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Breeding Biology of the Eurasian Kestrel in the Steppes of Southwestern Spain

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The Eurasian Kestrel (*Falco tinnunculus*) breeds in all countries of Europe. Its recent decline in the Palearctic has been linked to agricultural intensification (Tucker and Heath 1994), persecution, pesticides and climate change (Shrubb 1993). Several studies have shown large annual fluctuations in numbers of breeding pairs due to weather effects (Cramp and Simmons 1980, Kostrzewa and Kostrzewa 1990, Kostrzewa and Kostrzewa 1991) and rodent availability (Cave 1968, Cramp and Simmons 1980, Dijkstra et al. 1982, Bonin and Strenna 1986, Village 1990, Korpimäki and Wiehn 1998).

While population declines have been documented for the Palearctic, Tucker and Heath (1994) estimated that the breeding population of Eurasian Kestrels in Spain was relatively stable at 25 000 and 30 000 pairs. Aparicio (1997) postulated that the breeding population has been stable since the 1970s. Studies of the Eurasian Kestrel in Iberia have focused on the species' diet (Garzón 1974, Veiga 1982), nestling growth (Veiga 1985) and other ecological topics (Aparicio 1994a, 1994b, 1998). Data on the productivity of the breeding population in Spain are very scarce. The only published account to date is by Gil-Delgado et al. (1995), who reported on production in the Castellón province (eastern Spain).

Here, we report on the productivity of Eurasian Kestrels nesting in the steppe habitat of southern Iberia, Spain in 1989–90. We compare our results with data from other populations throughout the species' breeding range in the western Palearctic.

Study Area and Methods

We studied the breeding population of Eurasian Kestrels at La Serena, Extremadura, in southwestern Spain (38°50′N, 5°20′W). This area is characterized by dry pastures (64.2%) and cereal crops (28.4%; mainly wheat, barley and oats). There are also small areas of scrub (3.1%; mainly *Retama sphaerocarpa*) and areas with Holmoaks (1.1%; *Quercus rotundifolia*) as well as fruit trees (mainly almond [*Prunus dulcis*]; Sánchez and Sánchez 1991). The study area has a mesomediterranean climate (Rivas-Martínez 1987). More information on the study area and its climate are reported by Avilés and Sánchez (1998).

In 1986, the Forestry Agency of Extremadura began a conservation project in the area that consisted of placing 900 wooden nest boxes in steppe habitat on electric power line stanchions (Sánchez and Sánchez 1991, Sánchez et al. 1996). In 1989 and 1990, 76 nest boxes were monitored weekly from the first stages of breeding. Visits were increased to 3–4-d intervals during the nestling period to more accurately determine factors influencing final breeding success. Laying date for each nest was determined by subtracting the incubation period of the species (28 d; Cramp and Simmons 1980) from the hatching date. Hatching date was determined by experienced observers, who took into account that all eggs hatch in 4 d (Cramp and Simmons 1980). We measured percent hatching success as the percentage of eggs within each clutch that hatched, percent nestling mortality as the percentage of young hatched that died in the nest, the number of fledglings per successful nest, breeding success as the number of fledglings per pair that laid at least one egg and percent egg productivity as the number of fledglings in each nest as a proportion of the total number of eggs laid in each nest.

Temperature and rainfall in the month previous to the onset of egg-laying were obtained from the meteorological station of Orellana, which is in the study area.

We tested for normality of the data with Kolmogorov-Smirnov tests. Only data on fledglings per successful nest and breeding success were normally distributed. For these two variables, analyses of variance and covariance were used for statistical analysis following Sokal and Rohlf (1979). A chi-square test was used to compare data on clutch size distribution to a Poisson distribution. Distribution of data on hatching success, percent nestling mortality and percent egg productivity were compared to a binomial distribution, also with a chi-square test. In no case was the null hypothesis rejected ($P > 0.05$; data distribution did not differ from a Poisson or binomial distribution). Therefore, we ran a General Linear Model (GLM) for data with a Poisson distribution to study between-year and seasonal variation in clutch size, and a GLM for data with binomial distribution to study variation in hatching success, percent nestling mortality and percent egg productivity (Crawley 1993). We used the statistical software package "S-PLUS 4" to test GLMs with chi-square tests (MathSoft 1997). To avoid small sample sizes when clutch size was used as a factor, the extremely low clutch size of one egg was removed ($N = 2$) from analyses. A Mann-Whitney test was used to test for between-year differences in laying date.

