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First-time use of metal construction for mounting artificial nests on trees for Saker Falcons *(Falco cherrug)* in Bulgaria

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Abstract Artificial nests offer a promising solution to nest shortage, stemming from decreased breeding habitat for raptor populations. In Bulgaria, an area with declined raptor populations and increasing habitat loss, artificial nests offer an opportunity to re-establish breeding pairs of Saker Falcons *(Falco cherrug)*. As a part of the nonprofit Green Balkans' captive breeding and release programme for Saker Falcons, 20 artificial nests were installed in the Stara Zagora region from 2020–2021. Nests were made from a steel metal frame filled with dried sticks and vegetation and installed in old-growth trees. Each nest site was evaluated for characteristics such as habitat type and prey availability. None of the 20 artificial nests have been used by Saker Falcons yet, but they have been regularly monitored for activity since their installation. As Saker reintroduction efforts continue, ongoing monitoring of artificial nests will be essential in determining their effectiveness for future reintroduction projects. The specifications of construction and placement of artificial nests in this project can be used to inform other raptor reintroduction projects, considering location differences and individual species needs.

Keywords: raptors, birds of prey, conservation, reintroduction, biodiversity

Összefoglalás A mesterséges fészkek ígéretes megoldást kínálnak a ragadozómadarak élőhelyeinek zsugorodásából fakadó fészekhiány problémájára. Bulgáriában, ahol a ragadozómadár-állományok csökkennek, és egyre erőteljesebb az élőhelyvesztés, a mesterséges fészkek esélyt adnak a kerecsensólyom-párok újbóli megtelepítésére. A Green Balkans nonprofit szervezet tenyésztési és visszatelepítési programjának részeként 2020 és 2021 között 20 mesterséges fészek került kihelyezésre a Stara Zagora régióban. A fészkeket acélkeretből építették, amelyet száraz ágakkal és növényzettel töltöttek meg, és idős fákra helyeztek ki. Minden fészkelőhely értékelésre került olyan jellemzők alapján, mint az élőhely típusa és a zsákmányállatok elérhetősége. A 20 mesterséges fészek egyikét sem használta még kerecsensólyom, de kihelyezésük óta rendszeresen ellenőrzik a körülöttük zajló aktivitást. Ahogy halad előre a kerecsensólymok visszatelepítése, a mesterséges fészkek folyamatos monitorozása elengedhetetlen lesz a projektek hatékonyságának meghatározásához. A mesterséges fészkek ezen projektben alkalmazott konstrukciós megoldásai és a fészkek kihelyezésének jellemzői más ragadozómadarak visszatelepítési projektjeiben is hasznosak lehetnek, figyelembe véve a helyi különbségeket és az egyes fajok egyedi igényeit.

Kulcsszavak: ragadozómadarak, természetvédelem, visszatelepítés, biodiverzitás

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Introduction

Since the 19th century, raptor populations across Europe have declined, largely due to negative human-based interactions (Stroud 2003). Human impacts surrounding land-use changes present a major issue for raptors. Stroud (2003) found that 27 of the 29 most vulnerable European diurnal raptor species are adversely affected by habitat changes, often due to agricultural intensification. While habitat loss is likely to have a negative effect on any part of a population, land-use changes are particularly impactful on breeding populations of raptors. Tapia and Zuberogoitia (2018) note that raptor populations are highly constrained by available breeding habitat. Each species has unique specifications for the size, height, orientation, and overall location of a nest, and shortages of nest sites can limit the density of a species (Tapia & Zuberogoitia 2018). As habitat loss continues to negatively impact raptor populations across Europe (BirdLife International 2021), adequate raptor nest sites are also likely to decrease. In areas where nest sites are limited, the installation of artificial nests offers promise for retaining or increasing raptor populations. These human-made nests vary in construction depending on location and focus species, from placing nests on metal poles versus in trees (Björklund *et al.* 2013) to using flat platforms versus boxes (Dixon *et al.* 2008). Across Europe, artificial nests in various environments for various species have been shown to be an effective method for increasing breeding populations (Ivanovski 2000, Bakka *et al.* 2020). Not only do artificial nests provide space for breeding birds, but they may also provide areas away from electricity poles and other unsuitable nesting locations (Ragyov *et al.* 2012), pending a full analysis of selected nesting location safety (Björklund *et al.* 2013).

