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Population trend and conservation of Saker Falcon *(Falco cherrug)* in Austria (2012–2021)

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Abstract We present data on the population trend and nesting success of Saker Falcon *(Falco cherrug)* in Austria in the period of 2012–2021. 339 active nests were recorded, 262 of them were successful, resulting in a total of 726 fledglings. The 10-year average breeding success is 2.14 fledglings per monitored active nest and 2.77 fledglings per successful nest. The average breeding success per successful nest is 3.1 fledglings for nest boxes, 2.7 fledglings for natural nests on trees, 2.4 fledglings for both stick nests and artificial platforms on pylons. Our most recent data shows that in 2021, a total of 53 territorial Saker pairs were reported in Austria, 41 of them successfully bred, resulting in a total of 111 fledglings (2.71 chicks/successful nest). The Saker Falcon population in Austria exhibits a marked increase (concerning the number of breeding pairs, fledged chicks, and breeding success) in the period studied. Furthermore, a positive correlation was found between the number of available artificial nesting structures and the number of successful nests. Since the population has shown a steady increase for the past years, as opposed to rather stable or more moderately increasing nearby populations in Central Europe, it is important to better understand the underlying causes and contemporary threats to keep the positive trend and ensure effective conservation.

Keywords: Saker Falcon, *Falco cherrug*, breeding success, nesting structures, mortality, contemporary threats

Összefoglalás Bemutatjuk az ausztriai kerecsensólyom *(Falco cherrug)* állomány alakulását és költési sikerét a 2012–2021-es időszakban. Összesen 339 aktív fészket jegyeztünk fel, 262 sikeres költéssel, amelynek eredményeként összesen 726 fiatal repült ki. A tíz év átlagát tekintve a költési siker 2,14 fiatal volt fészkenként, 2,77 fiatal sikeres költésenként. Az átlagos költési siker a fészekládákban 3,1, a fán lévő természetes fészkekben 2,7, a nagyfeszültségű távvezetékek oszlopain lévő gallyfészkekben és fészektálcákon egyaránt 2,4 fiatal volt. A legfrissebb adataink alapján 2021-ben 53 kerecsensólyom pár volt ismert Ausztriában, közülük 41 pár sikeresen költött, aminek eredményeképpen 111 fiatal repült ki (2,7 fiatal/sikeres költés). Az ausztriai kerecsensólyom-állomány jelentős növekedésen ment keresztül (a fészkelőpárok, a kirepült fiatalok és a költési siker tekintetében). Emellett pozitív összefüggést találtunk az elérhető mesterséges fészkek száma és a sikeres fészkelések száma között. Mivel ez az egyetlen folyamatosan növekedő állomány Közép-Európában, fontos megérteni a háttérben húzódó okokat és a veszélyeztető tényezőket, hogy fenn tudjuk tartani a pozitív trendet és biztosítsuk a hatékony védelmet.

Kulcsszavak: kerecsensólyom, *Falco cherrug,* költési siker, mesterséges fészek, mortalitás, jelenlegi veszélyforrások

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Introduction

Global distribution of Saker Falcon

Saker Falcon (*Falco cherrug* J. E. Gray, 1834) is found across the Palearctic from Central and South-East Europe, across Central Asia and all the way to Western China and Mongolia. Most recent global population estimates suggest a total population of 12,200–29,200 mature individuals. The status of the species was recently reassessed by the IUCN Red List Committee, yet retained its "endangered" global conservation status, due to an on-going very rapid decline, especially taking the unclear status and negative trends in the Asian strongholds of the species (China, Russia and Mongolia) into account (BirdLife International 2021a).

Compared to this, the European population of Saker Falcon is small and limited to some 430–630 breeding pairs in 2021. The species has been recently up-listed from "vulnerable" (2015) to "endangered" (2021) on a European scale, mostly due small population size, combined with a 48% population decline over three generations and an on-going decrease (BirdLife International 2021b). The worsening of the population trend is mostly attributed to land use changes, capture for falconry, pesticide exposure and electrocution (BirdLife International 2021a).

European population trends

The European population is split into two main distribution centres: Central European (Pannonian) population and Eastern European population (comprising Ukraine, Moldova and eastern Romania), geographically divided by the Carpathian Mountains (Prommer *et al.* 2014, Bauer 2020). The Pannonian population is estimated at 252–278 breeding pairs, more than half of it being concentrated in Hungary (145–165 breeding pairs) (Bagyura *et al.* 2017).

Despite significant evidence that the Pannonian population has been positively affected by well-targeted conservation measures and installation of supplementary nesting aid (Chavko 2010, Bagyura *et al.* 2012, Prommer *et al.* 2012, Fidlóczky *et al.* 2014, Trgalová & Chavko 2016), recent studies show that increase in the Hungarian and Slovak populations slowed down considerably (Bagyura *et al.* 2022, Prommer *et al.* 2025, Chavko *et al.* 2025), while the Czech breeding populations are undergoing a slight decrease (Škorpíková *et al.* 2019). At the same time, although the species is considered a former breeder in Germany, nowadays it is only a rare visitor with a single recorded breeding pair around 2000s (August 2000, Barthel 2011, Prommer *et al.* 2012). Hence, the species is considered extinct in Germany (BirdLife International 2021b).

This makes the status and population trend of Saker Falcon in Austria particularly interesting to study and consider as the species reaches the western limit of its global breeding distribution here.

Population trend in Austria

Saker Falcon was considered a widely spread species in the regions of Burgenland and Lower Austria, bordering Hungary until the end of the 19th century (Baumgart 1991).

Definite proof of a wide distribution is mostly missing, but as faunistic research on the species was hardly conducted at the time, only the few available written sources can serve as a reference. Later on, the population of the species experienced a supposed decrease, reaching approximately 10 pairs at the end of the Second World War (Bauer 1977), and further declined to almost extinction with barely two to four breeding pairs reported in 1970 (Bauer 1977, Senn 1980).

A slow recovery started in the 1980s (Gamauf 1992, Baumgart 1994), and the population was estimated to 15–20 breeding pairs at the end of the 1990s (Baumgart 1994, Berg 2000), which continued to increase to 25–30 breeding pairs by 2010 (Gamauf 2012).

The species was once included in the national priority list of the 50 most threatened species in Austria (Umweltdachverband 2008) and is currently on the Austrian Red List (Dvorak *et al.* 2017). Due to the reported positive population trend of 21–30%, it has been recently down-listed from "critically endangered" (2005) to "endangered" (2016) (Dvorak *et al.* 2017). Its legal status is characterized by a year-round protection in all nine Austrian provinces, regulated in the respective provincial hunting or nature protection laws (Lower Austria Hunting Law (NÖ Jagdgesetz) 1974; Burgenland Hunting Law (Bgld. JagdG), Wildlife Regulation Ordinance 2017). Furthermore, the species benefits from its protection in federal criminal law, as offences against Saker Falcons can be punished with up to two years in prison (BMJ 2022, Schmidt & Hohenegger 2022).

