Spatial ecology of the Red Kite (*Milvus milvus*) during the breeding period in Spain

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Studies focusing on the spatial ecology of the Red Kite (*Milvus milvus*) during the breeding season are scarce, despite this season having major importance in its conservation. Spain has one of the largest breeding populations of this species, but it is very threatened in this country. Here, 28 Red Kites were tagged in Spain with GPS satellite transmitters to study the movements of breeding adults during the breeding season (March–June), evaluating the differences according to sex, and investigating the habitat selection. The area used by females was smaller than the used by males (95% KDE = 4.48 vs. 3.30 km^2). Females also traveled less distance per hour and remained closer to the nest. Thus, females had a higher frequency of locations at distances <250 m from the nest, while males had a higher frequency at distances >1 km. Distances recorded at >5 km were scarce for both sexes, and maximum distances reached were usually (61% of seasons) less than 15 km. Both sexes increased the frequency of movements between 1–3 km during the central hours of the day. Red Kites mainly used areas occupied by non-irrigated arable land, forests, scrubs, and herbaceous vegetation. The selection of certain types of crops highlights the importance of the agroforestry landscape for the conservation of the species. On the other hand, we documented for the first time how part of the Spanish breeding population is a short-distance migrant within the Iberian Peninsula while other part of the population makes post-breeding movements during summer.

1. Introduction

Understanding spatial ecology during the breeding season is fundamental for the conservation of birds, especially for threatened raptors, such as the Red Kite in Spain. The breeding strategies, which include incubation, chick-rearing, and fledging, result from a trade-off between current breeding success and parents' future condition (Trivers 1972, Nur 1988, Clutton-Brock 1991, Williams

2018). The knowledge about home range areas and movements performed by raptors during reproduction is essential for the delimitation of protected areas around the nests (Kays *et al.* 2015, López-López *et al.* 2016). Given that the Red Kite breeding population has decreased in Spain in recent years (Molina 2015), the study of its spatial ecology could help to design more effective conservation measures for the species in the Iberian Peninsula.

Despite the importance of this topic, studies concerning the spatial ecology of the Red Kite during the breeding season are scarce. Most of the previous studies on this topic were based on field observations or radio-tracking (Newton *et al.* 1989, Bustamante 1993, Newton *et al.* 1994, Mougeot *et al.* 2011), while the studies using GPS telemetry are uncommon (Mammen *et al.* 2014, Pfeiffer & Meyburg 2015). However, GPS telemetry could provide fundamental information about the behaviour of the species (López-López *et al.* 2010, Urios *et al.* 2015, López-López 2016). Studies based on this tracking technology, combined with direct observations to know the stage of development of chicks, are necessary to understand the breeding ecology of this species and other raptors.

The deeper the knowledge of its breeding ecology, the better conservation tools will be available to protect the species. In some countries, there has been a population increase in recent years (Aebischer 2010, Cereghettia *et al.* 2019, BirdLife International 2019), but the species is still listed as "endangered" in the Spanish List of Threatened Species because their breeding populations have clearly decreased in the last decades (Molina 2015). The main causes of this decline are human persecution (including poisoning and illegal hunting), collisions and electrocutions, car accidents, inter-specific competition, and habitat deterioration (Viñuela *et al.* 1999, Carter 2001, Sergio *et al.* 2005, Berny & Gaillet 2008, Knott *et al.* 2009, Mougeot *et al.* 2011, Mateo-Tomás *et al.* 2020, Viñuela *et al.* 2021).

Here we used 28 individuals tagged with GPS telemetry to study the spatial ecology of Red Kite during the breeding period (including laying, hatching, and fledging; from March to June) in Spain. Our goals were a) to estimate the home range, mean distance to nest, and hourly travelled distance during the reproductive season; b) to evaluate the differences in spatial ecology according to sex; c) to study the habitat selection during the breeding season; and d) to analyze the diversity of post-reproductive strategies (sedentarism, sedentarism with post-reproductive movements, or intra-peninsular migration) used by the Spanish breeding population of the Red Kites.

