Home range and habitat use of little owl (*Athene noctua*) in an agricultural landscape in coastal Catalonia, Spain

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Abstract
*Home range and habitat use of little owl (*Athene noctua*) in an agricultural landscape in coastal Catalonia, Spain.*— In recent decades agricultural landscapes in Catalonia have undergone a profound transformation as in most of Europe. Reforestation and urban development have reduced farmland and therefore the availability of suitable habitat for some bird species such as the little owl *(Athene noctua)*. The outskirts of the city of Mataró by the Mediterranean Sea exemplify this landscape change, but still support a population of little owl where agriculture is carried out. Three resident little owls were monitored with telemetry weekly from November 2007 until the beginning of August 2008 in this suburban agricultural landscape. Mean home range ± SD was 10.9 ± 5.5 ha for minimum convex polygon (MCP100) and 7.4 ± 3.8 ha for Kernel 95% probability function (K95). Home ranges of contiguous neighboring pairs overlapped 18.4% (MCP100) or 6% (K95). Home range varied among seasons reaching a maximum between March and early August but always included the nesting site. Small forested patches were associated with roosting and nesting areas where cavities in carob trees (*Ceratonia siliqua*) were important. When foraging in crop fields, the owls typically fed where crops had recently been harvested and replanted. All three owls bred successfully.

Key words: Little owl, *Athene noctua*, Telemetry, Conservation, Home range, Habitat use, Agricultural landscape.

Resumen
*Área de campeo y uso del hábitat del mochuelo europeo (*Athene noctua*) en un paisaje agrícola de la costa de Cataluña, España.*— El paisaje agrícola en Cataluña ha sufrido una profunda transformación en las últimas décadas, tal y como ha ocurrido en gran parte de Europa. La reforestación y especialmente el desarrollo urbanístico han reducido las tierras agrícolas y con ello se ha perdido hábitat adecuado para especies como el mochuelo europeo *(Athene noctua)*. Los alrededores de la ciudad de Mataró, a orillas del mar Mediterráneo, son un buen ejemplo de este cambio, pero todavía acogen una población de mochuelos allí donde se da actividad agrícola. Entre noviembre de 2007 y principios de agosto de 2008 se siguieron semanalmente con telemetría tres mochuelos residentes en este entorno agrícola periurbano. La media del área de campeo ± DE estimada con el polígono convexo mínimo (MCP100) fue de 10,9 ± 5,5 ha, y de 7,4 ± 3,8 ha, con el estimador de Kernel 95% (K95). Las áreas de campeo de las parejas vecinas se solapaban un 18,4% (MCP100) o un 6% (K95). Las áreas de campeo entre temporadas variaron a lo largo del seguimiento y llegaron a un máximo entre marzo y principios de agosto, aunque éstas siempre albergaron la zona del nido. Las pequeñas manchas arboladas se asociaron a áreas de reposo y nidificación, donde las cavidades naturales de los algarrobos (*Ceratonia siliqua*) eran importantes. Cuando los mochuelos se detectaron en los campos, fue en cultivos recién cosechados o replantados. Los tres mochuelos criaron con éxito.

Palabras clave: Mochuelo europeo, *Athene noctua*, Telemetría, Conservación, Área vital, Área de campeo, Uso del hábitat, Paisaje agrícola.

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Introduction

Landscape transformation and particularly changes in agricultural areas have resulted in reductions of little owl (*Athene noctua*) populations throughout Europe (Van Nieuwenhuyse et al., 2008). Similarly, in Spain where the species is still broadly distributed (Martí & del Moral, 2003), populations are in decline (Blas García & Muñoz Gallego, 2003). The owl's distribution in Catalonia, in northeast Spain, was reduced in 61 10 x 10 km quadrates (21%) in the 20–year period from 1982 to 2002. The most recent breeding population estimate in Catalonia was between 9,000 and 14,500 breeding pairs (Framis, 2004).

