Feeding ecology of the Common Kestrel *Falco tinnunculus* in the south of Alicante (SE Spain)

Adrian Orihuela-Torres, Pablo Perales, Daniel Rosado & Juan Manuel Pérez-García

The diet composition of the Common Kestrel *Falco tinnunculus* was studied in 15 territories in southern Alicante (Spain) in 2012–2014. In all, 571 pellets were analyzed. Insects occurred in 89.9% of samples, while birds occurred in 7.5%, mammals in 2.5% and reptiles in only 0.08%. Nevertheless, mammals represented 62.3% of the biomass of the diet. This diet composition differs from reports from northern and central Europe, where larger prey items such as micro-mammals predominate. This could be due to several factors including, above all, the lower density and richness of micro-mammals in the Mediterranean region and differences in the activity patterns of both micro-mammals and Kestrels in this region. We found local spatial differences in the consumption of birds that could be related to dissimilarities in land-use intensification or local primary prey abundance. Finally, we report the first records of the consumption by Kestrels of an exotic invasive Coleoptera, the red palm weevil *Rhynchophorus ferrugineus*.

Key words: Common Kestrel, *Falco tinnunculus*, diet, prey, Mediterranean, *Rhynchophorus ferrugineus*.

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The Common Kestrel *Falco tinnunculus* is a medium-sized falcon and one of the most abundant raptors in urban and suburban environments (Cramp & Simmons 1980). On a world scale, it has a Palaearctic, Afrotropical and Indo-Malayan distribution (Ferguson-Lees & Christie 2004), while in Spain it is found throughout almost the entire Iberian Peninsula, as well as on the Balearic and Canary Islands (Martínez-Padilla 2003). Iberian populations are mainly resident, while Central European populations are migratory and many individuals migrate to the Peninsula in winter (Martínez-Padilla 2003).

The Common Kestrel exhibits great trophic plasticity between populations since it ranges from a micro-mammal specialist in Northern Europe (e.g. Glutz von Blotzheim *et al.* 1973, Cramp & Simmons 1980, Korpimäki 1986, Żmihorski & Rejt 2007, Steen *et al.* 2011) to a generalist in Mediterranean areas, where it feeds on passerines, insects, reptiles, amphibians and even bats (e.g. Valverde 1967, Elósegui 1974, Veiga 1985, Negro *et al.* 1992, Gil-Delgado *et al.* 1995, Aparicio 2000, Souttou *et al.* 2007, Llorens Folgado 2012, Navarro-López *et al.* 2014, Navarro-López & Fargallo 2015). The same pattern is observed in Spain, where micro-mammals are the commonest prey in northern and central

regions (Elósegui 1974, Veiga 1985, Aparicio 2000, Navarro-López *et al.* 2014, Navarro-López & Fargallo 2015), while in the east and south mammals are gradually replaced by prey such as reptiles, birds and insects (Valverde 1967, Negro *et al.* 1992, Gil-Delgado *et al.* 1995, Llorens-Folgado 2012).

Despite existing information from the Iberian Peninsula on the diet of this raptor, no information is available for the semi-arid southeast of the Iberian Peninsula. The objectives of the present study were thus to determine the diet of the Common Kestrel in the south of Alicante, to evaluate the role of the different prey groups in the biomass consumed, and to explore spatial variations in its diet in terms of landscape composition.

Material and Methods

We studied 15 Common Kestrel territories, with both confirmed and unconfirmed reproduction, in the south of Alicante province, SE Spain (38° 9' N, 0° 43' W). The territories were grouped into two sub-areas (northern and southern) due to differences in landscape configuration. The southern subarea (n = 7), located in the municipalities of Torremendo, San Miguel de Salinas and Torrevieja, is characterized by the presence of citrus and dry crops, mixed in with remnants of the native vegetation consisting of thymes *Thymus* sp. and thermophilous scrub. By contrast, the northern subarea (n = 8), which encompasses rural areas in Elche, Sierra de Crevillente and El Hondo Natural Park, consists of a mix of palm groves, along with natural patches of *Pinus halepensis* and thermophilous scrub, irrigated crops and saltmarshes.

