recorded 169 failed nesting attempts. The mean brood size was 3.0 young birds per successful nesting attempt, and 2.4 young per all nesting attempts. The trend in population development was positive throughout the study period, with particularly significant growth observed after 1997 *(Figure 3)*. The development process was especially well-monitored in the case of pairs dwelling in nest boxes on transmission line towers.

During the reported period, there was a significant change in the nesting habitat preference of Saker Falcons. At the beginning of the study period, all known pairs in Western Slovakia nested in the forested environments of mountains and floodplains. Later, the population gradually shifted to lowland agricultural areas, where they began to use nest platforms and boxes installed on power transmission line towers.

Of a total of 84 known nest sites, in the beginning of the study period (1976–2008) 13 were recorded in the Little Carpathians, Kováčovské Hills and Strážovské Hills, five nest sites in floodplains (1988–1997) around the Morava River in the Borská Plain *(Figure 4)*, and subsequently 66 nest sites were recorded in the lowlands, in the agricultural areas of south-western Slovakia. The first nesting in agricultural area was recorded in Western Slovakia in 1988. The pair bred in a crow (*Corvus* sp.) nest on a transmission line tower. Following that year, the Saker Falcon population gradually expanded to the agricultural areas in the

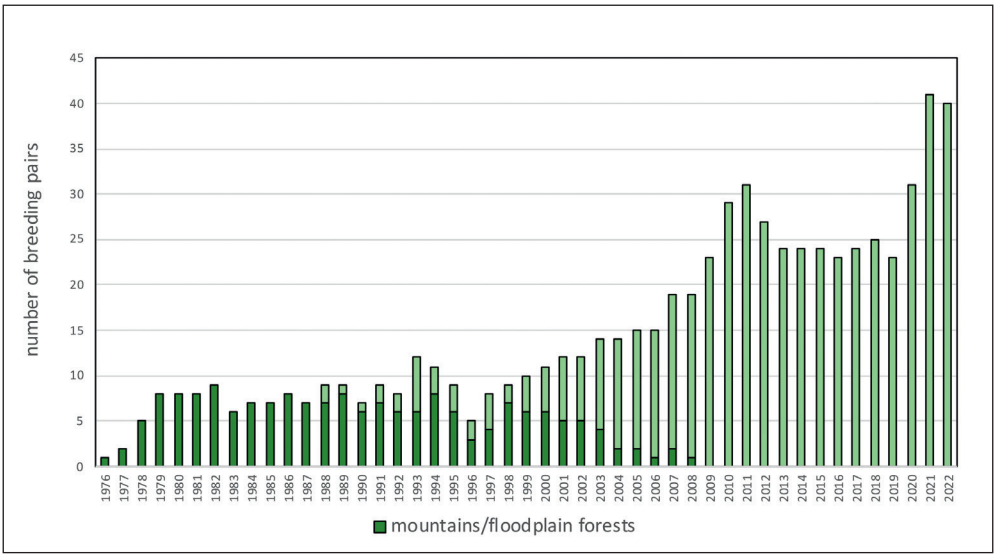

Figure 5. Changes in the Saker Falcon nesting habitats in Western Slovakia (1976–2022). Mountain and floodplains areas are highlighted in dark green, lowland agricultural areas in light green

5. ábra A kerecsensólyom fészkelőterületének változása Nyugat-Szlovákiában (1976–2022). A sötétzöld szín a hegyvidéki és az ártéren, míg a világosabb zöld az alföldi mezőgazdasági területen fészkelő párokat mutatja

Figure 6. An aluminium nest box can withstand also severe weather conditions (May 2021). Photo: J. Chavko

6. ábra Az alumínium fészekláda képes ellenállni a szélsőséges időjárási körülményeknek is (2021 május). Fotó: J. Chavko

Figure 7. A female Saker Falcon laid an egg in a nest built by ravens, but then left the nest (May 2004). Photo: J. Chavko

