Bird Study (2005) **52,** 137–144

Home range and territory of the Sardinian Warbler *Sylvia melanocephala* in Mediterranean shrubland

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Capsule Singing territories were well separated.
Aims To examine the spatial distribution of Sardinian Warbler males during the breeding period in Mediterranean shrubland and, specifically, their territories, home ranges and spatial overlaps.
Methods We studied a 12-ha plot of Mediterranean shrubland in the 1997 to 1999 breeding seasons. Sardinian Warblers were captured using mist-nets, colour-ringed and their territories mapped. In 1999, seven breeding males were radiotracked in order to map home ranges.
Results The Sardinian Warbler had an average of 7.3 breeding pairs/10 ha in the study plot. The mean territory size was 8779 m^2 and the mean home range was 22 321 m^2. A positive relationship was found between the area of the home range and singing territory. Home ranges of males born in 1998 were about half the size of those of the oldest males. Paired males who moved with a female had smaller home ranges than those that were either unpaired or whose mate was incubating. The degree of home range overlap was high with some overlap between neighbouring territories. The estimate of home range area increased by 10% when the information generated by a mapping method was added and the estimated territory area increased by 31% when data generated by radiotracking were added. Transmitters remained attached to birds for an average of 9.63 ± 3.46 days (mean ± se).
Conclusions Singing territories were segregated to a considerable degree. In contrast, the wide overlaps among home ranges was best explained by the presence of food resources that the males exploit at the same time and also by the search for extra-pair copulation in nearby territories. We consider radiotracking in this species to be feasible and valid, with no evidence of negative effects on activity levels, weight or mortality.

Sardinian Warbler *Sylvia melanocephala* is the commonest *Sylvia* warbler in shrubland with a Mediterranean climate with mild winters (Shirihai *et al.* 2001). It uses a wide range of habitats, such as scrublands and maquis, open forests containing bushy undergrowth, as well as agricultural areas and urban gardens (Cody & Walter 1976, Shirihai *et al.* 2001). It can breed in forests or maquis that have recently burned (Pons & Prodon 1996) although these have been found to be lower-quality habitats (Herrando & Brotons 2001). They are a site-tenacious, territorial and monogamous species during the breeding period (Cramp 1985). Although some data exist on the breeding densities and territory size for the species, there is none on home range. Territory is defined as a defended area, dominated and/or exclusive, where the bird drives off his congeneric neighbours or warns them of his territorial status (Maher & Lott 1995); home range is defined as the area traversed by the individual in its normal activities of food gathering, resting, mating and caring for young. The home range of the congeneric *Sylvia atricapilla*, studied by a capture–recapture method, is seven times bigger than its territory (Ferry *et al.* 1981). On the other hand, the information on territorial interspecific overlaps in the genus is divergent (Cody & Walter 1976 cf. Martin & Thibault 1996) and, in some cases, mapping has shown the existence of intraspecific overlaps (Pons 1996).

We aimed to: (a) measure territory and home range size of Sardinian Warbler males; (b) compare mapping and radiotracking methods; (c) investigate the spatial use overlap of neighbouring conspecifics; and (d) evaluate the application of this methodology for territorial passerines in Mediterranean shrubland.

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STUDY AREA

The study was carried out in the Muntanya Gran area on the Montgrí massif (42°05′N; 03°11′E) at an elevation range of 70–120 m, near the coast, in Catalonia (northeast Spain). This region is characterized by a Mediterranean climate with an annual rainfall of 630 mm, maximum average temperature in August (23.3°C) and minimum in January (7.2°C). The study plot comprised 12.25 ha of dense sclerophyllous shrubland dominated by 0.2–2 m shrubs (*Quercus coccifera*, *Rosmarinus officinalis* and *Cistus albidus*), with scattered trees (*Pinus halepensis* and *Olea europaea*) and was divided into a grid of 25 × 25 metres, limited by 1.5-m coloured stakes. The characteristics of the vegetation and pathways and the grid distribution allowed the observer to easily record bird sightings on a detailed map at 1:1250 scale.