The little owl, a species that primarily inhabits open, unforested areas, has occupied agricultural landscapes and has been influenced by the prevailing transformation of agricultural environments (Van Nieuwenhuyse et al., 2008). During the last decades, changes in agricultural landscapes have been characterized by two independent processes: a) agricultural intensification, and b) land abandonment with subsequent reforestation or urbanization. Intensification of agriculture is characterized by the elimination of interstitial elements such as hedgerows between arable fields, isolated trees and stone buildings, accompanied by the introduction of new farming techniques such as the use of fertilizers and pesticides and the introduction of extensive monocultures (Sanderson et al., 2005; Onrubia & Andrés, 2005). Intensification has been correlated with the decline of populations of other bird species that specialize in farmland environments (Krebs et al., 1999; Donald et al., 2001; Donald et al., 2002; Sanderson et al., 2005). Land abandonment results in the replacement of farmland with urban areas or shrubland and forest. In Catalonia, a region of slightly over 32,000 km^2, 61% of farmland was lost in 50 years, a reduction of 16 km^2 annually (Montasell, 2010). Total forested surface in Catalonia increased from 36% in 1970 to almost 61% in 2005 (Montasell, 2010). City enlargement has also transformed the landscape, especially throughout the Barcelona Metropolitan Region (Catalán et al., 2008). These changes in land uses and traditional agricultural practices have reduced little owl habitat availability (Baucells, 2010; Andino, 2005; Framis, 2004).

Little owls occupy small territories year round in Catalonia (Muntaner et al., 1983; Calvet et al., 2004; Aymí & Tomás, 2003). However, no attempt had yet been made to investigate their home range and habitat use in this region. The objectives of this study were to measure the home range of little owls within an intensive market–garden agricultural landscape on the Mediterranean coast, to analyze habitat use related to little owl's main activities, and to propose some conservation priorities to conserve the local population of little owls within the agricultural landscape.

Methods

The study area is located north–east of the city of Mataró, a town of 120,000 inhabitants in the Maresme county on the Mediterranean Sea (N 41º 33' E 2º 28', fig. 1). The study area is within the 263 ha fertile gentle slope called the Cinc Sènies, where the main activity is intensive market–garden agriculture (Montasell, 2006). Main crops are celery, parsley, spinach, onion and potatoes. Small forest patches of carob trees (*Ceratonia siliqua*), littoral oak (*Quercetum ilex*) and stone pine trees (*Pinus pinea*) occur mainly around the hill named Turó d'Onofre Arnau (131 m a.s.l.) at the centre of the Cinc Sènies. The area extends longitudinally, between the coast and the so–called littoral mountain range, from 10–131 m a.s.l. The agricultural and surrounding open area is categorized as peri–urban environment due to its proximity to a medium size city (Montasell, 2006). Industrial sites, railroad tracks, roads, highways, and suburbs have an obvious impact on this landscape whose infrastructure is still under intensive development.

The local Mediterranean climate is characterized by an annual average temperature between 15–16ºC. In the summer, temperatures as high as 30ºC occur but are not normal. However, the annual relative humidity of 72% makes the weather sultry (Andino et al., 2005). In winter, temperatures decline to 5–7ºC (Atles Climàtic Digital de Catalunya) but frost is rare and it does not snow due to the nearby sea. Precipitation is between 550–600 mm annually (Andino et al., 2005). The climate is mild enough to support continuous cropping of the market garden agriculture.

Intraguild predation is known to influence little owl densities and behavior (Zabala et al., 2006; Zuberogoitia et al., 2008). Barn owl (*Tyto alba*) and scops owl (*Otus scops*) are present in the study area; tawny owl (*Strix aluco*) is absent, but distributed in the nearby areas where woods are continuous (Framis, 2008). The effect of predators was not taken into account for this study.

Radio telemetry

Knowledge of owl territories from a previous census in 2007 (Framis, 2008) allowed us to decide where to trap owls, for telemetry. Little owl call playback was used to attract individuals into mist nets just after dark in early November 2007. The nets were checked for trapped owls every 15'. Eleven owls were trapped in a week and handled following the Catalan Ornithological Institute ringing standards (1/03 edition; ICO, 2003). Age was assigned following Martínez et al. (2002).

We attached transmitters to five of the 11 trapped owls using the backpack style harnesses with 4 mm wide Teflon® webbing (Bally Ribbon Mills Inc, Pennsylvania, USA). Battery life of the transmitters was 9 months and frequencies were between 172.097 and 172.659 MHz (Holohil Systems Ltd, Ontario, Canada). The mass of the transmitters was 6.3 g and together with the attaching material, the total mass was ~4.3% of the owl's mass which did not exceed the maximum of 5% recommended by Kenward (2001). An R–1000 telemetry receiver (Communication Specialists Inc., Orange, California, USA) and a three element Yagi antenna were used to triangulate the locations of the transmitters. The effective range of the transmitters was limited by line–of–sight and was 1–3 km depending upon terrain and location of the owls.

