DIET STUDY OF COMMON KESTREL (*FALCO TINNUNCULUS* LINNAEUS, 1758) IN THE HYPER-ARID REGION OF SOUTHEAST ALGERIA (SOUF REGION): ECOLOGICAL ROLE OF A RAPTOR IN A FRAGILE DESERT ENVIRONMENT

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Abstract. This study focuses on the diet of the common kestrel (*Falco tinnunculus*, Linnaeus, 1758) in the Souf region, southeast Algeria, based on analysis of 46 regurgitated pellets. A total of 22 prey species were identified, spanning 5 orders and 11 families. Rodents were the primary food source, accounting for 63.8% of all prey items and 80.3% of the total biomass. The lesser Egyptian gerbil (*Gerbillus gerbillus*, Olivier, 1801) alone contributed 46.5% of the biomass. Insects constituted 27% of prey by number, while birds and reptiles contributed 11.6% and 5.9% of the biomass, respectively. An equitability index of approximately 0.73 reflects a balanced exploitation of available prey, consistent with the kestrel's generalist and opportunistic feeding behavior. These findings highlight its ecological role as a natural pest controller in agricultural landscapes. The study also contributes to regional faunistic knowledge and underscores the importance of conserving this raptor to support ecosystem stability and sustainable agriculture.
Keywords: *pellets, generalist, opportunistic, ecosystem stability, sustainable agriculture*

Introduction

Predation, defined as the consumption of live prey following an attack (Grognard and Mailleret, 2013; Frei et al., 2019), is a key driver of natural selection and species evolution. Birds of prey, or raptors, exemplify this interaction due to their reliance on hunting for survival (Ramade, 1984). Raptors targeting rodents (rats, mice, meriones), birds (sparrows, pigeons), lagomorphs, and reptiles provide unique research opportunities. Notably, they produce regurgitated pellets containing indigestible remnants of their prey, such as hair, bones, and shells, offering valuable insights into their dietary habits (Cacciani et al., 2004).

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As top predators in the food chain, raptors regurgitate compact pellets made up of indigestible prey remains compressed in the gizzard. Raptors are broadly classified into two main orders: Strigiformes (nocturnal raptors) and Falconiformes (diurnal raptors) (Cacciani et al., 2004). The Falconiformes order includes five families: *Cathartidae, Accipitridae, Sagittaridae, Pandionidae,* and *Falconidae,* comprising approximately 307 species of diurnal raptors worldwide (Dufour, 2010). Algeria is home to 33 species of diurnal raptors (Bochando Bleda, 1983, 1986; Isenmann and Moali, 2000).

The kestrel (*Falco tinnunculus Linnaeus, 1758*) is a small diurnal raptor widely distributed across Algeria, thriving in diverse environments (Souttou et al., 2007). Numerous studies have examined the diet of kestrels in Europe (Garratt et al., 2011; Huchler et al., 2020; Montoya et al., 2021; Zahorodnyi et al., 2021; Filipiuc et al., 2024), Asia (Anushiravani and Roshan, 2017), and Africa (Van Zyl, 1994; Carrillo et al., 1994). In Algeria, research has been conducted by Baziz et al. (1999), Baziz (2001, 2002), and Souttou et al. (2001-2015) across various environments, including suburban, agricultural, and steppe regions.

Despite this extensive body of research, little attention has been paid to the diet of *Falco tinnunculus* in Algeria's Saharan regions, particularly the Souf region (southeastern Algeria). These kestrels are valuable in agriculture, preying on small terrestrial mammals and birds that harm crops. Understanding their diet is crucial for biodiversity assessments and studies of geographical distribution (Blagosklonov, 1987; Souttou et al., 2015). Furthermore, kestrels play an essential role in biological control and ecological balance (Vibe-Petersen et al., 2006; Caroulle and Baubet, 2006; Anderu, 2012; Hubert, 2015).

This study aims to elucidate the ecological role of the common kestrel in regulating prey populations and to expand our understanding of its trophic habits. Specifically, it investigates the diet of kestrels in the Souf region of southern Algeria, an area that remains understudied in terms of avian ecology. By focusing on the trophic habits of this diurnal raptor, this research also addresses the knowledge gap regarding its diet in arid environments and contributes to faunistic records of the region, with potential implications for understanding kestrels' role in local ecosystems and agricultural pest control.

Materials and methods

Study area

The Souf region is located in southeast Algeria (33° 12' to 33° 35' N; 6° 50' to 6° 51' E) on the northern edge of the Eastern Erg (*Figure 1*).

