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ARTICLE

Lesser Kestrel (*Falco naumanni*) ground prey abundance during its breeding season in central Greece

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ABSTRACT The Lesser Kestrel (*Falco naumanni*) is a bird of prey, highly dependent on agricultural landscapes for foraging. This study examines the availability of its prey in different crop types within the Thessalian Plain, central Greece, and assesses how agricultural practices in different cultivations influence prey abundance. Results indicate variations in prey abundance among different crops and study periods. Fallow/uncultivated fields and legume crops provided the highest prey availability, particularly for key prey groups such as Coleoptera and Orthoptera, making them crucial for Lesser Kestrel foraging. In contrast, intensive crops such as maize and cotton exhibited lower prey abundance, particularly in early growth stages, thus limiting their suitability as foraging habitats. The findings highlight the impact of intensive and extensive agricultural practices on Lesser Kestrel prey populations. Sustainable land management strategies are essential for supporting Lesser Kestrel conservation in agroecosystems.
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Introduction

The Lesser Kestrel (*Falco naumanni*) is a small, migratory bird of prey of the Falconiformes order and Falconidae family. Its length ranges from 28 to 33 cm and weight from 120 to 140 g (Rodriguez et al. 2014). The species breeds in Southern Europe, North Africa and Central Asia, while during the winter it migrates to sub-Saharan Africa (Bensusan and Cortés 2007; Catry et al. 2011; Liminana et al. 2012; Tella and Forero 2000; Iñigo and Barov 2010). It is a social species, nesting in colonies, mainly in buildings and agricultural warehouses, while colonies are surrounded by extensive open areas suitable as foraging habitats (Franco et al. 2005; Negro et al. 2000).

Prey availability is one of the most important factors regulating bird populations (Kopij 2002). Therefor, many species synchronize their breeding activity with periods of increased food abundance to ensure optimal chick growth (Catry et al. 2012). For the Lesser Kestrel, breeding success depends on the availability and quality of food, and on the physical condition of the parents. Strong and healthy individuals are more likely to start breeding earlier and produce more offspring (Catry et al. 2012).

During the breeding season (from pair formation to chick rearing) the energy requirements of the Lesser Kestrels increase significantly; the species energy intake is directly related to the availability and abundance of prey (Franco, et al. 2004). Furthermore, the variations in the distribution of the total prey resources in the landscape as well as the different species of prey availability, result in differences in the diets of Lesser Kestrels from adjacent colonies, or in cases within the same colony over time (Perez-Granados 2010).

The breeding success can be compromised by the lack of prey, at any stage of the Lesser Kestrel breeding (Franco, et al. 2004), while small differences in prey abundance between colonies lead to significant variations in their reproductive success (Rodriguez et al. 2006). Insufficient quantity or quality of food can prevent or delay the species reproduction, as females may not achieve the necessary physical condition for egg production and incubation. In addition, adverse weather conditions can limit foraging activities, and access to suitable prey before and during reproduction (Catry et al. 2012). Moreover, prey size is important. The minimum average prey biomass required for successful breeding ranges from 0.6 g (Rodriguez et al. 2006) to 1.7 g (Perez-Granados 2010).

The breeding season of the Lesser Kestrel in Thessaly seems to be synchronized with the maximum abundance of its prey populations (Sfougaris et al. 2004). The species chooses as its main foraging habitats all arable crops, as long as the height of the vegetation does not limit access to prey (Rodriguez, et al. 2014). Many studies find cereals as its preferred foraging habitats, together with plowed or low height growing crop fields, uncultivated edges and some irrigated crops, such as alfalfa, especially after mowing (Tella et al. 1998; Franco et al. 2004; Calabuig et al. 2010; Ursua et al. 2005; Gustin et al. 2014; Christakis and Sfougaris 2021).

The diet of the species mainly consists of insects, and of small mammals, such as mice and shrews, in small percentages (Tella et al. 1996). Orthoptera and Coleoptera are the main prey categories. Its diet also includes Dermaptera, Hymenoptera (especially Formicidae), Isoptera, and other Arthropods, such as Scolopendridae and Arachnids of the Solifugae order (Negro 1997; Rodriguez et al. 2010). In Thessaly, a recent study by Christakis et al. (2023), also found that Lesser Kestrel's diet consists of 98% insects, with Orthoptera and Coleoptera orders forming the majority of its diet.

The Greek population of the Lesser Kestrel was considered "Vulnerable" (Legakis and Maragou 2009), and from 2023, it is reclassified as "Least Concern" (LC) (NECCA 2024). Its feeding ecology is directly linked to agricultural land and changes in agricultural ecosystems (Rodríguez and Wiegand 2009). Intensive agricultural practices, extensive pesticide use, and the reduction of natural habitats directly affect the abundance and distribution of prey species, which may affect the breeding success of the species (Catry et al. 2012). The aim of the present study is to assess the availability of Lesser Kestrel ground prey in its foraging habitats of the Thessalian Plain, an area that hosts the largest population in Greece, consisting almost 70% of the total national population. The study goal is to investigate the extent of agricultural land use effects on the species prey availability, providing valuable insights for the conservation of the Lesser Kestrel in Thessaly and other similar rural landscapes.

Materials and Methods

Study area

The study area is a 150 km^2 rural area surrounded by the settlements of Armenio, Sotirio, Velestino and Mega Monastiri. The area includes the settlements of Stefanovikeio and Rizomylos, while its east and west boundaries are the artificial Lake Karla and the National Road network respectively (Fig. 1). All mentioned settlements host big Lesser Kestrel colonies; thus, the study area constitutes foraging habitat for Lesser Kestrels from all these colonies. This area was chosen because it constitutes a typical agricultural ecosystem of the Thessalian plain, characterized by intensive crop cultivations.

