

Breeding ecology of the southern shrike, *Lanius meridionalis*, in an agrosystem of south-eastern Spain: the surprisingly excellent breeding success in a declining population

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Abstract

Breeding ecology of the southern shrike, Lanius meridionalis, in an agrosystem of south-eastern Spain: the surprisingly excellent breeding success in a declining population.— The southern shrike, *Lanius meridionalis*, is declining at the Spanish and European level. One cause of this decline could be low reproductive success due to low availability of prey in agricultural environments. To investigate this possibility we analysed the breeding ecology of a population of southern shrike in an agrosystem in Lomas de Padul (SE Spain). Our results suggest the population is declining in this area. However, contrary to expectations, the population showed the highest reproductive success (% nests in which at least one egg produces a fledgling) reported for this species to date (83.3%), with a productivity of 4.04 fledglings per nest. Reproductive success varied throughout the years, ranging from 75% in the worst year to 92.9% in the best year. Similarly, productivity ranged from 3.25 to 5.0 fledglings per nest depending on the year. Other aspects of reproductive biology, such as clutch size, brood size, and nestling diet, were similar to those reported in other studies. Based on these results, we hypothesise that the determinant of population decline acts on the juvenile fraction, drastically reducing the recruitment rate, or affecting the dispersion of adults and recruits. Nevertheless, the exact factor or factors are unknown. This study shows that a high reproductive success does not guarantee good health status of the population.

Key words: Agrosystems, Breeding success, Reproductive ecology, Southern shrike, Clutch size, Nestling diet

Resumen

Ecología reproductora del alcaudón meridional, Lanius meridionalis, en un agrosistema del sudeste de España: el desconcertante excelente éxito reproductivo en una población en decrecimiento.— La población de alcaudón meridional, *Lanius meridionalis*, está disminuyendo a escalas europea y española. Una posible causa de este decrecimiento podría ser la disminución del éxito reproductor debido a la escasa disponibilidad de presas en medios agrarios. En este estudio se analiza la ecología reproductora de una población de alcaudón meridional en un agrosistema situado en las Lomas de Padul (SE de España). Los resultados sugieren que la población de Padul se encuentra en decrecimiento; no obstante, en contra de lo esperado, la población mostró el mayor éxito reproductivo (% de nidos en los que al menos un huevo termina convirtiéndose en volantón) encontrado en esta especie (83,3%), con una productividad de 4,04 volantones por nido. El éxito reproductor osciló notablemente entre años, entre el 75% en el peor año y el 92,9% en el mejor año. De igual forma, la productividad osciló entre 3,25 y 5,00 volantones por nido según el año. Otros aspectos de la biología reproductiva de la población, como el tamaño de puesta o de nidada o la alimentación de los pollos, fueron similares a lo observado en otros estudios. Sobre la base de estos resultados, se sugiere que el factor determinante del decrecimiento de la población está actuando sobre la fracción juvenil, lo que reduce de forma drástica la tasa de reclutamiento, o bien afecta a la dispersión de adultos y reclutas. No obstante, se desconocen cuáles son los factores exactos. En cualquier caso, este estudio demuestra que un elevado éxito reproductor no garantiza el buen estado de salud de la población.

Palabras clave: Agrosistemas, Éxito reproductor, Ecología reproductora, Alcaudón meridional, Tamaño de puesta, Alimentación de los pollos

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Introduction

Humans are causing many changes in landscapes, with direct consequences for species conservation (McKinney & Lockwood, 1999). Shifts in land use are mainly due to agriculture intensification (Matson et al., 1997; see also Stoate et al., 2009), which diminishes bird biodiversity and abundance (Siriwardena et al., 1998) as a consequence of habitat alteration, fragmentation or simplification, and pesticide use. In Spain, for example, approximately 50% of the surface area is occupied by farmland (Moreno–Rueda & Pizarro, 2009), illustrating the vast scale of the impact of agriculture on nature and the importance of its study for conservation.