MATERIAL AND METHODS

Mist-net capture and mapping method

Sardinian Warblers were captured, measured and individually marked with colour rings and sexed and aged according to Svensson (1992) and classified as either yearlings (EURING age 5) or adults (EURING age 6). A total of 30 days was spent mapping territories, distributed in 9-, 10- and 11-day periods in 1997, 1998 and 1999 respectively. The plot area chosen (12.25 ha) is within the range recommended in mapping studies in dense vegetation (Bibby *et al.* 1992). The method involved following all the paths of the plot and recording the location and behaviour of all territorial males on the map. Special emphasis was put on obtaining simultaneous songs of neighbours (definitely different birds) and to observing individual marks, especially visible when the males were singing from the top of shrubs.

Transmitter attachment

During the 1999 breeding period, nine Sardinian Warbler males were fitted with a miniature transmitter (weight 0.9–1.0 g, 1.2 cm long × 0.7 cm thick × 0.8 cm wide, battery life 29–30 days, with an 8-cm linear antenna; Wildlife Materials Inc., Carbondale) (Fig. 1). Only males were tagged because (a) the small number of individuals that could be followed made it necessary to minimize variability due to sex or age and (b) the reproductive role and territorial attachment of adult males avoids the problem of inactivity during long periods of time (incubation in females).

Figure 1. Transmitter attached to Sardinian Warbler male 28.

The birds were checked for good body condition by looking at feather condition, pectoral musculature and weight (ICO 2003). The transmitters were then attached to the back, with the antenna pointing towards the tail, to avoid interfering with flying. The interscapular feathers on a 10 × 10 mm central area between the wings were shortened and the transmitter glued to the shafts using cyanoacrylate glue (Kenward 1987). Before the transmitter was attached, the shafts were cleaned with acetone to improve adhesion. Nine males, mostly previously colour-ringed, were equipped with transmitters after discarding one male because of its poor condition. In one case, however, the transmitter stayed attached for just three days, which meant

insufficient locations were obtained to delimit the bird's home range. Another bird disappeared after one day and so data from seven birds were analysed.

Bird radiotracking and data analysis

After releasing, each bird was observed to check for normal behaviour during the first two hours. The tracking did not begin until the day after the capture. A TRX-48S receiver was used for tracking with directional Yagi antenna with three elements (Wildlife Materials Inc., Carbondale). The individuals were placed on the map, mainly by triangulation (Johnstone 1992, Hill & Cresswell 1997), and the time was recorded.

Due to the high shrub cover of the plot and to the mobile behaviour of birds, it was not possible to record locations at fixed intervals. Nonetheless, the frequency of the locations was relatively constant (mean frequency = 2.54 minutes ± 2.06 sd). Signal acceleration on the receiver allowed us to detect displacements and the location was often facilitated by visual contact with the tracked bird. In addition, radiotelemetry made it easier to locate nest sites. The location of the individuals by radiotracking was carried out for 20 days in the plot, making a total of 10 065 minutes on seven marked individuals (Table 1). The average time of tracking was 1437.9 minutes per individual (se = ±521.2 minutes, range = 570–1935 minutes/individual, n = 7). The approximate home range of each bird was determined by the standard estimator MCP (minimum convex polygon) by connecting the outer points of the mapped locations (White & Garrott 1990).

RESULTS

Territories and home range characteristics

Based exclusively on the mapping, the Sardinian Warbler had an average of 7.35 breeding pairs/10 ha in the plot (range = 7.14–7.55 territories/10 ha, n = 3 years) (Fig. 2). There were no significant differences in territory size in the three years studied (one-factor ANOVA with logarithmic transformation; $F_{2,31} = 0.25$, $P = 0.78$) (Table 2). The spatial distribution of the singing territories, however, did change and showed an important turnover of marked males from one year to the next (Fig. 2). Adult males (two years old or older) had bigger territories (mean ± se = 9959.0 ± 3379.3 m^2) than the males that were born in 1998 (mean ± s.e = 7570.9 ± 2382.2 m^2), although this difference was nearly significant ($t = –1.68$, $P = 0.11$).

