Importance of the premigratory areas for the conservation of lesser kestrel: space use and habitat selection during the post-fledging period

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Abstract

The conservation importance of the post-fledging period in migratory birds has been scarcely assessed. In this study, we examined the space use and habitat selection of radio-tagged lesser kestrels *Falco naumanni* at two spatial scales during summer in north-western Spain, where premigratory aggregations of around 1000 lesser kestrels occur. Space use was estimated by kernel accounting for the spatiotemporal autocorrelation of the radio locations, and habitat selection was analysed by weighted compositional analysis accounting for the intensity of use. Kestrels moved within 9 km around roosts during daylight and returned daily during sunset to the same roosts, exhibiting refuging behaviour. They foraged on average 3.7 km from the roost in an area of 346.8 ha (home range), 92.7 ha of which were used intensively (core area). Within these areas, lesser kestrels intensively used more farmland than any land-scale habitat. Within farmland, kestrels significantly avoided the irrigated crops. This avoidance seemed to be due to the difficulty of prey access and/or scarcity of prey available. Conservation plans of lesser kestrel should include the post-fledging period by legally protecting roost sites and maintaining dry farmland systems around the communal roosts.

Introduction

The post-fledging period in migratory birds is considered to be a part of the avian life cycle scarcely known (Rappole & Ballard, 1987; Baker, 1993; Rivera et al., 1998). It has been defined as the period ranging from fledging to departure on fall migration (Rivera et al., 1998; Rivera et al., 1999; Pagen et al., 2000) and can last several months in some bird species [e.g. up to 2 months for lesser kestrels *Falco naumanni* (Olea et al., 2004)]. The lack of knowledge of this period is mainly due to the difficulties of observing individuals either because they usually are more inconspicuous in their breeding areas [e.g. they stop singing (Rappole & Ballard, 1987)] or because they leave their breeding areas before migration to remain in premigratory areas (Rappole & Ballard, 1987; Rivera et al., 1999; Olea et al., 2004). Consequently, the ecological and conservation importance of the post-fledging period for migratory bird species is still not well known in spite of its importance due to birds must build up fat reserves (Rivera et al., 1999) and moult (at less partly; see Rivera et al., 1998) prior the fall migration. Because moultling is a demanding process in terms of energy, the availability of sufficient food resources during moultling is important not only for their survival but also for their conservation. However, conservation strategies of migratory birds usually regard only the breeding and wintering periods (e.g. Rivera et al., 1998; Mabey & Watts, 2000), ignoring other stages in which individuals may move or disperse into other different areas [e.g. stopover areas (Petit, 2000) and premigratory areas (see Olea, 2001, 2004)]. These areas could play an important role in survival, dispersal and recruitment processes of the population (e.g. for post-fledging period see Penteriani et al., 2004; Sergio et al., 2004). However, the factors limiting and regulating the populations of migratory birds are still poorly known during these stages, jeopardizing consequently the efficacy of migratory bird conservation and management. For instance, the post-fledging period is not taken into account in the International Action Plan for the lesser kestrel (Biber, 1996). Here, we studied a population of a threatened migratory bird species, the lesser kestrel, during the post-fledging period.

Lesser kestrel is considered to be a globally threatened species listed as vulnerable (BirdLife International, 2007). This migratory species is a small falcon breeding in the Palaearctic and wintering mainly in Africa (Siegfried & Sked, 1971; Cramp & Simmons, 1980). After breeding, the post-fledging dependence period of lesser kestrels is short, in which juveniles gain independence from their parents very soon after fledging (5 days; Bustamante & Negro, 2004) and move large distances from natal sites before migration (Olea, 2001). Large aggregations of lesser kestrels occur during the post-fledging period (i.e. in summer) in several Spanish areas where population size attains to be several
orders of magnitude larger than local breeding populations, suggesting that part of these post-breeding populations come from other areas (Olea, 2001; Ursúa & Tella, 2001; Olea et al., 2004). The areas occupied during summer by lesser kestrels at least during 2–2.5 months have been suggested to be regular premigratory areas and have ecological and conservation importance for lesser kestrel populations (Olea et al., 2004). Spatial pattern of lesser kestrel abundance in the premigratory areas has not been clearly explained by landscape variables (De Frutos, Olea & Vera, 2007), highlighting the need of studies more detailed on habitat selection and space use at different scales to improve the understanding of the post-fledging biology and the efficacy of lesser kestrel conservation and management programmes.