The variations in artificial nest construction and placement across regions and species exemplify the required specificity of artificial nest use to an individual raptor conservation project. Up to this point, there has been no published information on artificial nest use for Saker Falcons *(Falco cherrug)* in Bulgaria despite ongoing conservation efforts (Lazarova 2021). To avoid reliance on meta-analyses from across Europe and Asia, individual case studies of Saker Falcons and their artificial nest use are necessary in strengthening reintroduction biology (Armstrong *et al.* 2008). Another notable gap of information exists surrounding the specifications of artificial nests, notably in details on construction and design (Lambrechts *et al.* 2011). The remainder of this paper focuses heavily on artificial nest use by Saker Falcons in Bulgaria to act as a case study, sharing details on the species' conservation status, the construction and installation of artificial nests for Saker Falcon use in Bulgaria, and the monitoring of these nests as a part of Saker Falcon reintroduction.

The IUCN currently lists the Saker Falcon as an endangered species (BirdLife International 2017). During the 20th century, heavy pesticide use, nest robbing, hunting, poisoning, and land-use changes due to agricultural intensification led to the loss of Saker Falcons as a breeding species in Bulgaria (Ragyov *et al.* 2014). Even today, habitat loss from agricultural intensification, fuelled by Bulgaria's accession into the EU, continues to cause declines in bird populations (Spasov *et al.* 2017). The effort to reintroduce Saker Falcons to Bulgaria is a multistep process. In 2015, the nonprofit Green Balkans began a breed-and-release programme to try and establish a breeding population of Saker Falcons in the country. As of

2023, two confirmed breeding pairs formed of birds from the reintroduction programme are living in the wild in Bulgaria.

An important component of Green Balkans' reintroduction effort is the use of adaptation aviaries called hacks. Between 2015–2023, 143 Saker Falcons were released near Stara Zagora using the hacking method, and 160 were released in total in Bulgaria from 2011–2023. Saker Falcon chicks hatched at the Green Balkans Wildlife Rehabilitation and Breeding Centre were moved to closed hacks at around 30 days old (Petrov *et al.* 2021). After 10 days, the lids of the hacks were opened, and the chicks were able to independently move in and out of the nest. Food was provided in the hacks and on nearby feeding tables. The longer fledglings stayed in the area, the more likely they were to survive into adulthood (Lazarova 2021) – one and a half month being the average estimated post-fledging dependence period (PFDP) for Saker Falcons (Prommer *et al.* 2012). Juvenile Saker Falcons often disperse from the area after the PFDP but will return to breeding territories in early spring (CITES 2008). Helping Saker Falcons establish a territory with a reliable food source at a young age through the hacking method can encourage them to return to the area when they reach breeding age.

Even with having successfully released Saker Falcons, a lack of enough available nests for breeding pairs poses another challenge. Saker Falcons do not build their own nests. Instead, they use nests made by other large birds or raptors (Rahman *et al*. 2014) – (Common Raven *Corvus corax*, Long-legged Buzzard *Buteo rufinus*, Eastern Imperial Eagle *Aquila heliaca*, Common Buzzard *Buteo buteo*, Hooded Crow *Corvus cornix*). Because of a decline in overall raptor populations over the last century (Stroud 2003, Donázar *et al.* 2016), fewer nests are available. Furthermore, many of the old-growth trees in which these raptors would build nests have since been removed because of agricultural intensification (Spasov *et al.* 2017), leaving only cliff edges which may not be abundant in habitats with the most optimal food base.