The southern shrike, *Lanius meridionalis*, like other shrikes, is a predatory passerine species that lives and nests in open habitats with shrubs or trees (Hernández, 1994), allowing it to inhabit mixed agricultural/natural landscapes. Nevertheless, Laniidae populations in general show a worldwide decline (Yosef, 2008). In Spain, for example, the southern shrike population is shrinking notably (Hernández & Infante, 2004; SEO/BirdLife, 2015), a decrease attributed mainly to agriculture–related changes in land use and pesticide applications (Hernández & Infante, 2004). Other shrike species (e.g., the great grey shrike, *Lanis excubitor*), however, are declining even in zones where they do not inhabit farmland (e.g., Kuczynski et al., 2010).

The exact causes of the decline of the southern shrike are unknown. Campos et al. (2011) found that breeding success (% nests in which at least one egg produces a fledgling) for this species in Toro was low (37.9%), and suggested that this was the cause of their decline. Given that shrike nestlings are fed mainly arthropods (Hernández, 1993b; Campos et al., 2010), nestling survival may be reduced in agrosystems as a consequence of pesticides. Moreover, cereal farmlands (frequently used for foraging in the Toro population) constitute a habitat where shrike foraging is constrained, and this may in turn depress the breeding success (Campos et al., 2006).

Most studies on the breeding biology of the southern shrike in Spain have been conducted in Extremadura (de la Cruz & de Lope, 1985), León (Hernández, 1993a), Zamora (Campos et al., 2011), and Navarra (Campos et al., 2006, 2007). Information concerning the biology of the southern shrike in the southern Iberian peninsula is lacking. In effect, in their review of the population trends of the species in Spain, Hernández & Infante (2004) did not refer to Andalusia because of the lack of data.

We here provide information concerning the population trend of the southern shrike in an agrosystem located in Lomas de Padul (Granada, SE Spain), and present basic data concerning the reproductive biology of this population, including information on nestling diet.

The main goal of our study was to examine whether the decline of this population is related to low breeding success.

Material and methods

The study was conducted from 2009 to 2011 and in 2014 in a population of southern shrikes in Lomas de Padul (SE Spain: 37° 01' 13" N, 03° 41' 30" W; fig. 1). The study area consists of a typical Mediterranean agrosystem, with a mix of almond and cereal farming interspersed with natural steppe meadows, plus isolated holm oaks, *Quercus ilex*, and scattered kermes oaks, *Q. coccifera*, where shrikes mainly nest.

To locate nests, we exhaustively searched inside the oaks starting in mid–March. The sampling effort progressively increased over the years. The exact position of each nest found was recorded using a GPS device. For each nest located, we checked the presence and number of eggs. If nests were found during laying, considering that shrikes lay one egg per day (Yosef, 1992), we used the number of eggs to estimate the day that the first egg was laid (laying date). On subsequent visits, one week later, we recorded clutch size (number of eggs laid). At that time, we estimated the day of hatching of the first egg (hatching date) according to the normal time of incubation (15 days; Harrison, 1991), given that southern shrikes start incubation with the last egg (Hernández, 1993a). Meanwhile, we did not visit the nest to avoid any disturbance that could affect breeding (Antczak et al., 2005; see also Tryjanowski & Kuźniak, 1999). Around the estimated hatching date, we visited the nest to determine the correct hatching date. We estimated the incubation period as the number of days between the laying of the last egg and the hatching of the first egg.

We recorded the brood size (number of nestlings per nest) at hatching, and estimated the hatching success (number of nests in which at least one egg hatched) and the average percentage of eggs hatched per nest with hatching success. The cause of hatching failure was recorded considering three options: (1) embryo mortality or unfertilized egg (the egg simply did not hatch), (2) predation (normally the complete clutch disappeared), or (3) abandonment (the clutch was found cold). Some nestlings were used in begging experiments in 2010 and 2011 (Moreno–Rueda & Redondo, 2011, 2012). These nestlings were removed from the nest in the afternoon when they were 6 days old (hatching day = 0), and returned to the nest during the morning when 8 days old. Nestlings used in experiments and their siblings left in the nest during the experiments did not differ in behaviour, survival, or body size from those in unused nests.