It is enclosed by the Melghir and Merouane chotts to the north, the big Oriental Erg to the south, the Oued Righ valley to the west, and the Tunisian Chott El-Djerid to the east (Voisin, 2004; Côte, 2006; Guezoul et al., 2017). Based on weather data from 1980 to 2021 (*Figure* 2), the study area experiences a Saharan climate with significant temperature fluctuations both daily and seasonally (Khechekhouche et al., 2018).

This allows it to be classified within the Saharan bioclimatic zone with a mild winter. Strong and constant winds are frequent in the region, with their influence being reinforced by the absence of ground obstacles, relief, and the scarcity of vegetation.

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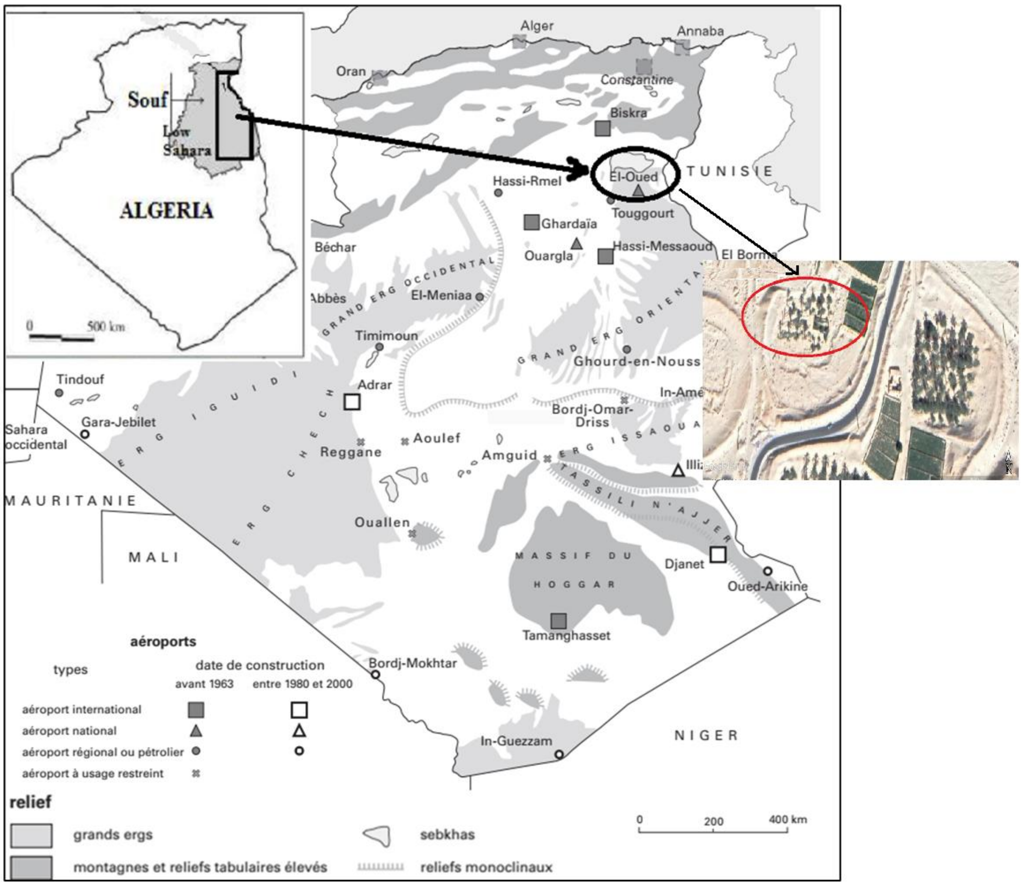

Figure 1. *Geographic location map of the Souf region (Algeria) pellets collection station*

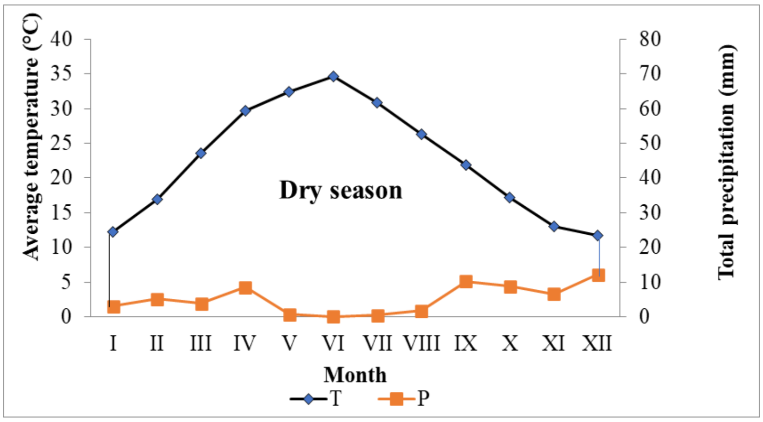

Figure 2. *The Bagnouls and Gaussen ombrothermic diagram, based on a 10-year period (2010–2021), is applied to the study area*