2. Materials and methods

2.1. Study species

The Red Kite (*Milvus milvus*) is a medium-sized opportunistic raptor from western Palearctic (Cramps & Simmons 1980, IUCN 2018). It is a facultative colonial bird that can form breeding aggregations when food is abundant (Ortlieb 1980, Villafuerte *et al.* 1998, Mougeot & Bretagnolle 2006). Red Kites usually start to breed at 2–4 years of age, but they can take up to 7 years to reach sexual maturity. Egg laying usually takes place in March–April, and the clutch size is typically 1–3, up to 5. Eggs are incubated for 31–32 days, and fledging takes place at the age of 50–60 days (Davies & Davies 1973, Bustamante 1993, Newton *et al.* 1989, Veiga & Hiraldo 1990, Newton *et al.* 1996, Evans *et al.* 1999, Sergio *et al.* 2005, Mougeot & Bretagnolle 2006). Most Red Kites in north-eastern Europe are migrants (García-Macía *et al.* 2021), and they move southward, mainly to the Iberian Peninsula and France, to spend the wintering season (Del Hoyo *et al.* 1994, Fabienne 2009, De la Puente & De la Torre 2015). However, there are also breeding populations in the southern distribution range as in Spain, which has the third largest population after Germany and France (BirdLife International, 2019). In the most recent census, the breeding pairs in Spain were estimated at 2,312–2,440 pairs (Molina 2015).

2.2. Tagging

From 2013 to 2017, 28 adult Red Kites (6 males and 22 females) were captured and tagged in different Spanish provinces (Supplementary Material Table S1). We used the data of 47

breeding events (Supplementary Material Table S2), and a total of 55,869 locations, with an average of 1,190 ± 432 locations per event. Adult birds were trapped using a dho-gaza net with an Eagle Owl (*Bubo bubo*) decoy (De la Puente & Cardiel 2009), while one individual was tagged as a chick in the nest. All individuals were weighed and ringed, and a blood sample was obtained for sex determination by DNA. Birds were tagged using a GPS/satellite transmitter that was affixed to the back using a Teflon harness, a non-abrasive material, fixed with several cotton thread stitching points to be safely released from the birds once they ceased to function after about five years (Garcelon 1985; García *et al.*, 2021). The weight of tags was below the recommended 3% of the birds' body mass (Kenward 2001; mean percentage ± SD = 2.30 ± 0.19%, range = 1.90–2.62%). Birds were released within 30 min after capture.

We used different transmitter models: 20–23-g SAKER GPS-GSM (Ecotone Telemetry; n=26), 22-g PTT-100 solar-powered Argos/GPS (Microwave Telemetry Inc.; n=2) or 30-g PTT solar Argos/GPS (Microwave Telemetry Inc.; n=1). Ecotone and 30-g Microwave tags were programmed to collect locations every hour from 06:00 to 19:00 h (local hour), and 30-g Microwave tag had the same duty cycle but until 20:00 h. 22-g Microwave transmitters recorded 1 location per hour from 06:00 to 18:00 h. Thus, all tags provided fixes at a 1-hour frequency.

2.3. Spatial parameters and analysis

We defined the "breeding period" as the time from 1 March to 30 June, since the first laying takes place between March and April and chicks leave the natal area 10–12 weeks after hatching (Bustamante 1993, Newton *et al.* 1996, Mougeot *et al.* 2011, Nachtigall & Herold 2013). Hence, our study covered the crucial stages of the breeding period (incubation and chick-rearing). It was verified by field observations that all individuals used in this study reproduced successfully, and incubation and chick-rearing took place between March and June. We excluded the breeding events with less than 3 complete months of data from the analyses, due to individual deaths or transmitters failures.

We estimated the breeding home range for each breeding season with the 95%, 75%, and 50% fixed Kernel Density Estimation (KDE; Worton 1989) using the Animal Movement extension for ArcView 3.2 (Hooge & Eichenlaub 1997). We used the least squares cross-validation procedure to calculate the smoothing parameter S (Silverman 1986). We also calculated the 100% Minimum Convex Polygon (MCP) encompassing all the locations for each breeding season. The different polygons were transformed into an Equal-Area Cylindrical projection. We calculated the distance to the nest position (the nest used during the respective year) of every recorded location of all Red Kites and the distance covered (km) in 1 h using only consecutive locations (Mellone *et al.* 2012, García-Macía *et al.* 2021).

We analyzed sex differences in the home range sizes, distances to nest, and travelled distances. We used the different measurements of home range areas (MCP and KDEs), the average daily distances to the nest, and the average daily hourly travelled distances as response variables in six different linear mixed models (LMM). In all models, "sex" was included as fixed factor. "Year" was included as random effect in the models with the estimated areas (MCP and KDE; km^2) as response variables, while "individual" identity and "year" were included as random effects in the models with the distances to the nest and the hourly travelled distances as response variables. The requirements to perform the LMMs were verified, including the normality of residuals with the Shapiro-Wilk test. The response variables were log-transformed to fulfill that requirement (Mean ± SD after transformation: MCP=4.45 ± 1.28; KDE95=0.37 ± 1.64; KDE75=–0.60 ± 1.58; KDE50=–1.30 ± 1.58; travelled distances = –1.167 ± 1.59; distance to nest = 0.96 ±1.58).