The surface and MCP home range areas are shown in Table 3 & Fig. 3. There was no relation between the home range area of males and the tracked minutes dedicated to each one ($r = 0.57$, $P = 0.18$), nor was there between home range area and the number of locations ($r = –0.18$, $P = 0.70$). Three males born in 1998 had mean home ranges of 15 156 m^2 (range = 11 562–18 593 m^2): about half that of the oldest four, whose mean home range was 27 695 m^2 (range = 13 594–39 844 m^2), although without significant differences ($t = 1.61$, $P = 0.19$).

Due to low sample size, however, the effects of age on home range size cannot be excluded. The maximum length of the home range, evaluated after its perimeter, was 245.9 ± 105.1 m (mean ± se) but showed a wide variation (175.0 to 467.9 m, n = 7). The two nests found (of males M30 and M28) were 268 and 182 m away respectively from the most distant point of the home range, and 32 and 36 m from the near perimeter of the home range.

The five males that moved with a female had smaller home ranges (mean ± se = 14 968 ± 2618 m^2) than those that were unpaired or had a female incubating (mean ± se = 40 703 ± 1215 m^2) (Student's t with logarithmic transformation, $t = 7.61$, $P = 0.001$) (Table 1). On the other hand, a quadratic relation existed between the areas of the home range and of the singing

Table 1. Age, breeding phase, physical condition and duration of radiotracking for the birds monitored in 1999. Physical condition is expressed as fate (range: 0–5) and muscle (range: 0–3) (Svensson 1992).

Bird code	Birth date	Weight (g)	Fate/Muscle	Breeding phase	Tracking duration (min)
J192	98	12.1	0/2	Male and female paired; flying in home range. First brood finished	1740
M12	96	11.8	0/2	Male and female paired; flying in home range. First brood finished	1875
M17	< 96	12.2	0/2	Unpaired non-territorial male	1935
M28	< 98	12.4	0/2	Male and female making nest and beginning the brood	1170
M29	98	12.3	0/2	Male and female paired; flying in home range. First brood finished	570
M30	< 98	11.4	0/2	Paired male with female incubating the clutch	1755
M32	98	12.2	0/2	Male and female feeding fledging young	1020

J, bird non-sexed on day of ringing; M, male sexed on day of ringing.

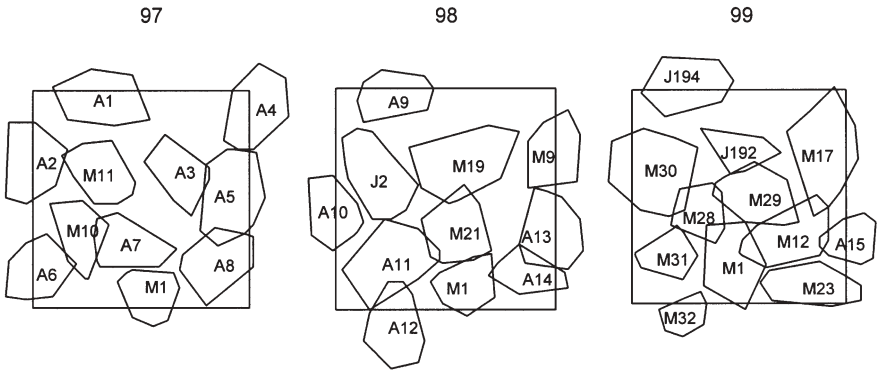

Figure 2. Breeding territories of Sardinian Warbler males in 1997, 1998 and 1999. The square represents the 12.25-ha study plot.

territory (r^2 = 0.68, F = 10.43, P = 0.02, n = 7), mainly due to two out of the seven points.