Analysis of pellets and identification of prey species

The wet method was used to examine the pellets (Brahmi et al., 2012; Khechekhouche et al., 2017). After maceration, only animal prey items were identified. Bone remains and sclerotized arthropod fragments were isolated and sorted by systematic affinity in separate Petri dishes.

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Mammalian prey was identified either by analyzing the skull and teeth (Smiddy, 2017) or, in the absence of skeletal remains, through microscopic examination of hairs. This latter method relies on the study of the shape and arrangement of cuticular scales, compared to a reference collection and an illustrated guide (Khechekhouche, 2018). However, this approach has limitations, especially in the case of highly degraded or non-distinctive hairs, which may restrict identification to the genus or family level.

Avian prey was identified based on beaks, characteristic bones (humerus, femur, tibia), and feathers, compared with a reference collection (Souttou et al., 2015). Arthropods were identified using major body parts such as the head, mandibles, antennae, legs, and especially the elytra (Carrillo et al., 2017). Nevertheless, species-level identification was difficult for certain taxa due to the fragmentary condition of remains or morphological similarity between closely related species.

The number of vertebrates was estimated based on the presence of the skull, or, when absent, by using long bones (Souttou et al., 2007; Ouarab and Doumandj, 2017; Boulanger, 2018). According to Alia et al. (2012), prey identification in pellets involves two stages: first, recognizing the class and order, and then, when possible, identifying the species, followed by counting the number of individuals present in each pellet.

The prey of the common kestrel includes both vertebrates and invertebrates. Pellet collection was conducted during the breeding season. A total of 46 pellets were collected in 2019 at the Miha Saleh station, beneath the nests and perches used by the kestrel (33°32'9.32"N, 6°51'7.28"E; altitude: 61 m), located east of Guémar, north of El Oued. This station spans several hectares and includes date palm groves up to 75 feet tall, market garden crops, and spontaneous plant species such as *Tetraena alba* L. and *Aristida pungens* Desf.

Exploitation of results by statistical methods

The results were analyzed using relative abundance (AR%), which represents the proportion of a taxon's items relative to the total number of identified items, and relative biomass (B%), which indicates the biomass of a specific taxon in relation to the total biomass of all identified taxa. Additionally, the occurrence frequency (FO%) of consumed species was determined by calculating the ratio of pellets containing a given species to the total number of pellets, with species categorized into frequency classes (Faurie et al., 2003). To further assess prey diversity, this study incorporated the Shannon diversity index (H'), the maximum diversity index (H' max), and the equitability index (E), providing insights into species distribution and ecological balance.

Results

The results from the diet analysis of the kestrel are used using ecological indices of composition and structure.

Characteristics of Kestrel pellets rejection paddle dimensions and weights

F. tinnunculus pellets are brownish-grey to light grey in the dry state. Kestrel pellets range in length from 17.8 mm to 62.9 mm, with an average of 33.7 8.6 mm (*Table 1*).

The large diameter ranges from 13.8 mm to 28.3 mm (Average = 21.9 3 mm). The weight ranges from 11.9 g to 71 g (Average = 29.6 12 g).

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Table 1. *Dimensions and weights of F. tinnunculus pellets collected in the Souf area*

	Large diameter (mm)	**Length (mm)**	**Weight (g)**
Maximum	62.89	28.32	70.97
Minimum	17.8	13.81	11.92
Average	33.69	21.89	29.6
Ecart-Error	8.55	2.97	11.96

Fluctuation in the number of prey per pellet of Falco tinnunculus

The number of prey per paddle ranges from 1 to 10, averaging 3.1 ±1.8 (*Figure 3*).

Pellets containing two preys are the most frequent, representing a rate of 43.5%. They are followed by those containing three prey (17.4%) and four prey (15.2%).