Kruskal-Wallis test (data were non-normal) was used to determine if there were significant differences in the travelled distance between the different hours of the day. Games-Howell test (Zar 1999) was used to check if there was a peak of hourly activity throughout the day.

All statistical analyses were performed with IBM SPSS Statistics v. 22.0 (IBM Corp. 2020) and R Statistics v. 4.0.5 (R Core Team 2022). The significance level was established at $p < 0.05$.

2.4. Habitat selection

To determine the habitat selection within the home ranges, we used the CORINE 2018 land cover map (raster resolution = 100 m) provided by the European Environment Agency (2018). We grouped the original land cover classes ("CLC") into nine categories to facilitate the interpretation of the results (Fig. 1): artificial surfaces (CLC codes: 111–142), non-irrigated arable land (CLC code: 211), permanently irrigated land (CLC code: 212), permanent crops and pastures (CLC code: 221–231), heterogeneous agricultural areas (CLC codes: 241–244), forests (CLC codes: 311–313), scrub and/or herbaceous vegetation associations (CLC codes: 321–324), open spaces (bare rocks or sparsely vegetated areas; CLC code: 331–335) and wetlands and water bodies (CLC code: 411–523).

We performed a third-order habitat selection (Johnson 1980) analysis to evaluate whether Red Kites are found in certain habitats more frequently than expected by their availability, comparing the observed values against a set of random samples (Gotelli & Ellison 2004). First, we generated 2000 random points within each MCP of each breeding season, which represents the maximum potential area used by the individuals. Then, we assigned the corresponding habitat type to

every random point and to every real location recorded during the breeding season. We used Monte Carlo simulations to determine habitat preferences, comparing the frequency of real tracking data with the generated random locations (Manly 1997, Soutullo *et al.* 2008, Limiñana *et al.* 2012, López-López *et al.* 2016, Vidal-Mateo *et al.* 2019). These expected frequencies were calculated by sampling the same number of real locations from the generated random points; this process was repeated 1,000 times using the "shuffle rows" option in Excel's PopTools add-in (Hood 2010). The observed values (tracking data) were compared against 1,000 generated random locations with Monte Carlo analysis using Excel's PopTools. Comparisons were two-tailed, and the significance level was established at $p < 0.05$.

3. Results

The average home range area during the breeding season was 3.65 km² according to 95% KDE, 1.48 km² to 75% KDE, 0.78 km² to 50% KDE, and 169.15 km² to MCP (Table 1). Males had larger 95% KDEs than females (4.48 km² vs. 3.30 km²). We did not find significant differences between sexes according to the rest of the home range sizes
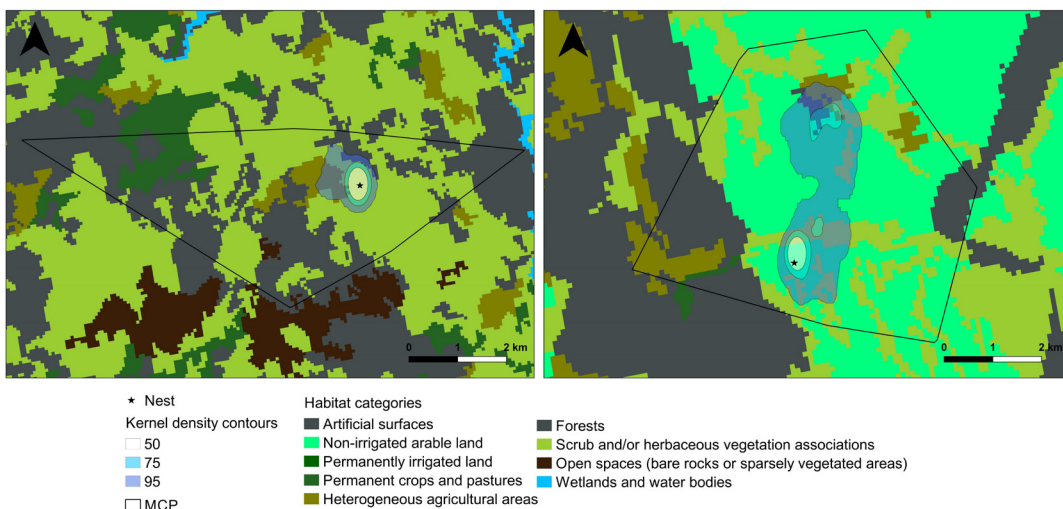

Fig. 1. Example of two home range areas of adult Red Kites tracked by GPS satellite telemetry during the breeding season. Polygons represent Kernel Density Estimations (KDE) and Minimum Convex Polygon (MCP). Left: male in Ávila; right: female in Madrid (Spain).