7. ábra Egy tojó kerecsensólyom lerakott egy tojást egy hollófészekbe, de azután elhagyta a fészket (2004 május). Fotó: J. Chavko

Figure 8. We also installed nest platforms in a few numbers on several transmission line towers, which falcons also like to occupy (ringing, May 2003). Photo: J. Chavko
8. ábra Kis számban fészektálcákat is helyeztünk ki néhány nagyfeszültségű távvezeték oszlopra, amelyeket a sólymok szintén előszeretettel foglalnak el (gyűrűzés, 2003 május). Fotó: J. Chavko

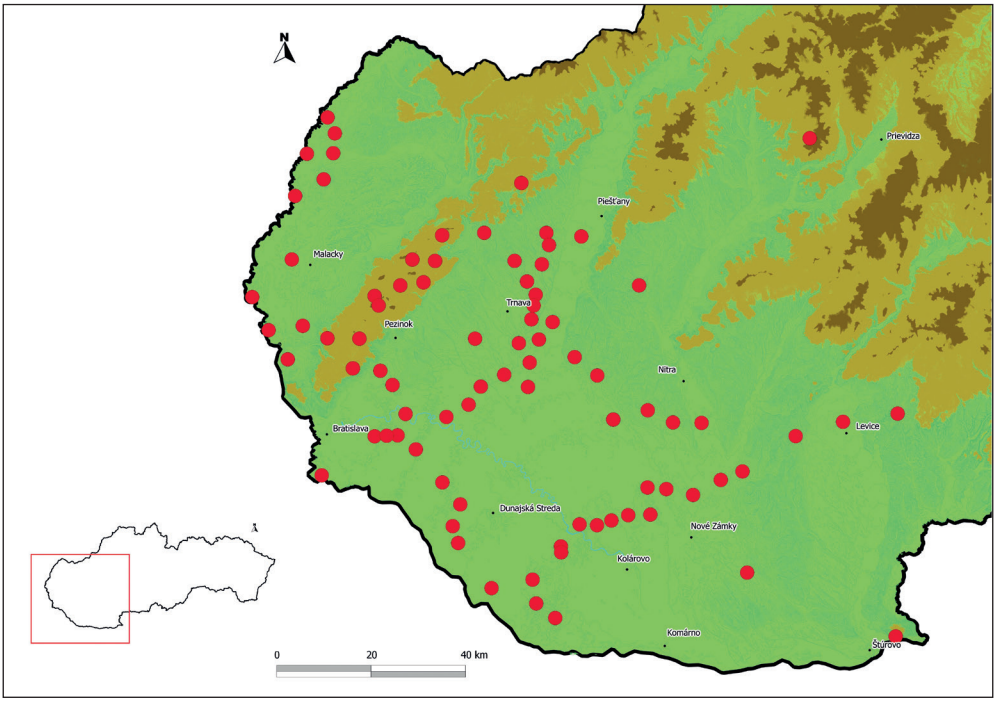

Figure 9. The distribution of nest sites in Western Slovakia (1976–2022)
9. ábra A fészkelőhelyek eloszlása Nyugat-Szlovákiában (1976–2022)

lowland. Eventually, the species' breeding range in Western Slovakia has shifted from the mountains to the lowland, and all pairs but one have nested on transmission towers since 2009 *(Figure 5)*. The only exception was a single pair, which nested in an artificial nest in the Danube plain until 2011. About 95% of the new pairs have preferred nesting in nest boxes on transmission line towers *(Figure 6)*. A few nesting attempts occurred in nests of Ravens *(Corvus corax)*, built either on the metal structure of transmission line towers *(Figure 7),* or in the nest boxes, or on nest platforms also on transmission line towers *(Figure 8)*. The distribution of nest sites in Western Slovakia is shown in *Figure 9*.