According to Municipality of Rigas Feraios, during the study years, 36% of the wider study area were covered by rangelands (mainly in the hilly areas around the study area), while cereal crops occupied 27.8% of the total area. Intensive cotton crops occupied 20.3%, maize cultivations to 1.7% and fallow areas to 1.4%. Other cultivations covered approximately 7% of the total Municipality area.

Fieldwork stations

Fieldwork was carried out in 2014 and 2015 during the breeding season of the Lesser Kestrel. For the purpose of this study, 20 fieldwork stations were randomly selected by ArcGIS software within the study area, maintaining a minimum distance of ≥500 m between each station (Fig. 1). At each fieldwork station, the nearest fields of cereals, legumes (alfalfa), cotton, maize, as well as fallow/uncultivated fields or rangelands were identified and used for pitfall trap installation throughout the whole study.

Assessment of ground invertebrate abundance

Pitfall trap method was utilized for assessing ground prey abundance. Pitfall traps is a simple, economical and widely used method for recording ground invertebrates, mainly arthropods (Woodcock 2005; Skvarla et al. 2014). This is effective in assessing the abundance of active organisms such as Coleoptera, Spiders and Ants (Formicidae) and is recommended for areas with low or sparse vegetation (Ausden and Drake 2006). They are suitable for ground Orthoptera, such as Crickets (Gryllidae), while for other families of Orthoptera can provide only presence information (Nagy et al. 2007).

The pitfall traps consist of a cylindrical container, buried at ground level that trap organisms passively. Their continuous operation allows the collection of diurnal and nocturnal species. Preservative liquids are used to prevent escape, decomposition and cannibalism of the collected organisms (Ausden and Drake 2006; Skvarla, et al. 2014). Automobile antifreeze, containing ethylene glycol or propylene glycol, are particularly reliable, although they require protective cover due to their toxicity to larger animals (Woodcock 2005; Schmidt et al. 2006). The pitfall cover also prevents evaporation of the liquid and overflow due to rainwater (Ausden and Drake 2006).

Pitfall trap characteristics (size, shape, material) and the preservative fluid used, affect organism collection (Weeks and McIntyre 1997; Woodcock 2005). Standardization of these parameters, as well as fixed number, spacing and same distribution of pitfall traps, ensures comparability of the collected data (Greenslade and Greenslade 1971). Organism collection can also be affected by weather conditions, season and vegetation structure (Greenslade 1964), so sampling should be done in homogeneous areas and similar season periods (Woodcock 2005). Furthermore, the presence of organisms that secrete pheromones may cause overestimation of some taxa (Skvarla et al. 2014). In