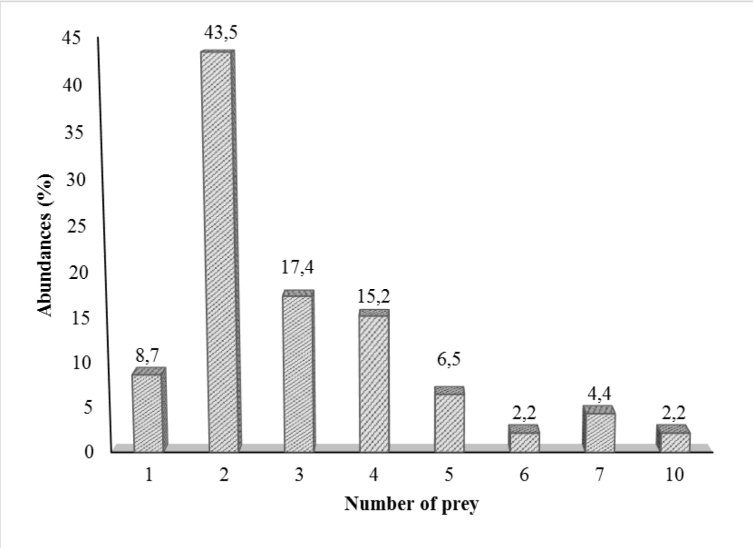

Figure 3. *Fluctuations in the number of prey per pellet of the Kestrel at Miha Saleh Station*

Study of the diet of F. tinnunculus using ecological composition indices

Relative abundances of prey categories and species found in the Kestrel trophic menu

The analysis of Kestrel pellets allowed us to identify 141 individuals belonging to 22 species, divided into 4 trophic categories, 6 orders and 10 families (*Figure 4*).

The most common class is rodents (AR = 63.8%), followed by insects (AR = 27%). The other trophic categories are represented by values that do not exceed 7%. In terms of prey species (*Figure 5*), *G. gerbillus* (36.2%) and *B. megacephalus* (17.7%) are the most frequently consumed prey by the Kestrel. Followed by *Acanthodactylus* sp. (6.4%), *Gerbillus pyramidum* and *Mus musculus* (6.4%).

Relative biomasses of prey categories and prey species consumed by kestrel

There are four main categories for food categories (*Figure 6*).

Rodents occupy a prominent place in terms of the amount of food consumed (representing 80.3% of the total biomass) in the diet of the kestrel. They are followed by birds (representing 11.6% of the biomass). In third position are reptiles (representing

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5.9% of the biomass), and in last position are insects. Among the prey species, *Gerbillus gerbillus* is the dominant prey by biomass, accounting for 46.5% of the kestrel's diet (*Figure 7*).

