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Can photography be employed to analyze the diet of the Lesser Kestrel (Falco naumanni Fleischere 1818)?

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Abstract. Understanding the dietary composition of the Lesser Kestrel (*Falco naumanni*) is crucial for effective conservation, particularly in regions such as Bulgaria, where the species has recently been reintroduced. This study examines the feasibility of photography and videography as non-invasive methods for dietary analysis of this small colonial falcon. A total of 275 photographs and videos depicting feeding behavior were reviewed, 85 from Bulgaria and 190 from Türkiye. Prey items were identified and classified into major taxonomic categories. In both countries, insects dominated the diet (44.71% in Bulgaria, 52.11% in Türkiye), with Orthoptera being the most frequently consumed group (>90% of insect prey). Additional prey included small mammals, reptiles, millipedes, and birds, with notable regional differences in their proportions. The findings closely align with previous indirect studies (e.g., pellet analysis), validating the effectiveness of photographic methods. The study demonstrates that photography represents a valuable complementary tool for studying the diet of Lesser Kestrels, offering minimal disturbance and potential for citizen science applications. This approach enables large-scale data collection and supports long-term ecological monitoring and conservation management of the Lesser Kestrel in Bulgaria.

Key words: prey, Lesser Kestrel, non-invasive method, Bulgaria, Türkiye.

Introduction

Understanding the diet of birds of prey plays a key role in revealing their ecological requirements, behavioral adaptation, and supports effective conservation and population management strategies (Bakaloudis, 2009, 2010; Marti et al., 2007; Newton, 1979). The diet of a species can vary between sexes and different age groups, having a large effect on their populations (Newton, 1998). There are various methods for studying the feeding habits of raptors, each with its own advantages and disadvantages. Researchers frequently compare indirect techniques with direct observations to assess their reliability and to determine the most suitable approach for diet studies (Bakaloudis et al., 2012; Kostonas et al., 2017; Margalida et al., 2007; Real, 1996; Redpath et al., 2001; Sanchez et al., 2008; Selas et al., 2007). Traditional methods for analyzing birds of prey's diet – such as pellet dissection, stomach content analysis, and direct observations – provide valuable data but may be invasive, time-consuming, or disruptive to the studied species (Marti et al., 2007). These indirect methods have the disadvantage of underestimating the daily frequency of catch and feeding and inaccurately assessing the feeding of

chicks in the nest (Sanchez et al., 2008). Visual and video-based methods are widely regarded as robust and objective tools for quantifying feeding behavior, particularly in studies of nestling provisioning (Bakaloudis & Vlachos, 2011; Marti et al., 2007). Nest cameras have successfully identified prey deliveries in other raptors (Margalida et al., 2005). Photography has emerged as a non-invasive alternative, enabling researchers to document feeding behaviors with minimal interference (Biggs et al., 2025). Nevertheless, limitations exist: prey may be obscured, and lighting conditions can hinder identification (Kruger, 2002).

The Lesser Kestrel (*Falco naumanni* Fleischere 1818) is a small, colonial falcon with a peculiar conservation history (Simeonov et al., 1990). This migratory species prefers mainly steppe habitats (Catry et al., 2011; Cramp & Simmons, 1997; Negro, 1997; Rodriguez et al., 2009; Rodrigues et al., 2011). Before the mid-20th century, the Lesser Kestrel was recorded as a widespread and abundant raptor across Europe (Bijleveld, 1974). Probably due to intensive agriculture, a significant decline in the European population of this kestrel has been reported in recent decades (Tella et al., 1998; Birdlife International, 2004).

In Bulgaria, the Lesser Kestrel declined from being described as 'breeding everywhere' (Radakoff, 1879) to having no confirmed breeding between 2000 and 2010, and is currently listed in the Red Data Book of Bulgaria as a critically endangered species (Barov et al., 2007, 2011). A breeding population was rein-troduced in Bulgaria in 2014 through a conserva-tion project implemented by the Green Balkans Federation (Gradev et al., 2016). By 2021, at least 3 breeding colonies of this species have been recor-ded in the country (Gradev et al., 2021). The Lesser Kestrel's population in Türkiye is the second lar-gest in Europe with between 5,000 and 7,000 breeding pairs, but in recent years the species has been declining there as well (Iñigo & Barov, 2010; Kmetova et al., 2020).