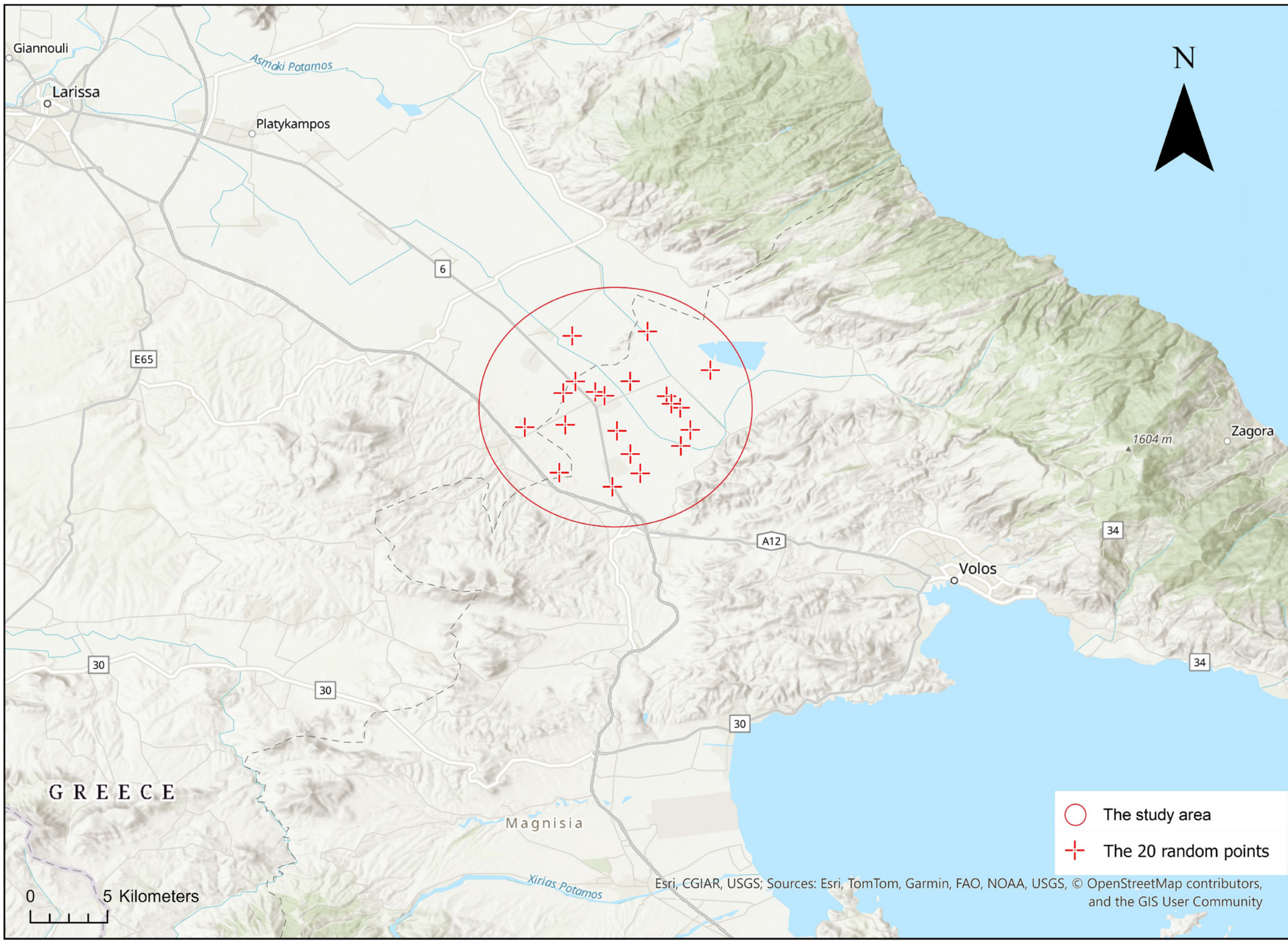

Figure 1. The study area with main sampling/observation sites indicated

general, pitfall traps reflect the relative activity of the soil fauna but can be characterized as a quantitative method also (Topping and Sunderland 1992) and since each species responds differently to pitfall collection, the method can be considered semi-quantitative (Woodcock 2005).

Pitfall trap installation

Pitfall traps were placed over three separate periods of both years (2014 and 2015) corresponding to key phases of the Lesser Kestrel's biological cycle: 1) Arrivals and pair formation (late March to early May), 2) Incubation of eggs and chick rearing /Breeding (mid-May to late June), 3) Nest abandonment / Pre-migratory phase (July and August).

To assess the soil fauna and study the availability of prey (Coleoptera, Orthoptera, Dermaptera, Chelopoda, etc.), pitfall traps were installed in the selected fields of the fieldwork stations. Although the method is not suitable for non-soil taxa (e.g., Diptera, Hymenoptera), these were identified and counted in the total content of the traps without further analysis of their abundance.

In each field five pitfall traps were installed, placed in a straight line with a distance of ≥10 m between each individual pitfall trap as well as the field boundaries. The traps consisted of a 1L plastic container (upper diameter: 13 cm, bottom: 9.5 cm), buried at ground level. Each trap contained 330 ml of preservative solution (250 ml water, 80 ml car coolant-Paraflu with 25% ethylene glycol) and a drop of odorless soap to reduce the surface tension of the liquid. Each pitfall trap was covered by a small plastic plate keeping a gap of a few centimetres height.

The pitfall traps remained active for one week. During collection, the captured organisms were stored in zip-lock bags and kept in a freezer (-20 °C) for further analysis. Chordata (Amphibians, Reptiles, Mammals) were recorded on site and were not included in the laboratory analysis. The remaining liquid content of the traps were collected in a special container for later disposal.

Prey species identification

In the laboratory, the collected organisms were thawed, cleaned, classified and counted using a stereoscope (Novex RZB-SF 65.550) and several identification keys (Willemse 1984; Willemse 1985; Chatenet 1986; Chinery 1993; McGavin 2000). The organisms were classified into various taxonomic categories. For this study, Coleoptera are accounted as a single taxonomic group.

Data analysis

Data were converted to individuals/100 days, based on the formula N=(N/t*d)*100, where N is the number of individuals captured per field, t is the number of active traps, d is number of the pitfall's active days. This conversion ensured comparability between different periods and cultivations.

Normality and homogeneity of variance tests were performed. Data with non-normal distributions were logarithmically transformed. For normal distributions with homogeneous variance, one-way ANOVA was used, and data were additionally compared pairwise with Tukey's post-hoc test. In case of unequal variance, Welch ANOVA was applied, and when both conditions were not met, the non-parametric Kruskal-Wallis analysis of variance test and the pairwise post-hoc Mann-Whitney test were used. Microsoft Excel 365, IBM Statistics v25 and PAST v4.02 programs were utilized.

Results

A total of 1,820 pitfall traps were installed in 364 fields (5 traps/field) during 2014 and 2015 in three different periods each year. Of these, when collected, 1,720 were suitable for analysis. The total number of 134,869 individuals was collected, 68,946 in 2014 and 65,923 in 2015. For comparability, all data are shown as individuals/100 days.

In total 41 taxa were identified, mainly Arthropods, but also Gastropod, Molluscs and Annelids. In addition, small Mammals (Rodents, shrews), Amphibians and a Reptile were recorded. Of the Arthropods, 8 orders of insects were identified, including 4 families of Orthoptera, 18 families of Coleoptera, as well as Ants, Hymenoptera, Diptera, Hemiptera, Dermaptera, Dictyoptera and Lepidoptera. Coleoptera larvae and other Insects were classified as separate categories. In addition, Chilopods, Diplopoda, Isopods and Spiders were collected. Some Coleoptera were not identified and were recorded as a separate category.