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). As part of a 5-year project that began in 2020, Green Balkans is continuing its Saker Falcon reintroduction efforts, which include installing artificial nests based on international experience. Their goal is to install 80 nests in the Stara Zagora, Yambol and Sliven regions by 2025. Funding for 20 nests is from the Mohamed bin Zayed Raptor Conservation Fund (United Arab Emirates) and Armeec JSC (Bulgaria), and funding for the next 60 is from the LIFE for Falcons project LIFE20 NAT/BG/001162. Research by Palma *et al.* (2019) offers evidence that installing artificial nests in combination with species reintroduction through captive-breeding can increase reintroduction success. The aim of this article is to report the part of preparation process for the reintroduction of Saker Falcon in Bulgaria, where appropriate nest sites are constructed for future breeding pairs. The study provides details about the technical parameters of artificial nests and describes the considerations towards their instalment in potential Saker Falcon breeding areas.

Materials and Methods

Artificial nest construction

Between 2020 and 2021, 20 artificial nests were built *(Table 1)*. Each nest was constructed of a 10-sided steel frame that was filled with vegetation. Steel was used as it was easily accessible, relatively lightweight, and would likely last longer than wood, a material used in previous artificial nests built by Green Balkans. The measurements shown in *Figure 1* are based on a single nest frame but are representative of a typical artificial nest. The exact measurements of each nest vary, similar to natural, bird-built nests. Nests were made with steel mesh bottoms that could hold nesting material while allowing for water drainage. Colours of the frame were chosen based on what was likely to blend in with the nest's surroundings once installed (typically brown, green or grey). Dried vines were woven between the rods along the sides of the nests. Once placed in a tree, material was added into the nest, starting with a layer of small sticks (approximately 1 cm in diameter and 0.3 m in length). Each layer used increasingly smaller sticks, followed by dried leaves. Material from walnut trees *(Juglans regia)* was ideal for nesting material due to its antimicrobial properties (Vieira *et al.* 2019). As walnut is a protected species in Bulgaria, it was only used for nesting material if trees were legally felled.

Table 1. Specifics about the installed nesting platforms
1. táblázat A kihelyezett fészektálcák paraméterei

	Nests (*n*)
Region	
10 km from hack site	10
30–60 km from hack site	10
Tree species	
Field elm *(Ulmus minor)*	1
Black poplar *(Populus nigra)*	11
English oak *(Quercus robur)*	8
Nest height	
10–16 m	10
17–23 m	10
Nesting material	
Dried ivy *(Hedera helix)*	20
Grapevines *(Vitis vinifera)*	20
Old man's beard *(Clematis vitalba)*	20
Poplar *(Populus nigra)* twigs and leaves	20
Mulberry *(Morus alba)* twigs and leaves	20

Placing artificial nests

Nest locations were chosen primarily based on tree availability and surrounding habitat, followed by vehicle accessibility. Choosing sites accessible by car (namely farm and orchard dirt roads) allowed for materials to be brought in when installing nests and will increase the ease of future monitoring. Nests were installed approximately 5 km apart, with some nests being 1 km apart based on tree availability. Trees were selected based on their height, overall health, and species. Nests were placed as high as possible, dependent on the branches' ability to support the weight of the nest. Habitat surrounding the trees was

also assessed. When available, areas near grazed pastures were chosen as suslisks are often found in these habitats. Suslisks make up the largest part of Saker Falcon diets (Watson & Clarke 2000). Chosen nest sites were adjacent to agricultural land, as this is a common land use in the study area. Crops in these fields included rice *(Oryza sativa)*, sunflowers *(Helianthus annuus)*, wheat *(Triticum)*, rapeseed *(Brassica napus)*, barley *(Hordeum vulgare)*, and orchards of cherries *(Prunus avium)*, apricots *(Prunus armeniaca)*, peaches *(Prunus persica)*, and blue plums *(Prunus domestica)*. Vegetative buffers separate crop fields. The available habitat indicated other prey species of small rodents and birds could be found in these areas (Watson & Clarke 2000). To provide any nesting Saker Falcons with a view of the surrounding habitat, single standing trees or trees at the edge of tree stands and fields were chosen.

Nest installation took place in late fall and early spring when trees were bare and easier to climb. The period when crops were more than 10 cm tall was avoided. Once a site and a tree was selected, a rope was used to lift the nest and nesting materials into the tree. Two triangular metal supports were screwed into the tree trunk. The artificial nest was placed on top of these supports and screwed down. If tree branches were positioned in a way that provided adequate support, only one or no metal support was used. Once secured to the tree, nesting material was added. As a final step, calcium oxide was added in the nest to imitate bird droppings. Doing so was meant to indicate that the nest was previously used, implying the existence of a food source and safe location.