When nestlings were 12–days old, we recorded the number of surviving fledglings per nest. With these data, we further determined the productivity of the population, such as the number of fledglings produced per nest (for which we considered both successful and unsuccessful nests). We also estimated fledging success (percentage of nests in which at least one hatchling fledged), breeding success (percentage of nests in which at the least one egg produced a fledgling), and the average percentage of nestlings and eggs fledged per nest. The cause of fledging failure was recorded. The potential causes were:

abandonment (nestlings in good condition found dead or cold), predation (nestlings in prime body condition that disappeared), and starvation (nestlings found in poor condition before death).

Moreover, to ascertain parental feeding behaviour (feeding rate and food delivered to nestlings), we made a one-hour recording (following Pagani-Núñez & Senar, 2013) of 12 nests in 2009 when nestlings were 10-days old, with a Sony® Handycam HDR-XR155B. Parent birds quickly accepted the videocamera and usually resumed feeding in less than 5 min (sometimes as soon as one minute after the researchers had left the proximity of the nest). None of the nests were abandoned because of the camera. We later analysed filming, identifying the prey delivered to the nestlings, to the taxonomic level of order as a minimum.

In addition to describing the reproductive parameters of southern shrike in our study population, we compared whether breeding parameters varied from year to year. To do so, we used the Kruskal-Wallis ANOVA test to examine differences in the mean of variables such as clutch size, brood size, and productivity. We used non-parametric statistics given that most of these variables did not fulfil the assumptions of normality and homoscedasticity (Quinn & Keough, 2002), and non-parametric statistic estimations are less affected by the violation of these assumptions (Siegel & Castellan, 1988). To compare frequencies (for variables based upon percentages), we used the Chi-square test. The means are given with their corresponding standard error. Moreover, for a better comprehension of inter-annual variation in breeding parameters, we compiled meteorological data (mean temperature and total precipitation) during the breeding season (March, April, and May) for the complete study, from the weather station of Padul.

Results

Population trend in Lomas de Padul

Over the study years, we gradually found fewer southern shrike nests in the study area. The number of nests decreased from 17 nests in 2009 to 11 in 2014 (table 1) even though the study area was gradually expanded over the years (fig. 1). The average distance between nests over the 4 years of the study was 1.67 ± 0.013 km ($n = 54$ nests).

Breeding phenology

The average laying date was 5 IV (± 8.98 days, $n = 54$ nests); nesting began between 23 III and 29 IV. We found no significant differences in average laying date across years (table 1). The incubation period averaged 14.94 ± 1.01 days (median = 15 days; $n = 51$ nests, in which hatching occurred), ranging from 13 to 18 days. The average hatching date was 26 IV (± 11.55 days; $n = 51$), ranging between 12 IV and 16 V. We found no significant differences in average hatching date over the years (table 1).

Reproductive parameters

The average clutch size was 5.64 ± 0.09 eggs (range 4–7, but with 90.2% of nests containing 5–6 eggs; $n = 53$ nests; one nest from 2009 was depredated during laying and was not considered). No significant differences were found in clutch size over the years (table 1), but the variance differed depending on the year (Levene's test, $F_{3,49} = 5.81$, $P = 0.001$). Coefficients of variation were higher in 2009 (16.3) and 2011 (12.3) than in 2010 (7.4) or 2014 (7.0). Average hatching success was 94.4% ($n = 54$), a percentage that did not differ significantly between years (table 1). The percentage of nests in which all eggs hatched was 64.1% (33 out of 54). The average percentage of hatched eggs per successful nest was $91.2 \pm 2.0\%$ ($n = 51$). No significant differences were found in average percentage of hatching with years (table 1). Hatching failure reached 11.0% of the eggs ($n = 304$), 3.5% due to abandonment, and 7.5% due to embryo mortality or to the egg not being fertilized. Only one nest was depredated before hatching (during laying). Two nests were abandoned during incubation. The average brood size was 4.87 ± 0.21 chicks ($n = 51$ nests). Neither average brood size nor variance in brood size fluctuated between years (table 1). Of the total of 263 chicks, 47 (17.9%) did not survive to fledging. Five nests were depredated during the nestling period (9.6% of nests). Only in one nest did the whole brood die as a consequence of starvation (in 2010).