In this study, we radiotagged lesser kestrels in a premigratory area for examining the space use and habitat selection during the post-fledging period. We (1) examined the movements of lesser kestrels during the post-fledging using radio-tracking, (2) determined both their home-range and core-area sizes taking into account the autocorrelation of lesser kestrel locations and (3) evaluated habitat selection at multiple spatial scales taking into account the intensity of use for each habitat type using the weighted compositional analysis (WCA).

Materials and methods

Study area

The study was conducted in a 1200 km² area in northwestern Spain (centred at 5°15’W 42°17’N; Fig. 1). The landscape is flat with low hill and scarcely vegetated with little amounts of trees. The dominant habitat is extensive dry farmland, in rotation every other year. Dry cereals and ploughed fields dominate the agricultural landscape. When we carried out the study, almost all the dry cereal cultures had been harvested, remaining as stubbles and being exploited by a low grazing intensity (De Frutos et al., 2007). During summer this area holds a large post-breeding lesser kestrel population (800–1200 birds; Olea et al., 2004; pers. obs.) which gathers in four communal roosts at night (Fig. 1); these roosts have been used each year for at least 7 years (Olea et al., 2004, pers. obs.).

Trapping and marking

We captured lesser kestrels at two roosts (A and B) of the four located in the study area (Fig. 1). Both roosts were separated by 24.5 km and were made up of scattered holm oaks Quercus ilex between 3 and 8 m high. The maximum number of lesser kestrels counted in roost A was 138 and 270 in 2004 and 2005, respectively, while in roost B was 280 in 2004 and 2005. Birds in roost A were trapped in summer of 2004 and 2005, whereas in roost B only in 2004. To capture lesser kestrels we set a net that partly covered the roosting trees 2 h before sunset (i.e. before lesser kestrels gathered at the roost; see Olea et al., 2004). Lesser kestrels were captured by flushing out them at full night while roosting. We fitted VHF radio-transmitters to 17 lesser kestrels (eight in 2004 and nine in 2005) over the synsacrum using a figure-8 harness with two loops that slide over the legs (Rappole & Tipton, 1991). After radiotagging, the captured birds were released at the same trees that used as roost. Captured lesser
kestrels used the same roost at the next days at that of its capture. Although no negative effects have been detected using tail-attached transmitters (Donázar, Negro & Hiraldo, 1993; Tella et al., 1998; Franco et al., 2004), studies on the impact of the transmitters mounted with body harness on lesser kestrel are lacking. Transmitters (PD-2, Holohil System Ltd., Carp, Ontario, Canada) weighted 2.3 g (c. 1.6% of mean lesser kestrel mass) and had a life expectancy of 3 months.

**Radiotracking**

We monitored radio-tagged lesser kestrels from the first day after bird tagging until the transmitter failed to remain attached or bird dispersed from the study area [14 August to 19 September in 2004, and 28 July to 16 September in 2005; this accounts for a substantial portion (> 50%) of the post-fledging period; Table 1]. Birds were tracked via ground-based homing-in (Kenward, 2001) using a receiver (RX-98E, Televilt, Lindeberg, Sweden) and two hand-held or vehicle-mounted 2- or 4-element directional Yagi-antennas (Kenward, 2001). Homing-in technique allows obtaining direct observations and getting very accurate data compared with other tracking methods as triangulation (Mech, 1980). Lesser kestrels were observed directly away from us using binoculars and × 20–60 telescopes. Each day two randomly selected birds were searched and followed by one person using a car for a 2-4 h period each bird, between 1 h after sunrise and 1 h before sunset [i.e. when the birds were active outside their roosts (Olea et al., 2004)]. Once located the bird, we registered locations every 1 min until completing the 2-4 h session. For each individual location, we recorded x-y-coordinate positions, time of detection, habitat type and bird activity. For analytical purposes, we considered observations of foraging lesser kestrels, including when they were perching on posts or on ground (we frequently observed them capturing prey while perching). We only exclude all observations of high speed, directional flights because birds may fly above unfavourable habitats.

Additionally to the daylight tracking, the roost use at night by radio-tagged lesser kestrels was verified by scanning them at night with the telemetry equipment. Since we did not know at the beginning of our study whether birds move between roosts, when a bird was not located at its roost we scanned the study area checking all the known roosts at night.