Saker Falcons courtship starts in mid-February and egg laying is in early March (The Peregrine Fund 2021). Artificial nests

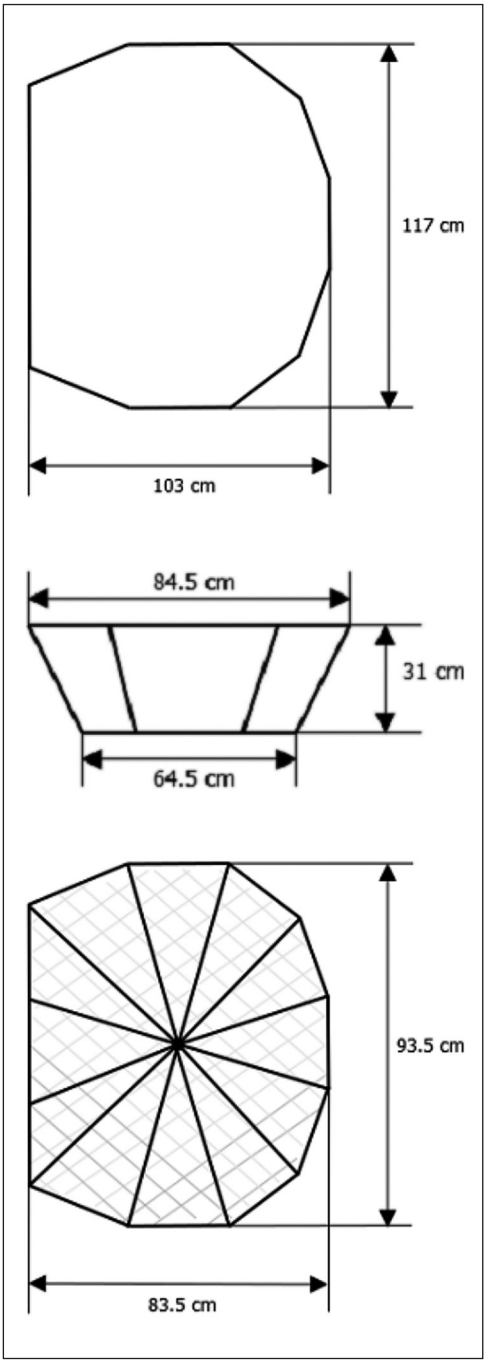

Figure 1 Upper, side, and the bottom view of an artificial nest

1. ábra A mesterséges fészek felül-, oldal- és alulnézete

are visited a minimum of twice a month in February, March, and April to look for breeding pairs. If Saker Falcons begin using a nest, monitoring will be extended into May and June, when chicks would occupy the nest (The Peregrine Fund 2021).

Results and Discussion

Although the Saker Falcon was historically reported as common, the breeding population in Bulgaria became extinct in the late 1990s (Ragyov *et al.* 2014). The Bulgarian population was part of the Eastern European population and had no direct connection to the Central European population, even though satellite-tracked Central European Saker Falcons regularly visit the region (Prommer *et al.* 2025). Given the long-standing decline of the Eastern European population (Ajder *et al.* 2025, Fântânâ *et al.* 2025, Prommer *et al.* 2025), natural recolonisation from that population was not expected. Recognising this, Green Balkans launched a captive-breeding and release programme in 2015. Since falcons do not build nests and suitable nesting sites near high-quality foraging areas are limited, it was essential to include the construction and installation of artificial nests in the programme.

