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Reintroduced Saker Falcons (Falco cherrug Gray, 1834) are dependent on European ground squirrels during the breeding period in Bulgaria

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Abstract. This study examines the diet of the reintroduced Saker Falcon (*Falco cherrug*) population in Bulgaria. By combining food-remain analysis, visual observations, and camera-trap monitoring, we documented 144 prey items taken by Saker Falcons during the 2020, 2024, and 2025 breeding seasons. The analysis revealed a pronounced dietary specialization: the European ground squirrel (*Spermophilus citellus*) was the overwhelmingly dominant prey, representing 80.56% of all identified occurrences (N=144). Other rodent species accounted for 8.3% of the food items and birds represented 10.42% of the food items. The pronounced dependence on *S. citellus* underscores its essential role in the diet of the falcons. Consequently, conservation efforts should prioritize the protection and restoration of pasture systems, and the recovery of declining ground squirrel populations.

Key words: reintroduction, birds, diet, ground squirrel, pastures.

Introduction

The Saker Falcon (*Falco cherrug* Gray, 1834) is a raptor of open grasslands, steppes, and semi-desert areas, typically occupying areas with scattered trees or cliffs (BirdLife International, 2023). This species does not construct its own nest but instead usually occupies old stick nests built either on cliffs on trees by other large birds such as ravens, buzzards, or eagles (Ferguson-Lees & Christie, 2001). In recent years, artificial nest boxes installed on powerlines have proven highly attractive to Saker Falcons, which readily and consistently occupy them as preferred breeding sites (Chavko et al., 2014; Bagyura et al., 2025; Prommer et al., 2025; Puzovic, 2025). Unlike the Peregrine Falcon (*Falco peregrinus* Tunstall, 1771), which typically captures prey in a high-speed stoop, the Saker Falcon hunts mainly through low-level pursuit flight (Dixon et al., 2017). Its diet consists primarily of small mammals and birds; in Central

Europe, ground squirrels (*Spermophilus citellus* Linnaeus, 1766) and feral pigeons (*Columba livia* f. *domestica* Gmelin, 1789) are among the most frequent prey species (BirdLife International, 2023; Chavko et al., 2019; Bagyura et al., 2025). However, due to ground squirrels' population declines, their share in the diet dramatically declined in the last 25 years (Bagyura et al., 2025).

According to the IUCN Red List, the Saker Falcon is listed as Endangered due to rapid population declines, especially in Central Asia (BirdLife International, 2023). The main threats include illegal trapping for the falconry trade, particularly for markets in the Middle East, as well as habitat loss and degradation of steppe ecosystems. In Europe, its population is fragmented - stable and well-protected populations persist only in parts of Central Europe, particularly in Hungary, where successful conservation programmes have been established (Bagyura et al., 2025; Gál et al., 2018).

In Bulgaria, the population of the Saker Falcon experienced a dramatic decline during the 20th century due to poisoning, direct persecution, nest robbery and habitat loss (Iankov et al., 2013). By the 2000s, only a few breeding pairs remained, with the last well-documented successful breeding recorded in 1997 (Ragyov et al., 2014). In response to this decline, a reintroduction programme using captive-bred Saker Falcons began in 2011, with pilot releases followed by a full-scale programme starting in 2015 (Dixon et al., 2020; Lazarova et al., 2021). Conservation efforts included captive breeding at the Wildlife Rehabilitation and Breeding Centre of Green Balkans NGO, release of the breeding pairs' offspring via hacking, installation of artificial nests and nest boxes to encourage breeding in the wild (Petrov et al., 2025), and threat management such as insulating dangerous powerlines (Ragyov et al., 2012). These conservation actions have culminated in the recovery of wild breeding in Bulgaria, evidenced by the first successful fledging of young in 2018 and an increasing number of breeding attempts documented thereafter (Arkumarev et al., 2025).

Understanding the diet of the newly established Saker Falcon population in Bulgaria is essential for effective conservation planning. Given that prey type and availability strongly influences the species' breeding success (Bühler et al., 2024) and moving patterns (Batbayar et al., 2024), but also survival (Amar et al. 2012), it is crucial to identify and protect the critical prey species and their habitats. Such efforts are fundamental for ensuring the long-term viability and stability of the Saker Falcon population in the country.