Telemetry started in November 2007 and lasted until the first week of August 2008. Intensive work at day and night took place in the first 10 days after captures to find the roosting areas. As soon as owls' roosts were located, each owl's movements were determined one or two days a week, starting with a different owl each afternoon just before sunset to confirm daily roost sites and continuing with the other owls alternatively through the night to determine foraging locations (from 1 to 4 hours/session). Intensive individual owl tracking was conducted for one of the owls in each session, and at least one random location was secured for the other two owls. Each location was considered to be independent from the others and they were analyzed regardless of the time spent at each point. The telemetry schedule after sunset and before sunrise coincided with the high–activity foraging time as described for the little owl (Van Nieuwenhuyse et al., 2008).

The mosaic of arable plots and access roads, at different elevations, prevented us from taking compass bearings from specific vantage points, so we had to move regularly to get bearings on owls. All owl locations were plotted on a map (1:3,400) during each session, generating a different map each day. Locations were frequently confirmed by spontaneous calls of the owls and by direct observations, made possible by the light pollution from the city and from the scattered houses in the area.

When adverse conditions of wind or rain occurred, telemetry sessions were cancelled to avoid poor reception. Locations were recorded with a GPS device (Garmin Etrex, Garmin Ltd. 2000–2003). Whenever possible, for each location, we recorded time, landscape type, owl activity and the structural feature where it was detected (table 1). When appropriate, crop variety, height and density were also recorded.

Transmitters were removed from two of the owls in August and October 2008 and the other three were not retrapped. Monitored pairs bred successfully (2.3 fledglings/pair), two in naturally occurring chambers in carob trees and one most probably in an old concrete irrigation canal.

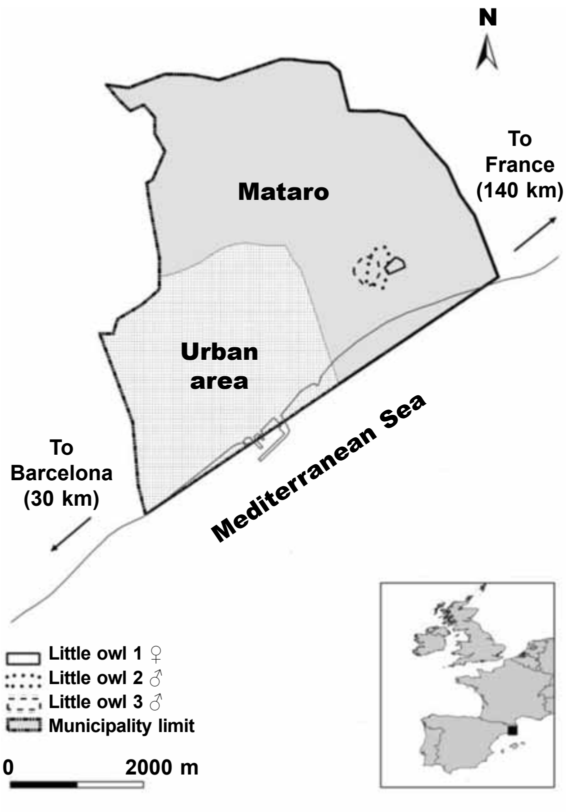

Fig. 1. Location of the study area and minimum convex polygons 100% (MCP100) of the three monitored little owls within the limits of the Mataró municipality.

Fig. 1. Localización del área de estudio y mínimos polígonos convexos 100% (MCP100) de los tres mochuelos europeos monitorizados dentro de los límites del municipio de Mataró.

Table 1. Distribution (%) of the little owls' telemetry locations according to landscape (U. Urban; W. Woodland; C. Crop), activity (F. Foraging; R. Roosting; O. Other; Nk. Not known) and landscape feature (B. Building; P. Pole; G. Ground; T. Tree; Nk. Not known). (Number of locations for each owl in brackets, total = 469).