**Space use**

To examine the space use of tagged lesser kestrels, we firstly estimate the utilization distribution (UD), which is a probability density function that quantifies the animal’s relative use of space (Van Winkle, 1975; Silverman, 1986). UD is commonly estimated using the kernel technique (Worton, 1989; Marzluff et al., 2004), which assumes that animal locations are temporally and spatially independent (i.e. not autocorrelated; Harris et al., 1990). As radio-tagged lesser kestrels were located and monitored in irregular time intervals, animal locations were temporally and spatially aggregated, and likely autocorrelated. To overcome this, we used a novel spatiotemporal variant of the kernel technique (TK STW; Katajisto & Moilanen, 2006) that gives less relative weight to both temporally and spatially aggregated locations. In TK STW analysis, there are two parameters [the temporal ($ht$) and spatial ($hs$) smoothing factors] that indicate the time or distance over which locations are temporally or spatially independent, respectively. Before TK STW calculations, these both factors must be set. According Katajisto & Moilanen (2006), we set 0.5 day for $ht$ as tagged lesser kestrels daily left foraging areas to return at the same roost at night [see below, 1 day for time to independence (TTI)], $ht \approx TTI/2 = 1$ day/2 = 0.5; Katajisto & Moilanen, 2006]. To set $hs$, we combined both the reference method (Silverman, 1986; Worton, 1995) and user-defined selection, as least square cross validation (LSCV) method fails to estimate $hs$ with location patterns of identical or quite clumped locations (as in our case; Seaman, Griffith & Powell, 1998; Gitzen & Millspaugh, 2003). For this, we firstly calculated the median of the $hs$ of each tagged lesser kestrel (Katajisto & Moilanen, 2006) with the reference method. We set the 0.4, 0.5, 0.6, 0.8 and 1 times the median $hs$ in TK STW to generate UDs for each lesser kestrel. After a visual exploration of these UDs, we decided which of these values estimated the more realistic UD relative to the observed animal locations (i.e. 0.5 times the median $hs$ which corresponded to 198.3 m). This approach,

**Table 1** Summary of the monitoring for each radio-tagged lesser kestrel ($n=9$) at two communal roosts in a Spanish farmland during summers of 2004 and 2005, including the day of tagging, the days of monitoring, the days in which each individual was sought but not located and the amplitude of the monitoring period (number in days between the first and the last radio location day).

<table>
<thead>
<tr>
<th>Year</th>
<th>Roost</th>
<th>Individual</th>
<th>Sex</th>
<th>Age</th>
<th>Tagging</th>
<th>Monitoring</th>
<th>Unlocated</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>A</td>
<td>1</td>
<td>Female</td>
<td>Adult</td>
<td>17.08.2004</td>
<td>14</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Female</td>
<td>Adult</td>
<td>17.08.2004</td>
<td>4</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Female</td>
<td>Adult</td>
<td>17.08.2004</td>
<td>10</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4</td>
<td>Female</td>
<td>Adult</td>
<td>13.08.2004</td>
<td>5</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>Male</td>
<td>Adult</td>
<td>13.08.2004</td>
<td>12</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>2005</td>
<td>A</td>
<td>6</td>
<td>Male</td>
<td>Adult</td>
<td>02.08.2005</td>
<td>24</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>Male</td>
<td>Adult</td>
<td>26.07.2005</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>Male</td>
<td>Adult</td>
<td>08.09.2005</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>Male</td>
<td>Sub-adult</td>
<td>06.08.2005</td>
<td>25</td>
<td>5</td>
<td>37</td>
</tr>
</tbody>
</table>
when LSCV method fails, has been recommended by various authors (see forum in www.faunalia.com, C. Callenge, author of ‘adehabitat package’ of R; J. Katajisto, pers. comm.). TK STW calculations were performed using the B-Range software (Katajisto & Moilanen, 2006), which calculates the number of effective locations (Neff) by summing the spatiotemporal weights of the original locations (i.e. the virtual number of spatiotemporally independent observations; Katajisto & Moilanen, 2006) and yields a digital UD layer. Based on this layer, we calculated the smallest area associated with a 90 and 50% probability of the use intensity (HR90 and HR50, respectively), using ArcGis 9.0 (ESRI, 2007). We used HR90 and HR50, as they are considered robust estimators of animal space use (Borger et al., 2006). These parameters estimate specifically the home range of animals (Borger et al., 2006) and the area of frequent use (core area; Samuel, Pierce & Garton, 1985). To calculate the size of both HR90 and HR50, we used tagged lesser kestrels with a Neff ≥ 10 for each bird (see Borger et al., 2006; Table 2).

