

NESTLING DIET AND FLEDGLING PRODUCTION OF EURASIAN KESTRELS (*FALCO TINNUNCULUS*) IN EASTERN SPAIN

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ABSTRACT.—We studied 81 Eurasian kestrel (*Falco tinnunculus*) nests in the Alto Palancia region (Castellón, eastern Spain) from 1982–87. Fledgling production was recorded in routine visits to the nests, and the diet was determined by pellet analysis. The mean date of laying was 8 May ($N = 24$, $SD = 11.5$), similar to that of populations breeding further north in Europe. On average, each successful pair produced four fledglings per year ($N = 47$, $SD = 0.7$, range = 2–5), and no significant differences in fledgling success were found among years. Grasshoppers formed the bulk of the diet during the nestling period. Mammals and birds were scarcely represented. The number of fledglings per successful pair was similar to or higher than that reported from Finland, Germany, and England where voles are the main prey brought to the nestlings. We suggest that a relative abundance of insects, and reduced energy requirements for thermoregulation in Mediterranean areas allow kestrels to successfully feed their young mainly on insects, without reducing fledgling production in relation to populations where voles form the bulk of the nestling diet.

KEY WORDS: Eurasian kestrel; *Falco tinnunculus*; fledgling production; laying date; nestling diet; Spain.

Dieta de los pollos y productividad del cernícalo vulgar (*Falco tinnunculus*) en el Este de España

RESUMEN.—Se estudiaron 81 nidos de cernícalo vulgar (*Falco tinnunculus*) en la comarca del Alto Palancia (Castellón, Este de España) entre 1982–87. La producción de pollos se estudió mediante visitas periódicas a los nidos, y la dieta analizando las egagrópilas recolectadas durante el periodo de permanencia de los pollos en el nido. La fecha media de inicio de la puesta fue el 8 de Mayo ($N = 24$, $SD = 11.5$), similar a las observadas en otros países de Europa. Cada pareja con éxito produce una media de cuatro pollos por año ($N = 47$, $SD = 0.7$, rango = 2–5), no habiendo diferencias significativas entre años. Los saltamontes forman la base de la dieta durante el periodo estudiado, estando los mamíferos y las aves escasamente representados. La producción de pollos por pareja con éxito es similar o mayor a las obtenidas en Finlandia, Alemania e Inglaterra, donde los topillos forman la base de la dieta de los pollos. Se sugiere que una mayor disponibilidad de insectos, y una reducción de los requerimientos energéticos de los pollos en las áreas mediterráneas, permiten a los cernícalos alimentar a los pollos con una dieta basada en insectos sin reducir su productividad con respecto a poblaciones donde los mamíferos son la base de la dieta.

[Traducción Autores]

The diets of several raptor species in the Mediterranean region differ from those of conspecifics breeding farther north in Europe (Delibes et al. 1975, Hiraldo et al. 1975). Some prey species are found in the diets of Mediterranean and non-Mediterranean populations in different proportions, and southern populations also have access to prey that are scarce or absent in northern regions (e.g., reptiles; Herrera 1973, Arnold and Burton 1982). Rodents, birds, and beetles are the main prey types consumed by the Eurasian kestrel (*Falco tinnunculus*) in northern Europe (Cramp and Simmons 1980, Yalden 1980, Village 1982, 1990, Kostrzewa and Kostrzewa 1990, Korpimäki and Norrdahl 1991),

while reptiles, birds, and grasshoppers are the major prey for populations living near the Mediterranean (Valverde 1967, Thiollay 1968, Araujo 1973, Garzón 1973, Cramp and Simmons 1980, Massa 1981).

In general, the number of fledglings reared by raptors is closely linked to prey abundance (Newton 1979, 1985, Kostrzewa and Kostrzewa 1990, Korpimäki and Norrdahl 1991). Because of the energy costs of transporting prey, Shrubbs (1980) suggested that, in British farmland, it is not possible for the parents to adequately provision the nestlings by increasing the proportion of insects in their diet while decreasing small mammals and birds. These two later groups are the main prey of some kestrel pop-

ulations in Great Britain (Yalden 1980, Village 1982, 1990), but are much scarcer in Mediterranean populations (Village 1990).