The highest percentage of individuals concerned Coleoptera (28.4%), followed by Hymenoptera (21.5%), Isopoda (18.6%) and Spiders (14.4%). Orthoptera, mainly Crickets, accounted for 6%, while Diptera for 5%. The remaining taxa recorded smaller percentages, with Gastropoda and Annelids accounting for 1.2% and 0.1%, respectively. Chordata (0.3%) mainly included small Mammals. During

Table 1. Ground prey abundance per study period

	2014						2015							
	1		2		3		1		2		3		Total	
	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%
Coleoptera	10987.9	34.6	26338.4	27.8	19477.4	22.7	15330.5	33.9	26036.2	35.9	17560.0	22.9	115730.2	28.4
Orthoptera	1765.7	5.6	1407.2	1.5	11028.6	12.9	824.5	1.8	567.3	0.8	8746.9	11.4	24340.2	6.0
Hymenoptera	6494.3	20.5	15814.6	16.7	26753.8	31.2	7798.3	17.2	16944.5	23.4	13661.2	17.8	87466.7	21.5
Diptera	745.0	2.3	2075.9	2.2	5641.7	6.6	2443.2	5.4	4580.3	6.3	4792.4	6.2	20278.6	5.0
Hemiptera	97.1	0.3	397.1	0.4	306.8	0.4	171.4	0.4	723.5	1.0	642.7	0.8	2338.7	0.6
Dermaptera	176.4	0.6	869.7	0.9	2426.8	2.8	506.5	1.1	1158.0	1.6	5111.7	6.7	10249.0	2.5
Other Insects	11.4	0.0	3.3	0.0	599.6	0.7	20.7	0.0	67.6	0.1	131.5	0.2	834.3	0.2
Insect larvae	325.0	1.0	631.2	0.7	130.7	0.2	348.6	0.8	390.7	0.5	238.2	0.3	2064.3	0.5
Chilopoda	52.9	0.2	130.6	0.1	74.6	0.1	105.4	0.2	85.0	0.1	142.9	0.2	591.4	0.1
Diplopoda	189.3	0.6	57.9	0.1	20.0	0.0	1950.9	4.3	83.7	0.1	0.0	0.0	2301.7	0.6
Isopoda	4017.9	12.7	33616.0	35.5	14313.6	16.7	4914.7	10.9	5642.0	7.8	13140.5	17.1	75644.6	18.6
Araneae	5305.7	16.7	13001.5	13.7	4809.3	5.6	8082.2	17.9	15161.9	20.9	12224.2	15.9	58584.8	14.4
Scorpiones	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	0.0	0.0	0.0	8.6	0.0
Gastropoda	1520.0	4.8	309.9	0.3	22.1	0.0	2547.4	5.6	402.3	0.6	151.4	0.2	4953.1	1.2
Annelida	51.4	0.2	0.0	0.0	0.0	0.0	167.1	0.4	11.9	0.0	6.2	0.0	236.7	0.1
Mammalia	0.0	0.0	144.5	0.2	110.0	0.1	49.7	0.1	35.1	0.0	32.9	0.0	372.2	0.1
Amphibia	0.0	0.0	16.0	0.0	5.0	0.0	0.0	0.0	561.2	0.8	238.9	0.3	821.2	0.2
Reptilia	0.0	0.0	0.0	0.0	2.5	0.0	2.9	0.0	0.0	0.0	0.0	0.0	5.4	0.0

1: Arrivals and pair formation; 2: Incubation of eggs and chick rearing / Breeding; 3: Nest abandonment / Pre-migratory phase.

Table 2. Ground prey abundance per crop type

	Cereals		Cotton		Fallow		Legumes		Maize	
	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%	Individuals / 100 days	%
Coleoptera	30031.4	26.6	20172.6	23.6	30523.2	24.1	43725.9	35.4	3048.4	40.3
Orthoptera	29292.2	3.2	18681.4	17.7	20243.2	5.0	1832.0	1.5	726.4	9.6
Hymenoptera	25845.2	26.0	13974.8	9.2	10776.3	36.3	19180.3	15.5	1174.4	15.5
Diptera	14526.4	3.3	7640.1	8.1	9820.9	3.0	7199.6	5.8	415.1	5.5
Hemiptera	3760.4	0.4	7296.7	0.2	4200.6	1.5	406.9	0.3	11.1	0.1
Dermaptera	3606.3	1.5	6414.2	9.7	2489.3	0.2	584.2	0.5	132.6	1.8
Other Insects	1695.4	0.4	4050.2	0.1	2243.0	0.3	55.4	0.0	5.7	0.1
Insect larvae	976.8	0.4	280.6	0.1	1262.6	0.6	1029.8	0.8	19.4	0.3
Chilopoda	947.7	0.2	197.5	0.1	859.6	0.2	89.1	0.1	12.2	0.2
Diplopoda	479.2	0.9	133.7	0.2	495.0	1.0	234.5	0.2	97.1	1.3
Isopoda	460.5	22.9	73.9	5.1	350.4	11.7	35721.7	29.0	206.6	2.7
Araneae	446.3	12.9	73.2	25.5	242.0	12.8	11483.5	9.3	1625.9	21.5
Scorpiones	255.8	0.0	64.6	0.0	196.7	0.0	8.6	0.0	0.0	0.0
Gastropoda	146.2	0.8	52.0	0.1	161.0	2.7	1655.3	1.3	42.5	0.6
Annelida	127.5	0.1	49.4	0.0	80.7	0.1	27.0	0.0	36.8	0.5
Mammalia	106.8	0.1	6.2	0.1	59.9	0.1	89.4	0.1	6.5	0.1
Amphibia	0.0	0.1	0.0	0.4	5.4	0.4	58.6	0.0	4.0	0.1
Reptilia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

the whole study, Coleoptera was the dominant class, with an exception for the 1st period of 2014, where Isopoda predominated. Coleoptera, Hymenoptera, Spiders and Orthoptera, constituted the most abundant recorded groups (Table 1).