Table 1. Home range size (in km^2), mean distance to nest and hourly distances of 47 breeding seasons of Red Kites tracked by GPS satellite telemetry in Spain according to their sex and migratory or resident behaviour. Results are expressed as mean and standard deviation. Minimum and maximum values appear in parenthesis. MCP: Minimum Convex Polygon; KDE: Kernel Density Estimation.

	n	MCP (km^2)	95% KDE (km^2)	75% KDE (km^2)	50% KDE (km^2)	Mean distances to nest (km)	Mean hourly distances (km per h)
Overall	47	169.15 ± 187.43 (7.30–832.71)	3.65 ± 4.26 (0.06–17.94)	1.48 ± 2.23 (0.02–10.47)	0.78 ± 1.26 (0.01–5.95)	1.14 ± 0.75 (0.15–3.96)	0.94 ± 0.61 (0.16–3.36)
Males	14	181.01 ± 128.51 (23.85–404.81)	4.48 ± 2.62 (0.84–9.36)	1.13 ± 0.92 (0.29–3.22)	0.46 ± 0.41 (0.15–1.58)	1.41 ± 0.36 (1.05–2.38)	1.48 ± 0.30 (1.17–2.39)
Females	33	164.12 ± 209.06 (7.30–832.71)	3.30 ± 4.78 (0.06–17.94)	1.64 ± 2.60 (0.02–10.47)	0.91 ± 1.47 (0.01–5.95)	1.02 ± 0.85 (0.15 – 3.96)	0.71 ± 0.56 (0.16–3.36)

estimators (MCP, 75% KDE, and 50% KDE), but the estimates of the models indicated the same trend, and female home range tended to be smaller (Table 1, Fig. 2).

We also found significant differences between sexes in the distances to the nest and the hourly travelled distances. Females stayed closer to the nest than males (EMMs = –1.58 vs. 0.04) and performed shorter movements (EMMs = –1.34 vs. 0.17; Fig. 2, Table 2). Males stayed at 1.41 ± 0.36 km from the nest, while females stayed at 1.02 ± 0.85 (Table 1). Females had a higher frequency of locations (69.1%) at distances <250 m from the nest (Fig. 3), while males had a higher frequency than females at distances > 1 km from the nest (45.7% and 16.7%, respectively). The frequency of distances recorded at > 5 km from the nest was low for both sexes (Fig. 3). The maximum distances reached during the entire breeding season ranged between 2.89 and 47.61 km, but they were usually (61% of seasons) less than 15. (Supplementary Material Table S2). On the other hand, males travelled 1.48 ± 0.30 km per hour, while females travelled 0.71 ± 0.56 (Table 1). 67.5 % of movements for females had a length <250 m (Fig. 4), with differences in these frequencies comparing them to males (χ^2 = 9294.01, df=6, p<0.001). Only 22.6% of movements for males were <250 m, whereas they had a higher frequency of longer distance movements (>1 km): 53.8% vs. 18% of females (Fig. 4).

The frequency of movements varied according to the hour of the day, in both sexes (males: χ^2=2220.67, df=78, p<0.001; females: χ^2=1595.57, df=78, p<0.001). Although we observed no prominent peak of activity in the analyses, the frequency of short movements were higher during the first and last hours of the day, whereas the frequency of long movements increased during the central hours of the day (10–16 h). This temporal pattern was shown by both males and females (Fig. 5). The Red Kites in our study mainly used areas occupied by scrub, herbaceous vegetation, and crops (Fig. 1, Table 3). Most locations occurred in scrub and/or herbaceous vegetation associations (34.83%) and non-irrigated arable land (23.05%), which were used more frequently than expected from their availability. Red Kites also showed a preference for permanent crops, pastures, and heterogeneous agricultural areas. In contrast, forests were used less than expected from their availability, although the number of locations recorded in this habitat was high (21.87%). Permanently irrigated lands and open spaces were also avoided.