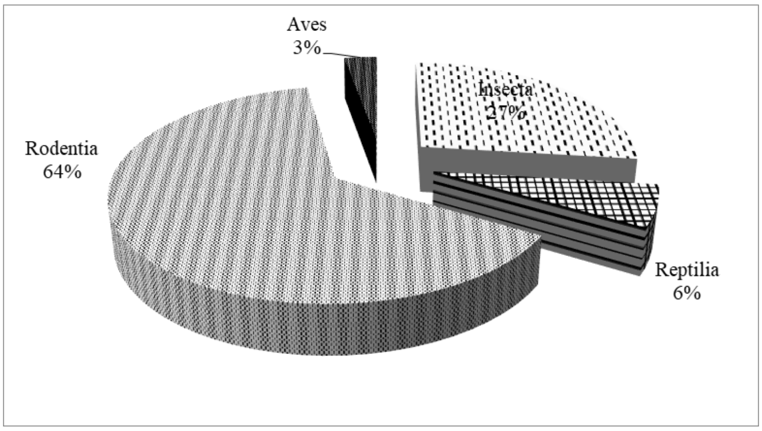

Figure 4. *Relative abundances by food categories found in kestrel pellets*

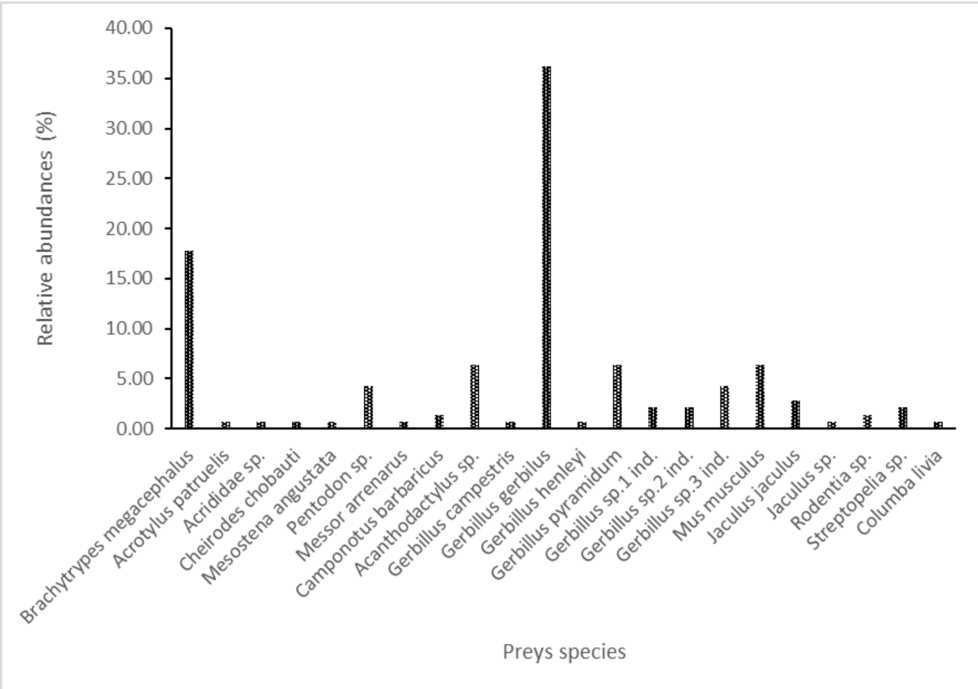

Figure 5. *Relative abundances by prey species noted in Kestrel pellets*

Followed by another species of rodents, *Gerbillus pyramidum*, which constitutes 9.5% of the total biomass consumed. In third position is a species of bird, Streptopelia sp., representing 6.6% of the total biomass, followed by *Jaculus jaculus* (6.2%), *Acanthodactylus* sp. (5.9%) and *Mus musculus* (5.3%). Other prey species are less frequent in their diet.

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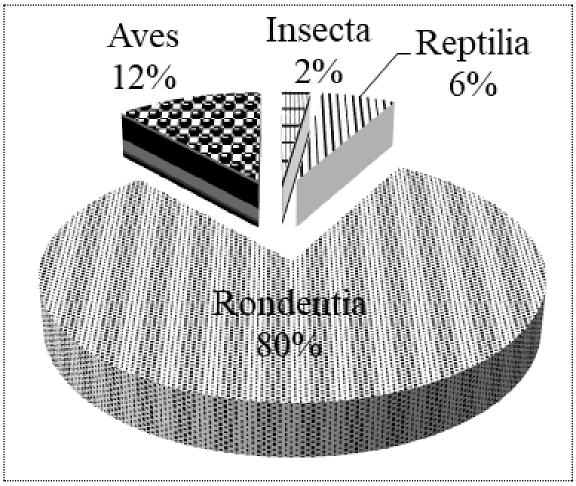

Figure 6. *Relative prey category biomass found in Kestrel pellets*

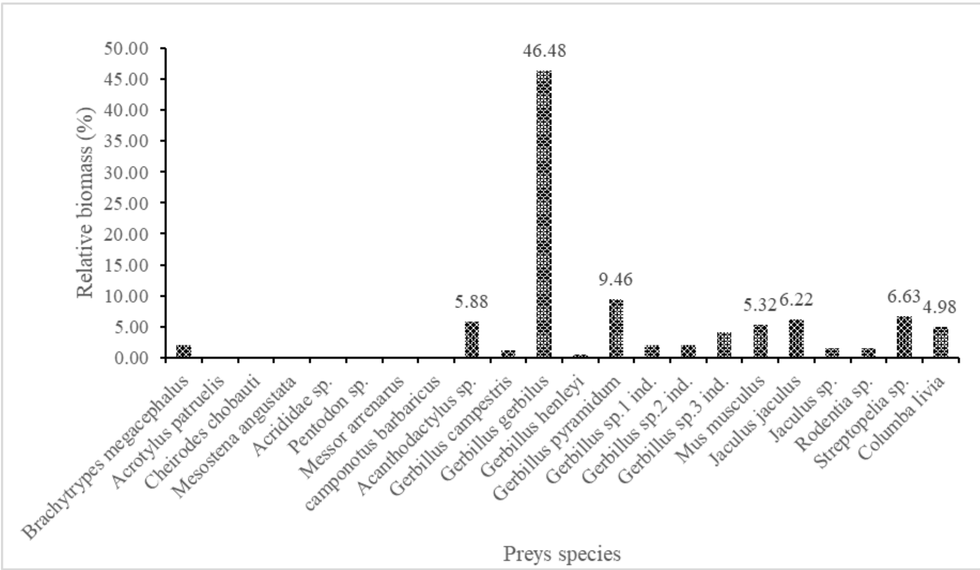

Figure 7. *Relative biomasses of prey species reported in kestrel pellets*

Frequency of occurrence of prey species of F. tinnunculus

Given the abundance of rodents in the area, the diet analysis of the kestrel at Miha Saleh station reveals that *Gerbillus gerbillus* accounts for 67.4% of its food (*Fig. 8*).