Contemporary threats

Some of the threats that previously caused the rapid decline of Saker Falcon populations in Central Europe have been largely reduced or eliminated through legislative measures. The following contemporary threats, however, still affect the species in Central Europe: shift to intensive agriculture, land use changes, direct persecution (poisoning and shooting), and trapping and egg collection for falconry (Nagy & Demeter 2006, Chavko 2010, Kovács *et al.* 2014). Newer threats that have been identified more recently include electrocution (Nagy & Demeter 2006, Prommer 2011, Kovács *et al.* 2014, Nemček *et al*. 2014, Bagyura *et al.* 2017), possible hybridization with escaped falconry birds (Nittinger *et al*. 2005, 2007, Kovács *et al.* 2014) and wind farm collisions (Dereliev & Ruskov 2005, Nagy & Demeter 2006). A potential risk that has not been studied in sufficient detail yet is secondary poisoning through rodenticides and other environmental pollutants (Kovács *et al.* 2014).

Conservation efforts

One of the measures, which has proven successful for increasing the Saker populations in Hungary, Slovakia and the Czech Republic, has been the installation of artificial nesting structures on high-voltage pylons (Chavko 2010, Beran *et al*. 2012, Chavko & Deutschová 2012, Chavko *et al.* 2014). This is explained by the fact that Sakers do not build nests themselves and can therefore be limited by nest site availability (Newton 1994). At the same time, natural breeding of Sakers on an electricity pylon has already been reported in Austria in 1999 (Straka 1999).

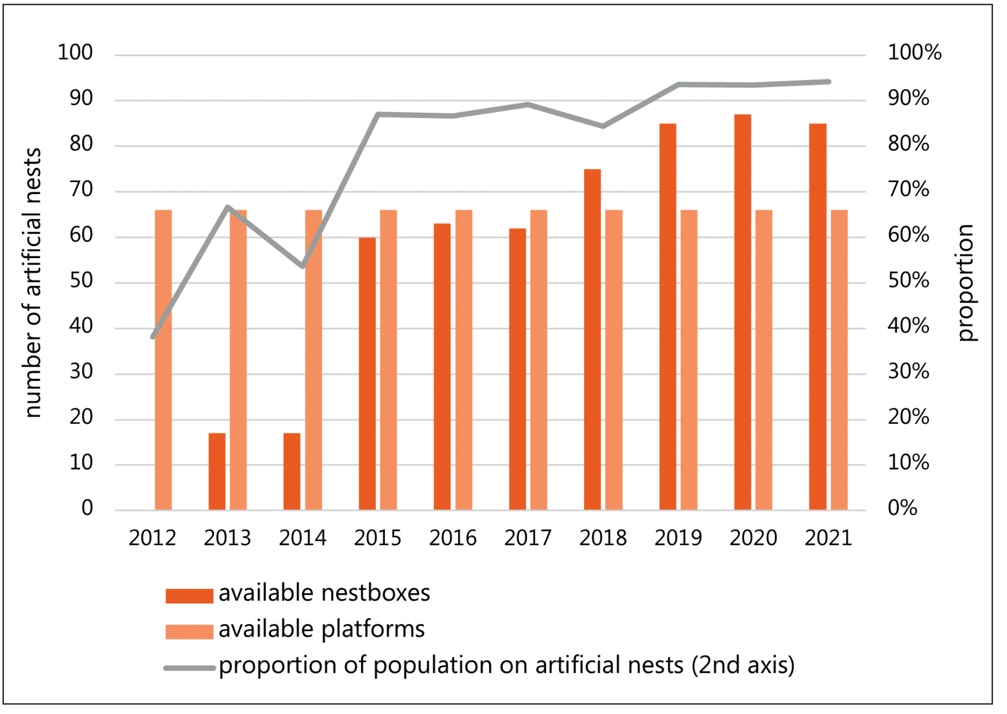


Figure 1. Temporal development of the number of available nesting aids in the period of 2012–2021
1. ábra A kihelyezett mesterséges fészkek számának alakulása 2012–2021 között

As a result, the Research Institute for Wildlife Ecology (FIWI) at VetMedUni Vienna and the Austrian Power Grid AG (APG) initiated a project to provide artificial nesting platforms on high-voltage electricity pylons in Lower Austria in 2004 (Zink & Sachser 2015). The project has continued in close cooperation with BirdLife Austria from 2010 onwards and in 2018 FIWI was replaced by the Austrian Ornithological Centre (AOC) at the VetMedUni Vienna. From 2012 onwards, also nesting boxes have been provided and the initiative has been joined by other electricity providers, such as NÖ Netz (formerly EVN), ÖBB Infra and Netz Burgenland (formerly BEWAG). As a result of all these efforts in the breeding season of 2021, there were a total of 151 nesting structures (platforms and nesting boxes) in Austria, offering suitable breeding sites, safe from human persecution and disturbance *(Figure 1, 2).*

Since the start of these conservation measures, the Austrian population of Saker has showed an even more rapid increase (Zink *et al.* 2016).

The current publication therefore aims to present the contemporary population trend and nesting success of Saker Falcon in Austria in the period of 2012–2021, following the conservation measures initiated and carried out by the Austrian Ornithological Centre at VetMedUni Vienna and BirdLife Austria.