In this paper, we present data on the nestling diet and the production of fledglings of Eurasian kestrels in eastern Spain. Our main objective was to examine the effect of a change in the composition of the diet on fledgling production by comparing our data with those of populations breeding further north. We also present information about the nesting sites and laying dates of the population studied.

STUDY AREA AND METHODS

The 1500 km² study area was located in the Alto Palancia (eastern Spain, 39°55'N, 0°38'W) at an altitude varying between 300 and 1400 m. The area had a variety of vegetation types including pines (*Pinus halepensis*, *P. pinaster*), oaks (*Quercus ilex* and *Q. faginea*), and agricultural areas. Common shrubs included *Ulex parviflorus*, *Rosmarinus officinalis*, *Quercus coccifera*, *Erica multiflora*, *Genista scorpius* and others typical of mediterranean areas (Rigual 1983). Two rivers, the Palancia and the Mijares, crossed the study area. The riverside vegetation included *Scirpus holochoenus*, *Populus nigra* and *Tamarix gallica* among others. Cliffs were abundant along the rivers and gorges.

Breeding data were collected between 1982 and 1987, although we also included pellets collected until 1992 in the analyses. We did not try to find all the kestrel nests within the study area, but each of the 81 active nests found during the study was monitored periodically, depending on the nesting stage and priorities imposed by the study of other raptor species (Verdejo 1994). During this study, we tried to find nests of all the diurnal raptors, both in trees and in cliffs (Verdejo 1994), so we think that the kestrel nests found were representative of the nest sites of this population. Laying dates were estimated by backdating from the known dates of some events (laying of the eggs, hatching, appearance of quills, fledging; see Village 1990). The number of nestlings was assessed on each visit, the last of which was about 1 wk before the estimated fledging date calculated assuming typical laying, incubation, and nestling periods (Cramp and Simmons 1980, Village 1990). We also visited the nests a few days after the estimated fledging date, and counted the fledglings, which by this time were wandering near the nest.

One hundred and twenty-three complete pellets were collected from 24 nests (range 3–10 pellets per nest) during the nestling period, and 1280 prey items were identified. Each pellet was analyzed under binocular magnifying glasses following the methods of Village (1982, 1990) and Yalden and Yalden (1985). Many soft-bodied invertebrates consumed by kestrels rarely leave traces in the pellets (Village 1990). We did not find remains of soft-bodied invertebrates, so we do not know whether they were consumed or not. If they were, the proportion of vertebrates presented here would be overestimated.

Grasshopper density was obtained in 1992, after we realized their importance in the nestling diet. We performed counts on 24 line transects 25-m long and 1-m

wide from 0900–1200 H and 1800–2000 H, on areas where kestrels were seen hunting, and spaced over about 200 km², thus including a relatively large number of kestrel territories. Thirty-four grasshoppers were caught after the counts and weighed to the nearest 0.01 g with an electronic balance.

RESULTS

Reproduction and Diet. We observed 81 active kestrel nests in the Alto Palancia. Of these, 69% were on ledges on cliffs, 28.5% in buildings (in holes in the walls of abandoned houses in the countryside), and 2.5% in trees.

The mean laying date in the Alto Palancia was 8 May (SD = 11.5, range 21 April to 31 May, $N = 24$). Most pairs (70%) started laying before 10 May. The last nestlings left the nests by the end of July or beginning of August.

Only one of the 81 active nests observed did not fledge any young. This nest was in a tree, and was destroyed by humans. However, since the search was not exhaustive, nests that failed early in the nesting period could have been overlooked. The exact number of fledglings was known for 47 nests. The average number of fledglings per successful pair was 4.0 (SD = 0.7; one nest produced two fledglings, eight nests three fledglings, 26 nests four fledglings, and 12 nests five fledglings). The number of fledglings produced per pair varied 3.9–4.5 in different years (Table 1), although the differences between years were non-significant (Kruskal-Wallis, $H = 3.39$, $P > 0.05$).

Although a small proportion of shrews, mice, birds, and reptiles were also caught, kestrels of the Alto Palancia consumed mainly insects during the nestling period (Table 2). Among insects, grasshoppers and beetles were the most abundant prey (Table 2). Small mammals were present in 8% of the pellets, beetles in 34%, and grasshoppers in 69%. The following species were identified in the pellets: *Crocidura russula*, *Apodemus sylvaticus*, and *Mus spretus*, among small mammals; *Passer domesticus*, *Carduelis carduelis*, and *Coturnix coturnix* among birds; and the lizard *Podarcis hispanica*.