From the 29 tagged Red Kites, 17 remained close to the breeding area during the whole year (58%), 4 individuals (14%) performed short distance migrations (range = 299–560 km) within the Iberian Peninsula, and 8 individuals (28%) made post-reproductive movements after the chicks had left the nest. These movements covered distances between 100 and 600 km and lasted between 2 and 8 weeks. In some cases, this was a consistent pattern in subsequent years, but not in others.
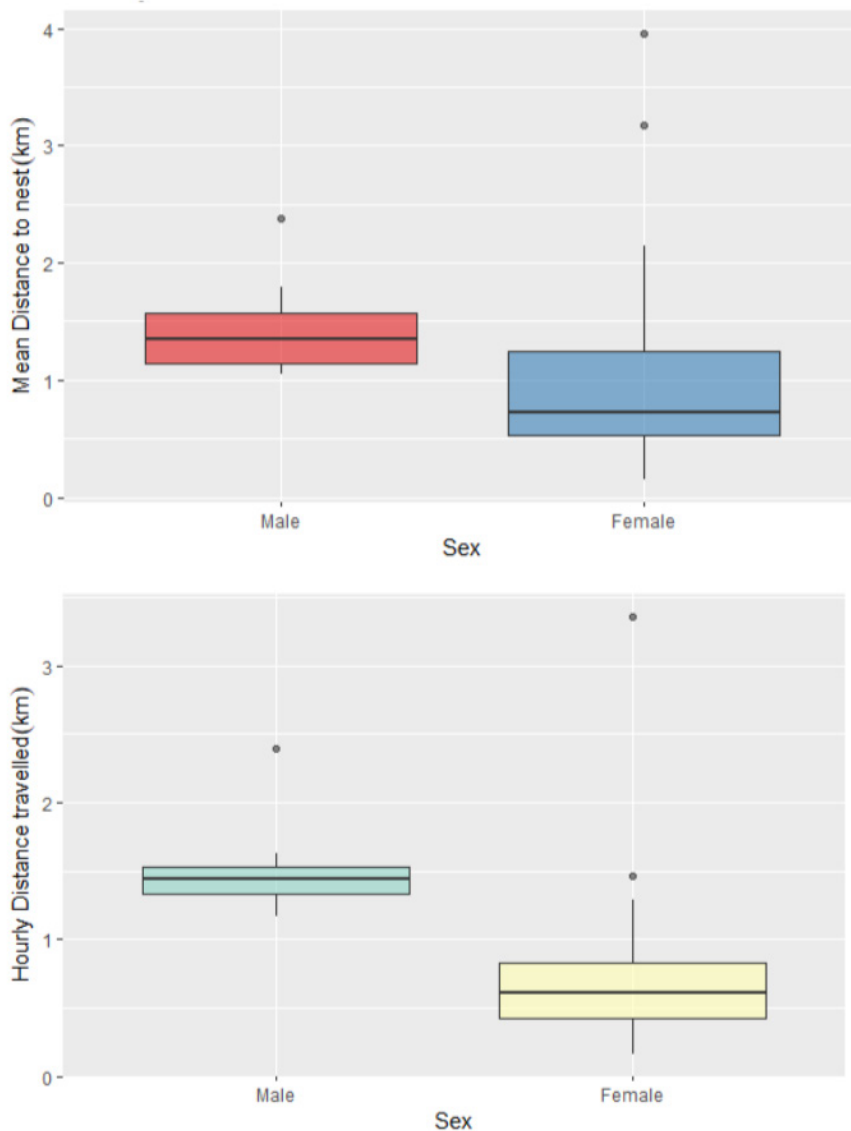
Fig. 2. Differences between sexes according to mean distances to nest and hourly travelled distances (raw data).

4. Discussion

Our study provides the first description, and comparison between sexes, of breeding home ranges and movement patterns of Red Kites breeding in Spain. We showed how female Red Kites had smaller breeding areas than males, stayed closer to the nest, and had lower mobility during the reproductive season. We also studied the habitat preferences of the species, highlighting the importance of the agroforestry landscapes for its conservation.

According to the Minimum Convex Polygon, the home range size was 169 km² on average, similar to other home MCP estimations for the Red Kite using both GPS tracking (Mammen *et al*. 2014, Pfeiffer & Meyburg 2015), and direct observations or VHF tracking (Porstendörfer 1994, Porstendörfer 1998, Walz 2001, Nachtigall *et al*. 2010, Nachtigall & Herold 2013, Mammen

Table 2. Results of the linear mixed models (LMM) of home range areas and distances. A) Comparison between sexes (fixed effect), B) Information about random effects of the model. Estimates, standard error (SE), standard deviation (SD), degrees of freedom (df), and p-value are shown. MCP: Minimum Convex Polygon; KDE = Kernel Density Estimation. Response variables were log-transformed to comply with the normality of residuals.