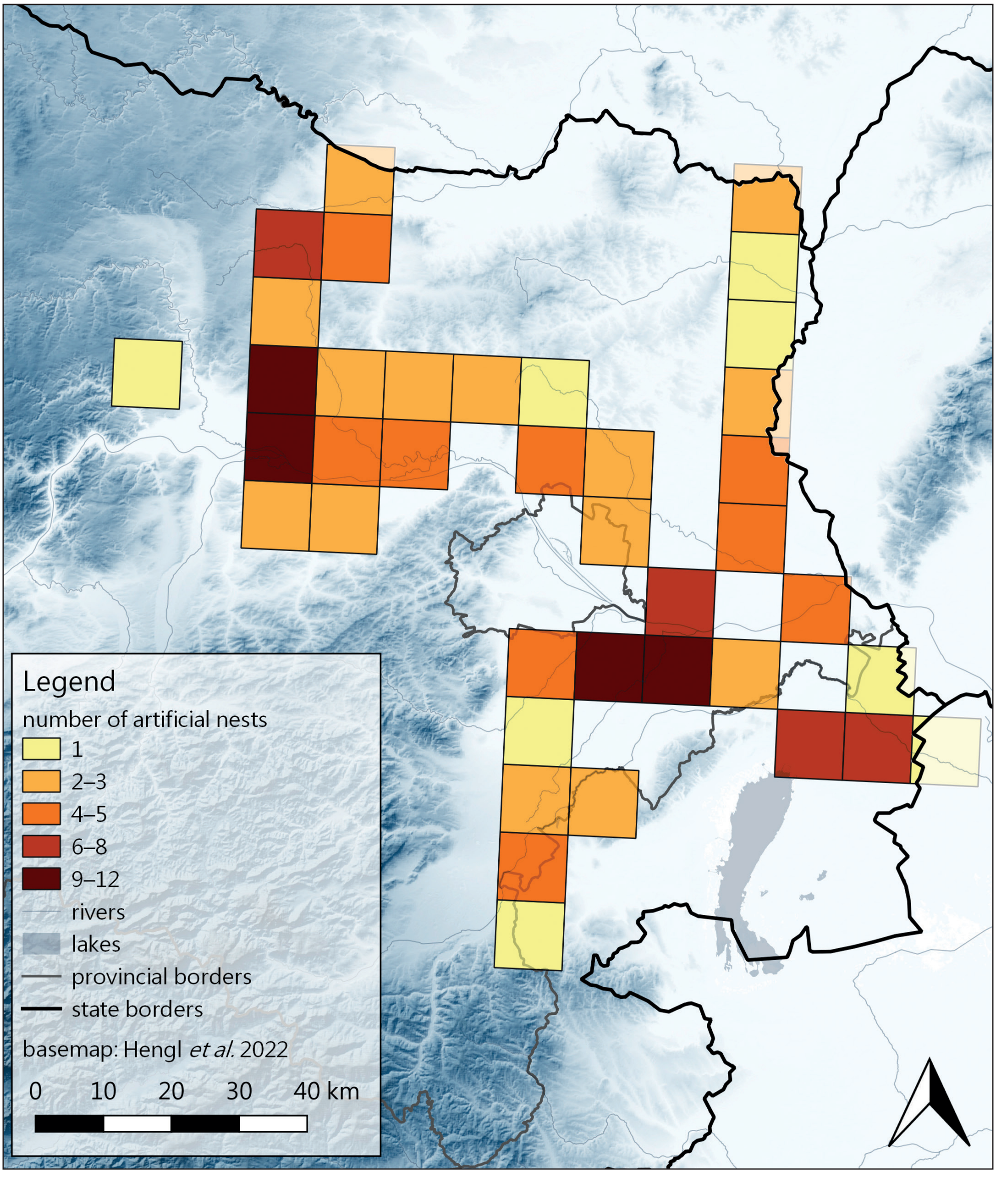


Figure 2. Total number of installed nesting aids available per grid cell in 2022
2. ábra A kihelyezett mesterséges fészkek száma négyzetenként 2022-ben

Material and Methods

Our study is an overall summary of a set of internal annual reports on the breeding success of Saker Falcon, developed together or separately by the Austrian Ornithological Centre (AOC) at VetMedUni Vienna and BirdLife Austria in the period of 2012–2021. The information from all annual reports, prepared in German, has been translated, merged, and processed

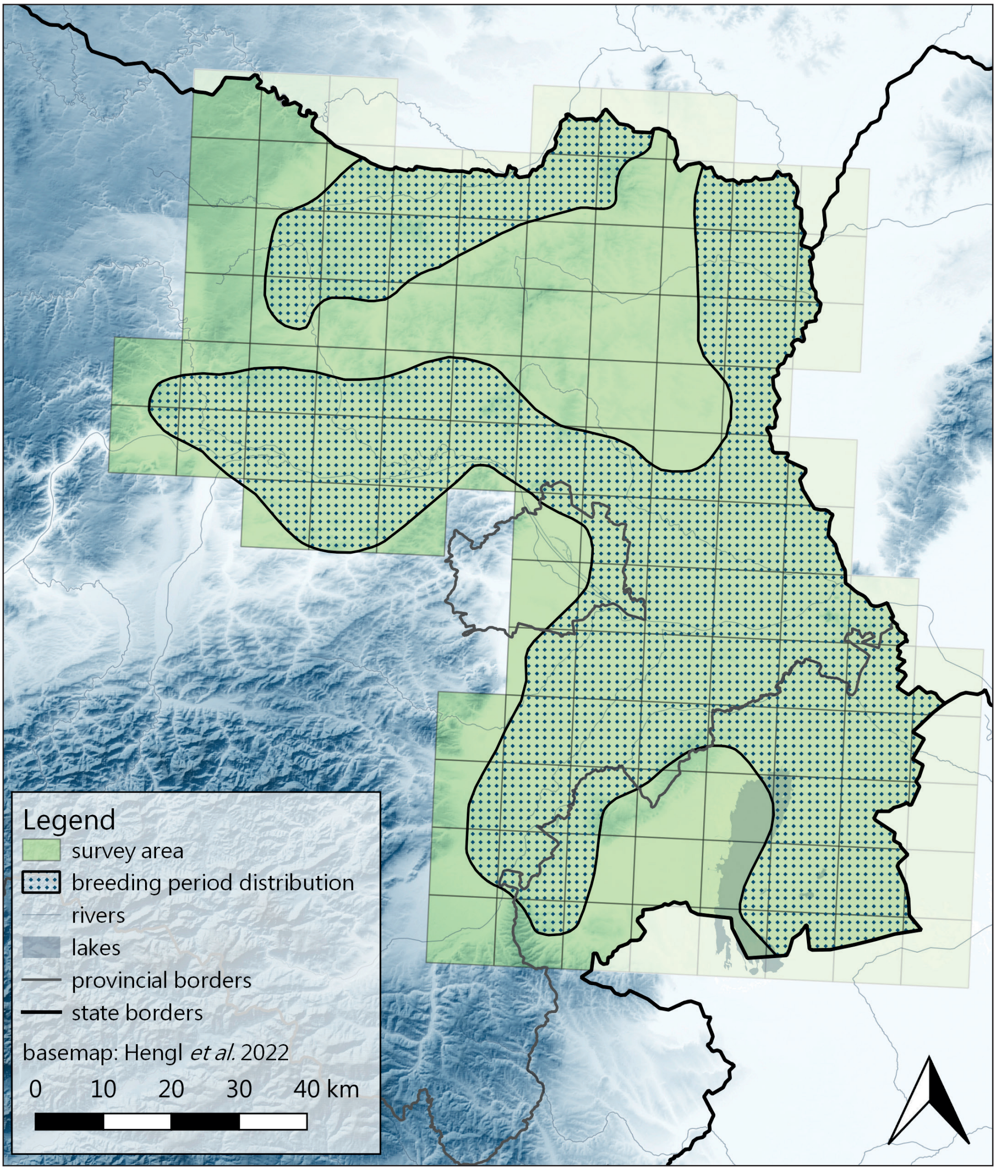


Figure 3. Survey area and breeding period distribution of Saker Falcon in 2012–2021
3. ábra A felmért terület és a kerecsensólymok elterjedése (költési időszakban) 2012–2021 között

together to produce summary results. Following the consolidation of the two datasets, population numbers published here marginally differ from the information published in the original internal reports.

The data presented below is based on the standardized monitoring of all known breeding pairs of Saker Falcon in Eastern Austria. The monitored area comprised parts of the state provinces of Burgenland, Lower Austria and Vienna *(Figure 3)*.

However, the detection of pairs breeding in natural stick nests in regions without artificial nesting structures can be difficult and it is possible that individual pairs have successfully bred without notice. In 2015, a total of 87% of all recorded breeding pairs in Austria were nesting on artificial structures (Rozsypalová *et al.* 2022), so the presented results can be considered quite comprehensive and thorough.

To optimize the monitoring effort and coordinate the teams of AOC and BirdLife, since 2014, the study area has been divided to regions, and staff, experts or volunteers of one of the two organizations have been assigned to single regions. The AOC expert team focused on monitoring the nesting structures installed and carried out individual ringing of non-fledged chicks, while BirdLife Austria staff members and volunteers additionally monitored natural broods in some of the areas. Known territories of tree-breeding Saker Falcons were also included in the surveys and unsystematic observation data collected by BirdLife Austria were used to identify additional possible territories (Hohenegger *et al.* 2020).