Feeding rate and nestling diet

We recorded the ingestion of 85 prey by nestlings (table 2); 87% were arthropods, mainly Coleoptera (22%) and insect larvae (14%). Furthermore, we recorded the intake of small vertebrates (12%). The average feeding rate was 11.08 ± 0.59 feeds/hours ($n = 12$ nests). The feeding rate was not correlated with clutch size ($r = 0.06$, $P = 0.88$; $n = 12$ nests), brood size ($r = 0.10$, $P = 0.75$), or number of fledglings produced ($r = 0.32$, $P = 0.30$).

Productivity

Fledging success occurred in 88.2% of nests with hatchlings ($n = 51$). In successful nests with at least one fledgling, 92.7% of nestlings fledged ($n = 45$ nests), with no significant differences between years (table 1), suggesting a low rate of brood reduction. Thus, the total breeding success was 83.3% of nests ($n = 54$ nests). In fact, in 21 of 54 nests, all eggs produced a fledgling. The percentage of eggs that produced fledglings tended to vary, almost significantly, between years (table 1). Shrikes lost fewer eggs in 2010 and 2014 (80–85% of the eggs produced fledglings) than in 2009 and 2011 (about 60% of eggs fledged; table 1). Finally, the average productivity was 4.04 fledglings per nest ($n = 54$ nests). Productivity differed significantly between years (table 1), the highest being recorded in 2010 and 2014. Productivity in 2009 was significantly lower than in 2010 and 2014 (Kruskal-Wallis; $H > 3.95$; $P < 0.05$).

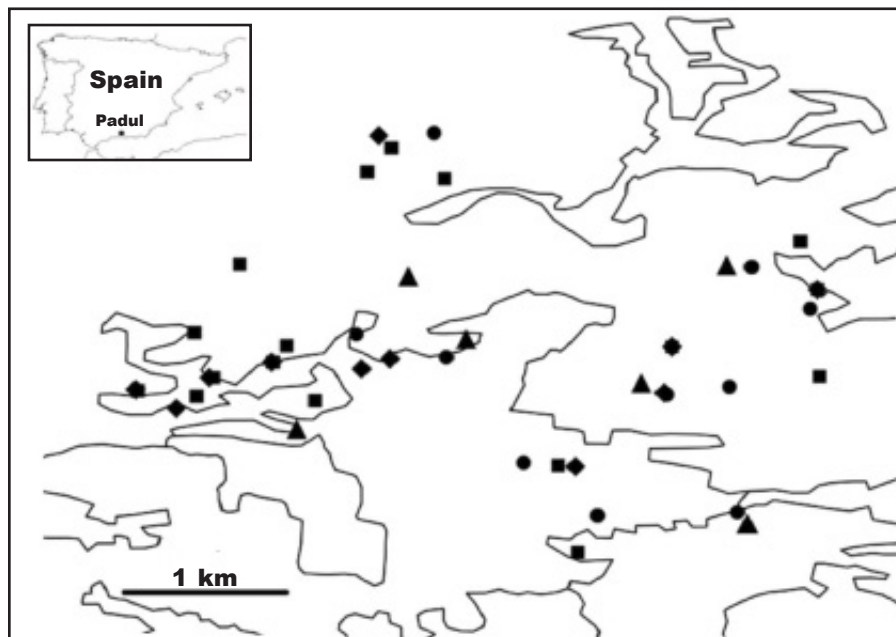


Fig. 1. Map showing the location of Lomas de Padul (SE Spain), and the situation of each nest in the study area: ◆ Nests in 2009; ■ Nests in 2010; ▲ Nests in 2011; ● Nests in 2014. Given that shrikes reused some nests (or nested in the same tree) between years, some symbols are superimposed. (Lines indicate level curves, 1,000-1,100 m a.s.l.).