A) Fixed effect (Sex)

Variable	Fixed factor	Estimate	SE	df	p-value
KDE 95% (n=47)	Intercept	0.278	0.107	45	0.0130
	Sex (Male)	0.281	0.107	45	0.0115
KDE 75% (n=47)	Intercept	−0.206	0.109	45	0.065
	Sex (Male)	0.141	0.109	45	0.202
KDE 50% (n=47)	Intercept	−0.553	0.125	1.75	0.059
	Sex (Male)	0.083	0.109	43.99	0.453
MCP (n=47)	Intercept	1.946	0.127	2.23	0.003
	Sex (Male)	0.151	0.085	43.59	0.085
Distance to nest (daily average; n=5302)	Intercept	−0.234	0.120	6.50	0.0444
	Sex (Female)	−0.370	0.061	19.67	<0.001
Hourly distance (daily average; n=5302)	Intercept	−0.3215	0.133	7.43	0.0445
	Sex (Female)	−0.396	0.074	19.61	<0.001

B) Random effects

Variable	Random effects	SD
KDE 95% (n=47)	Year	0.0004
	Residuals	0.06
KDE 75% (n=47)	Year	0.002
	Residuals	0.681
KDE 50% (n=47)	Year	0.101
	Residuals	0.686
MCP (n=47)	Year	0.164
	Residuals	0.532
Distance to nest (n=5302)	Individual	0.2503
	Year	0.228
	Residuals	0.631
Hourly distance (n=5302)	Individual	0.305
	Year	0.246
	Residuals	0.671

et al. 2014). However, the smaller home range sizes estimated and the great frequency of distances close to the nest indicate the Red Kites concentrated their movements on smaller surfaces during breeding. Indeed, the 95% KDE (3.65 km^2) was fifty times smaller on average than MCP estimations, and more than 90% of the total locations were less than 5 km from the nest. The Kernel Density Estimations (or similar analyses to estimate home range sizes) based on GPS telemetry provide very useful information to understand the breeding and foraging behavior of raptors, because they exclude unrepresentative outliers and provide accurate estimations of the core territory of the species.

The variability found in the home range sizes estimators (*e.g.*, 95% KDE range = 0.06–17.94; Table 1) may be due to several factors. Better environmental conditions and food resources allow birds to reduce their home range (Hernández-Pliego *et al.* 2017, Tucker *et al.* 2019). On the other hand, the smaller number of fledglings per nest, the larger the adults' breeding area (Pfeiffer & Meyburg 2015). The period considered for the analyses may also affect the home range estimations. 95% KDE provided by Pfeiffer and Meyburg (2015) was thirty times larger than ours, probably because they included a few weeks more than we did, when individuals had greater mobility. The breeding season could be divided into several phases, characterized by different degrees of movements in the couple, being the chick-rearing and post-fledging the phases with higher mobility (López-López *et al.* 2021). Other factors, such as the nutritional stage of the chicks and GPS sampling frequency, might also explain the differences in the home range estimations between different studies or within the individuals in the same study. More studies with Red Kites' pairs, and considering the different phases of breeding, should be conducted in the future to have more specific knowledge about the spatial ecology of this species during breeding (Worton, 1989).
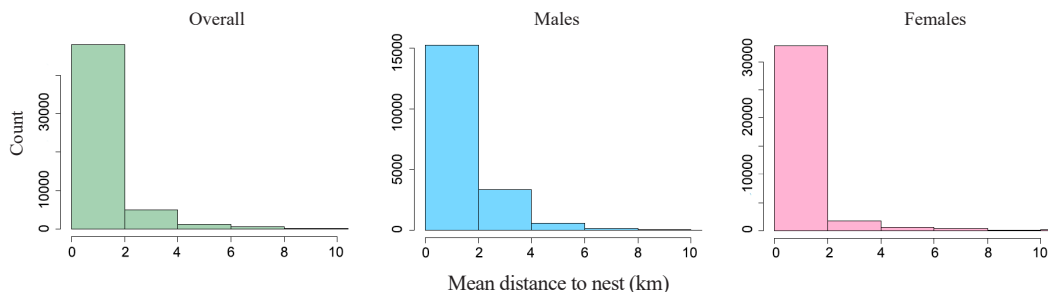
Fig. 3. Frequency of movements according to the distance to the nest categorized by sex.
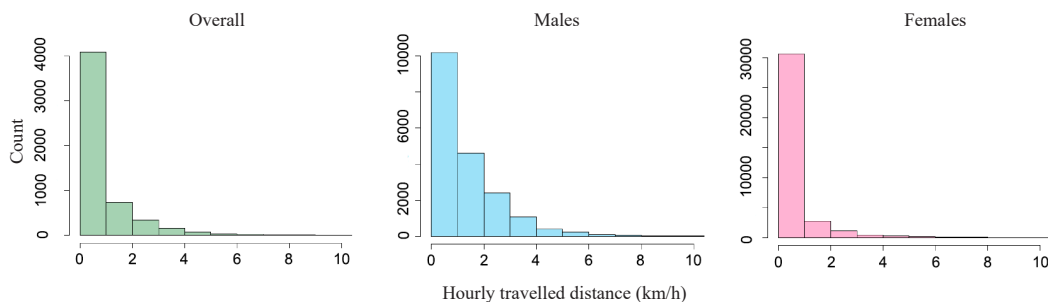