The Kestrels' diets were studied by pellet analysis (Marti *et al.* 2007). In 2012–2014, pellets were collected around nest sites (territories with confirmed reproduction; n = 10) and roosts (territories with unknown reproduction status; n = 5) at least once every two months. Each pellet was wrapped in foil to prevent it from mixing with other pellets and was kept dry until analysis. The determination of pellet content was carried out following a modified version of Marti *et al.* (2007) for small samples. First, each pellet was dissected under dry conditions and all the remains were affixed to pieces of adhesive tape for later identification. Remains were identified using specific identification guides for each taxon (Harde & Severa 1981, Moreno 1985, Zahradník 1985, Chinery 1988, Gosálbez-Noguera 1987, Bellman 1994) or were compared with specimens in private collections. Prey remains were identified to species level whenever possible.

Prey items were classified into four taxonomic groups (birds, mammals, reptiles and insects). The frequency of occurrence was defined as the number of prey items from a species or taxonomic group divided by the total number of analyzed prey items. The consumed biomass was calculated as the mass contribution of each species or taxonomic group according to their standard weights to the total biomass consumed (Geng *et al.* 2009). Standard prey weights were taken from Rodríguez-López (2004). The weights of unidentified passerines were calculated using the standard weight of the Common Sparrow *Passer domesticus* since the remains were similar in size to this species.

To assess dietary differences between northern and southern areas we compared the biomass of the four main taxonomic groups using Kruskal-Wallis tests. All analyses were carried out with R statistical software version 2.12.2 (R Core Team 2016).

Results

A total of 571 pellets from 15 different territories were analyzed (mean sample size = 38 pellets/territory ± 46.3 SD). We identified a total of 2,314 prey items corresponding to a mean of 154 ± 278.1 SD prey items per territory (Table 1). There was a minimum of 17 species of four taxonomic classes: mammals (3 sp.), birds (2 sp.), reptiles (2 sp.) and insects (8 at family level and 2 sp.) (Table 1). Prey size varied from 0.01 g (Hymenoptera) to 300 g (juvenile lagomorphs).

In terms of the frequency of occurrence, insects were by far the most important prey group (89.9%), followed by mammals and birds (Figure 1). At species-prey level, Orthoptera (over 50%), Hymenoptera (almost 15%) and Coleoptera (13.3%) had the highest frequency of occurrence. In terms of prey biomass, mammals represented 62.28% of the consumed biomass, followed by birds (23.80%), insects (12.28%) and reptiles (1.72%) (Figure 1).

Table 1. Diet composition of the Common Kestrel *Falco tinnunculus* in the south of Alicante, Spain. Number of individuals (Nº), frequency of occurrence (FO) in percentage (%), and total biomass consumed (B) in grams (g) and percentage (%), are shown. Only the most relevant insect species are included (FO>1%).
Composició de la dieta del Xoriguer comú Falco tinnunculus *al sud d'Alacant, Espanya. Es mostra el nombre d'individus (Nº), la freqüència d'aparició (FO) en percentatge del total (%) i la biomassa total consumida (B) en grams (g) i en percentatge (%). En els insectes únicament es van mostrar aquelles espècies més significatives (FO>1%).*