Results

Kestrels initiated egg laying on 10 April in 1990 and 23 April in 1989. The majority of pairs started laying dur-

Table 1. Comparisons of the reproductive performance of Eurasian Kestrels in southwestern Spain, 1989–90.

	1989 MEAN ± SD (N)	1990 MEAN ± SD (N)	STATISTIC P	BOTH YEARS MEAN ± SD (N)
Laying date	5 May ± 15.5	3 May ± 16.5	$U = 633.5$	3 May ± 16.1
	(26)	(49)	0.856[a]	(75)
Clutch size	4.6 ± 1.9	3.9 ± 1.3	$\chi^2_{74} = 85.8$	4.2 ± 1.3
	(26)	(49)	0.171[b]	(75)
Percent hatching success	84.4 ± 16.9	60.6 ± 37.5	$\chi^2_{289} = 375.2$	68.8 ± 33.4
	(24)	(43)	0.0009[b]	(67)
Percent nestling mortality	0.0 ± 0.0	4.8 ± 15.0	$\chi^2_{206} = 139.3$	2.9 ± 11.9
	(22)	(37)	0.491[b]	(59)
Fledglings per successful nest	4.0 ± 1.0	3.1 ± 1.4	$F_{1,55} = 8.2$	3.4 ± 1.4
	(22)	(34)	0.006[c]	(56)
Breeding success	3.9 ± 1.3	2.4 ± 1.8	$F_{1,65} = 11.8$	2.9 ± 1.8
	(23)	(43)	0.001[c]	(66)
Percent egg productivity	80.4 ± 24.3	57.4 ± 37.4	$\chi^2_{284} = 368.6$	65.2 ± 34.8
	(23)	(43)	0.009[b]	(66)

[a] Mann-Whitney test.
[b] General Linear Model.
[c] Analyses of the Variance.

ing the first and second weeks of April. Mean clutch size was 4.2 ± 1.3 eggs (±SD, range = 1–6 eggs, $N = 75$; Tables 1 and 2). The most common clutches consisted of 4 (27.6%) and 5 eggs (33.5%; Table 2). A clear seasonal decline in clutch size was observed both in 1989 (b = −0.048 eggs/day; $\chi^2_{24} = 52.6$; $P < 0.001$) and 1990 (b = −0.036 eggs/day; $\chi^2_{48} = 91.1$; $P < 0.001$). We did not detect between-year differences in the seasonal trend in clutch size (interaction of year x laying date; $\chi^2_{72} = 71.3$; $P = 0.43$).

We detected no effects on reproductive performance when we evaluated the interactions among year, laying date and clutch size (χ^2 test and analysis of covariance; $P > 0.05$ in all cases).

DISCUSSION

The onset of egg laying, percentage of eggs laid in April, clutch size and other reproductive rates observed in our study were within the range described for this species (Cave 1968, Shrubb 1970, Glutz 1971, Gordon and Ridley 1979, Cramp and Simmons 1980, Bonin and Strenna 1986, Beukeboom et al. 1988, Hasenclever et al. 1989, Gil-Delgado et al. 1995). However, since our study was restricted only to pairs breeding in nest boxes, reproductive success may have been higher due to the potential for lower predation rates.

Some studies have shown large annual variation in laying dates, clutch sizes and reproductive rates in Eurasian Kestrels (Dijkstra et al. 1982, Beukeboom et al. 1988). Some of these have related variation in reproductive performance to weather conditions before egg laying (Kostrzewa and Kostrzewa 1990, Kostrzewa and Kostrzewa 1991). In our study, mean temperature in the month previous to the onset of egg laying did not vary between years and was 14°C in 1989 and 13.5°C in 1990 ($P > 0.05$, $N = 30$ in both years). However, in 1989, the month previous to the onset of reproduction was very rainy (84.1 mm in 1989 vs. 14.1 mm in 1990). Mean egg laying date and mean clutch size did not vary between years. Kestrel breeding performance, as measured by fledglings per

Table 2. Clutch sizes of Eurasian Kestrels in southwestern Spain, 1989–90.