Fig. 4. Frequency of movements recorded at 1 h intervals categorized by sex.

Female Red Kites usually used smaller areas and had less mobility than males during the breeding season. Females showed smaller 95% KDEs, higher frequencies of locations very close to the nest, and shorter movements than males. Not all sex comparisons using the rest of the home range estimators (MCP, 75% KDE, and 50% KDE) were significant, but the slopes of the models were always positive for the males compared to the females, which indicates the same tendency. The absence of significance in some models may be due to the small sample size (n=47), or other environmental factors not considered in the models. In any case, the sex differences may be due to the different roles assumed by the members of the pair. On the one hand, females probably spent more time incubating the eggs, protecting the chicks, and providing food to the nest from its surroundings. On the other hand, males may travel to habitats with higher productivity for hunting, even if these were far from the nest. Thus, this role differentiation allows both the protection of the nest and the feeding of the chicks, improving breeding performance (Keeley & Bechard 2017, Martínez *et al.* 2020, López-López *et al.* 2021).

Red Kites showed a preference for lands occupied by scrub, herbaceous vegetation, and non-irrigated crops, which may influence the location of the nests in those habitats (Heuck *et al.* 2013). In fact, our results showed that Red Kites concentrated their movements around the nest. We suggest that the selection of open wooded lands (Del Hoyo *et al.* 1994, Bird Life International 2019) could be linked to the location of carrions and preys. Although this species has scavenging habits, visiting supplementary feeding stations or dumps, they can also hunt small mammals and birds, or even reptiles and amphibians (Cramp & Simmons 1980, Blanco *et al.* 1990, García *et al.* 1998, García & Viñuela 1999, Mougeot & Bretagnolle 2006). The selection of certain types of crops highlights the importance of conserving the agroforestry landscape and its heterogeneity. The Red Kite may be sensitive to changes in land use, including the substitution of traditional crops and the homogenization of landscapes (Viñuela *et al.* 1999, Knott *et al.* 2009).

The striking diversity of post-reproductive strategies performed by the Spanish breeding population of the Red Kite may be one of the keys for

Table 3. Habitat selection for Red Kite in Spain during the breeding season. The percentage of locations in each habitat type is indicated for the observed locations and for the expected values. P-value for the comparison between the observed locations and random points is indicated. (+), habitat is selected; (–), habitat is avoided.

| Habitat type	Random points (%)	GPS locations (%)	p-value
Artificial surfaces	3.00	0.93	<0.001 (–)
Non-irrigated arable land	20.41	23.05	<0.001 (+)
Permanently irrigated land	1.83	0.45	<0.001 (–)
Permanent crops and pastures	5.41	6.66	<0.001 (+)
Heterogeneous agricultural areas	10.04	12.05	<0.001 (+)
Forests	24.57	21.87	<0.001 (–)
Scrub and/or herbaceous vegetation associations	32.39	34.83	<0.05 (+)
Open spaces (bare rocks or sparsely vegetated areas)	1.48	0.06	<0.001 (–)
Wetlands and water bodies	0.87	0.09	<0.001 (–)
Total number of locations	94000	55869	
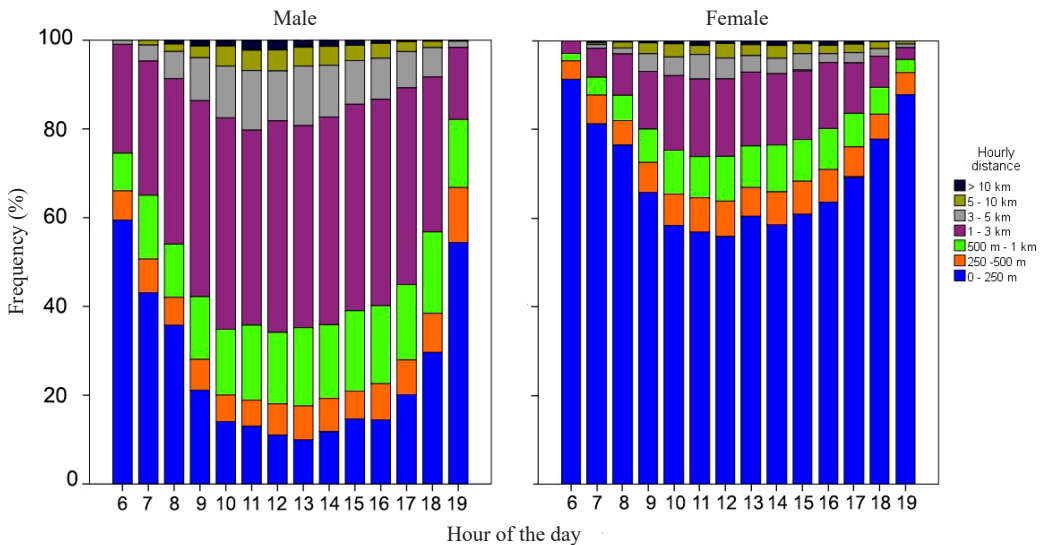
Fig. 5. Frequency of movements recorded at 1 h intervals categorized by different distance ranks per sex according to the time of day.