The survey areas primarily comprised areas known to have been occupied by Saker Falcon, regions with overhead power lines (with nesting structures), open/semi-open regions, and prospect "distribution gaps" between already established sites (Hohenegger *et al.* 2020).

Monitoring

The breeding sites were monitored using spotting scopes (such as Swarovski ATS 80 HD, 20-60 Zoom) as well as binoculars (ex. Swarovski 8×56 and 10×42) and documented with a digital camera.

When surveying pylons, the first viewing of a pylon was usually done from preliminarily agreed optimal observation points, at a minimal distance of 400-500 meters, but often way more to avoid disturbance, checking the nesting structures and the rest of the pylon for perching birds, stick nests, already present corvid nests or any other hints of possible occupation. The average time spent at each pylon varied between a few minutes and several hours depending on the conditions and the birds' behavior.

Each pylon with an artificial nesting structure was checked for the presence of Saker Falcons at least twice within the breeding season (starting from end of February). Between mid-March and end of April, a selected set of Saker Falcon nests was more frequently surveyed to guarantee that the newly hatched falcons could be marked with standard ornithological rings at an optimum age of approximately 20–30 days in the first half of May. Between mid-May and mid-June, all known nesting sites were additionally controlled to determine the number of "pre-fledged" chicks. This is, in our experience, the most effective method for assessing breeding success, since counting the freshly fledged Saker Falcons is time-consuming and often produces wrong numbers.

Nevertheless, the number of "pre-fledglings" in the nests can also be difficult to determine, due to the height of the nesting structures, poor viewing angle or big observation distance and these shortfalls must be considered when interpreting the breeding success data.

Data reporting and consolidation

In the first years of the project, the monitoring data was reported in paper monitoring forms, which were then transferred to a MS Excel table and location data was processed with open-source software, such as QGIS (https://www.qgis.org/en/site/). In the following years, a SQL online database was set up at the AOC to collect all relevant data: Saker Falcon observations, breeding status data, power line and pylon locations (with or without nesting structures) and all other nest locations.

At the same time, the staff members of BirdLife Austria used the online observation platform www.ornitho.at, set up in spring 2013 (Berg & Wichmann 2014). An extra input code was activated later to separate the breeding data from the non-standardized observations collected by other observers and hide it from public use.

The following data was collected by all field observers (AOC and BirdLife Austria) within the project: date and time of observation, nest site location, breeding status (possible, breeding, aborted, no breeding), number of birds, age, sex (if identifiable), observation content and any other information worth mentioning (e.g. suspected hybrid); photos.

At the end of the survey period each year, the results of BirdLife Austria were compared with those of AOC and jointly discussed after the young birds had fledged (Berg *et al.* 2017, Hohenegger *et al*. 2020). Observation data on breeding success was cross-checked through the chick ringing carried out by the first author of the current publication.

Finally, the summarized breeding status data of each pair was entered into the online database at www.saker-info.at, where a summary of the results is also publicly accessible (Berg *et al.* 2017, Zink *et al.* 2018).

Breeding parameters

The breeding parameters reported in this study should be read as follows:

- "territorial pairs" comprises all registered pairs, whether breeding successfully or unsuccessfully, and territorial, non-breeding pairs confirmed for the particular year, excluding sites with possible breeding attempts, where Saker Falcons were observed during the breeding season, but no territorial pair could be confirmed;
- "monitored active nests" comprises all active nests (whether successful or not) on artificial nesting sites, trees and electricity pylons (breeding behavior had to be observed for a possible nest site to qualify as "nest"); excluding non-breeding and possible territorial pairs as well as pairs with unknown nest site;
- "successful nests" comprises only pairs with confirmed breeding success from the known, monitored nests; excluding successful breeding, where the nest site could not be located precisely.

Breeding success is calculated as follows:

- "fledglings/successful nest" is based on the total number of fledged chicks from monitored nests, divided by the "successful nests";
- "fledglings/nest" is based on the total number of fledged chicks from monitored nests observed for the season, divided by the "monitored active nests" identified for the year.

Correlations and trendlines are calculated as follows:

- Correlation is calculated using MS Excel by dividing the covariance by the product of the two variables' standard deviations;
- Trendlines are added using MS Excel suggesting a linear trend and a steady increase over time and the automatically calculated R-square value, measuring the trendline reliability is used.

Results

Current breeding area of Saker Falcon in Austria

Our summarized results show that the breeding range of Saker Falcon in Austria is restricted to the lowlands and hilly regions in the Pannonian part of Lower Austria and northern Burgenland *(Figure 3, 4)*. The strongholds for Saker Falcons in Austria are the Thaya-March region, the Marchfeld, the Feuchte Ebene and the Parndorf Plateau (Zink *et al.* 2016), the northern and western part of the Weinviertel, the Wagram-Tullnerfeld region and the southern Vienna Basin. As a result of the nesting structure installation programme, breeding occurrences are clustered mainly along large overhead power lines within agricultural areas. Yet, despite targeted searches, breeding occurrences in large forest areas, such as those known from the Danube and the March floodplains, the Ernstbrunn Forest, the Hochleithen Forest and the Leithagebirge, are currently very rare and probably under-reported. The most important area for Saker Falcons breeding in natural nests is the northern Weinviertel, where the species uses corvid and Common Buzzard *(Buteo buteo)* nests on trees or powerline pylons within an open agricultural area. It should be noted that in this area there are no artificial nests.

Our results clearly show that Saker Falcons in Austria readily take the artificial nesting structures provided on high-voltage electricity pylons. Furthermore, the number of pairs using artificial nesting structures has increased from less than 30% in 2012 to over 90% in 2021 *(Figure 4)*. Additionally, we have established a positive correlation between the number of provided artificial nesting sites and the number of breeding pairs (r=0.7912).

Breeding population and trend

The breeding population of Saker Falcon in Austria has nearly doubled (89% increase) in 10 years from 28 territorial pairs in 2012 to 53 territorial pairs in 2021 *(Figure 5)*. Furthermore, there is an even greater increase in the number of successful nests from 16 nests in 2012 to 41 in 2021 (156% increase) and a positive trend in the proportion of successful nests compared to the total number of territorial pairs reported for the same year ($R^2 = 0.6248$). The average proportion of successful nests for all monitored active nests is 77%, with a maximum of 96.9% (2018) and a minimum of 62.5% (2013).