Fig. 1. Mapa de la localización de las Lomas de Padul (SE de España) y la situación de cada nido en la zona de estudio: ◆ Nidos de 2009; ■ Nidos de 2010; ▲ Nidos de 2011; ● Nidos de 2014. Dado que los alcaudones reutilizaron algunos nidos (o nidificaron en el mismo árbol) en diferentes años, algunos símbolos están superpuestos. (Las líneas indican las curvas de nivel, 1.000-1.100 m s.n.m.).

in both cases). In 2011 it was lower than in 2010 ($H = 5.43$; $P = 0.02$) and showed a trend to be lower than in 2014 ($H = 2.77$; $P = 0.096$). Meanwhile, there were no significant differences in productivity between 2009 and 2011 ($H = 0.02$; $P = 0.89$) or between 2010 and 2014 ($H = 0.34$; $P = 0.56$). Moreover, variance in productivity also varied statistically between years (Levene's test: $F_{3, 50} = 2.95$, $P = 0.04$). Coefficients of variation in fledglings per nest were higher—about double—in 2009 and 2011 (64.2 and 70.8, respectively) than in 2010 and 2014 (31.4 and 38.9, respectively). Productivity showed no detectable relationship with meteorological variables (summarized in fig. 2).

Discussion

Findings in the present study suggest that the southern shrike population of Lomas de Padul is declining. This trend is in accordance with the situation of the southern shrike in the rest of Spain (Hernández & Infante, 2004) and in Europe (Tucker & Heath, 1994). The results also show that this decline in Lomas de Padul is not due to reproductive failure, as breeding success and productivity were notably

high in the population studied. On average, 83% of the nests fledged at least one nestling, and 71% of eggs successfully developed to produce a fledgling. These values of breeding success are higher than those reported for several other populations: 63% in Extremadura (Spain, de la Cruz & de Lope, 1985), 67–71% in León (NW Spain, Hernández, 1993a), 64% en Olite (N Spain, Campos et al., 2006), 38% en Toro (approx. Central Spain, Campos et al., 2011); 63% in Sede Boqer (Israel, Yosef, 1992), and 68% en Hazeva (Israel, Budden & Wright, 2000). It is of note that breeding success was similar in the aforementioned populations (about 63–71%), with the exception of that in Toro (38%, the lowest) and that in Lomas de Padul (83%, the highest). On the other hand, Budden & Wright (2000) reported that only 31% of nestlings fledged, while Hernández (1993a) reported that 62–64% of nestlings fledged. In Padul, however, almost 93% of nestlings fledged, the highest fledging success reported for this species to date. Regarding productivity, this was higher in Padul (four fledglings per nest) than in Israel (1.1; Budden & Wright, 2000) or in southern France (1.54; Lepley et al., 2000), but similar to that reported for NW Spain (3.6; Hernández, 1993a).

Table 1. Values (\pm SE) of reproductive parameters measured or estimated in the population of southern shrike of Lomas de Padul (SE Spain), separated by year, and overall. For dates, SE indicates days. The statistical (H . Kruskal–Wallis ANOVA, χ^2 . Chi–square) comparison between years is also included: * $P < 0.05$; § $P = 0.06$; ns. Not significant $P > 0.10$). The definition of each parameter measured is also included. For some estimates (laying date, hatching success, breeding success) we used all nests found ($n = 17, 14, 12$ and 11 according to year). Other estimations require data on clutch size (average clutch size and % eggs fledged), and therefore one nest in 2009 could not be used ($n = 16$ for 2009). Other estimations were based on number of hatchlings (hatching date, % eggs hatched, brood size or fledging success). Thus, sample sizes per year were: 15, 14, 12 and 10. Lastly, in the case of % of nestlings fledged, we considered only nests that produced at least one fledgling ($n = 13, 13, 9$ and 10).