### Habitat selection

#### Spatial scales

Johnson (1980) and Aebischer, Robertson & Kenward (1993) recommended to assess the habitat selection at multiple spatial scales. This approach allows accounting for hierarchical differences in the selection process. Accordingly, we evaluated habitat selection at two scales: (1) at the study-area scale (SA scale, hereafter) and (2) at the home-range scale (HR scale, hereafter). At the SA scale the analysis examines whether animal home ranges are placed randomly in the study area with respect to habitat composition; and at the HR scale the analysis examines the habitat selection within an individual home range relative to the habitat availability measured within that home range.

### Measurement of habitat availability

For the SA scale, available habitat for lesser kestrels was measured within the area delimited by a 9 km radius around each roost (i.e. the distance of the outermost radio location registered pooling all radio-tagged lesser kestrels; see below); whereas for the HR scale, available habitat was measured within HR of each bird.

The available habitat within each scale (SA and HR) was measured in turn at two scales: landscape-scale habitat and fine-scale habitat. Five landscape-scale habitats were considered: farmland, wet grassland (pastures associated mainly with river beds), forest, urban and scrubland areas (Table 3). Available habitat was considered as the relative proportions of each habitat. For this, we estimated these proportions from a digital land-use layer obtained from aerial photographs using ArcGis 9.0. Regarding the fine-scale habitats, we only measured those within farmland because this landscape-scale habitat was the most used (the intensity of use by tagged lesser kestrel was on average of 96.2% ± 3.9; see below). Thus, we considered crop types (dry cereal stubbles, plugged fields, fallows, leguminous crops and irrigated crops; Table 4) and field margins (strips with grass vegetation separating fields from roads).

In our study area, farmland is made up by a large mosaic of crop fields meaning a logistic problem to measure on-ground this entire habitat on a large area. For this reason, at the SA scale, availability of each crop type and field margins (Table 4) was estimated by measuring it on-ground in 25–32 km² squares emplaced within the area delimited by a 9 km radius around each roost. To assess whether these sample sizes of squares were adequate to estimate the fine-scale habitat availability, we firstly created accumulation curves by plotting the relative proportion accumulated of fine-scale habitat. Five landscape-scale habitats were considered: farmland, wet grassland (pastures associated mainly with river beds), forest, urban and scrubland areas (Table 3). The available habitat within each scale (SA and HR) was measured within the area delimited by a 9 km radius around each roost.

### Table 2 Summary of telemetry data for each radio-tagged lesser kestrel (n=9) at two communal roosts in a Spanish farmland during summers of 2004 and 2005, including number of telemetry locations acquired (radio locations), effective number of locations (Neff), home-range size and mean linear distance from the roost to the center of the home range

<table>
<thead>
<tr>
<th>Individual</th>
<th>Radio locations</th>
<th>Neff</th>
<th>90%</th>
<th>50%</th>
<th>Distance from roost to HR (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>600</td>
<td>13.12</td>
<td>234.2</td>
<td>60.1</td>
<td>1.7</td>
</tr>
<tr>
<td>2</td>
<td>490</td>
<td>21.6</td>
<td>276.5</td>
<td>68.9</td>
<td>3.3</td>
</tr>
<tr>
<td>3</td>
<td>189</td>
<td>11.65</td>
<td>344.5</td>
<td>112.8</td>
<td>2.9</td>
</tr>
<tr>
<td>4</td>
<td>266</td>
<td>14.9</td>
<td>217.6</td>
<td>59.6</td>
<td>5.8</td>
</tr>
<tr>
<td>5</td>
<td>1 045</td>
<td>35.4</td>
<td>622.8</td>
<td>153.8</td>
<td>5.4</td>
</tr>
<tr>
<td>6</td>
<td>1 893</td>
<td>83.12</td>
<td>318.2</td>
<td>80.7</td>
<td>4.1</td>
</tr>
<tr>
<td>7</td>
<td>966</td>
<td>68.6</td>
<td>434.8</td>
<td>135.8</td>
<td>2.6</td>
</tr>
<tr>
<td>8</td>
<td>237</td>
<td>73.71</td>
<td>192.7</td>
<td>59.4</td>
<td>3.6</td>
</tr>
<tr>
<td>9</td>
<td>860</td>
<td>49.8</td>
<td>480</td>
<td>103.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Mean</td>
<td>727.3</td>
<td>41.3</td>
<td>346.8</td>
<td>92.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Median</td>
<td>600</td>
<td>35.4</td>
<td>318.2</td>
<td>80.7</td>
<td>3.4</td>
</tr>
</tbody>
</table>

