

Phenology and body mass dynamics of the Garden Warbler *Sylvia borin* on the island of Cabrera (Balearic Islands) and in the Aiguamolls de l'Empordà (NE Iberian Peninsula) during spring migration

Carles Barriocanal & David Robson

As part of the Progetto Piccole Isole the phenology and body-mass dynamics of the Garden Warbler *Sylvia borin* were studied between 1993 and 2001 on the island of Cabrera and in the Aiguamolls de l'Empordà. The migratory peak of the species occurred during the first week of May in the Aiguamolls and in the middle of May on the island of Cabrera. A seasonal increase in wing length was observed in both of these stopover sites. Depending on the year, passage through Cabrera occurred between one to eight days later than on the Iberian mainland. The lack of recaptures occurring more than one day after initial capture suggests that both localities are only used as brief stopover sites. The median number of days that birds stayed in the capture sites was one day. Body mass did not increase during stopovers, a finding that suggests that birds do not refuel in these locations. As reported in other studies, the Mediterranean islands are apparently not vital energy accumulation stopover points for birds such as the Garden Warbler migrating across the Mediterranean. The phenological and biometrical differences found in this study could correspond to some form of differential populational migration in the western Mediterranean.

Key words: Garden Warbler, *Sylvia borin*, spring migration, Mediterranean Sea, islands

Carles Barriocanal*, *Grup de Recerca en Medi Ambient i Tecnologies de la Informació Geogràfica. Universitat de Girona. Plaça Ferrater Mora, 1. 17071 Girona, Spain.*

David Robson, *c/Provença 139, 5^a 1^a, 08036 Barcelona, Spain.*

*Corresponding author: barriocanal@k.udg.es

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During trans-Saharan spring migration, passerines face two important ecological barriers prior to reaching their European destinations: after first crossing the Sahara Desert, birds must then cross the Mediterranean Sea, a second and even tougher ecological barrier. Strategies in passerine migration include direct crossings of the Mediterranean and continental migration through the Iberian or Italian peninsulas. In some species such as the Wood Warbler *Phylloscopus sibilatrix* a direct crossing of the sea is the preferred alternative (Spina & Pilastro 1999). The strategies used by spring migrants

over the western Mediterranean have been studied using the data provided by long-term ringing projects such as the Progetto Piccole Isole (PPI) (Spina *et al.* 1993). PPI is a large-scale programme that uses standardised mist-netting methodology at several stopover sites located on islands and the mainland in the western and central Mediterranean. Birds migrating over the Mediterranean rest on islands wherever a brief stopover is possible, although the decision to rest or not cannot be explained simply by critical physical conditions (Spina & Pilastro 1999). In order to improve knowledge regarding the

decision to land and stopover dynamics, further comparisons with data obtained at coastal locations are needed.

The Garden Warbler *Sylvia borin* is a very widespread long-distance migratory species (Cramp 1992) whose migration has been studied using the analysis of factors such as body mass and fat dynamics at stopovers (Bairlein 1985, 1987a), migratory directions (Gwinner & Wiltschko 1978), changes in organ size during migratory flights (see Biebach & Bauchinger 2003 and references therein) and phenology and body-mass changes in sub-Saharan West Africa (Ottosson *et al.* 2005). The species' passage across the western Mediterranean has been studied in detail during autumn migration (Bairlein 1987b), but less so in spring (Grattarola *et al.* 1999).

In this paper we analyse the stopover ecology of Garden Warblers on the island of Cabrera in the Balearic Islands using data from the PPI. Our aim was to determine the strategies used by migrants crossing the ecological barrier of the Mediterranean and to improve our knowledge of the role islands play as stopover sites in spring. Data from birds captured in the Aiguamolls de l'Empordà (a mainland coastal site) during the same project provided a comparison with the strategies used by birds crossing the sea.

Study area and methodology

Garden Warblers were captured during spring in the western Mediterranean as part of the PPI (Spina *et al.* 1993). Cabrera (39° 08' N, 2° 56' E), which was selected as an island station for studying the stopover ecology of the species, is located 10 km south of the large island of Mallorca (Balearic Islands) (Figure 1) and has Mediterranean open-shrub vegetation and a single small pinewood. The coastal station selected was Aiguamolls de l'Empordà, a natural park located in the north-east Iberian Peninsula (42° 00' N, 3° 00' E) (Figure 1), that consists largely of a marshy area dominated by common reeds *Phragmites australis*.

We analysed ringing data from the years 1993-2001. Although for some years ringing was carried out for more than one month, we restricted our analysis to the period 16 April to 15 May in order to ensure that results were com-



Figure 1. Location of the island of Cabrera and the Aiguamolls de l'Empordà within the western Mediterranean.