The percentage of the recorded organism categories varied among crop types. In summary, in cereals, Coleoptera accounted for 26.6%, Hymenoptera 26%, Isopoda 22.9% and spiders 12.9%. In cotton, spiders made up 25.5% of all individuals collected, followed by Coleoptera 23.6%, Orthoptera 17.7%, Dermaptera 9.7%, Hymenoptera 9.2% and Diptera 8.1%. In fallow/uncultivated fields, Hymenoptera constituted 36.3%, Coleoptera 24.1%, spiders 12.8% and Isopoda 11.7%. In legumes and maize, Coleoptera were dominant with 35.4% and 40.3% respectively, followed by Isopoda (29%) and Hymenoptera (15.5%) in fallow/uncultivated fields, whereas in maize Araneae (21.5%) and Hymenoptera (15.5%). The remaining classes were recorded at lower percentages in all other crop categories (Table 2).

The total abundance of organisms collected by pitfall traps differed statistically significantly among the different study periods (H=334.6, p<0.05). In 2014, the abundance increased from arrivals and pair formation (first period) to incubation of eggs and chick rearing (second period) and decreased during nest abandonment- pre-migratory phase (third period). On the contrary, in 2015 a progressive increase was observed from the first to the third period (Table 3). In addition, the abundance showed statistically significant differences among the different crop types (H=107.782, p<0.05), while all pair comparisons revealed significant differences.

Coleoptera abundance

A total of 38,967 Coleoptera (38,185 adults and 782 larvae) were collected with pitfall traps across all crop types and all study periods. Specifically, during the first study period of 2014, 3,817 Coleoptera (3,560 adults and 257 larvae) were collected, during the second 7,886 Coleoptera (7,722 adults and 164 larvae) and during the third period of the same year 6,903 Coleoptera (6,807 adults and 96 larvae) were collected. During 2015, 5,119 Coleoptera (4,977 adults and 142 larvae), 10,005 Coleoptera (9,924 adults

Table 3. Total abundance of collected organisms (individuals/100 days) for each study period

Study period	2014	2015
1	31,740.0	45,263.9
2	94,813.7	72,459.8
3	85,722.6	76,821.5
Total	212,276.3	194,545.3

1: Arrivals and pair formation; 2: Incubation of eggs and chick rearing / Breeding; 3: Nest abandonment / Pre-migratory phase.

and 81 larvae) and 5,237 Coleoptera (5195 adults and 42 larvae) were collected respectively for the three periods.

Total Coleoptera abundance among study periods showed statistically significant differences ($U=167.5$, $p<0.05$). Crop types also showed statistically significant differences, in terms of the total Coleoptera abundance ($F=37.25$, $df=1719$, $p<0.05$).

Other potential prey

Among all organisms collected, the taxa of Gryllidae and Gryllotalpidae, Dermaptera and Chilopoda (mainly of the Scolopendridae family) are considered prey of the Lesser Kestrel.

Gryllidae were recorded during all study periods and in all crop categories. The highest abundance was recorded in the third study period of each year. There were statistically significant differences between the study periods ($H= 330.6$, $p<0.05$). Gryllidae abundance was highest in cotton and maize cultivations, and lowest in legumes ($H=177.8$, $p<0.05$).

Gryllotalpidae were recorded in almost all crop types, except maize. Their highest abundance was recorded during the third study period of 2015, while the lowest during the first period of each year of the study. There were no statistically significant differences between periods ($H= 0.314$, $p>0.05$) or crop types ($H= 0.201$, $p>0.05$).

Formicidae were found in all periods and crop types, with the highest abundance during the third period of 2014 and the lowest during the first of each year. Differences between periods ($H= 192.1$, $p<0.05$) and crop types ($H= 192.1$, $p<0.05$) were statistically significant, while the highest Formicidae abundance was recorded in fallow/uncultivated land and the lowest in cotton and maize cultivations.

Dermaptera were also found in all study periods and crop types, while their abundance showed an increasing trend throughout the duration of the breeding season. The highest abundance was recorded in the third study period of 2015. The differences among periods ($H=83.68$, $p<0.05$) and crop types ($H=154.7$, $p<0.05$) were statistically significant, while the highest abundance was recorded in cotton fields and cereals and the lowest in legumes.

Chilopoda were present in all study periods and crop types. The highest abundance was recorded during the third study period of 2015. The differences between periods ($H=3.236$, $p<0.05$) and crop types ($H=7.299$, $p<0.05$) were statistically significant. Cereals and fallow/uncultivated land showed the higher Chilopoda abundance.

Discussion

This study investigates the relationship between different crop types and thus farming practices, and prey availability for the Lesser Kestrel. The results show significant differences in prey availability among different crop types. In terms of Arthropod abundance and thus Lesser Kestrel prey, fallow/uncultivated land of the study area was found to be the most suitable habitat. Weibull and Östman (2003) reported that semi-natural agricultural habitats vary in species composition more than any crop type in an agricultural landscape. Considering quantity of prey as a criterion for the suitability of foraging habitats, since it has a significant impact on Lesser Kestrel breeding success (Rodriguez et al. 2006), fallow/uncultivated land stands out in comparison to intensive cultivations. This finding agrees with other studies that support that the Lesser Kestrel prefers these semi-natural agro-ecosystems for foraging (Donazar et al. 1993; Ursua et al. 2005; Garcia et al. 2006, Christakis and Sfougaris 2021). However, the heterogeneity and scarcity of these habitats are a key disadvantage.