Tabla 1. Distribución (%) de las localizaciones por telemetría de los mochuelos europeos según las características del paisaje (U. Urbano; W. Bosque; C. Cultivo), la actividad llevada a cabo (F. Alimentación; R. Dormidero; O. Otras; Nk. No conocida) y las características del mismo (B. Edificio; P. Poste; G. Suelo; T. Árbol; Nk. No conocido). (Número de localizaciones para cada mochuelo entre paréntesis, total = 469).

	Landscape			Activity				Landscape feature				
Little owl	U	W	C	F	R	O	Nk	B	P	G	T	Nk
1♀	2(3)	49(70)	49(70)	43(62)	24(35)	16(23)	16(23)	1(1)	3(5)	43(61)	50(72)	3(4)
2♂	10(16)	62(102)	29(48)	41(69)	15(26)	12(21)	30(50)	1(2)	20(33)	15(25)	60(99)	4(7)
3♂	52(83)	16(26)	32(51)	52(83)	12(19)	11(18)	25(40)	33(53)	17(27)	10(16)	33(52)	8(12)

Table 2. Total home range estimates for each owl with minimum convex polygon 100% (MCP100), Kernel 95% (K95) and 50% (K50) (mean ± SD) in hectares. Seasonal variation of little owl home ranges estimated with MCP100 and K95. Study period 16 XI 07–6 VIII 08: W. Winter season (16 XI 07–28 I 08); B. Breeding season (1 III 08–6 VIII 08). (Number of locations for each owl in brackets, total = 469).

Tabla 2. Estimas del área de campeo para cada mochuelo con un mínimo polígono convexo 100% (MCP100) y un estimador de Kernel 95% (K95) y 50% (K50) (media ± DE) en hectáreas. La variación estacional de las áreas vitales de los mochuelos europeos se estimó mediante MCP100 y K95. Período de estudio 16 XI 07–6 VII 08: W. Estación invernal (16 XI 07–28 II 08); B. Estación de cría (1 III 08–6 VIII 08). (El número de localidades para cada mochuelo se incluye entre paréntesis, total = 469).

	MCP 100		K95				
Little owl	W	B	W	B	MCP100	K95	K50
1♀	3.1(81)	3.7(62)	2.8	2.3	4.8	3.2	0.6
2♂	7.5(72)	13.4(94)	7.2	10.9	15.5	10.5	2.7
3♂	9.0(64)	10.9(96)	5.9	8.5	12.5	8.4	2.0
Mean ± SD	6.6 ± 3.1	9.3 ± 5.1	5.28 ± 2.3	7.2 ± 4.4	10.9 ± 5.5	7.4 ± 3.8	1.8 ± 1.1

Home range analysis

Home range sizes were calculated using two estimators: MCP (minimum convex polygon) 100% and fixed Kernel 95% contours. The MCP created a polygon by connecting the most outer locations, (White & Garrot, 1990); MCP has been commonly used in similar studies of the species (summary in Van Nieuwenhuyse et al., 2008; Grzywaczewski, 2009). The Kernel method estimated the distribution of the locations creating contours of probability of the individual's presence (Sissons, 2003; Zuberogoitia et al., 2007; Sunde et al., 2009). Calculations were done using the location analysis application from Ranges 7 v0.67 software (South et al., 2005).

Little owls' basic habitat requirements are known to vary throughout the year to meet different life history needs, and home range dimensions change accordingly, particularly in the breeding season (Finck, 1990). In order to find variation in home range through the nine month monitoring period, which embraced most of the annual activity of the species, two main seasonal periods were defined: winter, November–February, as in Van Nieuwenhuyse et al. (2008), and breeding: March–August which included courtship,nesting, and early fledgling (Fink, 1990; Van Nieuwenhuyse et al., 2008; Grzywaczewski, 2009).

Monitoring of individuals within the same population allowed us to determine their interaction, particularly interesting for a territorial species with a well developed social activity (Hardouin et al., 2006; Zuberogoitia et al., 2007). The overlap application from Ranges 7 v0.67 software (South et al., 2005) was used to quantify shared space using the telemetry locations.

Habitat and activity data analysis

Habitat use was analyzed by means of Chi–square test, comparing the frequencies of telemetry locations in each land cover type with the expected frequencies according to the proportion of habitats within the 100% MCP range of each owl. Land use availability for each MCP was determined from the 2007 regional land cover map (Ibáñez & Burriel, 2008; CREAF, 2009). We calculated the proportions of different land cover types within the owls' home ranges and the distribution of owls' nocturnal locations (15 minutes after sunset to 15 before sunrise) (n = 343) within land cover types using MiraMon GIS (Pons, 2004) and ArcGis (v.9.2) software.