Localització de l'illa de Cabrera i els aiguamolls de l'Empordà en el context de l'oest de la Mediterrània.

parable between years. In order to assess the mean arrival date of Garden Warblers and to compare both localities we used the day of capture transformed into Julian day numbers. For each bird we recorded wing length and body mass following the standardised methodology of the PPI scheme (Spina *et al.* 2003). Body mass increased with wing length and was corrected using a linear regression, with wing length as the independent variable (body mass = $-3.021 + 0.248 * \text{wing length}$, $n = 1977$, $P < 0.0001$) and the residuals of this regression as a size-corrected estimate of body mass. Annual variation in the mean date of capture at each locality was analysed using a one-way ANOVA. A comparative analysis between island and the mainland for differences in mean arrival day, wing length and body mass, for both captured and recaptured birds, with the effect of year and location taken into account, were tested using a two-way ANOVA. Tukey's HSD test was used for an *a posteriori* comparison of means when the ANOVA was significant ($P < 0.05$). A linear regression was performed to study wing-length variation over time for each year by grouping data into five-day blocks (or pentades) (Berthold

1973). Data from recaptures provides information about changes in body mass in relation to stopover length. We only considered recaptures occurring more than one day after initial capture for these analyses. The number of days between the first and final capture was used as an estimate of the length of the stopover. Due to the highly skewed distribution of this variable median instead of mean values are given. All variables were normally distributed as per the Wilk-Shapiro test. Statistical analyses were carried out with the SPSS 11.0 software package.

Results

General aspects

During the nine years, a total of 1,938 Garden Warblers were captured on the island of Cabrera and 364 in the Aiguamolls de l'Empordà. The number of captures ranged between 364 individuals in 1996 and 102 in 2000 on Cabrera and 97 in 1996 and 9 in 2001 in the Aiguamolls de l'Empordà.

Phenology and arrival time

In the Aiguamolls de l'Empordà passage increases during the 24th pentade (25-30 April), with a peak during the 25th pentade (1-5 May) (Figure 2). On Cabrera passage increases during the 26th pentade (6-10 May), with an im-

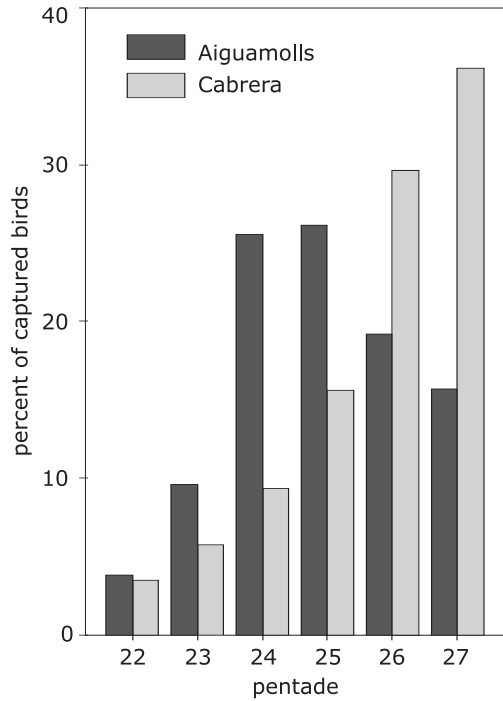


Figure 2. Percentage of trapped Garden Warbler by pentades on Cabrera and in the Aiguamolls de l'Empordà during the nine study years (1993-2001). *Percentatge de captures de Tallarol gros per pèntades a Cabrera i als aiguamolls de l'Empordà durant els nou anys d'estudi (1993-2001).*

portant peak during the 27th pentade (11-15 May) (Figure 2). The mean day of capture var-

Table 1. Data from captured migrating Garden Warblers in spring on Cabrera and in the Aiguamolls de l'Empordà (mean, SD, n-values, F values and differences are shown). Dates according to the Julian calendar. *Data mitjana de captura dels tallarols grossos durant la migració primaveral a Cabrera i als Aiguamolls de l'Empordà (es mostra la mitjana, la desviació estàndard, el nombre d'individus, el valor de F i les diferències). Les dates s'expressen en dies julians.*

| Year | Mean Trapping Date (Julian Days) | | | | F | P |
|------|----------------------------------|-----|---------------|----|-------|--------|
| | Cabrera | N | Aiguamolls | n | | |
| 1993 | 126.78 (6.24) | 369 | 123.60 (5.51) | 30 | 7.32 | 0.007 |
| 1994 | 125.22 (7.33) | 323 | 121.34 (6.51) | 41 | 10.40 | 0.001 |
| 1995 | 126.29 (7.25) | 163 | 130.14 (5.41) | 14 | 3.76 | 0.05 |
| 1996 | 130.68 (4.94) | 378 | 124.77 (6.36) | 97 | 97.19 | <0.001 |
| 1997 | 125.86 (8.40) | 153 | 125.44 (7.20) | 18 | 0.04 | 0.84 |
| 1998 | 128.21 (7.29) | 173 | 120.24 (5.77) | 37 | 38.85 | <0.001 |
| 1999 | 123.78 (5.02) | 130 | 121.68 (6.80) | 78 | 6.48 | 0.01 |
| 2000 | 124.49 (7.83) | 102 | 123.08 (7.23) | 40 | 0.98 | 0.32 |
| 2001 | 125.42 (6.22) | 147 | 121.11 (5.60) | 9 | 4.11 | 0.04 |