Eastern Slovakia

In Eastern Slovakia, we recorded 32 nest sites occupied by 32 pairs in the period 1979–2022. A total of 282 breeding attempts were recorded, out of which 213 were successful resulting in 677 juveniles. The number of failed nesting attempts were 68. The mean brood size was 2.5 young birds per successful nesting attempts, and 1.9 young per all nesting attempts. The trend of population growth was slightly increasing until 2010, but we have been experiencing a downward trend since then *(Figure 10)*.

Of the total 32 known nesting sites, 9 were in mountain ranges, and 23 in lowland agricultural areas. In Eastern Slovakia, the first records of nesting, dating back to 1979, were on historic nesting grounds in the mountains. However, the breeding population's range gradually shifted from the mountains to the lowlands, mirroring the trend observed in Western Slovakia. The last nesting events in the Slovak Ore Mountains were recorded in 1981, in the Slovak Karst in 1995, and in the Slanské Hills in 1996. In the Slovak Paradise Mountains, only one successful nesting was recorded in 1982, which also occurred on a cliff. The first nesting of a pair in the lowland was documented in 1986 in the Košice Basin

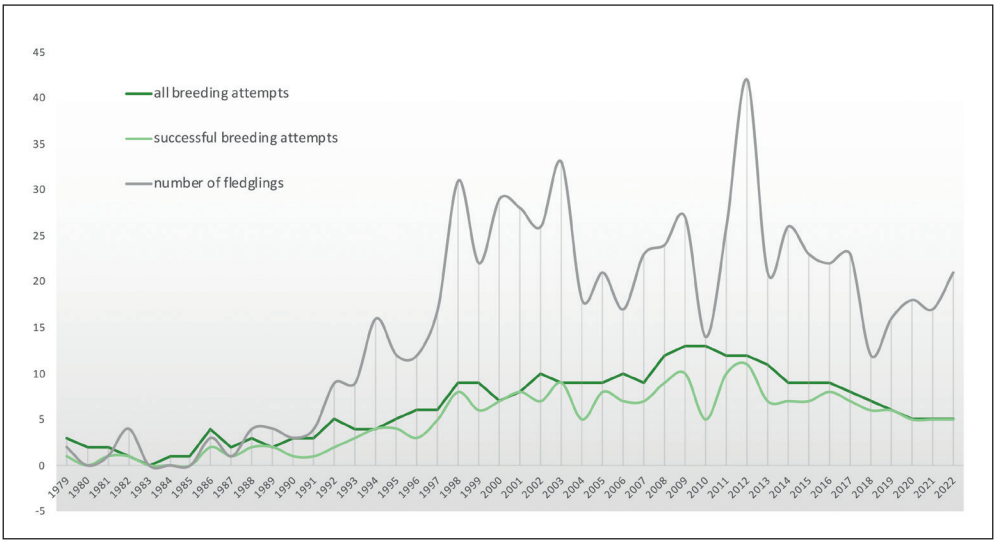

Figure 10. Population development of the Saker Falcon in Eastern Slovakia (1979–2022)
10. ábra A kerecsensólyom-állomány alakulása Kelet-Szlovákiában (1979–2022)

(South-Eastern Slovakia). Since 1997, all known pairs have nested in lowland agricultural areas, utilizing nest boxes installed on transmission line towers *(Figure 11)*. The complete shift from mountainous to lowland nesting sites in Eastern Slovakia occurred 13 years earlier than in Western Slovakia. The distribution of nesting sites in Eastern Slovakia is illustrated in *Figure 12*.