### Table 3 Proportion of used landscape-scale habitat (proportion of the intensity of use; see text) by lesser kestrels radiotagged (n=9) within their 90% home range at two communal roosts in a Spanish farmland during summers of 2004 and 2005

<table>
<thead>
<tr>
<th>Individual</th>
<th>Farmland</th>
<th>Urban</th>
<th>Scrubland</th>
<th>Forest</th>
<th>Wet grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>98.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>99.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>3</td>
<td>92.5</td>
<td>0.0</td>
<td>7.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>98.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.5</td>
<td>1.4</td>
</tr>
<tr>
<td>5</td>
<td>88.4</td>
<td>0.0</td>
<td>0.1</td>
<td>0.4</td>
<td>10.7</td>
</tr>
<tr>
<td>6</td>
<td>98.9</td>
<td>0.0</td>
<td>1.0</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>98.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>1.3</td>
</tr>
<tr>
<td>8</td>
<td>98.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>1.6</td>
</tr>
<tr>
<td>9</td>
<td>93.0</td>
<td>0.0</td>
<td>6.6</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Roost A</td>
<td>87.7</td>
<td>1.5</td>
<td>0.8</td>
<td>6.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Roost B</td>
<td>87.9</td>
<td>0.9</td>
<td>0.6</td>
<td>6.5</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Roost A and B shows the available habitat measured within the area delimited by a 9 km radius around each roost.
Statistical analysis

We evaluated habitat selection by radio-tagged lesser kestrels using a novel variant of the compositional analysis (CA, Aebischer et al., 1993), the WCA (Millspaugh et al., 2006). WCA not only compares the proportions of each used habitat type with respect to their available proportions, but it also takes into account the intensity of use for each habitat type (Millspaugh et al., 2006). Used habitat by lesser kestrels was the proportion of the intensity of use (i.e. the value of UD). WAC analysis was performed using the ‘adehabitat package’ version 1.4 (Calenge, 2006), which was run in the R statistical software (R, 2006).

Results

Radiotracking and space use

We tracked successfully nine radio-tagged lesser kestrels (Table 1). They were monitored during an average of 9.1 days (sd = 7.8; range 3–24 days; Table 1). Sizes of home range and core area were estimated using on average an Neff of 41.3 radio locations for each bird (sd = 28.3; range = 11.65–83.12). When the spatio-temporal autocorrelation was taken into account, the Neff of radio locations averaged 7.8% (range = 2.2–31.1%) of locations from the original data (n = 6546 original locations; mean ± sd: 727.3 ± 542.0), indicating thus the presence of high spatio-temporal autocorrelation. The Neff of locations was not significantly correlated to HR90 and HR50 sizes (for HR90: \( r_s = 0.065, P = 0.87, n = 9 \) birds; for HR50: \( r_s < 0.001, P = 1.0, n = 9 \) birds). HR90 and HR50 sizes were not significantly correlated to the amplitude of the monitoring period (number of days between the first and the last radio location day; for HR90: \( r_s = 0.511, P = 0.08, n = 9 \) birds; for HR50: \( r_s = 0.293, P = 0.22, n = 9 \) birds). We found no significant differences in HR90 and in HR50 sizes between male and female (Mann–Whitney U-tests; \( P = 0.33 \) and 0.21, respectively), between study years (\( P = 0.87 \) and 1.0) nor between roosts (\( P = 0.77 \) and 0.77); thus, data for each sex, year and roost were pooled prior home-range analysis. Mean HR90 size of tagged lesser kestrel was 346.8 ± 141.6 ha (range 622.8–127 ha, \( n = 9 \) birds), and 92.7 ± 35.5 ha (range 153.8–59.4 ha, \( n = 9 \) birds) for mean HR50 size (Table 2; see Fig. 1). The mean linear distance from the roost to the center of the HR90 was 3.7 ± 1.3 km (range 1.7–5.8 km, \( n = 9 \) birds). All lesser kestrel radio locations were registered within 9 km from the roost in all study years. In roost A, the maximum registered distance from the roost to the foraging place was 5.0 km in 2004 and 8.9 km in 2005; whereas it was 7.6 km in roost B in 2004. Each monitored tagged lesser kestrel returned daily during sunset to the same roost where it was captured. No change of roost by tagged lesser kestrel was reported.