Associations between activity variables and landscape or landscape feature variables were performed by cross tabulation analysis and Chi–square test. For this, we categorized owl locations into a simplified three principal landscape types (assigned from field data) to facilitate further analysis. The available land cover types from the regional map within the study area were distributed into the three categories as follows: crop (other irrigated herbaceous crops, greenhouse, greenhouse & market garden, fields & grassland); forest (shrubland, pine woods, nonbuild urban land, riparian shrubland); urban (housing development, farmland under transformation, greenhouse in a chicken farm). Significant differences between observed and expected frequencies on a given cell were evaluated by means of the standardized residuals. Statistical analyses were conducted with SPSS statistics software 15.0 for Windows (SPSS Institute, Chicago, Illinois, USA).

Results

Home ranges

Two of the five tagged owls were hatch–year age and three were adults (two males and one female). The hatch–year owls were not detected again in the study area despite random telemetry searches to

Table 3. Hectares of each land use type within each MCP range based on land cover maps, number of fixes within each category only at night (15' after sunset or 15' before sunrise) (n = 343), and significance of the Chi–square test results for owl night locations distribution in relation to habitat availability. (+) Land cover type is used more often than expected from its availability; (–) Land cover type is used less than expected; Sf. Surface; F. Fixes. S. Significance; NS. Non–significant difference between observed and expected frequencies; – Land cover not available for that owl; ** $p \leq 0.05$ and *** $p \leq 0.01$.

*Tabla 3. Hectáreas de cada uso del paisaje dentro de cada rango MCP, basándose en mapas de cubierta del suelo, número de fijos dentro de cada categoría sólo durante la noche (15' después de la puesta de sol o 15' antes del alba) (n = 343), y significación de los resultados del test de la ji–cuadrado para las distribuciones de las localizaciones nocturnas de los mochuelos en relación con la disponibilidad del hábitat: (+) El tipo de cubierta se usa con mayor frecuencia de la esperada por su disponibilidad; (–) El tipo de cubierta se usa menos de lo esperado; Sf. Superficie; F. Corrección; S. Significación; NS. Diferencia no significativa entre las frecuencias observadas y esperadas; – Cubierta del suelo no disponible para ese mochuelo; ** p ≤ 0,05 y *** p ≤ 0,01.*

	Little owl 1♀			Little owl 2♂			Little owl 3♂		
Land cover type	Sf	F	S	Sf	F	S	Sf	F	S
Other irrigated herbaceous crops	2.7	68	NS	6.8	40	**(–)	5.6	19	***(–)
Shrubland	0.5	9	NS	1.3	23	***(+)	0.3	7	NS
Pinewood (*Pinus pinea*) (> 20%)	0.5	34	***(+)	2.5	39	***(+)	0.84	0	NS
Housing development and isolated houses	0.2	0	–	2.4	11	NS	2.26	27	NS
Non–built urban land	0.4	2	***(–)	0.02	0	–	0	0	–
Greenhouse market garden agriculture	0.04	0	–	1.7	1	***(–)	2.4	26	NS
Farmland under transformation	0	0	–	0.1	0	–	0	0	–
Riparian shrubland	0	0	–	0.3	2	NS	0.1	2	NS
Fields and grassland	0	0	–	0.1	0	–	0.1	1	NS
Warehouse (Chicken farm)	0	0	–	0.03	0	–	0.8	32	***(+)
Total area / total number of fixes	4.34	113		15.25	116		12.4	114	

try to locate them through the study period (within a maximum radius of 1.1 km from the study area). The three adults stayed on the study area throughout the nine months of monitoring. Telemetry effort totaled 212.5 hours over 81 days, producing 469 locations for the three monitored owls (mean 156.3 ±11.9 SD locations/owl), yielding 5.7 ± 3.8 total locations/session. Monitoring effort was relatively evenly distributed between November 2007 and July 2008, 23.0 ± 5.7 hours/month and was terminated in early August 2008. Average MCP 100% home range was 10.9 ± 5.5 ha and mean home range estimated with Kernel 95% was 7.4 ± 3.8 ha.