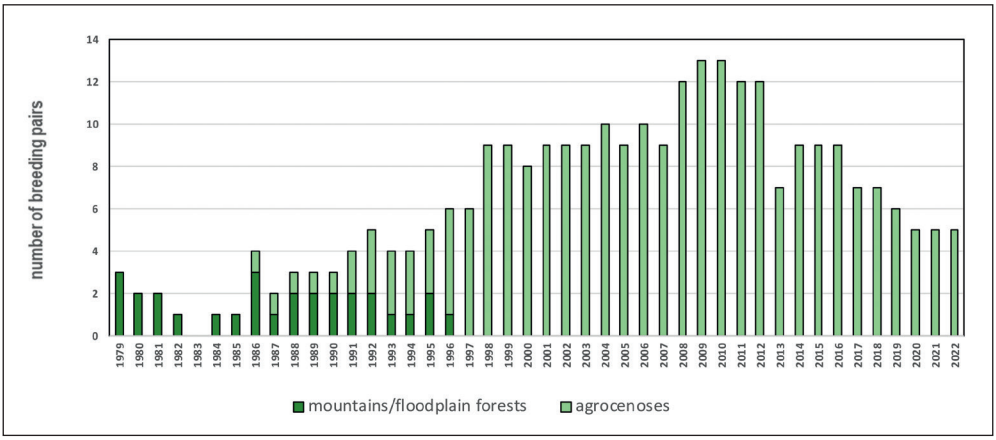

Figure 11. Changes in the Saker falcon nesting habitat in Eastern Slovakia (1979–2022)
11. ábra A kerecsensólyom fészkelőterület-változása Kelet-Szlovákiában (1979–2022)

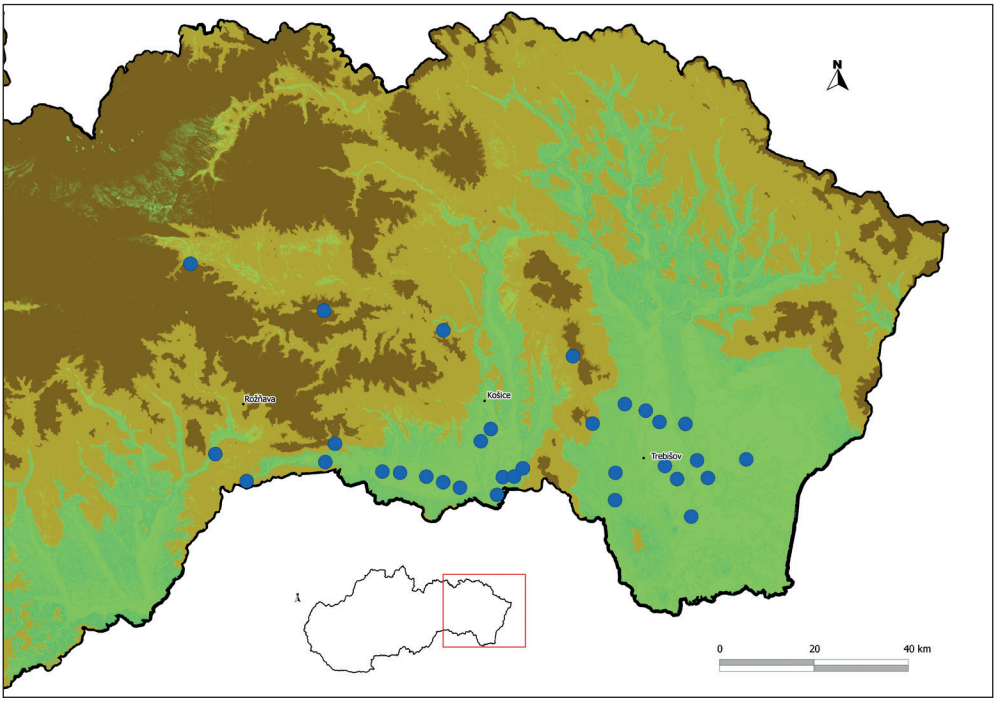

Figure 12. The distribution of nest sites in Eastern Slovakia (1979–2022)
12. ábra A fészkelőhelyek eloszlása Kelet-Szlovákiában (1979–2022)

Threats

During the period under review, we recorded three deaths because of a collision with power lines. In Western Slovakia four fledglings died in a nest box, and nine fledglings altogether died in Eastern Slovakia in three nest boxes when a lightning struck transmission line towers. Nevertheless, electrocution on flat consoles of 22 kV overhead lines can be considered the greatest threat where we recorded the death of a total of 14 individuals.