Some species are eaten opportunistically, while *Brachytrypes megacephalus* is occasionally consumed. The existence of common prey, such as birds and insects, indicates nutritional adaptability to seasonal and environmental fluctuations. As a major predator in the Miha Saleh environment, the kestrel's feeding habits demonstrate its vital role in controlling rodent populations, preserving ecological balance, and adjusting to changes in prey.

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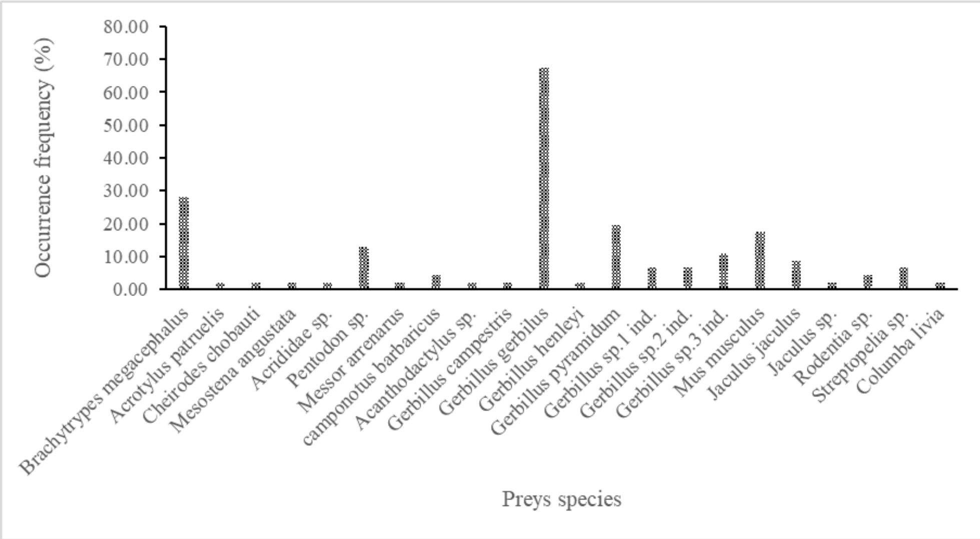

Figure 8. *Frequency of occurrence of prey species of F. tinnunculus identified in kestrel pellets*

Study of the diet of F. tinnunculus using ecological indices of structure

According to the results shown in *Figure 9*, the Shannon Diversity Index (H') is approximately 3.3 bits, while the maximum possible diversity (H'max) is 4.5 bits.

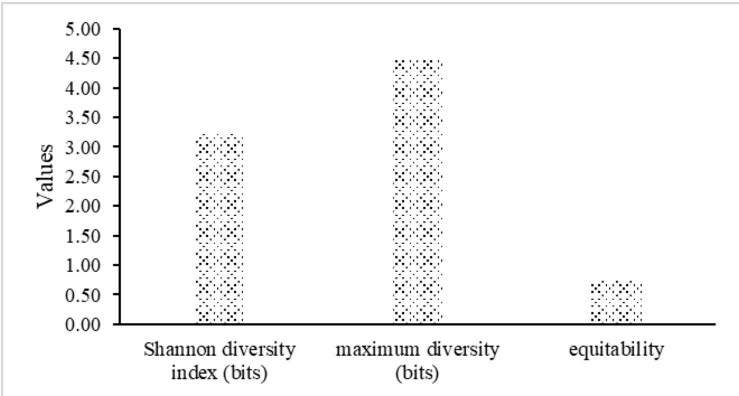

Figure 9. *Structural ecological indices applied to prey species*

This relatively high value of H' indicates a broad range of prey types in the diet, reflecting a high level of dietary diversity. The equitability index (J'), estimated at 0.73, suggests that prey species are relatively evenly distributed in the kestrel's diet, with no single species overwhelmingly dominant. This value, being close to 1, implies that the kestrel does not rely on a narrow subset of prey but instead exploits a wide variety of available resources. The types of values related to equitability and diversity illustrate that the common kestrel (*Falco tinnunculus*) qualifies as an opportunistic predator. Such patterns likely reflect the diverse ecosystem at Miha Saleh Station composed of agricultural fields, date palm plantations, and wild vegetation. This mosaic of habitats provides plentiful and diverse prey such as smaller mammals, birds, and arthropods, which allows the kestrel to modify its foraging tactics based on the local prey's seasonal availability.