Legume cultivations showed a high abundance of soil arthropods, especially Coleoptera. This seems to agree with Parisi et al. (2005), who reported that this crop is characterized by high values of soil microarthropods. This could be explained by the fact that legume plants are beneficial for the soil, by organic matter enrichment, one of the most important soil factors affecting coleoptera populations (McLaughlin and Mineau 1995). Legumes are one of the most favourable crop cultivations for the conservation of Lesser Kestrel prey and of particular interest for the management of agricultural landscapes (Christakis and Sfougaris 2021).

In most studies, a high diversity and abundance of Coleoptera is also observed in arable crops (Pfiffner and Luka 2003). Indeed, the results of the study showed that cereals maintain high abundances of Coleoptera and Orthoptera. This finding is also confirmed by Olfert et al. (1995). The same researchers found that the biotic potential of Orthoptera is highest in wheat crops followed by legumes. Furthermore, according to Stoate et al. (2000), cereal crops support a wide variety of large insects including Lepidoptera larvae and several Orthoptera.

Intensive crops in the study area recorded lower prey availability for the Lesser Kestrel. Cotton crops showed during the first two study periods very low abundance of Coleoptera. Cotton cultivations due to the low prey availability, which is confirmed by the present study, are not preferred foraging habitats by the Lesser Kestrel (Sfougaris et al. 2004; De Frutos et al. 2010; Christakis and Sfougaris 2021). However, it could be argued that these crops are occasionally used by the species, either when the prey is easily accessible due to low height and density of the plants, or when farming practices expose the prey thus making hunting easier for the predator (Rodriguez et al. 2014). Although cotton fields have been heavily disturbed by agricultural practices, they still maintain the highest abundance of Crickets and Dermaptera, preys of the Lesser Kestrel. During the third period of the study in both years, and when cotton plants are at the last stages of growth, an increase in fauna abundance was observed in these fields, making them potentially suitable for the Lesser Kestrel as foraging habitats, due to prey availability and accessibility.

Maize cultivations are unsuitable for Lesser Kestrel foraging in the area, due to plant density and height from the very early stages of their biological cycle, which make it difficult for the predator to manoeuvre and offering safe shelter to prey. During the initial stages of the breeding season, when vegetation cover is sparse and the maize plants are small, this crop category could be used by the species to prey, even though a small ground fauna abundance was recorded. It should be noted that during the second and third study period for both years pitfall traps installation was not possible in maize fields, due to the density and height of the plants. In general, maize cultivations are not used as foraging habitats by the Lesser Kestrel (Ursua et al. 2005), however, it is possible for any crop type to be selected for foraging by the species, even for a short period of time during their breeding season, when prey is available and accessible (Rodriguez et al. 2014).

The abundance of ground prey varied significantly between the three periods of the study, reflecting both seasonal variations of prey populations and the impacts of agricultural practices. Abundance was at its highest level in the second period of each year, indicating that this period coincides with increased activity or reproduction of the dominant arthropod groups. These differences can be explained by changes in crop growth during the species breeding season, as well as by the influence of agricultural practices (Rodriguez et al. 2014). Many of the arthropods, which are important prey items for predators, are vulnerable to agricultural practices (Holland 2004). Similarly, according to Ursúa et al., (2005), the availability of prey of different crops and their stages varies because of mowing, while harvesting also seems to determine the availability of prey (Franco et al. 2004). Coleoptera were the most abundant group of organisms recorded and showed significant variation between study periods. They constitute an important group of beneficial arthropods in agroecosystems (Carmona and Landis 1999) and together with Orthoptera the most important prey category of the Lesser Kestrel (Christakis et al. 2023). During the study, the highest abundance of Coleoptera occurred during the breeding period of the species, in agreement with Pietersen and Symes (2010), according to which beetles become an important part of the Lesser Kestrel diet during its breeding period. Their abundance peaked during the second period of 2015, probably due to the temperature and humidity conditions that favoured their growth and activity. Correspondingly, the populations of Crickets (Gryllidae) increased gradually, with the highest abundance recorded in the third period of each year.

Overall, the results confirm that the abundance and composition of ground arthropods do not remain constant, but vary significantly in numbers between periods and crop types, which could affect prey availability for the Kestrel and other predators in the area.

Farming practices and Lesser Kestrel prey abundance

Agricultural management practices play a critical role in the availability of the Lesser Kestrel prey. Intensive agricultural practices, such as pesticide use and extensive monoculture, reduce the abundance of arthropods and limit the predator's foraging options. Cereal crops show higher prey abundance, while harvesting can improve food availability when performed during the critical period of chick rearing. In addition, the maintenance of semi-natural habitats, such as uncultivated field margins and pastures, can enhance arthropod biodiversity and contribute to the maintenance of prey abundance. These areas can act as stable prey resource, reducing the bird's dependence on crops with low prey availability. This study highlights the need for sustainable agricultural practices that can support the conservation of the Lesser Kestrel. It is suggested that intensive and extensive crop management could coexist, while preserving natural field margins, which act as arthropod refuge. In addition, strategies such as crop rotation, reducing pesticide use, and maintaining areas with legume and cereals can enhance food availability for the species.