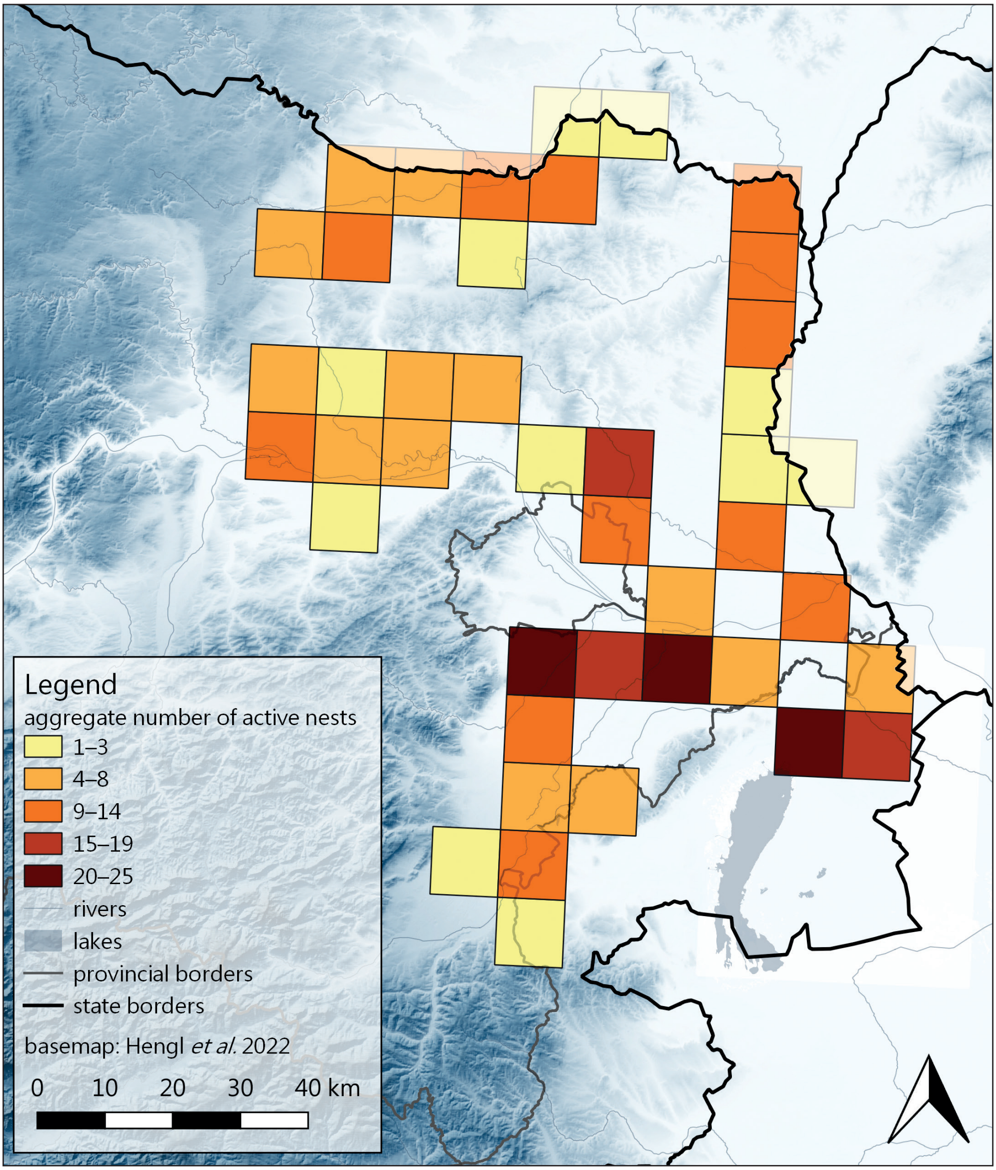


Figure 4. Total number of monitored active nests of Saker Falcon per raster cell (2012–2021)
4. ábra A felmért aktív kerecsensólyom-fészkek összesített száma cellánként (2012–2021)

Breeding parameters

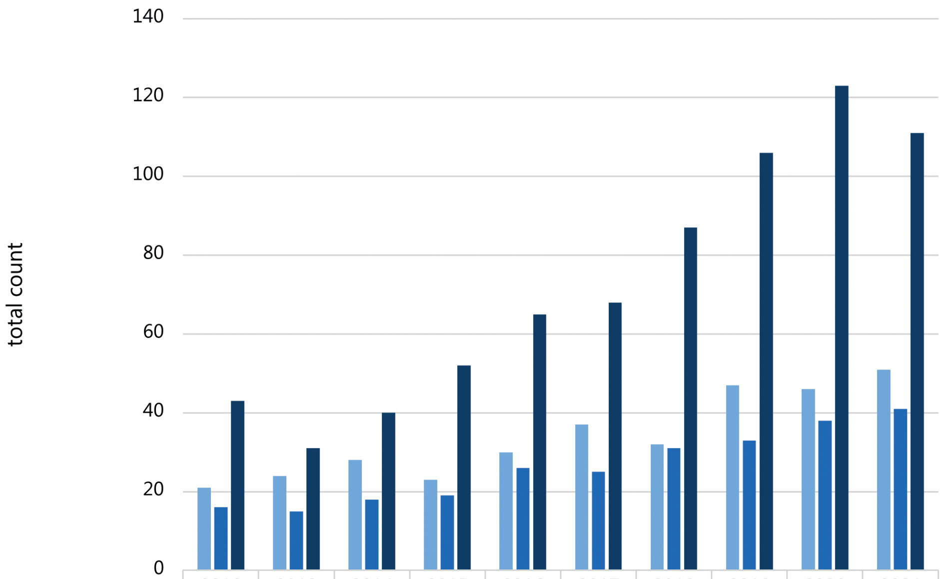
The ten-year average breeding success of Saker Falcon in Austria in the period of 2012–2021 is 2.14 fledglings/monitored active nest and 2.77 fledglings/successful nest *(Table 1)*. A total of 726 fledglings have been recorded from both artificial and natural Saker Falcon nests between 2012 and 2021 in all monitored nests in Austria *(Figure 5, 6)*.

Table 1. Breeding success parameters per nest type (aggregate numbers for 2012–2021)
1. táblázat Fészektípusonkénti költési siker (összesített adatok 2012–2021 között)

	Natural tree nests	**Natural nests on pylons**	**Platforms**	**Nest boxes**	**All nests**
Monitored active nests	26	33	118	155	339
Success rate (%)	65	76	62	90	77
Fledglings per nest	1,73	1,64	1,50	2,77	2,14
Fledglings per successful nest	2,65	2,16	2,42	3,09	2,77

While the population is growing over this ten-year period, there is also a slight positive trend in the number of juveniles per known breeding pair ($R^2 = 0.3993$), as well as number of juveniles per successful nest ($R^2 = 0.4649$) *(Figure 7)*. Strikingly, the average number of fledglings per nest grows by cca. 10% per year over the ten-year period. Furthermore, the proportion of pairs, which have abandoned their nests (failure rate), although fluctuating over the years (mostly due to the weather conditions or occasional disturbance that year), is generally decreasing.