Discussion

Population development

During the study period, the most conspicuous change observed in the Saker Falcon population was the cessation of historical breeding territories in the mountains, which were present at the beginning of the conservation program. By the late 2000s, this resulted in the species' distribution area in Slovakia shifting entirely to the lowland. The last nesting attempt in a mountain range (Little Carpathians) in Slovakia was recorded in 2008.

Interestingly, the new territories formed mostly near larger cities, likely due to the availability of food, such as city-dwelling feral pigeons. Since the falcons predominantly used natural nests and artificial nest boxes on transmission lines, their distribution closely followed the routes of these power lines. The shift in nesting preferences was influenced by two main factors. First, the disappearance of pastures harbouring large colonies of European Ground Squirrels *(Spermophilus citellus)*, particularly near the foothills of the Little Carpathians, led to a significant reduction in food sources. The dwindling prey sources compelled Saker Falcons to cover greater distances, reducing energetic efficiency and leaving their broods more exposed to predators and adverse weather for extended periods. Second, the introduction of numerous nest boxes on transmission towers in lowlands, where food was more plentiful, provided new nesting opportunities. Additionally, the return of the Peregrine Falcon *(Falco peregrinus)* to Slovakia after 1994, taking over nesting sites on mountain cliffs, may have pushed Sakers from at least a few of these areas, as indicated by Chavko (2002b).

The marked increase in nesting pairs on transmission towers highlights that lowland areas remain attractive to Saker Falcons for their trophic resources, despite a general decline in prey diversity (Karp *et al.* 2012). The previously favourable nesting conditions in the mountains have gradually deteriorated due to the intensive economic exploitation of these habitat (Chavko & Deutschová 2012). Similar trends are increasingly apparent across various European countries (Donald *et al.* 2001, Butler *et al.* 2010, Vermouzek & Zámečník 2017).

However, this shift in habitat has evidently benefited the species, as seen in the improvement of their reproductive success. In the new, predominantly agricultural environment, the nesting success significantly increased from 57.1% in the mountains to 81.1% in the lowland, which is reflected also in mean brood size per all breeding attempts of the population in Western Slovakia *(Figure 13)*.