*Tabla 1. Valores (\pm EE) de los parámetros reproductivos medidos o estimados en la población de alcaudón meridional de Lomas de Padul (SE de España), separados por cada año y en total. Para las fechas, el error estándar se expresa en días. También se indica la comparativa estadística (H . Kruskal–Wallis ANOVA, χ^2 . Chi–cuadrado) entre años: * $P < 0,05$; § $P = 0,06$; ns. No significativa $P > 0,10$. Asimismo se incluye la definición de cada parámetro medido. Para algunas estimaciones (fecha de puesta, éxito de eclosión y éxito reproductor) se usaron todos los nidos encontrados ($n = 17, 14, 12$ y 11 según el año). Para otras, era necesario conocer el tamaño de puesta (tamaño de puesta medio y % de huevos que se convierten en volantones), por lo que uno de los nidos de 2009 no pudo usarse ($n = 16$ en 2009). Para otras estimaciones se partía del número de pollos eclosionados en el nido (fecha de eclosión, % de huevos eclosionados, tamaño de nidada o éxito de vuelo). Los tamaños de muestra de los distintos años fueron: 15, 14, 12 y 10. Por último, en el caso del % de pollos que vuelan, se consideraron solo los nidos que habían producido al menos un volantón ($n = 13, 13, 9$ y 10).*

Parameter (definition)	2009	2010	2011	2014	Test	All years
Nests (number of nests found)	17	14	12	11		54 (total)
Laying date (average date of the first egg laid)	08/04 \pm 10.0	03/04 \pm 8.4	05/04 \pm 6.4	03/04 \pm 10.4	$H = 2.29$ ns	05/04 \pm 9.0
Hatching date (average date of the first egg hatched)	28/04 \pm 9.5	26/04 \pm 13.8	25/04 \pm 5.4	27/04 \pm 17.0	$H = 1.26$ ns	26/04 \pm 11.6
Clutch size (average number of eggs laid)	5.50 \pm 0.16	5.79 \pm 0.17	5.50 \pm 0.19	5.82 \pm 0.20	$H = 2.24$ ns	5.64 \pm 0.09
Hatching success (% nests in which at least one egg hatched)	88.2	100	100	90.9	$\chi^2_3 = 2.25$ ns	94.4
% Eggs hatched (average % of eggs hatched per successful nest)	90.9 \pm 3.7	93.6 \pm 3.9	90.0 \pm 4.2	90.0 \pm 4.6	$H = 3.13$ ns	91.2 \pm 2.0
Brood size (average number of hatchlings per nest)	4.47 \pm 0.37	5.43 \pm 0.42	4.92 \pm 0.45	4.73 \pm 0.47	$H = 3.09$ ns	4.87 \pm 0.21
Fledging success (% nests in which at least one chick fledges)	86.7	92.9	75	100	$\chi^2_3 = 3.83$ ns	88.2
% Nestlings fledged (average % of chicks fledged per successful nest)	85.7 \pm 4.2	96.2 \pm 4.2	92.6 \pm 5.0	97.5 \pm 4.8	$H = 4.73$ ns	92.7 \pm 2.3
Breeding success (% nests in which at least one egg produced a fledgling)	76.5	92.9	75	90.9	$\chi^2_3 = 3.18$ ns	83.3
% Eggs fledged (average % of eggs become in fledglings)	59.5 \pm 8.5	85.7 \pm 9.4	60.8 \pm 10.2	80.3 \pm 10.6	$H = 7.36$ §	70.8 \pm 4.9
Productivity (average fledglings produced per nest)	3.29 \pm 0.48	5.00 \pm 0.53	3.25 \pm 0.57	4.64 \pm 0.59	$H = 10.74$ *	4.0 \pm 0.28