The highest breeding success (fledglings per successful nest) was recorded in 2020 (3.24) and 2019 (3.21). Both 2019 and 2020 were characterized by dry and warm spring seasons



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
monitored nests	21	24	28	23	30	37	32	47	46	51
successful nests	16	15	18	19	26	25	31	33	38	41
fledged young	43	31	40	52	65	68	87	106	123	111

Figure 5. Temporal development of the Saker Falcon breeding population in Austria, in 2012–2021
5. ábra A kerecsensólyom fészkelőállományának alakulása Ausztriában 2012–2021 között

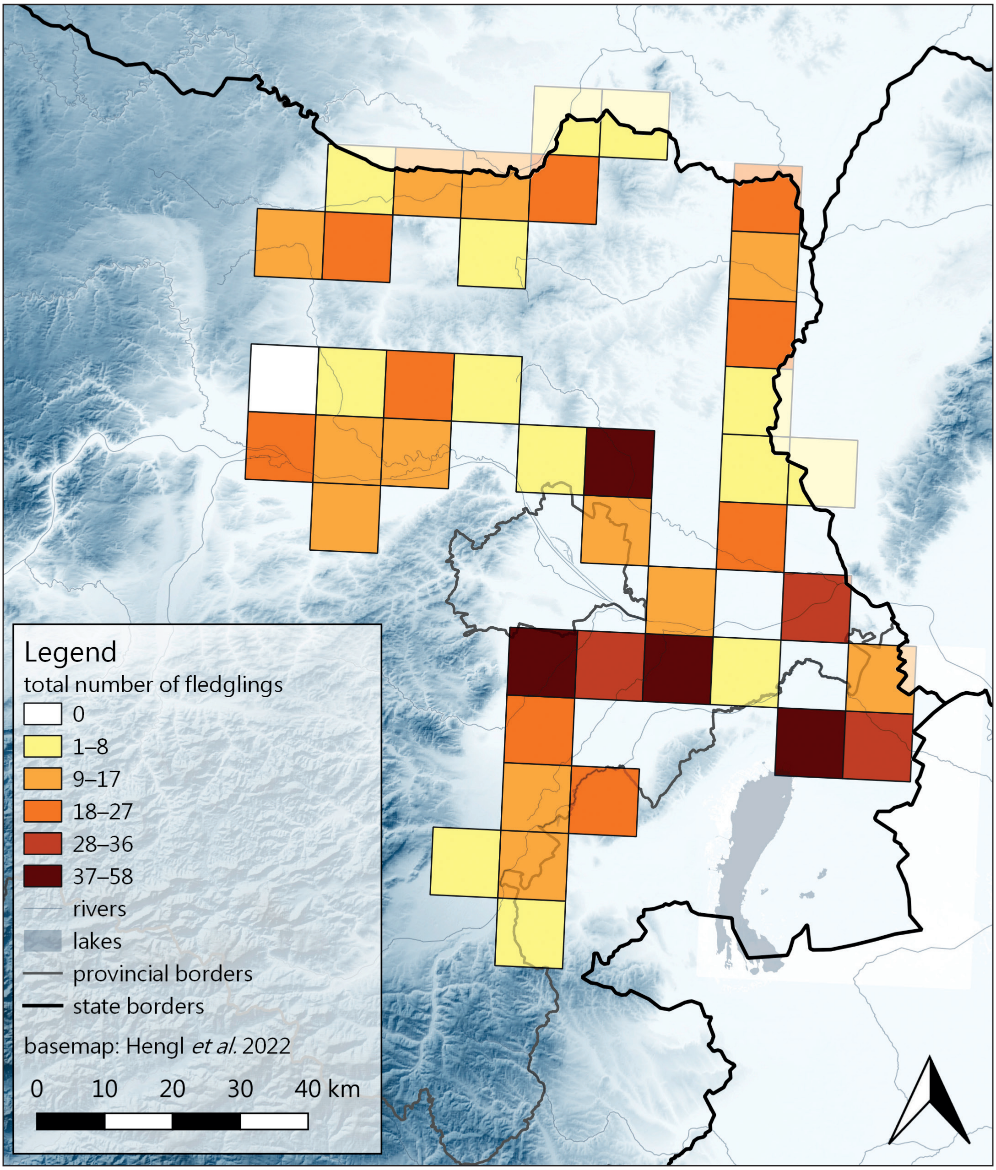


Figure 6. Aggregated number of fledglings of Saker Falcon per raster cell (2012–2021)
6. ábra A kirepült kerecsensólyom fiatalok összesített száma cellánként (2012–2021)

(February – April), providing excellent conditions until the hatching of the young birds. Despite several days of heavy rain and storms around the turn of the month April – May 2019 (ZAMG 2022a), the prolonged period of good weather in June 2019, providing good hunting conditions for the adults, likely had a positive effect on the survival rate of the young, especially combined with the extreme prevalence of voles that year (Hohenegger *et al.* 2020). On the contrary, June 2020 was characterized by relatively high precipitation

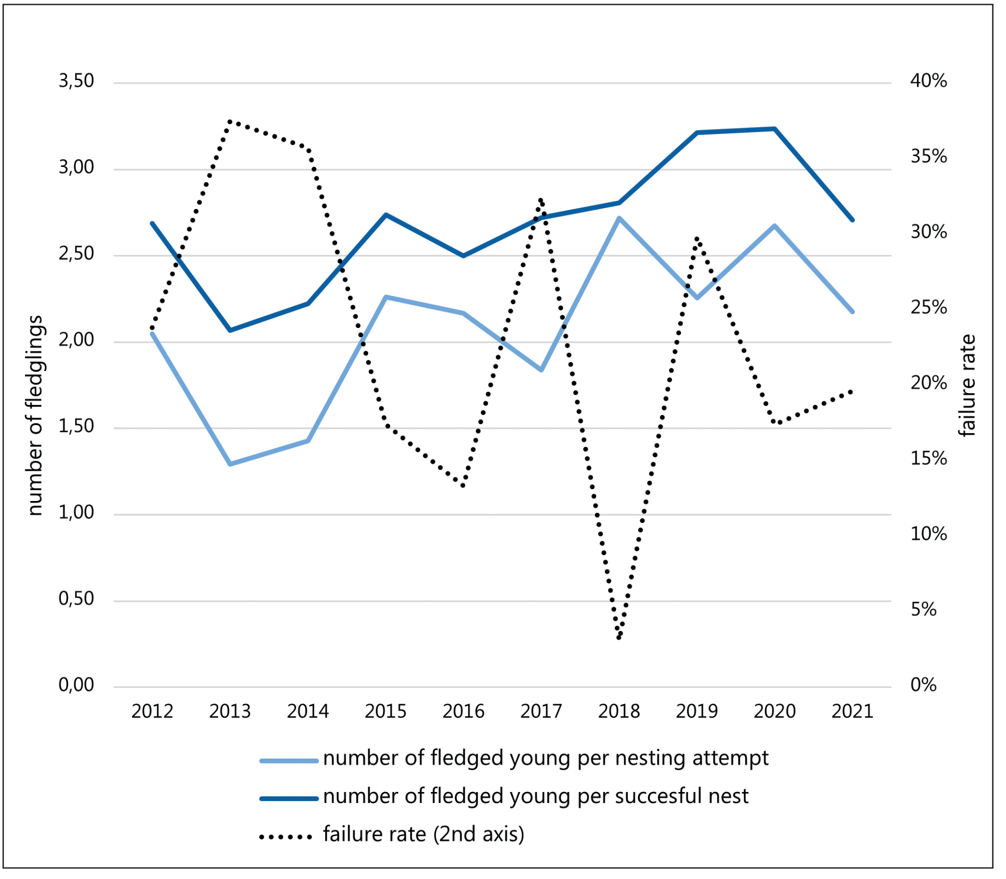


Figure 7. Temporal development of abortion rate and fledgling number of Saker Falcon in Austria (2012–2021)
7. ábra A meghiúsult költések arányának és a kirepült fiatal kerecsensólymok számának alakulása Ausztriában (2012–2021)

and mild weather (ZAMG 2022a), which obviously did not compromise the high breeding success.