Habitat selection by tagged kestrels

Landscape-scale habitats

Lesser kestrels used mainly farmland within HR90 (mean farmland = 96.2 ± 3.9% per used habitat). At the SA scale, WCA results showed that lesser kestrels did not establish their HR90 at random within a 9 km radius from the center of any roost (\( \Lambda = 0.00016, P = 0.008 \), see Table 5). The ranking habitat in decreasing order of selection by lesser kestrel was farmland > wet grassland > scrubland > forest > urban areas (see Table 5). Farmland was significantly more used than any other habitat, while urban areas were significantly the least utilized habitat. There was no detectable significant difference in use among the other three habitats.
At the HR scale, urban areas were absent from the HR90 of all birds, while scrubland was it from the HR90 of 450% of birds. To reduce effects of inflated Type I error rates on our results, urban areas and scrubland were excluded (see Aebischer et al., 1993; Bingham & Brennan, 2004). At this scale, habitat selection by lesser kestrel was similar to the SA scale (Lambda = 0.0418, \( P = 0.01 \), Table 5), with farmland as the significantly more used habitat, and with no detectable differences between the use of wet grassland and forest (Table 5).

**Fine-scale habitats**

At the SA scale, WCA results showed that habitat use was nonrandom (Lambda = 0.0084, \( P = 0.028 \), Table 6), with irrigated crops as the significantly less used habitat. The decreasing order of selection by lesser kestrel of the remaining five habitats was dry cereal stubbles > plugged fields > fallows > field margins > leguminous crops (Table 6), although this ranking habitat was no significant.

At the HR scale, irrigated crops were absent from the HR50 of all birds except for one, so this habitat was dropped in the within-HR50 comparisons. At this scale, WCA results indicated that radio-tagged lesser kestrel were nonselective in their fine-scale habitat selection (Lambda = 0.3924, \( P = 0.66 \)).

**Discussion**

**Space use**

Results from this study revealed that radio-tagged lesser kestrels returned daily to the sites used as communal roost at night and foraged in the area around them during daylight. This behaviour agrees with Hamilton’s refuging theory, which states that animals would use a roost as a central place within the area of food supply and disperse from this roost daily to forage (Hamilton et al., 1967; Hamilton III & Watt, 1970). The refuging behaviour exhibited by tagged lesser kestrels indicates high roost fidelity, especially because we did not report tagged lesser kestrels changing of roost within the study area in the same summer. This roost fidelity may suppose an advantageous process to the individual, as the lesser kestrels would be familiar with the area around roost and the local food resources, decreasing their search time (see Morrison & Caccamise, 1990).

The lesser kestrels moved up to 9 km from the roost, which is in accordance with results of De Frutos et al. (2007), who found that abundance of summering lesser kestrel decreased monotonically with the increase of the distance from roosts up to 9 km. Lesser kestrels foraged on average 3.7 km from the roost in an area of 346.8 ha. This suggests that home ranges in the premigratory and breeding periods are roughly similar (see Negro, Don´azar & Hiraldo, 1993; Tella et al., 1998; Reis & Rocha, 2001; Franco et al., 2004; Liven-Schulman et al., 2004). Lesser kestrels (and migratory birds in general) need both to recover their energy

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**Figure 2** Accumulation curve of the relative proportion accumulated of a, dry cereal stubble crops; b, fallow and c, irrigated crops as a function of the number of sampled squares \( n_{total}=32 \) 1 km\(^2\) squares) around the A communal roost of lesser kestrel *Falco naumanni* in a Spanish farmland during summer 2005. Accumulation curves were created from 20 randomizations of sample order. Each line represents a randomization.
reserves invested into breeding and fat for migration during the post-fledging period (Aparicio, 1990). Therefore, it is probably that availability of areas with sufficient food supply during this period [e.g. with high densities of Orthoptera, the main prey of lesser kestrel during the post-fledging period (Franco & Andrada, 1977; Tejero et al., 1982; A. de Frutos and P. P. Olea, unpubl. data)] may be important for survival and conservation of post-breeding lesser kestrels (Olea et al., 2004). For example, the high post-fledging mobility of lesser kestrel juveniles probably seeking food-rich areas (Olea, 2001) might increase their risk of mortality affecting thus population dynamics (see Hiraldo et al., 1996).