Therefore, the population decline in Lomas de Padul clearly cannot be ascribed to low reproductive success, given that it is probably one of the highest reported for this species. Other causes should be examined in the future. We can rule out habitat loss due to changes in land use as a possible cause of the decline because the only change of note in land use between 2009 and 2014 was the erection of wind turbines in a corner of the study area, and southern shrikes near the turbines did not abandon their territories as a result of this change. Therefore, given the high productivity of nestlings, the decline might be due to high mortality of fledglings or juveniles, depressing recruitment. Otherwise, even if adult mortality were high, recruitment should be sufficient to maintain the population size. The causes of such hypothetical juvenile mortality are unknown as it is difficult to ascertain what might provoke such a heavy loss of juveniles when nestling survival is so high. A high density of potential predators of juveniles or adults was not observed during the study (though not formally analysed), while potential nest predators were frequently detected (Montpellier snake *Malpolon monspessulanus*, dormouse *Elyomys quercinus*, red fox *Vulpes vulpes*, and magpie *Pica pica*). Nest predation, in effect, is one of the main causes of reproductive failure in southern shrike. In fact, Lepley et al. (2000) reported a nest–predation rate of 44%, while Hernández (1993a) reported a rate of 20%. In our population, 11% of the nests were depredated. In view of the information gathered, other unstudied possibility is that mortality is provoked by parasites or pathogens for which the transmission rate is higher in juveniles or adults than in nestlings (Valera et al., 2006; see also Casanueva et al., 2012). Another possibility is that fledglings produced in the Padul population are recruiting in other populations (Padul would be a source population). It is striking that shrikes (adults and yearlings) show very low philopatry (Giralt & Valera, 2007; Krištín et al., 2007; Tryjanowski et al., 2007). However, if the site is so good for reproduction, it is strange that territories are being lost and no new shrikes occupy them.

Breeding success, nevertheless, varied between years (although not significantly), from 75% in 2009 and 2011 to more than 90% in 2010 and 2014. Overall productivity was also higher in 2010 and 2014 than in 2009 and 2011. Therefore, it seems that 2009 and 2011 were bad years for shrike reproduction in Padul. Indeed, our findings in these poorer years were a slightly (non–significantly) smaller clutch size, lower fledging success, and a lower percentage of fledged nestlings. Moreover, clutch size, and also number of fledglings produced, showed higher variance in the bad years. Higher variance in reproduction in the bad years suggests that low–quality parents suffered more than did high–quality parents those years, this situation leading to increased variance. Campos et al. (2007) also found similar inter–annual variation in breeding success in a population in northern Spain. In their study, however, breeding success in the bad years was below 60% (while in Padul was around 75%), and in the good years it was 70–84%

Table 2. Number and percentage of each type of prey delivered to southern shrike nestlings in Lomas de Padul (SE Spain) (N = 12 nests, when nestlings were 10 days old): * Three Coleoptera found were identified as the red–striped oil beetle, *Berberomeloe majalis*.

Tabla 2. Número y porcentaje de cada tipo de presa entregada por los padres a los pollos de alcaudón meridional en las Lomas de Padul (SE de España) (N = 12 nidos, cuando los pollos tenían 10 días): * Tres Coleoptera se identificaron como aceiteras, *Berberomeloe majalis*.

Prey type	Number	Percentage
Coleoptera	19*	22.35
Insect larvae	12	14.12
Lepidoptera	8	9.41
Miriapoda	5	5.88
Orthoptera	5	5.89
Unidentified insects	25	29.41
Total arthropods	74	87.05
Lizard tail	1	1.18
Vertebrates (rodents)	10	11.77
Total Individuals	85	

(in Padul, more than 90%). That is to say, shrike breeding success during the bad years in southern Spain was similar to that recorded during the good years in northern Spain. However, the causes of such inter–annual variation are unknown, and neither Campos et al. (2007) nor ourselves found a relationship between breeding success and weather conditions. This should be taken with caution, however, given the low sample size (four years), and the fact that meteorological conditions might act in a subtle way that is difficult to detect. Indeed, other studies did find an effect of weather on shrike reproduction. For example, Keynan & Yosef (2010) reported an effect of weather on reproduction in Israel, and Moreno–Rueda et al. (2014) reported a possible relationship between weather and reproductive parameters such as clutch size and brood sex ratio in N Spain.