Materials and methods

The survey was carried out during 2020, 2024 and 2025 in the known nesting sites of Saker Falcons in the Balkan Mountain in Bulgaria. To obtain a more comprehensive overview of the species' diet, we used three data-collection methods: (1) collection of food remains, (2) camera trap monitoring, and (3) direct observations of prey deliveries. In total, 69 prey items were identified across all methods combined.

Collection of food remains

Food remains (pellets, bones, feathers) were collected from occupied Saker Falcon nests after the end of the breeding season. Samples were obtained from three nests: one nest sampled in 2020, three nest sampled in 2024, and one nest sampled in 2025. The nests were accessed using climbing equipment, and all material was collected both from within the nest and from the ground below. Prey items were later identified to the highest possible taxonomic level.

Camera trap monitoring

In 2024 and 2025, camera traps were installed at two active nests to document prey deliveries throughout the breeding season. Unfortunately, due to technical failure the cameras recorded only four days of data in 2024 and two days in 2025. Images were reviewed, and all identifiable prey items brought to the nest were recorded.

Direct observations of prey deliveries

In 2025, direct observations were undertaken at one nest during the chick-rearing period to record prey deliveries. Field observations were conducted over 14 days, distributed across the entire chick-rearing period. Each observation day consisted on average of 6 hours 29 min ± 2 hours 13 min of monitoring between 07:00 and 18:00, and only days with favourable weather and adequate visibility were selected. All prey items delivered to the nest were identified to the highest possible taxonomic level.

The frequency of occurrence was calculated for each prey taxon.

Results and Discussion

The analysis of food remains and prey deliveries (N=144) collected from reintroduced Saker Falcons in their breeding areas in Bulgaria revealed the species composition and frequency of occurrence of their prey. Direct observations documented 58 prey deliveries, camera-trap monitoring recorded an additional 17 deliveries, and 69 prey items were identified from food remains collected in or near the nests. The results are summarized in Table 1.

The diet composition clearly indicated that the breeding Saker Falcons in Bulgaria rely predominantly on mammals, with small rodents comprising 88.9% of all identified prey items, while birds accounted for 10.4% and reptiles for 0.69%.

The most frequently occurring prey species was the European Ground Squirrel (*S. citellus*), which accounted for an overwhelming majority of the diet with 116 occurrences, representing 80.56% of the total identified individuals. This finding aligns with established knowledge that ground squirrels are a key prey item for the Saker Falcon in European steppes (BirdLife International, 2023). The high frequency of *S. citellus* in the diet suggests that the nesting sites provide adequate populations of this critical food source, which is essential for the breeding success (Bold et al., 2025) and establishment of the species.

The frequency of other identified mammals was low, including *Mus* sp. (0.69%), *Apodemus* sp. (0.69%), *Microtus* sp. (1.39%), and *Glis glis* (0.69%). Unidentified rodents contributed an additional 7 occurrences (4.86%), further confirming the high preference of this group.

Birds represented a secondary prey category. Feral pigeons (*Columba livia* f. *domestica*) were the most significant avian prey, found in 6 occurrences (4.17%). Other bird species recorded in the diet were *Sturnus vulgaris* (1.39%), *Pica pica* (0.69%), *Cuculus canorus* (0.69%), *Turdus merula* (0.69%), and *Turdus visvicorus* (0.69%).

Only one occurrence of a large lizard, *Lacerta* sp. (0.69%), was recorded, indicating that reptiles are an opportunistic or negligible component of the diet in this specific area and period.

Table 1. Diet composition of breeding Saker Falcons in Bulgaria.

Prey Species	N (Number of occurences)	%F (Frequency of occurrence)
Lacerta sp.	1	0.69
Columba livia forma domestica	6	4.17
Cuculus canorus	1	0.69
Sturnus vulgaris	2	1.39
Turdus merula	1	0.69
Turdus viscivorus	1	0.69
Pica pica	1	0.69
Mus sp.	1	0.69
Apodemus sp.	1	0.69
Microtus sp.	2	1.39
Glis glis	1	0.69
Spermophilus citellus	116	80.56
Unidentified rodents	7	4.86
Unidentified birds	3	2.08
Total Identified Occurrences	144	

Our results are consistent with the findings of Daskalova et al. (2024), who described the diet of the first documented Saker Falcon breeding pair in Bulgaria in the 21st century based on direct observations. Our results indicate that the reintroduced falcons have successfully adopted the typical foraging strategy of the species, concentrating on abundant and energetically efficient small mammals as main source of food. The relatively low frequency of birds, particularly compared to ground squirrels, distinguishes this reintroduced population's diet from some other European populations where pigeons and other rodents are more dominant, especially in regions with depleted ground squirrel populations (Kovács et al., 2014; Gál et al., 2018; Škorpíková et al., 2019; Puzovic 2025).