The two years with lowest breeding success are 2013 (2.07 fledglings/successful nest) and 2014 (2.22 fledglings/successful nest). The weather in 2013 was characterized by relatively cold spring (March, start of April and May), as well as high precipitation in May (ZAMG 2022a), which also caused a high rate of breeding failures (more than 37% of all monitored active nests that year failed). The nearby Slovakian population was also affected by the poor weather in 2013, with a record-low breeding success of 1.79 chicks/nest (Chavko *et al.* 2014). The respective number for Austria (1.29) is also the lowest recorded in the reporting period.

In 2014, despite a warm and dry March, high precipitation was recorded all through April-July (ZAMG 2022b).

In terms of nest substrate and breeding success, it should be noted that the average breeding success of Sakers breeding on artificial nesting structures (nesting boxes or nesting platforms

Table 2. Total number of ringed Saker Falcons in Austria (2015–2021)
2. táblázat Az Ausztriában összesen gyűrűzött kerecsensólymok száma (2015–2021)

Year	All nests	Platforms	Nestboxes	Recoveries* (year in brackets)
2015	24		24	1 x Czech Republic (2015)
2016	30	9	21	1 x Poland (2016) 1 x Algeria (2017) 1 x Austria (2021)
2017	22	1	21	
2018	37	14	23	[2 x recently fledged iuv.] 1 x Austria (2018) 1 x Serbia (2018) 1 x Slovakia (2018)
2019	31	3	28	
2020	51	7	44	1 x recently fledged iuv.
2021	26	7	19	
Total	**221**	**41**	**180**	

on high-voltage power lines) of 2.86 fledglings/successful nest (2012–2021) is higher than the average success of the total Saker pairs using natural stick nests on power lines or trees (average of 2.37 fledglings/successful nest for the period 2012–2021) *(Table 1).* It should however be noted that breeding success on natural stick nests on trees (2.65 fledglings/successful nest) exceeds the breeding success of stick nests on pylons (2.16 fledglings/successful nest) and artificial platforms (2.2 fledglings/successful nest) *(Table 1)*. At the same time the combined breeding success for all three nest types (artificial nesting structure; natural nests on power lines and natural nests on trees) shows a positive trend between 2012 and 2021. When testing for different artificial nest types, both platforms and nest boxes show an increasing nesting success in recent years. However, the average number of fledged chicks per successful nest is clearly higher in nest boxes (3.09) than on platforms (2.42). Furthermore, the breeding success trend of platforms exhibits higher fluctuations than in nest boxes. We consider that further research is needed to determine the environmental factors influencing this difference.

Ringing and ring recoveries

Between 2015 and 2021, a total of 221 chicks (30.3% of all fledged young) hatched in artificial nesting structures (platforms and nesting boxes) were marked by AOC with Austrian standard ornithological rings. A total of 10 of the AOC-ringed birds (4.5%) have been recovered injured or dead in Austria or abroad *(Table 2)*.

Information about the recovery of Saker Falcons in Austria is kept separately by the Austrian Ornithological Centre, BirdLife Austria, and the Owl & Birds of Prey Rescue Station, Haringsee. These databases comprise information about a total of 14 birds found dead or injured in Austria *(Table 3)* and a total of 5 Austrian-ringed birds found abroad between 2012 and 2022 *(Table 2)*. It should be noted that there are no data entries from 2012 till 2014, while there are two data entries in 2022 alone.

The most distant recovery of an Austrian-ringed bird was reported in Algeria in 2017 of a Saker trapped for falconry. Other foreign recoveries of Austrian-ringed birds were reported in the Czech Republic in 2015, Poland in 2016 (115 days post-release and 265 km from ringing site); Central Serbia in 2018 and Trnava district and Slovakia in 2019 and 2020. The bird found in Slovakia (AUW G000327) was once found in 2019 near Opoj, Trnava injured by suggested collision with wires (70 days post-ringing and 76 km from the ringing site). A year later, in 2020, the same bird was found freshly dead from electrocution with a total of 286 days post-ringing and 89 km from ringing site *(Table 2)*.

Table 3. Inland recoveries of Saker Falcons, found on the territory of Austria in the period 2012–2022
3. táblázat Ausztriában 2012–2022 között megkerült kerecsensólymok száma

Ring origin	Total number of birds	Tagged with transmitters
AOC-ringed	4	
Hungarian-ringed	2	1
Slovakian-ringed	5	4
Non-marked	3	
Total:	**14**	**5**

Causes of death and current threats

Between 2015 and 2022 a total of 14 dead or injured Saker Falcons were found in Austria.

Our recovery data shows that the main reason for these findings is collision with man-made objects (a total of 57% of reported fatalities): wires and power line structures (36%), wind turbines (14%) and vehicles (7%); followed by territorial fights (22%), and electrocution

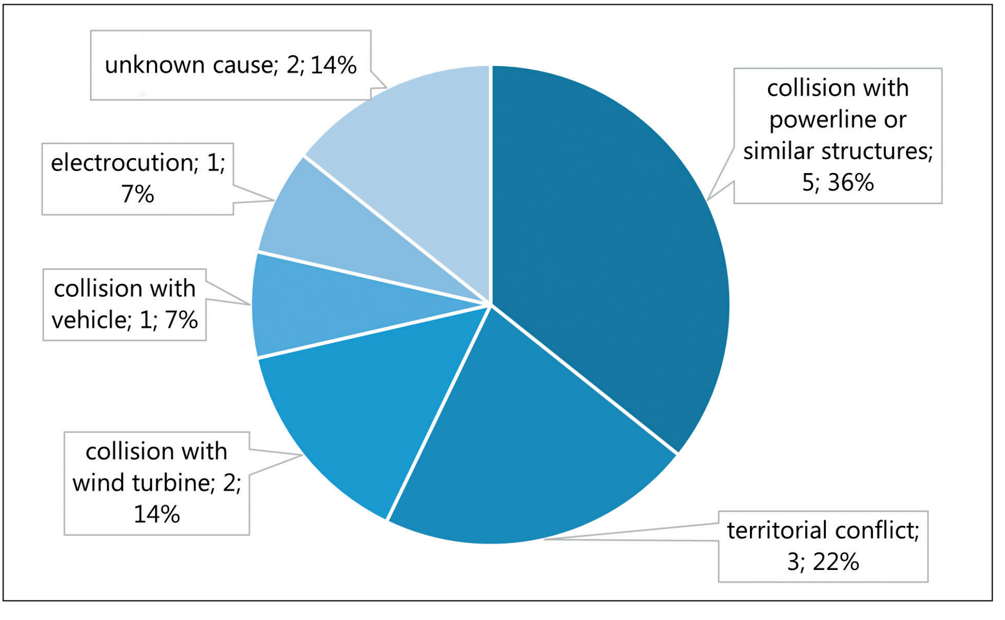


Figure 8. Reasons of injury/death of Saker Falcons found injured/dead in Austria from 2015 to 2022
8. ábra A kerecsensólyom sérülések/pusztulások okai Ausztriában 2015 és 2022 között

(7%) *(Figure 8)*. It should be noted that in 2022 alone, a total of two Saker Falcons have been irrecoverably injured by wind turbines.