Other reproductive parameters, such as clutch and brood size, were similar in Lomas de Padul to those reported in other populations (Yosef, 1992; Hernández, 1993a; Campos et al., 2007). Clutch size, for example, seems highly conservative, being around 5.7 in all populations (Yosef, 1992; Hernández, 1993a; Campos et al., 2007; this study), although Budden & Wright (2000) reported a clutch size of only 3.9 in Israel.

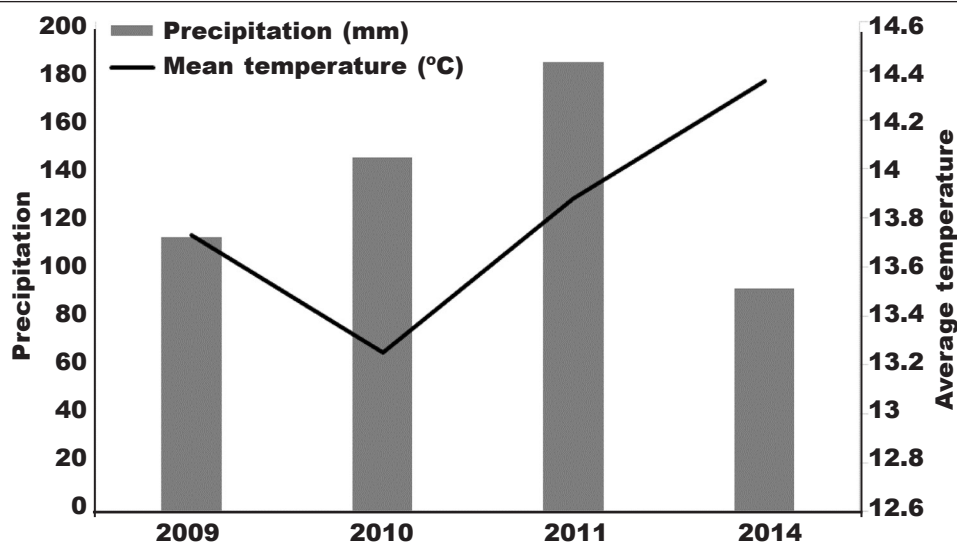


Fig. 2. Total precipitation and average temperature in Lomas de Padul (SE Spain) during the breeding period of the southern shrike, for each year of study.

Fig. 2. Precipitación total y temperatura media en las Lomas de Padul (SE de España) durante el periodo de cría del alcaudón meridional, para cada año de estudio.

Regarding nestling diet, arthropods were the main food (87%), especially Coleoptera (22%), which matches most previous studies on southern shrike nestling diet, indicating that the diet consists primarily of arthropods (Hernández, 1993b; Budden & Wright, 2000; Padilla et al., 2009; Campos et al., 2010). Nevertheless, Orthoptera were the main prey consumed by nestlings in Valladolid (Central Spain, Campos et al. 2010). In fact, Campos et al. (2010) reported that, in Valladolid, shrikes feed on Coleoptera less than expected by chance according to their availability; however, Coleoptera constitute the main prey of shrikes in the population studied here (Padul) and in León (near Valladolid; Hernández, 1993b). In general, the nestling diet matches well with the adult diet, i.e. mainly arthropods and occasionally small vertebrates (Hódar, 2006; see also Hernández et al., 1993; Lepley et al., 2004; Padilla et al., 2009). However, the portion of vertebrates in the diet should not be understated; although the frequency of items is low, they may represent a major portion of the biomass (which we failed to measure). For example, Hódar (2006) reported similar frequencies of vertebrates in the adult diet of a population near ours, and this represented more than 50% of the biomass.

In conclusion, this study suggests that the population of southern shrike in Lomas de Padul (SE Spain) is declining despite one of the highest rates of breeding success reported for this species. This decline therefore indicates that some unknown factor hampers recruitment in the population. Finally, our results highlight the need to exercise caution in

ecological management, given that a high breeding success should not be immediately interpreted as a healthy population, and breeding success, without additional information, should not be used as a surrogate of the population trend.

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