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Discussions

Pellet-based dietary analysis is a well-established method for studying feeding behavior in nocturnal raptors (Balestrieri et al., 2019; Wells and Miller, 2021; Kannan et al., 2023). However, its application to diurnal raptors remains comparatively limited (Matos et al., 2015; Wells and Miller, 2021). The present study contributes to this less-explored area by analyzing the morphometric characteristics of common kestrel (*Falco tinnunculus*) pellets in the Souf region of southeastern Algeria.

Our results show that kestrel pellets in this region vary in length from 17.8 mm to 62.9 mm, with a mean of 33.7 ± 8.6 mm. The maximum diameter ranges between 13.8 mm and 28.3 mm (mean: 21.9 ± 3 mm), and the weight varies from 11.9 g to 71 g (mean: 29.6 ± 12 g). These values are significantly higher than those reported by Souttou et al. (2006) for kestrels in El Harrach (Algiers), where pellet length ranged from 10 mm to 45 mm (mean: 24.5 ± 7.5 mm) and diameter from 10 mm to 20 mm (mean: 13 ± 2.3 mm).

When comparing with a related diurnal species, the Lanner falcon (*Falco biarmicus*), studied by Souttou et al. (2005), we find that the latter produces even larger pellets, ranging from 25 mm to 78 mm in length (mean: 42 ± 10.36 mm) and 18 mm to 30 mm in diameter (mean: 24.38 ± 4.0 mm).

In terms of nocturnal raptors, Sekour (2010) recorded that *Athene noctua* in Djanet produces smaller pellets, measuring 10 mm to 47 mm in length (mean: 28.8 ± 8.2 mm) and 7 mm to 17 mm in diameter (mean: 12.7 ± 2.2 mm). In contrast, *Bubo ascalaphus* (the common barn owl), also studied by Sekour (2010) in the Souf region, produces larger pellets, ranging from 21 mm to 70 mm in length (mean: 36.7 ± 8.7 mm) and 18 mm to 55 mm in diameter (mean: 26.4 ± 5.8 mm).

Generally, the pellets of the common kestrel in the Souf region are larger than those of *Athene noctua*, slightly smaller than those of *Bubo ascalaphus*, and clearly smaller than those of the Lanner falcon. Such comparative data illustrate the trophic and ecological position of the common kestrel in relation to other raptors. The intermediate size of its pellets - smaller than those of *Bubo ascalaphus* and *Falco biarmicus*, yet larger than those of *Athene noctua* - suggests a diet consisting primarily of medium-sized prey. This aligns with the kestrel's generalist predator lifestyle, capable of adapting to varying prey availability.

The relatively large size and mass of the pellets found in the Souf region are likely indicative of a diet rich in rodents, especially *Gerbillus gerbillus*, a species well adapted to arid environments. This dietary breadth underscores the kestrel's ecological role, particularly in the regulation of rodent populations, which are often agricultural pests in the region. In this context, the kestrel's ability to exploit a wide range of prey contributes to its survival in diverse habitats and supports its role in maintaining ecosystem balance.

Furthermore, the anatomical analysis of these pellets provides valuable insights into the species' foraging behavior, local prey availability, and its potential contribution to sustainable pest control in agricultural ecosystems, especially in sensitive regions like southern Algeria. Thus, these data not only expand our understanding of kestrel diet but also highlight the bird's importance in integrated pest management strategies, further emphasizing the need for its conservation.

In this study, 141 identified species and four trophic classes were counted thanks to the analysis of kestrel pellets from the Miha Saleh area. The most common category was rodents (AR = 63.8%), followed by insects (AR = 27%). Values for the other

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nutritional categories did not exceed 7%, particularly for birds (AR = 2.8%) and reptiles (AR = 6.4%). These results confirm those found in this study. Similarly, Souttou et al. (2006) reported nearly seven categories in 1999 after studying El Harrach's diet for two years (1999-2000). The most common order was insects (AR = 43.2%), followed by birds (AR = 37.4%), then chiroptera and mammals (AR = 9.4%) and myriapods (AR = 5.8%). In the suburbs of Algiers, Souttou et al. (2015) found that vertebrate prey was the most consumed by kestrels (64.8%), while invertebrate prey accounted for 35.2%.

These results are similar to those of Jones et al. (2024) in England, Orozco-Valor and Grande (2021) and Sarasola et al. (2024) in the Semiarid Forests of Central Argentina, and Boal et al. (2021) in the southern high plains of Texas (USA).