Numerous studies describe the Lesser Kestrel as a predominantly insectivorous bird. Its diet includes taxa of insects, some millipedes, and, much less frequently, reptiles, birds, and small mammals (Anderson et al., 1999; Avci 2018; Khaleghizadeh & Javidkar, 2010; Kok et al., 2000; Kopij & Liven-Schulman, 2012; Krištín et al., 2020; Selçuk et al., 2021). The recent study (Berlusconi et al., 2025), corroborates that the Lesser Kestrel is primarily insectivorous, preying on voles only opportunistically, depending on local prey availability. Its diet reflects ecosystem health and agricultural impacts, making it a key species for ecological monitoring. However, direct observations of prey capture are challenging due to the bird's rapid hunting tactics and wide foraging areas (Tella et al., 1998).

Only a few studies have examined the diet of the Lesser Kestrel in Bulgaria, and these have relied exclusively on pellet analysis (Gradev et al., 2023; Mihtieva, 2015). The current study was motivated by the fact that until now, information on the food of the Lesser Kestrel in Bulgaria has been collected only through indirect methods. By comparing the data obtained with direct methods with those obtained through pellet analysis, it will be possible to verify the reliability of photographic and video observations for future large-scale studies of the trophic niche of this species.

Materials and methods

Over 1,000 photos and videos from specialized birdwatching and photography sites were reviewed to select only photos of Lesser Kestrels with food, taken in Bulgaria and Türkiye (www.birdsinbulgaria.org/; www.birdpx.com; www.create.vista.com; www.depositephotos; www.ebirds; www.natureinstock; www.rawbirds; www.trakus.org, etc.),. Photos from the Green Balkans Federation's archive were also used, as well as information from the video surveillance system installed in one of the species' colonies in Bulgaria (Stamova et al., 2017). All photos and videos were carefully reviewed to avoid duplication and subsequently categorized according to food type. The analyzed material was collected mainly during the breeding period of the birds. A total of 275 photos and videos (85 from Bulgaria and 190 from Türkiye) were used in the study.

Species used for food were identified and classified into 1 of 8 categories: earthworms, arachnid, insects, millipedes, reptiles, passerine birds, small mammals and unspecified. In addition, the insect category was divided into 5 subcategories: Orthoptera; Hemiptera, Hymenoptera, Coleoptera and Odonata.

The frequency of each prey category was calculated as a proportion of the total number of identified prey items.

Results

Analysis of 85 photos and videos of Lesser Kestrels with food, taken in Bulgaria, confirms that the species feeds mainly on insects, which constitute 44.71% of their recorded catches, followed by small mammals (rodents) with 22.35%, millipedes (*Scolopendra* spp.) – 18.82%, reptiles and birds with 3.53% each (Table 1). The relatively high proportion of mammals may be attributable to a pair of Lesser Kestrels from the colony in the village of Levka, in whose nest box 11 common Grey Voles (*Microtus arvalis*) were recorded in 2020. An interesting case is a filmed male Lesser Kestrel catching an earthworm.

Table 1. Occurrences and percentages of different prey items of Lesser Kestrels, determined by photos taken in Bulgaria and in Türkiye.