	Nº	FO %	B (g)	B (%)
Coraciformes				
Merops apiaster	1	0.04%	50	0.78%
Passeriformes				
Turdus merula	1	0.04%	80	1.24%
Unidentified passerines	56	2.42%	1400	21.78%
AVES	**58**	**2.50%**	**1530**	**23.80%**
Rodentia				
Mus spp.	5	0.22%	65	1.01%
Apodemus sylvaticus	2	0.09%	32	0.50%
Microtus duodecimcostatus	25	1.08%	500	7.78%
Rattus spp.	3	0.13%	450	7.00%
Unidentified micromammals	135	5.83%	1755	27.30%
Lagomorpha				
Oryctolagus cuniculus (juvenile)	4	0.17%	1200	18.67%
MAMMALIA	**174**	**7.52%**	**4002**	**62.28%**
Squamata				
Lacertidae				
Psammodromus algirus	1	0.04%	10	0.16%
Timon lepidus	1	0.04%	100	1.56%
REPTILIA	**2**	**0.08%**	**110**	**1.72%**
Dermaptera				
Forficulidae				
Forficula auricularia	63	2.72%	5	0.08%
Coleoptera				
Curculionidae				
Rhynchophorus ferrugineus	66	2.85%	66	1.03%
Unidentified beetles	243	10.49%	70.9	1.13%
Orthoptera				
Acrididae				
Anacridium aegyptium	35	1.51%	91	1.42%
Unidentified grasshoppers	1228	53.06%	454.4	7.09%
Hymenoptera				
Formicidae	336	14.51%	3.4	0.05%
Hemiptera				
Cicadidae	92	3.97%	92	1.43%
Unidentified insects	17	0.73%	3.4	0.05%
INSECTA	**2080**	**89.9%**	**786.1**	**12.28%**

One of the most interesting results was the presence of an exotic Coleoptera, the red palm weevil *Rhynchophorus ferrugineus*, which appeared in 66.67% of territories and in some even represented up to 10–12% of the frequency of occurrence.

We found that in northern territories more birds were consumed than in southern territories, in terms of both frequency of occurrence and biomass (H = 4.01, d.f. =1, p = 0.04; medians: northern area = 137.5, southern area = 25). By contrast, no differences were found between
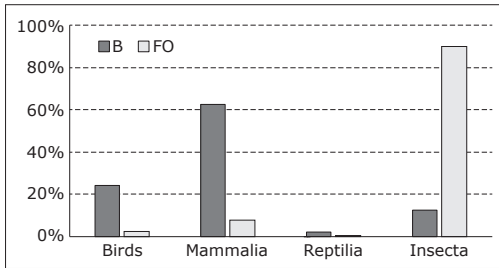
Figure 1. Percentage of prey frequency of occurrence (FO) and of biomass consumed (B) in the diet of the Common Kestrel *Falco tinnunculus* in the south of Alicante, Spain.
Freqüència d'aparició de les preses (FO) i biomassa consumida (B) en la dieta del Xoriguer comú Falco tinnunculus *al sud d'Alacant, Espanya.*

north and south in the consumption of other taxonomic groups (mammals, reptiles and insects).

Discussion

The diet composition of Common Kestrels in southeastern Spain differs little from the dietary patterns found in other Mediterranean areas, in which insects are the most frequent prey item (Veiga 1985, Gil-Delgado *et al.* 1995, Navarro López *et al.* 2014, Navarro-López & Fargallo 2015). Nevertheless, micro-mammals represented most of the consumed biomass. Reptiles appeared in low frequencies in the sampled diets, unlike in other Mediterranean populations of Kestrels (Veiga 1985, Gil-Delgado *et al.* 1995, Navarro-López *et al.* 2014, Navarro-López & Fargallo 2015). This is surprising because reptiles are abundant and well distributed throughout the study area (Pleguezuelos *et al.* 2002). However, this bias could be related to the fact that more pellets were collected in winter than in the seasons of the year in which reptiles are most active.

Optimal foraging theory states that Kestrels should hunt preferentially the energetically most advantageous prey items (Stephens & Krebs 1986). In our study, Kestrels captured many more invertebrates than other prey items such as birds or mammals. This was probably due to a trade-off between energy investment in capture and nutritional benefits. For example, the high rate of capture of invertebrates in SE Spain could be related to the low richness, diversity and abundance of micro-mammals in this area

(Palomo & Gisbert 2002). Specifically, voles (Fam. Microtidae) are one of the principal prey items in most Common Kestrel populations in central and northern Europe, as well as in Asia (Korpimäki 1985, 1986; Rejt 2004, Żmihorski & Rejt 2007, Steen *et al.* 2011, Geng *et al.* 2009). However, in our study area voles are scarce (Palomo *et al.* 2007). Moreover, most of rodents present in our study area are mainly nocturnal and so there is a temporal mismatch between the daily activity patterns of prey and predators (Roll *et al.* 2006, Monterroso *et al.* 2013).