Other research has also highlighted the significance of invertebrate prey in the diet of common kestrels (Yalden and Warburton, 1979; Carillo et al., 1994). Insects were the largest category of invertebrate prey in these studies. In the marshes of Saint-Suiil and Camargue, common kestrels feed mainly on insects (16.8%) (Zahorodnyi et al., 2021). In a suburb of Rome, Italy, Fattorini et al. (1999) recorded 1,108 insect prey species (46.9%) out of a total of 2,361 prey species in kestrel pellets. The significance of insects in the diet of this raptor was also validated by Salvati et al. (1999) in urban (37.7%), suburban (41.1%), and agricultural (50.4%) areas of Rome.

In the same circumstance, Piatella et al. (1999) observed that insects were the most frequently consumed prey by kestrels in urban environments. This finding was corroborated by Huchler et al. (2020), Zahorodnyi et al. (2021) in Ukraine, and Filipiuc et al. (2024) in Romania. However, kestrels that rely primarily on invertebrates must capture a large number of small prey to obtain the same energy content as a single vertebrate prey (Van Zyl, 1994).

The study findings reveal that in the Souf region, the kestrel's primary food source is rodents, which make up 80.3% of its food biomass. Among them, *Gerbillus gerbillus* is the most significant prey, accounting for 46.5%. After rodents, birds are the second most important food source, making up 11.6%, followed by reptiles at 5.9%. *Gerbillus pyramidum*, another rodent species, represents 9.5% of the food biomass. These results are somewhat in line with those of Souttou et al. (2015) in Djelfa, Algeria, where rodents accounted for 55.4% of the food biomass, and *Meriones shawii* was the dominant species, making up 52%.

In contrast, Souttou et al. (2006) reported from El Harrach (North of Algeria) that birds constituted the dominant prey, accounting for 78.0% of the kestrel's diet. Several authors have confirmed the importance of rodents as preferred prey in the kestrel diet, including Korpimäki (1985, 1986), Souttou et al. (2015), Piatella et al. (1999), Romanowski (1996), Zmihorski and Rejt (2007), and Cornell et al. (2023). In another study on rodent population and predation monitoring, Vibe-Petersen et al. (2006) showed that predation reduces population size during the period of rodent population growth (post-breeding). In this study, two species of rodents, the small sand gerbil (*Gerbillus gerbillus*) and the large gerbil (*Gerbillus pyramidum*), Are recognized as the primary elements of the kestrel's diet in the agricultural regions of Souf. These two species of rodents are also known to cause significant losses in crops in Algerian desert regions (Alia, 2019; Alia et al., 2025).

These findings are consistent with those of Souttou et al. (2015), who also reported that the common kestrel's diet in the semi-arid grasslands of Djelfa (Algeria) was primarily composed of two rodent species, *Meriones shawii* and *Gerbillus campestris*.

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Notably, *Meriones shawii* poses a significant threat to various crops in the southern Mediterranean basin, particularly wheat and barley (Ettiss et al., 2020; Wahid et al., 2021; Haida et al., 2022) Which can lead to significant crop losses.

Rodents like gerbils and mice, often seen as agricultural pests, play a crucial role in the kestrel's diet. This observation supports previous research on kestrel feeding habits, highlighting their natural role in controlling rodent populations (Tulis et al., 2017; Fargallo et al., 2020; Montoya et al., 2021; Singleton et al., 2021; Jurišić et al., 2022; Witmer, 2022).

The kestrel is recognized as beneficial in the protection of agricultural crops because it acts as a biological control agent by reducing the populations of species harmful to crops, including rodents, birds, and insects. Therefore, the preservation of these raptors is essential to maintain this beneficial balance.

Conclusion

This study highlights the importance of pellet analysis as an effective tool for understanding the feeding ecology of diurnal raptors, particularly the common kestrel (*Falco tinnunculus*) in southern Algeria. The morphometric and dietary data from the Souf region show that this raptor predominantly feeds on rodents, especially *Gerbillus gerbillus*, reflecting its adaptability to arid environments and its generalist predation strategy. The kestrel occupies an intermediate trophic position, targeting prey of moderate size, which positions it as a key regulator of local prey populations. Its diet supports its role as a natural biological control agent, especially in agricultural ecosystems where rodent pests can cause significant damage.

These findings underscore the ecological and agronomic importance of conserving kestrel populations. By controlling pests naturally, kestrels contribute to sustainable agriculture and ecosystem health. Promoting their protection should thus be an integral part of integrated pest management strategies in arid and semi-arid regions.

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