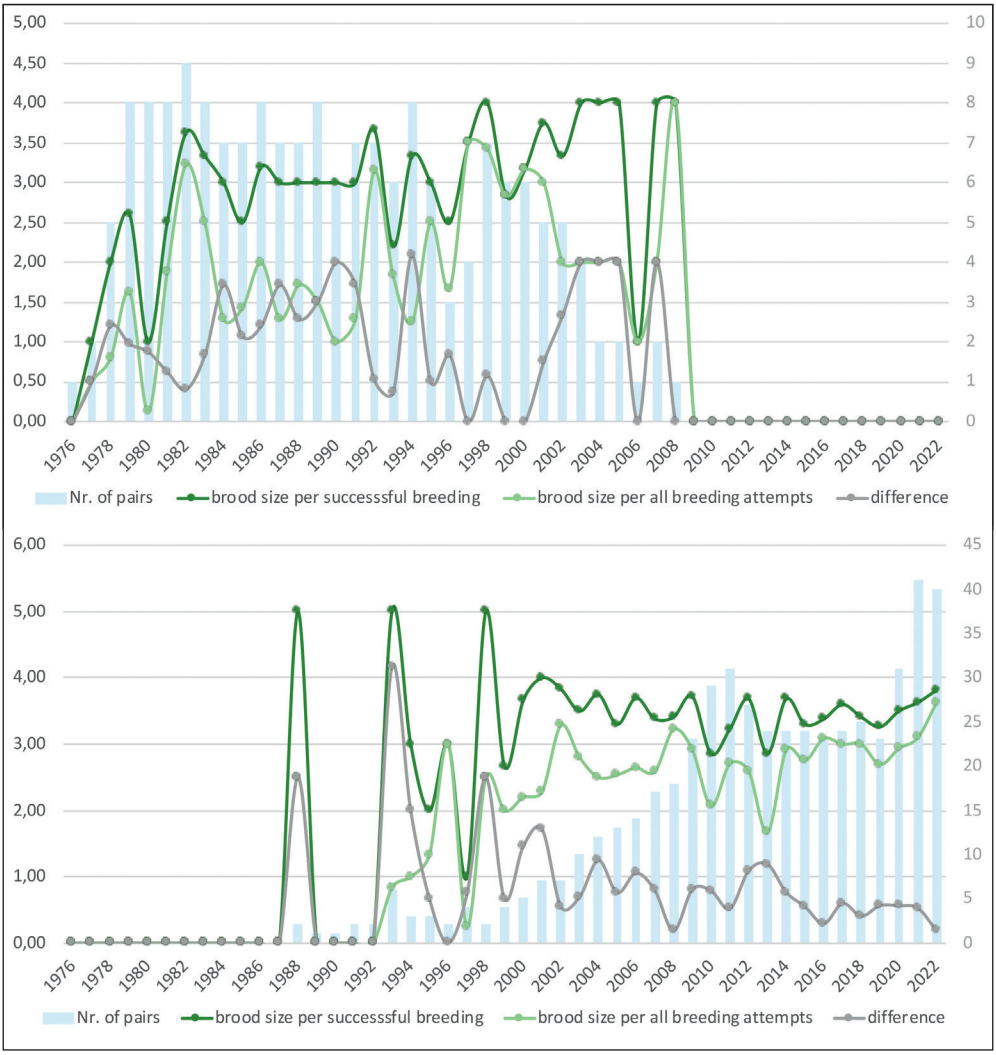

Figure 13. Reproductive performance of mountain (above) and lowland (below) breeding pairs in Western Slovakia. The number of breeding pairs is shown in light blue, with the corresponding y-axis on the right.

13. ábra A hegyvidéki (fent) és alföldi (lent) fészkelő párok reprodukciós sikere Nyugat-Szlovákiában. A fészkelő párok száma világoskékkel van jelölve, a hozzá tartozó y-tengely pedig jobbra található

Pairs in the mountains struggled, with the mean brood size often being two or fewer young per breeding attempt, rather than more. Conversely, excluding the initial years and the notably poor breeding year of 2013 for raptors, this value consistently exceeded two in the lowlands, sometimes even surpassing three. This difference in reproductive success cannot be attributed merely to the smaller sample size, as the lowland population maintained a stable, high reproductive outcome even with a limited number of pairs. The most plausible

explanation for the poorer breeding performance of mountain pairs is a combination of factors: inefficient provisioning for the young due to reduced prey availability, a higher predation rate – especially due to the more pronounced presence of Goshawks *(Accipiter gentilis)* – reported in the 1980s and 1990s (Chavko 2010).

A high abundance of prey enhances reproductive success (e.g. Martin 1987, Ontiveros & Pleguezuelos 2000, Krištín *et al.* 2017). In the lowlands, this advantage was coupled with the wide availability of nest sites and a lower level of threats (Kovács *et al.* 2014), further supporting population growth. Particularly, the installation of nest boxes has induced a significant positive change in the nesting conditions for Saker Falcons within the intensively cultivated lowlands, as documented by Zink and Izquierdo (2012) and Chavko *et al.* (2014).