Estimates of home range size are dependent, in part, on the number of telemetry points used to determine the home range (Kenward, 2001). As the number of points increased, the estimated home range size reached an asymptote. For the three owls the total numbers of locations over the monitoring period reached the asymptote at around 100 locations, for both MCP and Kernel analysis.

Home ranges were calculated for the winter and the breeding periods using both MCP and Kernel analysis (table 2). For both these periods a minimum of 30 locations was used to define home range (Kenward, 1987). Seasonal home ranges of each individual were nested within each other. While the size of the home ranges varied seasonally, these areas largely overlapped and always included the nest site for all three owls.

The three owls held contiguous territories. Overlap of home ranges was low, accounting for 6 and 18.4% (22.2 ha K 95% and 32.79 ha MCP 100% respectively) of the total home range used by all three owls.

Habitat use

Crop fields (see methods section for land cover typology) accounted for 45–63% of the total available home range of the owls. Each owl had a particular habitat use pattern. Forest areas were visited more than expected by two owls, and urban landscape by the third owl (table 3). Activity was not independent of habitat type (table 4). Woodland was preferred for roosting for two owls, while crops were preferred for foraging by the same owls. The third owl showed no significant relationship between the variables landscape

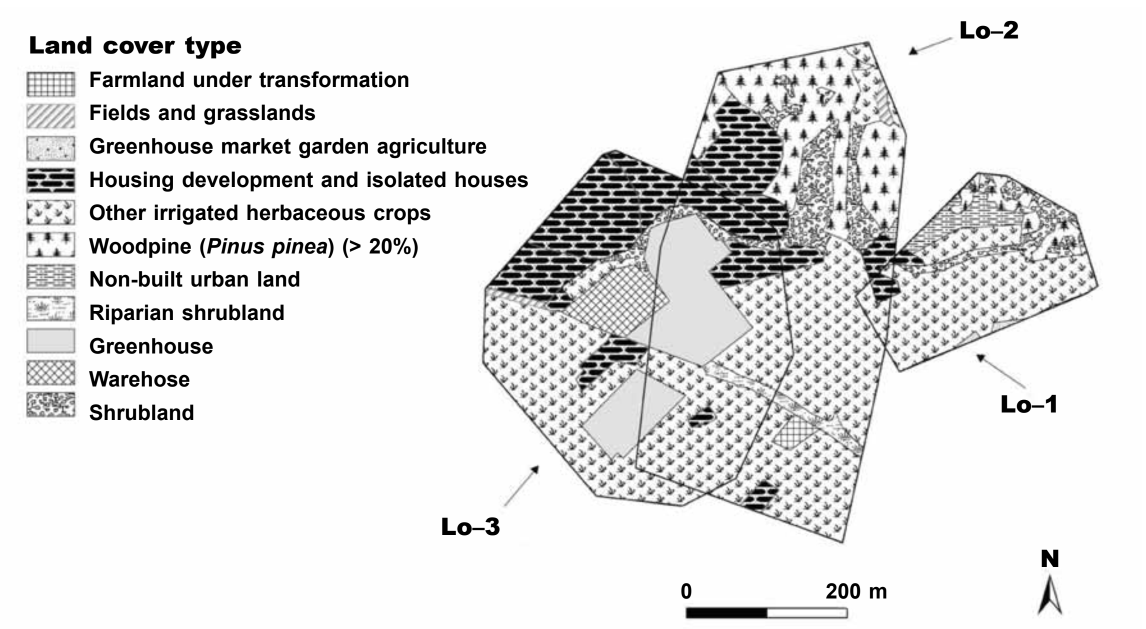

Fig. 2. Home ranges of little owl (Lo) 1, 2 and 3, MCP100 and land cover typology within them.

Fig. 2. Áreas de campeo de los mochuelos europeos (Lo) 1, 2 y 3, MCP100 y usos del suelo dentro de ellas.

and activity, since it nested in the chicken farm and roosted in trees both in and outside the farm.

When owls foraged at night in open ground they avoided dense crop cover; 93% (85–97%) of the foraging locations were in fields with < 60% crop cover and 82% (71–90%) were in fields with crops ≤ 15 cm height. Locations (n = 82) were recorded in up to eight field varieties; bare soil accounted for 61% of fields and parsley accounted for the highest percentage of crop visits (31%), mainly by the female.