Despite the relative lack of mammalian remains in the pellets, their biomass was greater than that of other taxa. However, this could be an overestimate given the presence of the remains of medium-sized items such as rats *Rattus* sp. and rabbits, for which the percentage of consumption could vary. Moreover, in the case of rabbits, Kestrels rarely attack live animals but will scavenge carcasses (Llorens Folgado 2012). In fact, the lagomorph population in southern Alicante is very high (Pedauyé & Pérez-García 2014) and Kestrels are often observed feeding on rabbit carcasses (pers. obs.).

Although birds were the second prey group by biomass in the pellets found in our study area, our values differed greatly from those found for the city of Valencia (East Spain) by Llorens-Folgado (2012). However, this difference may be in part methodological given that this author studied kestrels directly at nests, which may have led to an overestimation of larger prey items in relation to the number of arthropods (Sánchez-Zapata & Calvo 1998).

The Common Kestrel is able to adapt to different habitats due to its highly plastic trophic requirements (Navarro-López *et al.* 2014). In this study, we show how diet composition could be affected by changes in the configuration of land use at local scale. We detected a significantly higher consumption of birds in the southern area, which could be explained by two, non-mutually exclusive hypotheses. Kestrels may consume a greater proportion of this secondary prey item (i.e. birds) in southern areas due to a relative absence of the most profitable prey items (micro-mammals). Alternatively, Kestrels may consume a greater proportion of birds in southern areas because of a greater abundance of birds as opposed to mammals, which would make their capture more profitable (i.e. shorter search time). In the
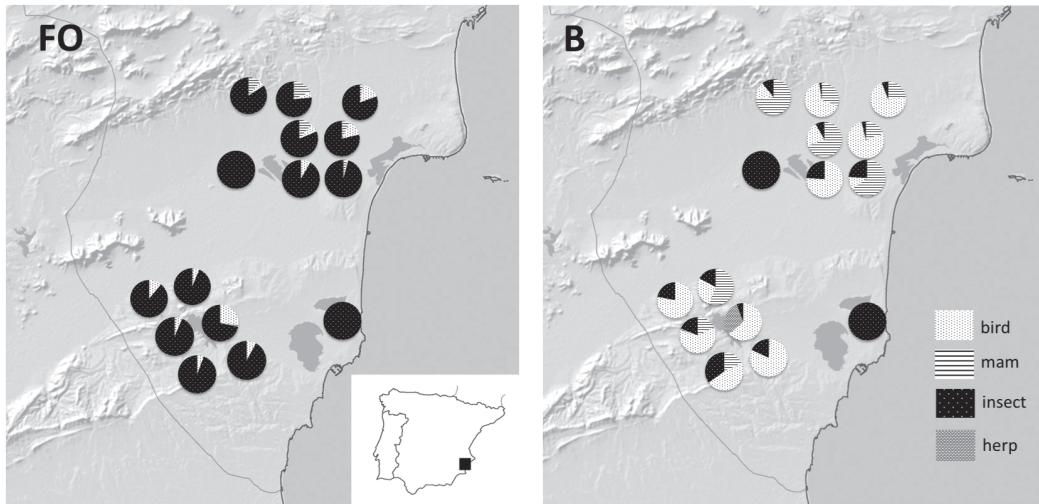
Figure 2. Spatial distribution of the frequency of occurrence (FO) and of biomass (B) of the main taxonomic groups consumed by the Common Kestrel *Falco tinnunculus* in the south of Alicante, Spain. The following prey categories are shown: birds (bird), mammals (mam), insects (insect) and reptiles (herp).
Distribució espacial de la freqüència d'aparició (FO) i biomassa (B) dels principals grups taxonòmics consumits pel Xoriguer comú Falco tinnunculus *al sud d'Alacant, Espanya. Mostrem les següents categories de preses: ocells (bird), mamífers (mam), insectes (insect) i rèptils (herp).*

northern area there is greater human disturbance, which could favour the presence of rodents as such rats *Rattus* sp. and mice *Mus* sp. that are associated with human habitation. Additionally, this area is covered by low scrublands and saline grassland in the area the El Hondo Natural Park, which is occupied by the Mediterranean pine vole *Microtus duodecimcostatus*. On the other hand, the populations of the most consumed bird species – namely, House Sparrow *Passer domesticus*, Spotless Starling *Sturnus unicolor* and Blackbird *Turdus merula* (Navarro-López *et al.* 2014, Llorens-Folgado 2012) – do not seem to differ greatly between the two studied subareas. Nevertheless, it would be worthwhile to carry out studies on prey availability in order to test these two hypotheses.