Home range and territory overlaps

During the breeding period studied, the degree of home range overlap, calculated from the overlap of their respective MCPs, was high (Fig. 3), ranging from one to four males in the same area at the same time. Although not all males were tracked in the plot, we found that in the area of the plot in which a home range existed, 46.7% of it contained no overlapping, 28.5% contained overlapping with one other male, 19.4% contained overlapping with two males and 5.4% with three males. The same area of territory was occupied by no more than two males (Fig. 2). In particular 2.9%, 3.5% and 5.9% of the study plot was shared by two birds in the years 1997, 1998 and 1999 respectively. A large area of the plot was not occupied by any territory (40.8% in 1997, 30.4% in 1998 and 32.5% in 1999) and 11.5% of the plot was never defended by any male in the three years of this study.

Radiotracking versus mapping methods

In 1999, all locations (both with and without song) of colour-ringed males derived from the mapping method were added to the home range polygon, derived from radiotracking, to analyse the effect of additional locations on home range size. As a result, the estimated home range area increased by 10% (Table 3). Similarly, in 1999, the song locations of radiotracked males were added to the standard territory polygon, which increased by 31% (Table 3 & Fig. 4). Nonetheless, the size of the defended territories did not change when we used the two methodologies independently (Student's t with logarithmic transformation, t = –0.23, P = 0.82).

Table 2. Territory surface area of males during 1997–99. The age of the males is represented by the year of birth.

1997	Birth year	Territory area (m^2)	1998	Birth year	Territory area (m^2)	1999	Birth year	Territory area (m^2)
A1	–	10336	A9	–	7177	A15	–	5417
A2	–	9422	A10	–	7124	J192	98	5107
A3	–	7083	A11	–	12587	J194	98	10148
A4	–	9886	A12	–	9241	M1	96	10181
A5	–	11922	A13	–	9308	M12	< 98	10786
A6	–	8031	A14	–	5900	M17	< 98	14335
A7	–	7896	J2	97	10423	M23	< 98	8548
A8	–	9415	M1	96	6633	M28	98	6210
M1	96	6673	M9	< 97	7668	M29	98	9442
M10	96	6902	M19	< 97	13232	M30	< 98	15121
M11	< 96	7937	M21	97	9456	M31	< 98	5148
						M32	98	3777
Mean		8682			8977			8697
se		±1647			±2387			±3859

A, Males that were not captured and marked (it would be improbable to overlook a previously-marked male in one breeding season); J, bird non-sexed on day of ringing; M, male sexed on day of ringing.

Table 3. Surface area for radiotracked males using the different methods.

	Home range (m^2)			Territory (m^2)		
Bird code	From radiotracking	Increase from mapping	Total both methods	From mapping	Increase from radiotracking	Total both methods
J192	18 593	661	19 254	5 108	–	–
M12	13 594	1215	14 809	10 786	–	–
M17	41 562	4046	45 608	14 335	–	–
M28	15 781	2965	18 746	6 210	1597	7 807
M29	15 312	5732	21 044	9 442	3534	12 976
M30	39 844	1212	41 056	15 121	9014	24 135
M32	11 562	179	11 741	3 777	2284	6 061
Mean	22 321	2287	24 608	8 401	4107	12 745
se	±12 747	±2034	±13 221	±4 987	±3368	±8 141

J, bird non-sexed on day of ringing; M, male sexed on day of ringing.