Most mature crops in this intensive market garden area were very dense, with little space between crop stems. The proportion of mature crop cover increased up to 83.3% for celery, 96.1% for spinach and 100% for parsley. Within these crop fields the pattern of owl foraging was quite distinct, as will be discussed.

Discussion

Home range analysis and interactions

These little owls were permanent residents of the agricultural area of Cinc Sènies in coastal Catalonia. Mean value of the home ranges of the three owls was smaller than elsewhere (average MCP 100% home range was 10.9 ± 5.5 ha and with Kernel 95% was 7.4 ± 3.7 ha) and showed large variation between them. In four studies in Germany and France annual home ranges were 14.5 ha, 14.6 ha, 27.4 ha and 31 ha (n = 12, n = 19, n = 4, n = 8, respectively; Van Nieuwenhuyse et al. 2008). In northern Spain, annual home range was 15.1 ± 2.4 ha (range 10.3–18.6 ha, n = 9) estimated in MCP 95% (Zuberogoitia et al., 2007). Large variation in home range size was also shown in other studies (Grzywaczewski, 2009; Sunde et al., 2009). Even smaller home ranges have been found elsewhere in northern Europe (Van Nieuwenhuyse et al., 2008). Nonetheless, our study sample size is smaller than that used in other similar approaches (Grzywaczewski, 2009; Sunde et al., 2009; Van Nieuwenhuyse et al., 2008; Zuberogoitia et al., 2007), and must be taken into account when making generalizations (Hebblewhite & Hidon, 2010).

Small home ranges in our study may be due to several factors. Mild Mediterranean weather conditions throughout the year with average temperatures of 15–16ºC and humid summers of almost 30ºC (Andino et al., 2005) may facilitate the foraging of owls compared to areas with snow cover in winter at higher latitudes (Finck, 1990). Additionally, the monitored owls would have had the advantage of good feeding opportunities throughout the year due the mosaic of intensive market–garden agriculture that is continuously cropped.

The home range was larger in the breeding season than in winter, as opposed to findings in other studies (Finck, 1990; Zuberogoitia et al., 2007; Van Nieuwenhuyse et al., 2008). Winter home range is usually the largest because this is the time of year when owls are not related to a specific area, and therefore enjoy greater mobility, in contrast to the breeding season

Table 4. Association between habitat type and activity. Each cell indicates the significance and sign of the association between habitat categories and activities for each owl (Chi–square tests for contingence tables between activity and habitat): (+) The combination occurs more frequently than expected; (–) The combination occurs less frequently than expected; Blanks indicate a non–significant difference between observed and expected frequencies. Results for urban habitat and activity are lacking since no combination showed significance: C&R. Crop and roosting; C&F. Crop and foraging; W&R. Woodland and roosting; W&F. Woodland and foraging; W&O. Woodland and other activity; E(< 5). Percentage of frequencies under 5. (Significance level: ** $p \leq 0.05$; *** $p \leq 0.01$).

Tabla 4. Asociación entre tipo de hábitat y actividad. Cada celda indica la significación y el signo de la asociación entre las categorías de hábitat y las actividades para cada mochuelo (test de la ji–cuadrado para las tablas de contingencia entre actividad y hábitat): (+) La combinación se da con mayor frecuencia de lo esperado; (–) La combinación se da con menor frecuencia de lo esperado. Las celdas en blanco indican que no existe una diferencia significativa entre lo observado y lo esperado. No se representan el hábitat urbano y la actividad urbana, dado que ninguna combinación presentó significación: C&R. Cultivo y descanso; C&F. Cultivo y alimentación; W&R. Bosque y descanso; W&F. Bosque y alimentación; W&O. Bosque y otras actividdes; E(< 5). *Procentaje de frecuencias por debajo de 5. (Nivel de significación:* ** p ≤ *0,05;* *** p ≤ *0,01).*

Little owl	C&R	C&F	W&R	W&F	W&O	E(< 5)
1♀	***(–)	***(+)	***(+)	***(–)		0%
2♂	***(–)	***(+)	***(+)			0%
3♂	**(–)				**(+)	16.7%

when they are linked to their nest site. Accessibility and availability of resources in the study area might have favored this uncommon situation.