Therefore, investigation on post-fledging movements and survival as well as to ascertain the value of the areas used intensively (home ranges) as food resource during the premigratory period is a promising work that would aid to improve the understanding of the post-fledging biology and the efficacy of lesser kestrel conservation and management programmes.

**Habitat selection**

Our results revealed that tagged lesser kestrels showed clear preferences of habitat during summer. Lesser kestrels intensively used more farmland than any habitat. Excluding urban, the remaining landscape-scale habitats were used intermediate by lesser kestrels, and the decreasing order of preference: wet grassland, scrubland and forest could be characterized by an increase of cover and height of the vegetation in the study area (pers. obs.), decreasing thus their use by lesser kestrels. This could be due to the lesser accessibility of prey for aerial hunting lesser kestrels (see Donazar et al., 1993; Vlachos et al., 2003). The scarce use of scrubland by lesser kestrel is compatible with the negative selection by lesser kestrels during the breeding period reported in other areas (Tella et al., 1998; Franco & Sutherland, 2004; García et al., 2006). Therefore, crop abandonment at long term within the used areas by lesser kestrel is not recommended for conservation of lesser kestrel. On the other hand, we found that the negative selection of forest habitat by lesser kestrels agrees with previous studies on the species during the breeding period (Donazar et al., 1993; Franco &

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**Table 5** Landscape-scale habitat selection at both the study-area and home-range 90% scales as determined by weighted compositional analysis of lesser kestrel radiotagged (n=9) at two communal roosts in a Spanish farmland during summers of 2004 and 2005

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Study-area scale</th>
<th>Home-range 90% scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Habitat ranka</td>
<td>Rank differencesb</td>
</tr>
<tr>
<td>Farmland</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>Wet grassland</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>Scrubland</td>
<td>2</td>
<td>B</td>
</tr>
<tr>
<td>Forest</td>
<td>1</td>
<td>B</td>
</tr>
<tr>
<td>Urban</td>
<td>0</td>
<td>C</td>
</tr>
</tbody>
</table>

aFollowing Aebischer et al. (1993), habitat was ranked in order of increasing relative use, where 0 is the less used habitat.
bWCA analysis indicated that habitat types with the same letter code were not different (P>0.05) from each other.
–, habitat was excluded from the analysis (see text); WCA, weighted compositional analysis.

**Table 6** Selection of fine-scale habitat of farmland at both the study-area and home-range 50% scales as determined by weighted compositional analysis of lesser kestrel radiotagged (n=7) at two communal roosts in a Spanish farmland during summers of 2004 and 2005

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Study-area scale</th>
<th>Home-range 50% scaleb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Habitat rankc</td>
<td>Rank differencesd</td>
</tr>
<tr>
<td>Dry cereal stubbles</td>
<td>5</td>
<td>A</td>
</tr>
<tr>
<td>Plugged fields</td>
<td>4</td>
<td>AB</td>
</tr>
<tr>
<td>Fallows</td>
<td>3</td>
<td>AB</td>
</tr>
<tr>
<td>Field margins</td>
<td>2</td>
<td>B</td>
</tr>
<tr>
<td>Leguminous crops</td>
<td>1</td>
<td>AB</td>
</tr>
<tr>
<td>Irrigated crops</td>
<td>0</td>
<td>C</td>
</tr>
</tbody>
</table>

aInformation of crop types within the HR50 was complete for seven birds.
bWCA analysis showed a non-significant selection at the home-range scale.
cFollowing Aebischer et al. (1993), habitat was ranked in order of increasing relative use, where 0 is the less used habitat.
dWCA analysis indicated that habitat types with the same letter code were not different (P>0.05) from each other.
WCA, weighted compositional analysis.
Habitat selection of lesser kestrel in premigratory areas

Á. de Frutos and P. P. Olea

Sutherland, 2004). Forest habitat can be increased with the encouragement of the agri-environmental schemes promoted by the Common Agriculture Policy to farmers to forest their farms (MAPA, 2007). Suggestions for avoiding land abandonment and afforestation have been highly recommended in breeding areas of lesser kestrel (Ursúa, Serrano & Tella, 2005).