YEAR	CLUTCH SIZE 1	2	3	4	5	6
1989	0	1	3	7	9	6
1990	2	8	5	14	18	3
Both years	2	9	8	21	27	9
	(2.6%)	(11.9%)	(10.5%)	(27.6%)	(35.5%)	(11.9%)

successful nest and breeding success, was higher in 1989 when more rain fell. Grasshoppers (*Dociostaurus marrocanus*) are the primary prey of Eurasian Kestrels during the nesting season in Spain (Veiga 1985, J.M. Avilés and D. Parejo pers. obs.). Higher rainfall in the spring did result in an increase in grasshopper availability in our study area (Arias et al. 1993). Our study was not designed to evaluate potential relationships among rainfall, food supply and breeding performance so we could not be certain of the relationship, if any, among these factors.

We detected a clear seasonal decline in clutch size and fledglings per successful nest and breeding success in the La Serena population of Eurasian Kestrels. This trend has been found for other raptors (Newton and Marquiss 1984, Picozzi 1984, Hörnfeldt and Eklund 1990, Korpimäki and Hakkarainen 1991), including Palearctic populations of the Eurasian Kestrel (Cramp and Simmons 1980, Dijkstra et al. 1982, Meijer et al. 1988, Beukeboom et al. 1988).

The productivity of this population of Eurasian Kestrels was within the range described previously for this species in other areas. Although we found some evidence of improved reproductive output related to rainfall, more focused research is required to confirm our observations.

RESUMEN.—Se ha estudiado dos años la biología reproductora del cernícalo vulgar (*Falco tinnunculus*) nidificando en nidales artificiales en zona esteparias del sudoeste en España. El inicio de la reproducción, la fecha media de puesta, el tamaño de puesta y el resto de tasas reproductoras estuvieron dentro del rango descrito para la especie en la región Paleártica. La especie mostró un descenso estacional significativo de su valor reproductivo. El número de pollos volados por nido exitoso y el éxito reproductor fueron mayores el año en que existieron mayores precipitaciones primaverales, sin emabrgo, la escasa serie temporal disponible no permite establecer una relación entre el nivel de precipitaciones y el éxito de la especie.

[Traducción de Autores]

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BREEDING DENSITIES AND HABITAT ATTRIBUTES OF GOLDEN EAGLES IN SOUTHEASTERN SPAIN

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KEY WORDS: *Golden Eagle*; Aquila chrysaetos; *habitat*; *Mediterranean*.

Predictions on how animals respond to habitat changes are the primary aim of many conservation studies. Development of easy wildlife habitat models is an important tool for conservation and ecosystem management (González et al. 1992, Donázar et al. 1993). Progress has been made using Generalized Linear Models (GLMs) (Dobson 1983, McCullagh and Nelder 1989) to summarize the relationships between species distributions and environmental variables (Vincent and Haworth 1983, Nicholls 1989, Donázar et al. 1993).

It is known that patterns and processes in nature are sensitive to the scale at which they are viewed (Cody 1985, Wiens et al. 1987, Wiens 1989, Levin 1992, Lima and Zollner 1996). The scale at which systems are studied has a powerful influence on final conclusions and species-habitat relationships determined at one scale may not apply to others. Populations are influenced by the complex arrangement of habitat patches within landscapes and multiscaled studies seem to be the proper way to approach their study (Wiens 1989, Levin 1992).

The Golden Eagle (*Aquila chrysaetos*) is a raptor with a widespread distribution in the northern hemisphere. In North America, Steenhof et al. (1997) showed an important interaction between jackrabbit (*Lepus californicus*) abundance and weather on eagle reproduction and more recent work using radiotracking data (Marzluff et al. 1997) has noted the preference of Golden Eagles for some habitat types, particularly shrub and open lands. In