Efficiency and effects of transmitter attachment

It appeared to us that the birds adapted rapidly to the transmitter. The transmitters stayed attached to the birds for an average of 9.63 ± 3.46 days (mean ± se, range = 3–15 days) although signal emissions lasted up to 32 days. On release, radiotracked birds immediately flew strongly and behaved apparently normally. In particular, the warblers M28 and M30 continued to actively take part in nest making and incubation shifts, respectively. The transmitters did not appear to hamper the birds or affect them, and there was no significant increase or decrease in body mass of radiotagged birds when compared to initial capture. The male M30 was recaptured after 7 days of carrying the transmitter and was 0.2 g heavier than before. On the other hand the male J192 was captured 57 days after the installation of the transmitter, which it had carried for 11 days. It did not present skin anomalies and the scapular feathers had re-grown completely. These qualitative observations suggest that the transmitters had few negative effects on territorial behaviour and survival. The loss of the signal from one male (M31), no longer detected the day after marking, may suggest depredation shortly after its release.

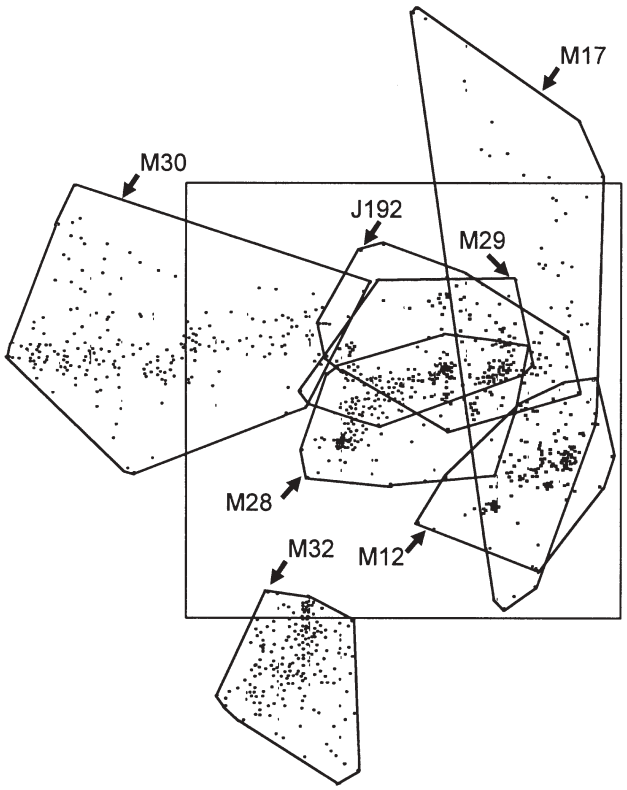

Figure 3. Minimum convex polygon home-range areas (n = 1047 locations) for seven Sardinian Warbler males during the 1999 breeding season. ●, Locations of males inside home ranges: M30, 216 locations; M29, 51; J192, 183; M28, 158; M32, 217; M12, 148; M17, 64. J, bird non-sexed on day of ringing; M, male sexed on day of ringing. The square represents the 12.25-ha study plot.

DISCUSSION

The density (7.35 breeding pairs/10 ha) and territory area (mean of 0.88 ha) of the Sardinian Warbler have been measured for three breeding seasons in a dry garrigue. These figures are similar to those from other studies carried out in habitats favourable for this species, in the Mediterranean basin (7.6–10 pairs/10 ha and 1 ha, respectively; Pons 1996, Shirihai *et al.* 2001). It is clear that recording of simultaneous song by neighbouring conspecifics and in the location of the nests (see Fuller & Marchant 1985) has improved our mapping. In addition, the increase in the sampling effort, by using the singing locations recorded during