As farmland was the more used habitat, we carried out a detailed analysis within this habitat. Preferences of fine-scale habitat within farmland only showed a significant negative selection of irrigated crops. No significant selection of other crops could be due to the small sample size or to the fact that lesser kestrels use different crop types within farmland habitat according to their availability (with the exception of irrigated crops). Despite weak preferences, tagged lesser kestrels used all the fine-scale habitats (except irrigated crops), so that all these types of crops may be important in any time during the period before migration. The avoidance of the irrigated crops could be due to the dense and tall structure of the vegetation of both still unharvested maize (≈ 200 cm) and irrigated alfalfa (≈ 60 cm), that would difficult the prey access. Also, this type of crops has an intensive management with chemical treatments that may reduce the abundance of insects prey for lesser kestrel (Donzázar et al., 1993; Rodriguez, 2004). Importantly, part of our study area, the surroundings roost A, is being transformed into an irrigated zone (MAPA, 2007). Currently, there are almost 863 ha devoted to irrigated crops (i.e. 3.4% of the total extent of the area around roost A), but it is expected to increase the surface of irrigated crops around this roost (up to 21–62%) and thus foraging areas of lesser kestrels will be probably reduced. Therefore, irrigation may affect negatively to lesser kestrel numbers in the study area. Although lesser kestrels can select irrigated crops once they have been harvested (Ursúa et al., 2005), in general they are avoided during the winter (Tella & Forero, 2000), breeding period (Tella et al., 1998) and summer (this study). In our area, maize accounts for almost 90% of the crops once the area is irrigated and remains unharvested throughout summer hampering use by lesser kestrel. Therefore, a significant fraction of this area could turn into unsuitable for use by lesser kestrel if their roosts (namely roost A, C and D; see Fig. 1) and surroundings are not protected against agricultural intensification. We know that roosts within our study area have been used each year by around of 800–1200 lesser kestrels for at least 7 years (Olea et al., 2004, pers. obs.), but if these birds are flexible in their dispersing behaviours to find other suitable premigratory areas, the surroundings roost A, is being transformed into an irrigated zone (MAPA, 2007). Currently, there are almost 863 ha devoted to irrigated crops (i.e. 3.4% of the total extent of the area around roost A), but it is expected to increase the surface of irrigated crops around this roost (up to 21–62%) and thus foraging areas of lesser kestrels will be probably reduced. Therefore, irrigation may affect negatively to lesser kestrel numbers in the study area. Although lesser kestrels can select irrigated crops once they have been harvested (Ursúa et al., 2005), in general they are avoided during the winter (Tella & Forero, 2000), breeding period (Tella et al., 1998) and summer (this study). In our area, maize accounts for almost 90% of the crops once the area is irrigated and remains unharvested throughout summer hampering use by lesser kestrel. Therefore, a significant fraction of this area could turn into unsuitable for use by lesser kestrel if their roosts (namely roost A, C and D; see Fig. 1) and surroundings are not protected against agricultural intensification. We know that roosts within our study area have been used each year by around of 800–1200 lesser kestrels for at least 7 years (Olea et al., 2004, pers. obs.), but if these birds are flexible in their dispersing behaviours to find other suitable premigratory areas is still unknown. Therefore, given that this irrigation plan is unavoidable and applying the precautionary principle, special agri-environmental measures should be implemented around the lesser kestrel roosts affected (see Ursúa et al., 2005).

Conservation strategies of lesser kestrel should consider the post-fledging period by: (1) legally protecting roosts and the area around them at least up to 9 km (i.e. about 260 km² of surface), during summer especially from mid-August up to migration in mid-September coinciding with game period; (2) encouraging the establishment of the current agri-environmental schemes focusing on agricultural extensification; these agri-environmental schemes may also benefit other farmland birds of our study area, several of which are threatened too (e.g. great bustard Otis tarda and little bustards Tetrax tetrax); (3) preventing the application of highly toxic pesticides that may affect both directly and/or indirectly (by reducing prey abundance) to lesser kestrel (e.g. Ortego et al., 2007); (4) implementing monitoring programmes of summer roosts of lesser kestrel and the investigation of other premigratory areas.

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