Conclusion

This study investigated the availability of prey for the Lesser Kestrel (*F. naumanni*) in the agricultural landscape of the Thessalian plain and how agricultural practices affect the ground fauna, an important food source for the species. The results showed that the abundance and diversity of Arthropods show significant variations between crop types and study periods, which are linked to both the seasonal dynamics of the organisms' populations and agricultural interventions. The highest abundance of ground organisms was recorded in fallow/uncultivated land, and legumes, confirming the importance of these habitats for the conservation of Lesser Kestrel prey. In contrast, intensive crops such as cotton and maize showed a lower abundance of Arthropods, especially in the early stages of the growing season, making them less suitable for the species diet. However, the abundance of some taxa increased in the later stages of cotton cultivation, allowing occasional use of these fields for foraging. Data analysis also showed that changes in prey abundance are related to crop development and the impact of agricultural practices, such as pesticide use and harvesting. Differences in prey availability may affect the reproductive success of the Lesser Kestrel, as access to sufficient and suitable prey is a key factor for chick survival. This study shows that agricultural landscape management has a direct impact on the availability of the Lesser Kestrel prey, and demonstrates the importance of integrated management of agricultural ecosystems for the protection of the species.

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References

Ausden M, Drake M (2006) Invertebrates. In Sutherland WJ, Ed. Ecological Census Techniques: A Handbook. Cambridge University Press, New York, pp. 214-249.

Bensusan KJ, Cortés JE (2007) Decline of the Lesser Kestrel (*Falco naumanni*) in Gibraltar: Possible causes, conservation and action plan. Almoraima 35:185-190.

Calabuig G, Ortego J, Cordero PJ, Aparicio J (2010) Colony foundation in the Lesser Kestrel: patterns and consequences of the occupation of empty habitat patches. Anim Behav 80:975-982.

Carmona DM, Landis DA (1999) Influence of refuge habitats and cover crops on seasonal activity-density of ground beetles (Coleoptera: Carabidae) in field crops. Environ Entomol 28:1145-1153.

Catry I, Amano T, Franco A, Sutherland WJ (2012) Influence of spatial and temporal dynamics of agricultural practices on the Lesser Kestrel. J Appl Ecol 49:99–108.

Catry I, Dias MP, Catry T, Afanasyev V, Fox J, Franco AMA, Sutherland WJ (2011) Individual variation in migratory movements and winter behaviour of Iberian Lesser Kestrels *Falco naumanni* revealed by geolocators. Ibis 153:154-164.

Chatenet GD (1986) Guide des coleopteres d'Europe. Tome 1. Delachaux et Niestlé, Paris.

Chinery M (1993) Insects of Britain and Western Europe. Collins Field Guide. HarperCollins, New York.

Christakis C, Sfougaris A (2021) Foraging habitat selection by the Lesser Kestrel *Falco naumanni* during the different phases of breeding and the post breeding period in central Greece. Ornithol Sci 20(2):175-183.

Christakis C, Makri M, Alivizatos H, Sfougaris A (2023) Lesser Kestrel *Falco naumanni* diet during different phases of breeding and post breeding periods in central Greece. Avocetta 47:2023F002.

De Frutos A, Olea P, Mateo-Tomas P, Purroy FJ (2010) The role of fallow in habitat use by the Lesser Kestrel during the post-fledging period: inferring potential conservation implications from the abolition of obligatory set-aside. Eur J Wildl Res 56:503-511.

Donázar J, Negro J, Hiraldo F (1993) Foraging habitat selection, land-use changes and population decline in the Lesser Kestrel *Falco naumanni*. J Appl Ecol 30:515-522.

Franco A, Catry I, Sutherland W, Palmeirim J (2004) Do different habitat preference survey methods produce the same conservation recommendations for Lesser Kestrels? Anim Conserv 7:291-300.

Franco A, Marques JT, Sutherland WJ (2005) Is nest-site availability limiting Lesser Kestrel populations? A multiple scale approach. Ibis 147:657-666.

Garcia JT, Morales MB, Martinez J, Iglesias L, De-la-Morena EG, Suarez F, et al. (2006) Foraging activity and use of space by Lesser Kestrel *Falco naumanni* in relation to agrarian management in central Spain. Bird Conserv Int 16:83-95.

Greenslade P, Greenslade PJM (1971) The use of baits and preservatives in pitfall traps. J Aust Entomol Soc 10:253-260.

Greenslade PJM (1964) Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). J Anim Ecol 33(2):301-310.

Gustin M, Ferrarini A, Giglio G, Pellegrino SC, Frassanito A (2014) Detected foraging strategies and consequent conservation policies of the Lesser Kestrel *Falco naumanni* in Southern Italy. Proc Int Acad Ecol Environ Sci 4(4):148-161.

Holland JM (2004) The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agric Ecosyst Environ 103:1-25.

Iñigo A, Barov B (2010) Action plan for the Lesser Kestrel *Falco naumanni* in the European Union. SEO|BirdLife and BirdLife International for the European Commission.

Kopij G (2002) Food of the Lesser Kestrel (*Falco naumanni*) in its winter quarters in South Africa. J Raptor Res 36(2):148-152.

Legakis A, Maragou P (2009) The Red Book of Endangered Animals of Greece. Hellenic Zoological Society, Athens, Greece.