Another evidence of the trophic plasticity of this raptor was the detection of red palm weevil in pellets that thus reveals its ability to incorporate novel prey items into its diet. These exotic beetles were found mainly in the northern subarea, in lowland territories with terraces of the *Phoenix* palms. The red palm weevil was first identified in the Iberian Peninsula in Almuñécar (Granada) in 1996, in palms imported from Egypt (Martínez-Tenedor 2006). It quickly spread to the southeast of the peninsular, where it has begun to cause severe damage in palm

groves including the Palmeral de Elche, a World Heritage Site declared by UNESCO (Molina 2007) located in our study area. Our results thus suggest that Common Kestrels could be used as an efficient sentinel of the presence of this invasive beetle as it may form part of its diet. Nevertheless, further evidence is still needed of this dietary shift if we are to evaluate its role as a potential pest controller.

Acknowledgments

Resum

Ecologia tròfica del Xoriguer comú *Falco tinnunculus* al sud d'Alacant (SE d'Espanya)

Es va estudiar la composició de la dieta de 15 territoris de Xoriguer comú *Falco tinnunculus* al sud d'Alacant

entre els anys 2012 - 2014. Aquest estudi es va realitzar mitjançant la recollida i l'anàlisi de 571 egagròpiles durant tot l'any. Els insectes van aparèixer en el 89,9% de les mostres, mentre que les aus tan sols en el 7,5%, els mamífers en el 2,5% i, amb un percentatge molt baix, els rèptils amb el 0,08%. No obstant això, els mamífers van representar la major part de la biomassa amb un 62,3%. Aquesta dieta difereix de la registrada al nord i centre d'Europa, on predominen preses de major mida, com els micromamífers. Això podria ser a causa de diversos factors, principalment la baixa densitat i riquesa de micromamífers en la regió mediterrània i les diferencies en patrons d'activitat entre els micromamífers i els xoriguers. Vam trobar diferències espacials locals en el consum d'ocells dins del nostre estudi que podrien estar relacionades amb diferències en la intensificació de l'ús de la terra o l'abundància local de preses primàries. Finalment, informem del primer registre de consum d'un coleòpter exòtic invasor, el morrut roig *Rhynchophorus ferrugineus*.

Resumen

Ecología trófica del Cernícalo vulgar *Falco tinnunculus* en el sur de Alicante (SE de España)

Se estudió la composición de la dieta de 15 territorios de Cernícalo vulgar *Falco tinnunculus* en el sur de Alicante (España) entre los años 2012 - 2014. Este estudio se realizó mediante la recolección y el análisis de 571 egagrópilas, a lo largo de todo el año. Los insectos aparecieron en el 89,9% de las muestras, mientras que las aves en solo el 7,5%, los mamíferos el 2,5% y, con un porcentaje muy bajo, los reptiles con un 0,08%. Sin embargo, los mamíferos representaron la mayor parte de la biomasa con un 62,3%. Esta dieta difiere de las registradas en el norte y centro de Europa, donde predominan presas de mayor tamaño, como los micromamíferos. Esto podría ser debido a varios factores, principalmente la baja densidad y riqueza de micromamíferos en la región mediterránea y las diferencias en patrones de actividad entre los micromamíferos y los cernícalos vulgares. Encontramos diferencias espaciales locales en el consumo de aves dentro de nuestro estudio que podrían estar relacionados con diferencias en la intensificación del uso del suelo o la abundancia local de presas primarias. Finalmente informamos del primer registro de consumo de un coleóptero exótico invasor, el picudo rojo *Rhynchophorus ferrugineus*.

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