Threats

While reproductive performance is better in the lowlands, this habitat is not without its threats. A study on the post-fledging survival of juvenile Saker Falcons revealed high mortality rates among young birds shortly after fledging. None of the six monitored individuals survived the dispersion period, with at least three fatalities attributed to human activities – electrocution and hunting (Kouba *et al.* 2021). That highlights the problem that mid-voltage (22 kV) distribution lines pose a primary threat through electrocution (Dixon 2009, Kovács *et al.* 2014), which is a universal problem across the species' distribution range (Chavko 2002a, Beran *et al.* 2012, Kovács *et al.* 2014). It is reasonable to assume that electrocution represents the major threat to the species in Slovakia, and the actual number of electrocuted individuals is likely much higher than reported in this study. Many of the electrocuted falcons are never found, as their carcasses are quickly removed by predators such as the Red Fox *(Vulpes vulpes)* or the European Badger *(Meles meles)* (Ponce *et al*. 2010). Recently, this issue has gained more attention in Slovakia, with hazardous mid-voltage power line towers being secured as part of LIFE projects, particularly within the Sakers' home range (Gális *et al.* 2019a, 2019b). Saker Falcon mortalities were recorded on various crossarm types, with

Figure 14. Dangerous jumper in upper position on a 22 kV tower (left) and change of its placement under the plane of main wires (right). Photo: J. Chavko

14. ábra Veszélyes átkötés egy 22 kV-os vezeték oszlopán (balra), és módosítás után, amikor alsó helyzetbe került (jobbra). Fotó: J. Chavko

the most dangerous being those with top-positioned jumpers and branching towers (Gális 2022). That type clearly represents the highest risk of electrocution to raptor species (Dixon *et al.* 2013). As a part of making power line poles safer for birds, jumpers were repositioned under the plan of main wires, as well as insulated conductors were applied *(Figure 14)*. Such measures may achieve 100% efficiency (Gális 2022).

Paradoxically, while high-voltage transmission lines facilitate nesting, they also present a significant collision risk to Saker Falcons, which is another factor causing injury or mortality.

The widespread decline in key prey species, driven by human activities such as the regular artificial control of the Common Vole *(Microtus arvalis)* during population peaks, poses a threat in lowland habitats. Specifically, the inappropriate use of rodenticides can endanger raptors through secondary poisoning.

Conclusions

In summary, in recent years, the species has exhibited population growth in Europe (e.g. Prommer *et al.* 2025, Škorpíková *et al.* 2025, Zink *et al.* 2025), as the downward trend has been halted in some countries, including Slovakia, thanks to targeted conservation efforts. Following a shift in habitat usage in Slovakia, the results of monitoring indicate a relatively dynamic increase in the population, especially in the lowlands of south-western Slovakia. Concurrently, Saker Falcons face persistent threats that contribute to unnecessary increases in mortality rates, with electrocution being particularly concerning. Addressing these hazards remains a critical priority for organizations dedicated to the conservation of Sakers and other birds of prey. Efforts to mitigate these threats involve a multi-faceted approach, including habitat restoration, modification of power lines to prevent electrocution, and raising public awareness about the importance of conserving these vital raptor species. By focusing on these areas, conservation groups aim to reduce mortality rates, ensuring the future of Sakers and enhancing the overall ecosystem health.

Acknowledgements

The conservation efforts to save and stabilize the Saker Falcon population in Slovakia have received substantial financial support from the European Union through the LIFE programme. Several projects aimed at this goal have been implemented in the region since 2006. Thanks to these projects, nest boxes were manufactured and installed as alternative nesting sites for the species. Additionally, the safety of power line poles and towers, as well as the wires of power lines, was enhanced to protect raptors against electrocution and collisions. Various methods of species monitoring, including the use of satellite-tracking devices, were also implemented. Efforts to prevent, detect, and address cases of illegal activities where birds are victims have also received support. The aforementioned activities have been conducted under the following projects: LIFE13 NAT/SK/001272 LIFE ENERGY (9/2014-12/2019), LIFE15 NAT/HU/000902 LIFE PANNON EAGLE (10/2016-1/2023), LIFE18 NAT/

AT/000048 LIFE EUROKITE (08/2019-01/2027), and LIFE19 NAT/SK/001023 LIFE DANUBE FREE SKY (9/2020-2/2026).

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