As of December 2023, none of the 20 artificial nests installed near Stara Zagora were used by Saker Falcons. Field experts have observed unconfirmed nesting by Common Buzzards and Common Kestrels *(Falco tinnunculus)* in a number of the nests. The lack of use by Saker Falcons was expected, as the installation of these nests was a proactive portion of the latest stage of reintroduction that began in 2020. In 2020, 12 Saker Falcons were released using hacks in the study area, in 2021 – 17, in 2022 – 25, and in 2023 – 19. Saker Falcons reach sexual maturity after 2–3 years (CITES 2008), before which they may migrate throughout Eastern Europe, Asia, and Northern Africa (Prommer *et al.* 2012). As artificial nests were present when Saker Falcons were released in 2020–2023, they may be more willing to return to the area in which they know there are viable nests and available food sources. However, juvenile mortality is high for Saker Falcons (Ragyov *et al.* 2009, Kovács *et al.* 2014), thus many birds are needed to be released to account for the natural losses and for a local population to form, which would potentially utilise the nests. As installing artificial nests is a preliminary step in establishing breeding pairs of Saker Falcons in Bulgaria, the weight of determining reintroduction success is on future monitoring. So far, monitoring of the first installed nests – from 2020, revealed that more nesting material should be added when installing nests, as some of the material was displaced over the two winters.

Observing the lifespan of the nest frames will also be important, as Green Balkans has not previously used metal in artificial nest construction. Analyses in Spain found that raptor-built nesting platforms lasted an average of 12 years, depending on use and location (Jiménez-Franco *et al.* 2014). Previous attempts by Green Balkans to install artificial nests for other species indicated that wooden frames and platforms would last approximately 3 years. This short lifespan was attributed to rot from exposure to water and weather. Other attempts at building artificial nests for raptors have also found wooden platforms have a short lifespan, and saw more success using a metal construction (Fidlóczky *et al.* 2014). Specific to Saker Falcons, metal artificial nests are promising for encouraging use (Iankov &

Gradinarov 2012). Wanting a longer lifespan was a major factor in choosing to use metal for the frame construction in this project. It is estimated the metal nests will last 20–25 years. Green Balkans plans to install a total of 80 artificial nests in the 60 km radius of the Saker Falcon release site by 2025. After mounting the first 20, however, noted was the lack of tree availability, resulting in considerations of placing nest boxes on electricity pylons instead, in the same area, similarly to the ones placed as part of LIFE project *Falco cherrug* B-H-R-S LIFE09 NAT/HU/000384 (Chavko *et al.* 2014, Fidlóczky *et al.* 2014).

Finally, monitoring of artificial nest use will be important in estimating Saker Falcon populations. The current 5-year reintroduction plan estimates that 6 breeding pairs will form in Bulgaria by 2026, which would create the basis of a self-sustaining population and indicate reintroduction success (Lazarova *et al.* 2021). This population model is based solely on released chicks, meaning adequate available breeding territories with nests are necessary to maintain breeding pairs. Artificial nest use has been shown to have a positive impact on Saker Falcon breeding populations in surrounding countries (Rahman *et al.* 2014). Yet, individual site considerations remain critical to establishing the efficacy of artificial nests (Björklund *et al.* 2014). Continued monitoring of the artificial nests near Stara Zagora, as well as any natural nests, will be essential for determining reintroduction success of Saker Falcons in Bulgaria.

The details laid out in this paper can be used to inform tactics around artificial nests in future reintroduction projects both for Saker Falcons and for other species. While it is important to avoid reliance on meta-analyses (Armstrong *et al.* 2008), details from this project may be useful in determining construction, placement, and monitoring specifications for artificial nest use and captive-breeding-based reintroduction. Similarities between threats to Saker Falcons and other raptors across Europe suggest the transferability of the methods in this paper to other projects if possible. For example, habitat loss due to agricultural intensification is a problem across Europe, and specifically in Bulgaria (Spasov *et al.* 2017). A decrease in habitat leads to a loss of available nest sites for many raptors (Tapia & Zuberogoitia 2018), indicating a need for habitat restoration and nest creation. Another promising indicator for transferability stems from the fact that many of the studies concerning artificial nests referenced in this paper based their construction and placement of nests on research that differed in species focus or region (Ivanovski 2000, Björklund *et al.* 2013, Bakka *et al.* 2020). The success, and therefore reproducibility and transferability, of the materials and methods used in Bulgaria's Saker Falcon reintroduction project will become more apparent with continued monitoring.

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