Limiñana R, Romero M, Mellone U, Urios V (2012) Mapping the migratory routes and wintering areas of Lesser Kestrels *Falco naumanni*: new insights from satellite

telemetry. Ibis 154:389-399.
McGavin GC (2000) Insects, Spiders and Other Terrestrial Arthropods. Dorling Kindersley Handbooks. Dorling Kindersley, London, UK.
McLaughlin A, Mineau P (1995) The impact of agricultural practices on biodiversity. Agric Ecosyst Environ 55:201-212.
Natural Environment and Climate Change Agency (NECCA) (2024) The Greek Red List of Threatened Species. Athens, Greece. Available: https://redlist.necca.gov.gr. Accessed 18 March 2025.
Nagy A, Solymos P, Racz I (2007) A test on the effectiveness and selectivity of three sampling methods frequently used in orthopterological field studies. Entomol Fenn 18:149-159.
Negro J (1997) *Falco naumanni* lesser kestrel. J Birds West Palearct 1(1):49-56.
Negro JJ, Bustamante J, Melguizo C, Ruiz JL, Grande JM (2000) Nocturnal activity of lesser kestrels under artificial lighting conditions in Seville, Spain. J Raptor Res 34(4):327-329.
Olfert O, Hinks CF, Biederbeck VO, Slinkard AE, Weiss RM (1995) Annual legume green manures and their acceptability to grasshoppers (Orthoptera: Acrididae). Crop Prot 14:349-353.
Parisi V, Menta C, Gardi C, Jacomini C, Mozzanica E (2005) Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy. Agric Ecosyst Environ 105:323-333.
Perez-Granados C (2010) Diet of adult lesser kestrels *Falco naumanni* during the breeding season in central Spain. Ardeola 57(2):443-448.
Pfiffner L, Luka H (2003) Effects of low-input farming systems on carabids and epigeal spiders – a paired farm approach. Basic Appl Ecol 4(2):117-127.
Pietersen DW, Symes CT (2010) Assessing the diet of Amur falcon *Falco amurensis* and lesser kestrel *Falco naumanni* using stomach content analysis. Ostrich 81:39-44.
Rodríguez C, Wiegand K (2009) Evaluating the trade-off between machinery efficiency and loss of biodiversity-friendly habitats in arable landscapes: the role of field size. Agric Ecosyst Environ 129:361-366.
Rodriguez C, Johst K, Bustamante J (2006) How do crop types influence breeding success in lesser kestrels through prey quality and availability? A modeling approach. J Appl Ecol 43:587-597.
Rodriguez C, Tapia L, Kieny F, Bustamante J (2010) Temporal changes in lesser kestrel (*Falco naumanni*) diet during the breeding season in southern Spain. J Raptor Res 44(2):120-128.
Rodriguez C, Tapia L, Ribeiro K, Bustamante J (2014) Crop vegetation structure is more important than crop type in determining where lesser kestrels forage. Bird Conserv Int 24(4):438-452.
Schmidt MH, Clough Y, Schulz W, Westphalen A, Tscharntke T (2006) Capture efficiency and preservation attributes of different fluids in pitfall traps. J Arachnol 34:159-162.
Sfougaris A, Giannakopoulos A, Alivizatos C, Weigelt C (2004) Conservation of a raptor in an intensively cultivated agroecosystem: the case of lesser kestrel (*Falco naumanni*) in Thessaly plain, central Greece. In Arianoutsou M, Papanastasis VP (Eds) Proceedings of the 10th MEDECOS Conference. Millpress, Rotterdam, pp 1-10.
Skvarla MJ, Larson JL, Dowling APG (2014) Pitfalls and preservatives: a review. J Entomol Soc Ont 145:15-43.
Stoate C, Borralho R, Araújo M (2000) Factors affecting corn bunting *Miliaria calandra* abundance in a Portuguese agricultural landscape. Agric Ecosyst Environ 77:219-226.
Tella J, Hiraldo F, Donazar-Sancho J, Negro J (1996) Costs and benefits of urban nesting in the lesser kestrel. In: Bird D, Varland D, Negro JJ (Eds) Raptors in Human Landscapes: Adaptation to Build and Cultivated Environments. Academic Press, Cambridge, pp 53-60.
Tella JL, Forero MG, Hiraldo F, Donazar JA (1998) Conflicts between lesser kestrel conservation and European agricultural policies as identified by habitat use analyses. Conserv Biol 12(3):593-604.
Tella J, Forero M (2000) Farmland habitat selection of wintering lesser kestrels in a Spanish pseudosteppe: implications for conservation strategies. Biodivers Conserv 9:433-441.
Topping CJ, Sunderland KD (1992) Limitations to the use of pitfall traps in ecological studies exemplified by a study of spiders in a field of winter wheat. J Appl Ecol 29(2):485-491.
Ursua E, Serrano D, Tella JL (2005) Does land irrigation actually reduce foraging habitat for breeding lesser kestrels? The role of crop types. Biol Conserv 122:643-648.
Weeks RD, McIntyre NE (1997) A comparison of live versus kill pitfall trapping techniques using various killing agents. Entomol Exp Appl 82:267-273.
Weibull A, Ostman O (2003) Species composition in agroecosystems: the effect of landscape, habitat, and farm management. Basic Appl Ecol 4:349-361.
Willemse F (1984) Fauna Graeciae I. Catalogue of the Orthoptera of Greece. Hellenic Zoological Society, Athens, Greece.
Willemse F (1985) Fauna Graeciae II. A key to the Orthoptera species of Greece. Hellenic Zoological Society, Athens, Greece.
Woodcock BA (2005) Pitfall trapping in ecological studies. In Leather RS (Ed) Insect sampling in forest ecosystems. Blackwell Science, Oxford, pp 37-57.