Prey item	**Bulgaria**		**Türkiye**	
	N	%	*N*	%
Earthworms	1	1.18	0	0
Arachnid	0	0	3	1.58
Millipedes	16	18.82	12	6.32
Insects	38	44.71	99	52.11
Reptiles	3	3.53	29	15.26
Passerine birds	3	3.53	3	1.58
Small mammals	19	22.35	34	17.89
Unidentified	5	5.88	10	5.26

Orthoptera constitute 92.11% of the insects identified as prey of the Lesser Kestrel. These are representatives of Tettigonidae, Acrididae, and Gryllidae, including the Bronze Glandular Bush cricket (*Bradyporus dasypus*), crickets, and the European mole cricket (*Gryllotalpa* spp.). Other representatives of insects in the species' diet are Coleoptera. Analysis of 190 photographs of Lesser Kestrels with food taken in Türkiye showed a similar frequency of taxa used for food. Insects made up 52.11% of the catches, followed by small mammals with 17.89%, reptiles with 15.26%, millipedes (*Scolopendra* spp.) with 6.32%, birds and arachnids with 1.58% each. Orthoptera constitute 94.95% of the insects identified as prey in Türkiye. Although occurring at low frequencies, the kestrels also exploit species from four additional insect orders (Coleoptera, Hemiptera, Hymenoptera, and Odonata), in contrast to Bulgaria, where only two orders were recorded.

A comparison of the results for Bulgaria and Türkiye shows a similar composition of the food of the Lesser Kestrel (Fig. 1). Insects constitute the main part of the species' diet, followed by mammals, millipedes, and reptiles.

Discussion

The data on the diet of the Lesser Kestrel collected by direct methods – in our case by analysis of photos and videos from Bulgaria and Türkiye – clearly demonstrate a predominantly insectivorous feeding strategy of the species in both countries. This finding is consistent with numerous previous studies across the species' range (Avcı, 2018; Negro et al., 1993; Selçuk et al., 2021), which have also identified insects as the major dietary component. In our analysis, insects comprised 44.71% of prey items in Bulgaria and 52.11% in Türkiye, confirming the species' strong preference for this prey type throughout its distribution range. However, notable regional differences were observed, likely reflecting local prey availability and habitat structure. For instance, millipedes represented 18.82% of the diet in Bulgaria but only 6.32% in Türkiye, possibly due to microclimatic differences or higher abundance of these invertebrates at the Bulgarian sites. Conversely, reptiles accounted for a substantially higher proportion of the diet in Türkiye (15.26%) compared to Bulgaria (3.53%). This may indicate differences in habitat conditions, particularly the extent of dry, open

areas where reptiles are more active and accessible as prey. In both countries, orthopterans dominated among the insect prey, representing more than 90% of insect records. This likely reflects their high caloric value, ease of capture, and predictable availability in open habitats (Kopij & Liven-Schulman, 2012). Notably, species such as *Bradyporus dasypus* and *Gryllotalpa* spp. were documented in Bulgaria, indicating the Lesser Kestrels' capacity to exploit relatively large, slow-moving invertebrates. A comparison with previous literature from Bulgaria confirms the validity of our findings. Studies based on pellet and prey remains (Gradev et al., 2023; Mihtieva, 2015; Yankov & Nyagolov, 1987) have also reported insect-dominated diets, with Orthoptera, Coleoptera, and Hymenoptera as key components, with sporadic presence of reptiles and small mammals (Fig. 2).