The pronounced reliance of Saker Falcons on *S. citellus* highlights the reintroduced population's vulnerability to fluctuations in its abundance. Our findings represent a key ecological insight with direct implications for future reintroduction and conservation planning in the country. This predator–prey relationship highlights two priority considerations for ongoing management:

- ***Ensuring the preservation and restoration of open habitats and pastures***. Because *S. citellus* depends on open grasslands with short vegetation, the long-term recovery of the Saker Falcon in Bulgaria is linked with the maintenance of the grassland habitats. Conservation measures should therefore focus on sustaining traditional grazing practices, preventing scrub encroachment, limiting agricultural intensification, and protecting remaining open grassland areas from land-use changes.
- ***Implementing targeted studies on ground squirrel populations in southern Bulgaria***. The current abundance, and demographic status of *S. citellus* colonies in the region inhabited by the Saker Falcons are insufficiently documented. Comprehensive field surveys are required to assess colony viability and habitat conditions. Such data will inform conservation actions essential for stabilising this threatened prey species.

The observed diet composition also has important implications for the management of human–raptor conflict. As mentioned above, in several European countries where ground squirrel populations have collapsed, Saker Falcons have shifted their diet towards birds and especially feral pigeons (Chavko et al., 2014; Bagyura et al., 2025). This shift frequently brings them into conflict with pigeon fanciers, who in some cases in retaliation employ illegal lethal methods, including persecution and poisoning (Kettel et al., 2021; Stamenov et al., 2025). In Bulgaria, the current preference for *S. citellus* is therefore favourable from a conservation perspective, as it reduces the conflict with pigeon keepers. To minimise future risks, conservation strategies should prioritise (1) maintaining optimal habitats and stable small-rodent populations to prevent dietary shifts toward domestic pigeons, (2) ensuring collaboration with pigeon fanciers to develop and implement non-lethal mitigation approaches (Stamenov et al., 2025) and (3) encouraging biological rodent control (see Ronnen et al. (2025) and references therein), translocation with subsequent low cost reintroduction/restocking (especially for European ground squirrel) and ban on the use of anticoagulant rodenticides in key areas for endangered raptors, that are reliant on small rodents.

Analyses of pellets and other remains are a common, non-invasive method for determining the diet of birds of prey. However, they may over- or underestimate the occurrence of certain species (Simmons et al., 1991), as has been the case with the failure to detect Arctic ground squirrel (*Urocitellus parryii*) as the most used prey in the diet of Gyrfalcons (*Falco rusticolus*) (Robinson, 2017). Additionally, a substantial proportion of prey items recovered from pellets and remains may be unidentifiable, limiting the accuracy of dietary assessments (Bakaloudis et al., 2012). On the other hand, direct observations can have the downside of providing an incomplete picture of the diet of birds due to the subjectivity involved in nest selection - limited by accessibility, and in the recognition of prey items (Bakaloudis et al., 2012). Camera traps provide continuous visual data without the need for human presence but are subject to technical failures such as battery depletion or malfunctions, potentially leading to data gaps (García-Salgado et al., 2015), but may also cause disturbance to the studied animals (Meek et al., 2014; López-López, 2022).

Conclusions

Although our study is based on a small number of nests and a relatively limited sample of prey remains, it encompasses the entire current breeding population of the Saker Falcon in Bulgaria (three breeding pairs), and the results can therefore be considered representative. Additionally, all these methods provide limited information on the prey consumed by the birds away from the nest and during the non-breeding period when diet composition may differ substantially.

Therefore, a combined approach using multiple methods is recommended for future studies, in order to achieve the most accurate and least biased assessment of the Saker Falcon's diet throughout the year. A behavioral study on the foraging ecology of territorial birds in the non-breeding season is also needed to identify how the primary share of hibernating ground squirrels is substituted during winter (Bagyura et al., 2004). This comprehensive strategy will greatly support

ongoing conservation efforts aimed at establishing a stable Saker Falcon population in Bulgaria and conservation of the key habitats for the species.

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