its conservation. Our tracking data revealed that part of the breeding population in Spain performs short-distance migratory movements, whereas other part engages in post-breeding movements across the Iberian Peninsula. This variability in the post-reproductive behaviour of the Spanish Red Kites may respond to several environmental factors, but we consider that availability of food and knowledge of the breeding area could be the most important ones (McIntyre & Schmidt 2012). Moreover, the short migration and post-reproductive movements in the Spanish breeding population are not constant among years for the same individuals. The Red Kites might change their post-breeding strategy depending on availability of resources (Joseph *et al.* 2003, Bildstein 2006, Losos & Ricklefs 2009, Gangoso *et al.* 2013). Further studies could relate the inconsistency of

behaviour between consecutive years to the availability of resources or any other factor.

In conclusion, our study provides the first data about travelled distances and home range sizes of the Red Kites during the breeding season in Spain, proving the differences between sexes. This study allows a better knowledge of the reproductive spatial ecology of this species, which could be essential for the conservation of the threatened breeding Spanish population.

Isohaarahaukan lisääntymisajan spatiaalinen ekologia Espanjassa

Isohaarahaukan (*Milvus milvus*) lisääntymisen ajan spatiaalisesta ekologiasta tiedetään vähän, vaikka pesimisajan ekologian ymmärtämisellä on tärkeä merkitys lajin suojelun kannalta. Espanjasta löytyy Euroopan suurimpia pesiviä populaatioita, mutta kanta on pienemässä. Tässä tutkimuksessa asennettiin gps-lähettimiä 28 pesivään aikuiseen isohaarahaukkaan lisääntymisajanjaksolla (maalis–kesäkuu). Tavoitteena oli tutkia sukupuolten välisiä liikkumiseroja ja habitaatin valintaa. Havaitsimme naaraiden liikkumisalueiden olevan pienempiä kuin koiraiden. Naaraat myös liikkuivat hitaammin ja pysyivät lähempänä pesää. Naaraat olivat useammin alle 250 metrin päässä pesästä ja koiraat useammin yli kilometrin päässä pesästä. Yli viiden kilometrin etäisyydet pesästä olivat harvinaisia sekä naaraalla että koirailla, ja kaukaisimmat havainnot olivat yleensä alle 15 kilomteriä pesästä. Lentäminen oli yleisintä 1–3 kilometrin etäisyydellä keskipäivällä molemmilla sukupuolilla. Isohaarahaukat suosivat enimmäkseen keinokastelemattomia peltoja, metsiä, pensaikkoja ja ruohomaita. Koska isohaarahaukat suosivat tiettyjä viljelyjä, maa- ja metsätalouden ympäristöillä on tärkeä merkitys lajin suojelussa. Tutkimuksessa dokumentoimme myös ensimmäistä kertaa, että osalla tutkimastamme espanjalaisesta populaatiosta muuttomatkat ovat lyhyitä (ts. ne pysyvät Iberian niemimaan alueella), kun taas toinen osa populaatiosta liikkuu kesäisin laajemmalla alueella, kun pesintä on ohi.

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Online supplementary material

Supplementary material available in the online version includes Tables S1 and S2 with metadata and information on individual parameters.