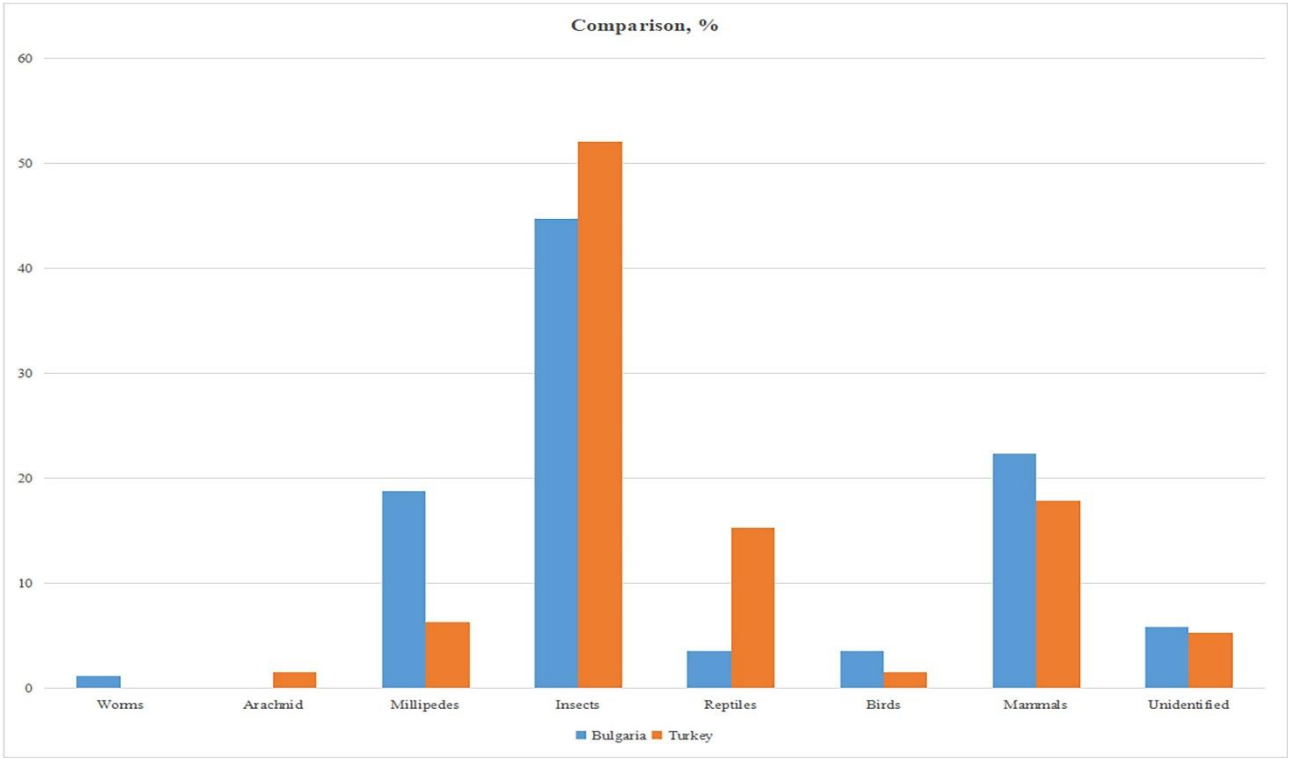

Fig. 1. Diet composition of Lesser Kestrel comparison between Bulgaria and Türkiye.

Fig. 2. Female Lesser Kestrel with caught a prey - small mammal (Muridae).

Ivanova et. al. (2021) reported some species from Chilopoda and small snakes. This congruence between direct (photographic) and indirect (pellet-based) methods strengthens the reliability of our photographic approach. An interesting observation was the greater taxonomic diversity of insect prey recorded in Türkiye, where four insect orders were identified, compared to only two in Bulgaria. This may reflect either the larger photographic sample size from Türkiye or genuine differences in local invertebrate diversity. The use of photographic and video materials, including publicly available platforms and colony-based surveillance systems, proved to be an effective non-invasive tool for studying feeding behavior, particularly in a vulnerable species like the Lesser Kestrel. This method also allows for real-time data acquisition, cross-regional comparisons, and the potential for long-term monitoring of diet composition. Despite its advantages, the photographic method possesses inherent limitations. These include potential bias in image selection, with a higher likelihood of photographing more conspicuous or larger prey items, and incomplete contextual information (e.g., time of day, prey provisioning rate). Nonetheless, as a complementary tool to classical dietary studies, it shows considerable promise in modern ornithological research.

Conclusions

This research demonstrates that photo and video analysis are credible tools for gathering dietary data on the Lesser Kestrel. The use of these direct methods can be the basis for the development and application of the so-called 'citizen science', as a modern and recognised approach, which, on one hand, allows for the wide participation of volunteers and non-professionals, and on the other, allows the collection of a broad range of data. In addition, the research could be expanded by analyzing sex-specific food preferences, contributions to nestling provisioning, and other aspects of foraging behavior. This approach would enable more precise implementation of management and conservation measures, aimed at effectively preserving the species in Bulgaria and increasing its breeding population.

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