Monitoring of three neighboring owls showed the territoriality of this species, since they had little overlap in home range all year round. The overlap of total home ranges of all three individuals was only 18.4% (MCP100) and 6% (K95). Social activity and interaction has been shown for little owl during the winter, especially in February (Zuberogoitia et al., 2007). This was not the case here, since the maximum home range overlap occurred between March and August; 5.4 ha (19%) with MCP 100%. However, overlap always occurred in the feeding grounds and at the boundaries of their territories and away from the core nesting and roosting areas.

The breeding success was within the average of the county (Andino et al., 2005) and those of the same area for the previous year (Framis, 2008). This suggests that transmitters did not adversely affect the normal activity of the owls outfitted with them.

Little owl habitat use

As expected, the owls embraced a high percentage of cropland within their home ranges as well as a large proportion of an adjacent housing development. However, the analysis of the telemetry locations showed a higher than expected use of woodland by two owls, where both had their main roosts and nests. Similarly, the third owl showed a higher than expected use of buildings in the chicken farm where he roosted and nested. In this case, holding a territory in a farm presumably offered shelter and plenty of feeding opportunities from the constant manure management. In contrast, the other two owls were frequently detected foraging in the crops. Both showed positive associations for crops as feeding grounds. While feeding in crops, owls were always on the ground associated with recently harvested and planted portions of fields that were actively irrigated and had 70–100% bare soil. Hedgerows of bushes or trees were extremely scarce between plots. *Arundo donax*, an invasive species of cane (Andreu & Vila, 2009), is the only common vegetation between them, but it did not offer support to perch on. Owls made use of wooden electricity poles as stopping perches or simply as vantage spots for surveillance at the edge of the agricultural area when flying from forest patches into the fields. In other Mediterranean areas of treeless pseudo–steppe, low piles of stones make equivalent foraging perches (Tomé et al., 2011).

Access to ground prey has been negatively correlated with the height of vegetation (Van Nieuwenhuyse et al., 2008; Grzywaczewski, 2009). Parsley, the most visited crop, was not harvested all at once, but was collected at irregular frequencies a few rows each time, allowing plant regrowth and at the same time making new foraging opportunities accessible to the owls. Foraging on the ground after harvesting was common all year round; it might have been based on availability of insects, and especially earthworms (Lumbricidae), common in the little owl diet (Finck, 1990; Hounsome et al., 2004; Van Nieuwenhuyse et al., 2008). Moreover, the sprinkle irrigation system in those fields might favor access to earthworms that come to the surface of very wet fields. Other resources were also occasionally used, such as manure piles, demonstrating the foraging plasticity of the owl to exploit new resources when they become available (Finck, 1990).

Conservation implications

The arable area of Cinc Sènies is the most likely site to find little owls in the landscapes surrounding the city of Mataró (Framis, 2008). The cluster of little owl territories found in surveys and by telemetry suggests that the 263 ha study area gives refuge to a relatively high density of litte owls. With home ranges of 7.4–10.9 ha, as many as 35–24 pairs of little owls could live in this agricultural area. However, regional farmland has been reduced in the past fifty years due to agricultural abandonment, and the growth of continuous forests and the city (Sabater et al., 1997, 2008). New urban plans are waiting to be approved for the remaining open space. A right–of–way for an orbital train and extension of the existing highway will isolate the agricultural area from other open spaces even more. Abundant roads have a negative effect on owl occupancy (Zabala et al., 2006). Thus, the continuity of farmland connected with the remaining open areas to the north of the city and beyond should be promoted to preserve little owl habitat (Framis, 2008). Any landscape restoration would also be a contribution towards the welfare of other farmland birds, undergoing negative trends countrywide (Herrando, 2008).

Results from this telemetry study show the need to protect patches of forest or traditional tree crops within farmland, especially carob trees, which provide natural chambers that the owls use as nesting and roosting sites. Restoration of hedgerows with trees would increase the chance to preserve nest sites in the centre of the plain, which now lacks much tree cover. Currently, some nest sites depend on the old irrigation canals which remain at risk of disappearing. It has also been suggested that the lack of perches is a limiting factor for foraging in open spaces (Van Nieuwenhuyse et al., 2008). Agricultural management should also preserve the mosaic character of the agriculture carried out in the area and promote patches of bare ground as foraging areas. Agricultural activity is not only an essential cultural and economical asset for the city of Mataró but is also a key element in the conservation of little owls (Sabater et al., 2008).

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