Prey Density. The density of grasshoppers in the study plots averaged 0.4 individuals/m² (SD = 3.1, $N = 24$, range 0.04–0.52). The fresh weight of *Anacridium aegyptium*, varied from 3.0–5.7 g ($\bar{x} = 4.2$, SD = 1.4, $N = 18$), while that of the other grasshoppers species (mainly *Oedipoda germanica* and *O. caerulescens*) varied from 0.4–0.9 g ($\bar{x} = 0.6$, SD = 0.12, $N = 16$). We do not know the density of small

Table 1. Number of fledglings (NF) of European kestrels in the Alto Palancia, Spain (this study), compared to other populations. Numbers in parentheses are standard errors of the mean.

YEAR	SPAIN		ENGLAND (ARABLE) ^a		ENGLAND (MIXED) ^b		GERMANY ^c		FINLAND ^d	
	NF	N	NF	N	NF	N	NF	N	NF	N
1982	4.5 (0.5)	6	3.8 (0.3)	4	3.4 (0.2)	14	4.6	<13	3.9	9
1983	4.0 (1.1)	7	3.4 (0.5)	7	3.6 (0.3)	19	4.3	<14	2.9	7
1984	4.0 (1.1)	9	3.5 (0.3)	18	3.4 (0.4)	12	3.7	<13	2.0	2
1985	4.0 (1.1)	10	3.1 (0.3)	14	3.7 (0.4)	9	3.9	<9	4.6	16
1986	3.9 (0.6)	8	3.5 (0.3)	19	2.3 (0.4)	9	5.1	<12	2.9	46
1987	4.0 (0.5)	7	4.0 (0.3)	15	2.8 (0.4)	5	3.8	<9	1.9	17
Total ^e	4.0 (0.1)	47	3.5 (0.1)	81	3.4 (0.1)	84	4.2		3.0	97

^a Farmland in eastern England, arable land (Village 1990).

^b Farmland in eastern England, mixed land (Village 1990).

^c Woodland in Germany (Kostrzewa and Kostrzewa 1990).

^d Mixed habitat in western Finland (Korpimäki and Norrdahl 1991).

^e The mean was calculated over the total number of nests except for Germany and Finland, where the values presented were the mean of the yearly means. The means of the British populations include the year 1981, because they were calculated by Village (1990) over the 7 yr.

mammals in the Alto Palancia. However, in his study on *Mus spretus* in orange groves, an optimum habitat for this species, García (1981) reported a maximum density of 0.0065 mice/m². Therefore, conservatively, grasshopper densities could be 61 times higher than mouse densities in the Alto Palancia. García (1981) also showed that the fresh weight of mice in orange groves varied from 9–15 g depending on sex and season. Thus, a mouse would be about three times heavier than *A. aegyptium* and about 20 times heavier than other species of grasshoppers. However, mice are crepuscular in Spain (García 1981), so they would be scarcely available to diurnal raptors.

DISCUSSION

Eurasian kestrels use a variety of nest sites including cliffs, tree cavities, stick-nests of other species, and even buildings (Village 1990). In the Alto

Palancia, most kestrel nests we found were on cliffs. Because we were unable to examine the possible nesting sites frequently, we may have missed nests that failed early in the breeding cycle. Thus, if failure was more frequent in trees than in cliffs, the proportion of cliff nests we report may have been overestimated. However, cliffs are relatively abundant in our study area, and kestrels may prefer nesting on cliffs rather than in trees where nests are more vulnerable to predators (Village 1990). In other areas where cliffs are abundant, Eurasian kestrels also commonly nest in the rocks (Village 1990, Aparicio 1994).

The laying dates of kestrels in the Alto Palancia were similar to those of other European populations (range for 10 European populations, 26 April to 13 May; see Village 1990, Table 37). Moreover, mean laying dates of five European populations, in which the density of voles has been studied, are earlier (range 16 April to 4 May) in good vole years than in the Alto Palancia. Aparicio (1994) found a mean laying date of 15 May in central Spain (data from control clutches). Therefore, no evidence exists that breeding in Spain occurs earlier than in central and northern Europe, as it seems to be the case for populations of other countries around the Mediterranean (Village 1990). If the kestrels in the Alto Palancia depend mostly on insects during the egg-laying period, they probably should wait for the insects to become abundant and active before initiating egg-laying. Supplemental feeding in central Spain has

Table 2. Composition of the diet of Eurasian kestrels in eastern Spain during the nesting period.