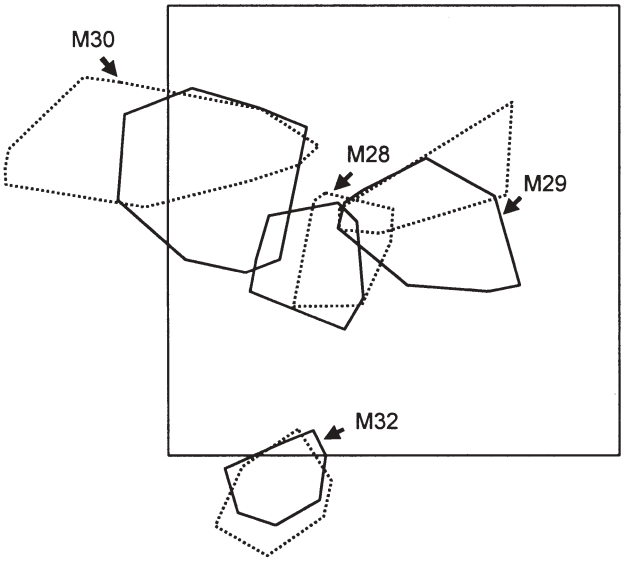

Figure 4. Example of territory distribution studied by mapping (—) and radiotracking methods (•••) of four males during breeding season. The square represents the 12.25-ha study plot.

radiotracking, has increased measured territory size to 1.27 ha on average.

These 'inside territories' (Hanski & Haila 1988) are similar to the ones described for other Silviidae, such as Blackcap *Sylvia atricapilla* (1.12 ha; Ferry *et al*. 1981), Dartford Warbler *Sylvia undata*,(1 ha; Catchpole & Phillips 1992, Pons 1996, Bas 2001), Marmora's Warbler *Sylvia sarda* (<1 ha; Lovaty 1992) or Chiffchaff *Phylloscopus collybita* (0.8 ha, Ferry *et al*. 1981), and those of other passerines of similar size, such as Great Tit *Parus major* (1.4 ha; East & Hofer 1985). A clear segregation of territories exists between nearby males, although some overlap slightly. Territorial exclusion is typical of non-colonial and semi-colonial species, in areas where resource defence is very important. The overlaps are, on the other hand, large when it involves the territories of another congeneric species in the plot (Dartford Warbler; Bas 2001).

This supports the niche segregation hypothesis of Martin & Thibault (1996) for Mediterranean *Sylvia* warblers, but is in contrast to the interspecific territoriality suggested by Cody & Walter (1976). The low interannual site tenacity of ringed males is either due to mortality or to territory shifts out of the study plot, and, despite the low sample, approximates to the return rates reported for the species in Catalonia (around 12% in ringing constant effort sites, ICO 2003).

Our study shows that the territory size is 2.6-times smaller than the home range; the latter includes an external area that is only partially, if at all, defended ('outside singing territories'; Hanski & Haila, 1988). Such areas might correspond to a less favourable habitat configuration or areas containing fewer resources. Territory overlaps involved only two males, whereas home range overlaps included up to four males.

The reason for such grouping in specific areas might be that there are resources in abundance at these specific places, in a season in which resources overall might be scarce. In particular, the presence of isolated plants with fleshy fruits during the breeding period, such as the Evergreen Buckthorn *Rhamnus alaternus* (Bas 2001), may lead to movements of greater-than-usual distance and thus increase home range size and overlaps. An alternative explanation is based on the fact that males accompanied by females have smaller home ranges than those that fly alone. The unpaired males are thought to visit territories of nearby conspecifics to seek extra-pair copulations (Trivers 1972).

In our plot, the decrease in the parental tasks of the males can be associated with the increase of extra-territorial locations in periods of preincubation of other females in nearby territories (Trivers 1985, Hanski 1992). Being more frequent in dense colonies (Moller 1987), extra-pair copulations are also common in territorial and monogamous species (Houtman 1992). The observation of bigger home ranges in adult males than in yearling males is in accordance with the hypothesis that factors such as promiscuity or foraging skill increase with the age of the male (Brooker & Rowley 1995). The most experienced males, with bigger territory and home range, will, however, use up more energy, because flights will be longer between the nest and the most peripheral points of the home range or territory.