Another documented threat is collision with vehicles (one confirmed case and a second possible one, excluded from the upper analysis). Two further unclear causes concern possible electrocution and botulism, while electrocution on medium-voltage power lines (< 20 KV) has been proven to be a relevant threat in many parts of the range, including the Pannonian basin (Rozsypalová *et al.* 2022).

It should be also noted that five of the dead birds recovered were carrying transmitters and the finding of the carcasses was not necessarily facilitated by the presence of the devices. In one of the cases in 2018, a collision was heard, and the bird was observed falling directly under the cable. The Saker died immediately, and the postmortem performed at VetMedUni Vienna showed an approximately six-year-old female with signs of attack from another bird, but also severe transmitter-induced trauma (subcutaneous chest muscle rupture exactly under the harness). The injuries clearly suggested direct contact between the backpack-mounted transmitter and the power line cable, which most probably happened when the bird tried to fly under the cable, yet the transmitter hit it, causing an abrupt stop and chest muscle rupture.

In addition to that, a total of 5 birds ringed in Austria have been recovered dead or injured abroad between 2015 and 2022. Main causes of finding were collision with power lines and electrocution (one case in Poland and two cases in Slovakia) and trapping and keeping for falconry (Algeria and Serbia). The bird (AUW G000267) kept in Serbia was reported as found exhausted after being harassed by Ravens and maintained in captivity (Milan Ruzic, BirdLife Serbia via Matthias Schmidt; Daliborka Stankovic, *pers. comm.*).

Other direct threats possibly affecting the species in Austria are illegal persecution and deliberately poisoned homing pigeons. Despite of the lack of recent evidence that Saker Falcons have been directly affected, findings regarding other birds of prey clearly suggest that these practices are still in place and represent a potential threat (WWF Österreich & BirdLife Österreich *in prep*.). Pesticides, especially persistent rodenticides, and lead, which have been recovered from different birds of prey in Austria in relevant concentrations, are also likely to affect the fitness and survival probability at least indirectly (Hauzenberger *et al.* 2020, Umweltbundesamt 2020).

Discussion

The population of Saker Falcon in Austria is currently the one of the very few exhibiting such a clear and stable increase in Central Europe.

The species quickly and positively responds to the provision of safe artificial nesting structures, as already confirmed in Hungary, Slovakia and the Czech Republic (Chavko 2010, Bagyura *et al.* 2012, Beran *et al*. 2012, Chavko *et al.* 2014). Considering the established correlation between the availability of supplementary nesting sites and the breeding population increase (r=0.7912), we also consider nesting site shortage as a contemporary limiting factor in Austria, which can be easily handled by targeted conservation measures. At the same time, the population trends in the countries mentioned above are either stable or decreasing, so the provision of sufficient number of safe nesting structures is obviously not the only factor determining the abundance and breeding success of Saker Falcon in Central Europe.

Looking at the average breeding success per successful nest of 2.69 fledglings for the period of 2012–2021 in Austria, the value remains lower than the most recent reports for Slovakia – 3.10 fledglings/successful breeding (2011–2014) (Chavko *et al.* 2014); Hungary – 3 chicks per nest (2014–2015) (Bagyura *et al.* 2014, 2015). It should, however, be noted that these are average values covering non-matching periods, when weather conditions, prey availability, etc. could have impacted the breeding success. Additionally, the installation of artificial nesting structures in Hungary started as early as 1991, with more consistent effort already in 2007, so that between 2009 and 2013, nearly 70% of Saker pairs already nested in artificially supplied nesting structures (Fidlóczky *et al.* 2014). In comparison, similar efforts in Austria only started in 2004, and by 2013, still less than 50% of the population occupied the aids provided *(Table 1)*. At the same time, several authors (Bagyura *et al.* 2014, 2015), similarly to us, reported a difference in the breeding success and failure rate on different nesting structures.

Considering the overall positive trend of the population in Austria, the average breeding success reported for only the past three years of our study (2019 and 2021) accounts for 3.05 fledglings/successful nest, which is comparable to the maximum values reported for Hungary, at the time where a steady increase of the Hungarian population was recorded (Bagyura *et al.* 2004, 2014, 2015).

The most recent breeding success in Austria significantly exceeds the comparable data for the Czech Republic, where only 2 chicks/successful pair were recorded between 2011 and 2018 (Škorpíková *et al.* 2019). The same authors observed a shift of the breeding pairs to Austria since 2013, suggesting that land use changes and intensive agriculture have led to a decrease in abundance of prey in the Czech Republic (Škorpíková *et al.* 2019).

We therefore consider that the breeding success of Saker Falcon in the past years in Austria is catching up with or, in some cases, is even higher than the breeding success of the species in the nearby countries.

In the case of Austria, we have provided an increasing number of safe supplementary breeding sites and apparently the prey sources are sufficient to maintain a growing population. A limiting factor gaining significance is securing the survival of the birds, especially the breeding adults, potentially threatened by the expansion of wind farm areas. Wind power use seems to be among the most important direct threats to Saker Falcons in Austria and increased conflicts are expected to emerge with the planned expansion of wind power plants in eastern Austria. In any case, the further development of wind parks should be carefully considered and coordinated with the existing breeding and hunting territories of the species.

As an additional measure to decrease mortality, considering our results as well as the evidence presented by Dixon *et al.* (2016), the potential negative effects of backpack-mounted transmitters on Saker Falcon fitness and survival should also be carefully considered.

It is particularly difficult to compare the success rate of Saker Falcon pairs in Central Europe, since the available datasets cover different time periods and there is a clear shift to nesting on artificial nesting structures, which could also impact the percentage of successful pairs. On overall, the reported values vary between 58.4% (Horák 2000) and 81.1% (Chavko 2010) with a median of 77%, which is exactly the average number of successful nests reported for Austria between 2012 and 2021 *(Table 1)*.

It should also be noted that the Austrian population is at the westernmost edge of the global distribution of the species, so there must be a factor affecting the further expansion of this highly mobile species. Climatic features might be among the factors determining the distribution or breeding success and we recommend further studies to establish the potential correlation.

When considering breeding success, we suggest that rain and lower temperatures potentially impact the chicks shortly after hatching, as well as the availability of prey and the hunting success of the adult birds, and therefore impede the provision of food, resulting in overall decrease of the breeding success and higher failure rates (such as above 35% in 2013–2014). Yet more focused research is needed to explain this potential causality.

In this sense, it becomes crucial to better study the underlying causes determining the development of Saker Falcon population in Austria, as well as to preserve the on-going positive trends, limiting potential anthropogenic threats, particularly wind farm development, poaching, collision and electrocution.

Conflict of interests

The Austrian Saker Falcon protection programme and the respective monitoring in the covered period were co-financed by the Austrian Power Grid AG, ÖBB Infrastruktur, AG Netz Niederösterreich GmbH and Netz Burgenland GmbH. However, project design, data collection and analysis were not influenced by the relevant financiers.

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