PREY TYPE	N	%
Total mammals	33	2.6
Total birds	9	0.7
Total reptiles	4	0.3
Total insects	1234	96.4
Grasshoppers	1064	83.0
Coleoptera	147	11.5
Other insects	24	1.9
Total prey	1280	

resulted in an advance of 2 wk in the mean laying date (Aparicio 1994).

Fledgling production per successful nest in the Alto Palancia was similar to that of Germany and the United Kingdom (see Table 1), where nestlings were fed mainly voles. The high production in Germany in 1986 was probably a consequence of the high number of voles available during that year (Village 1990). Only means were reported for this population, so we could not test for differences with the Alto Palancia. The British populations were studied from 1981–87 (Village 1990). Considering all the years, the mean number of fledglings of the two populations did not differ from that of the Alto Palancia. The production in Finland seems to be lower than in the Alto Palancia, but again, we cannot use statistics to test for significant differences. In any case, a study of the body condition of the chicks before fledging would be needed, to show whether the "quality" of the fledglings produced differs between populations.

In the Alto Palancia kestrels fed their nestlings mainly with insects, as is the case for other Mediterranean populations (Thiollay 1968, Araujo 1973, Garzón 1973). This contrasts with populations in Britain and central Europe where insects generally amount to less than 20% (Kostrzewska and Kostrzewska 1990, Village 1990, Korpimäki and Norrdahl 1991). The proportion of reptiles among vertebrates, and that of grasshoppers among insects, closely reflect predictions based on latitudinal trends (Village 1990, Fig. 17). However, the number of fledglings per successful nest in the Alto Palancia is similar to, or higher than, other European areas where the most abundant prey are small mammals, especially diurnal *Microtus* voles (Kostrzewska and Kostrzewska 1990, Village 1990, Korpimäki and Norrdahl 1991). Therefore, the substitution of grasshoppers for small mammals in the diet, at least to the amount we found, does not appear to adversely affect the fledgling production in our study area.

In northern Europe, low fledging success was correlated with years when voles were scarce (Village 1990, Korpimäki and Norrdahl 1991). In contrast, in the Alto Palancia, the average number of fledglings produced per successful pair per year remained similar over the years studied. Mean annual fledging success varies more in Germany ($F_{6,6} = 6.02$, $P < 0.05$) and in Finland ($F_{6,6} = 23.21$, $P < 0.001$; our calculations from data in Table 1). Therefore, the use of insects as major food during the nestling period

is related to a higher between-year stability in the production of fledglings. Long-term censuses of insect prey are needed to determine their patterns of abundance.

Two factors may help to explain how our population of kestrels managed to produce as many fledglings as populations subsisting on a diet of small mammals. Firstly, the main prey brought to the nests, grasshoppers, are much more abundant than small mammals, and both provide approximately the same energy per unit weight (Petrušewicz and Macfadyen 1970, Török 1981). Secondly, the food demands of the nestlings should be lower at higher ambient temperatures, since more energy is needed for thermoregulation in cold weather (O'Connor 1984, Kostrzewska and Kostrzewska 1990). Hatching in the Alto Palancia occurs by the end of May, so the young are in the nest when the ambient temperatures in Mediterranean areas are relatively high.

However, other aspects that would need further study have to be taken into account in explaining fledgling production in this population. Firstly, if the kestrels base their diet on insects, they would have to increase the delivery rate to the nest, which increases travel costs, to compensate for the lower mass per item. Studies on the relative costs of hunting techniques and comparisons between the costs of catching and transporting different prey types would be of value here. Secondly, we assumed that the costs of thermoregulation were lower than in northern populations. In fact, the costs may also be high if the temperature is above the thermoneutral zone. So, studies on the energy budget of nestlings are necessary. Finally, lifetime reproductive success of the parents should be studied to know whether raising this number of young per year has negative implications for their future by decreasing fecundity or survival prospects.

ACKNOWLEDGMENTS

We would like to thank Javier Bustamante, Andrew Village, and Karen Wiebe for comments and suggestions on an earlier draft.

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Received 19 March; accepted 11 July 1995