Radiotracking allows the movements of free-ranging animals to be quantified in a manner unavailable by any other method. Although it is assumed that radiotracking will obtain results that do not differ from unmarked and untracked individuals (White & Garrot 1990), it is necessary to be prudent when using the different techniques since they may influence animal behaviour (Kenward 1987, Rappole & Tipton 1990). Birds, in particular, need transmitters of low weight, preferably not exceeding 5% of the animal's own weight (Cochran 1980). For this reason, radiotracking has only rarely been applied to small European birds such as tits, Chaffinch, Skylark, Swallow, Sand Martin, Pied Flycatcher, Robin and Bluethoat (cf. for example Hanski & Haila 1988, Godfrey & Bryant 2000).

However, passerines can, in general, carry higher proportions of weight than bigger birds and transmitters that are slightly heavier than 5% of the bird's weight are considered to be acceptable (Caccamise & Hedin 1985). The bodily characteristics of the Sardinian Warbler allow transmitters of between 0.9–1.0 g (7.2–7.8% body weight) to be attached, without seeming to provoke any important negative effects. During tracking, the birds showed clearly territorial behaviour, singing or calling on a plant or in full flight. With proportions of transmitter weight to body weight (% bw) similar to those in our study, studies of other passerines have not detected negative effects on levels of activity, breeding success, weight loss or mortality: Swallow (6% bw; Brigham 1989), Sand Martin (4% bw; Alves & Johnstone 1994) and Robin (11% bw; Johnstone 1992).

The attachment method, using cyanoacrylate glue, has also been employed with other passerines (Brigham 1989, Naef-Daenzer 1994), and did not produce any negative impact on the Sardinian Warbler. Furthermore, this attachment system is better adapted for short-period studies and for species that are difficult to recapture. In our case, the retention time is short (3–15 days) and transmitters have never stayed attached for more than 2 months (Brigham 1989, Rappole & Tipton 1990). There are alternatives: transmitters attached to tail feathers may remain attached for longer periods, right up to the post-breeding moult (Johnstone 1992) using harnesses of indefinite duration; such harnesses, however, can alter behaviour and obstruct plumage cleaning (Rappole & Tipton 1990).

With regard to the analysis of the radiotracking data, the non-relationship between the number of locations and the home range area they occupy seems to indicate that there has been a sufficient number of locations to evaluate home ranges (Kenward 1992). For precision, a correct triangulation is important (Nams 1989). In our case, the birds could usually be approached and were often seen on bushes, and the location error was minimized (Hanski & Haila 1988, Hanski 1992). Using antennae similar to those used in this study, minor errors have been detected in locations by triangulation (Johnstone 1992). Because of the difficulty the observer has in moving out of pathways, the standard estimator MCP method for estimating home range was necessary, since it was not possible to carry out tracking at fixed and constant times.

In practice, however, the frequency of locations was quite constant. The territory size changed considerably on adding the singing locations using the radiotracking method (31% increase). However, it has to be remembered that the spatial shift of territories can arise partially from mapping and radiotracking the same individuals on different days (the difference in the mean date of monitoring between the two methods was 26 days). The small increase in home range area (10%) when adding the locations of the mapping method, more extended in time, indicates that the number of locations and the duration of tracking were sufficient.

The use of radiotracking for the Sardinian Warbler is a novel approach, in the face of the scarcity of spatial studies for Silviidae and other closely related groups, such as small Turdidae. The relative success obtained in radiotracking Sardinian Warbler breeding adults, in terms of the attachment method, the size of the transmitters and the methodology of tracking, suggests that the technique could be applied to other territorial passerines of similar size, since it has been shown to be an interesting tool for investigating small-scale patterns in such birds.

ACKNOWLEDGEMENTS

We thank L. Zamora and D. Saavedra for advice and comments related to transmitters and tracking methods and to J.M. Bas Senior for the manufacture of some useful radiotracking accessories. We would also like to thank S. Herrando and G. Gargallo for critical reading and comments on the draft. This work was partially financed by project DGES PB96-1164.

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(MS received 6 January 2004; revised MS accepted 27 April 2004)