ied annually in both localities (one-way ANOVA, Aiguamolls: $F_{8,363} = 5.08$, $P < 0.0001$; Cabrera: $F_{8,1937} = 25.79$, $P < 0.0001$). We found significant differences between the two localities for the mean arrival date (two-way ANOVA: locality, $F_{1,2301} = 34.94$, $P < 0.0001$; year, $F_{8,2301} = 13.35$, $P < 0.0001$; interaction, $F_{8,2301} = 6.12$, $P < 0.0001$). For all the studied years (except 1997 and 2000), the mean arrival date was from one to eight days earlier in the Aiguamolls de l'Empordà than on Cabrera (Table 1).

Wing length and passage data

The mean wing length of the Garden Warblers captured on Cabrera and in the Aiguamolls de l'Empordà differs significantly (two-way ANOVA: locality, $F_{1,2023} = 13.56$, $P < 0.0001$; year, $F_{8,2023} = 3.54$, $P < 0.001$; interaction, $F_{8,2023} = 2.12$, $P = 0.03$). In all the studied years (except for 1994), Garden Warblers had shorter wings on Cabrera (Table 2). At both sites, birds captured during the first pentades of the study period had shorter wings than those captured later in the season (Aiguamolls, $R^2 = 0.80$, ANOVA $F = 16.348$, $P = 0.02$, $n = 6$; Cabrera, $R^2 = 0.87$, ANOVA $F = 26.670$, $P = 0.07$, $n = 6$) (Figure 3).

Stopover period and body mass dynamics

Body mass (corrected for body size) at first capture of the Garden Warblers on Cabrera and in the Aiguamolls de l'Empordà ranged from 14.09

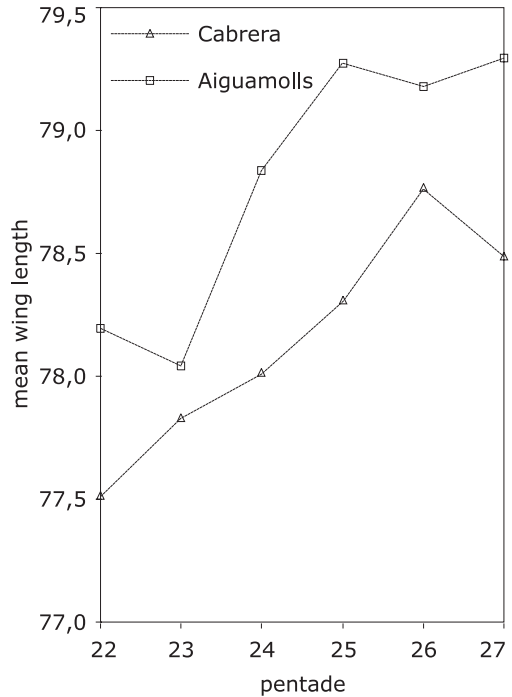


Figure 3. Mean wing length by pentades of spring migrating Garden Warblers on Cabrera and in the Aiguamolls de l'Empordà (pentade 22 corresponds to 16-20 April).

Mitjana de la longitud de l'ala per pèntades dels tallarols grossos en migració primaveral a Cabrera i als aiguamolls de l'Empordà (la pèntada 22 correspon al període 16-20 d'abril).

to 18.18 g during the study period. An average body mass of 16.42 g (SD 0.56) was recorded on

Table 2. Wing length of spring migrating Garden Warblers on Cabrera and in the Aiguamolls de l'Empordà (mean, SD, and n-values are shown).

Longitud de l'ala dels tallarols grossos en migració primaveral a Cabrera i als aiguamolls de l'Empordà (es mostra la mitjana, la desviació estàndard, i el nombre d'individus).

| Year | Wing length (mm.) | | | |
|------|-------------------|-----|--------------|----|
| | Cabrera | n | Aiguamolls | n |
| 1993 | 77.91 (2.09) | 369 | 78.48 (3.20) | 30 |
| 1994 | 78.67 (2.47) | 318 | 77.98 (2.29) | 41 |
| 1995 | 78.71 (2.60) | 161 | 79.25 (1.74) | 14 |
| 1996 | 78.39 (1.99) | 176 | 79.12 (2.24) | 69 |
| 1997 | 78.97 (2.15) | 134 | 79.44 (2.02) | 18 |
| 1998 | 78.40 (2.09) | 172 | 78.61 (2.32) | 36 |
| 1999 | 78.63 (2.22) | 130 | 79.18 (2.25) | 60 |
| 2000 | 78.97 (2.60) | 100 | 79.91 (1.83) | 40 |
| 2001 | 77.86 (1.87) | 147 | 80.00 (1.92) | 9 |

Cabrera and an average of 16.57 g (SD 0.57) in the Aiguamolls de l'Empordà (Table 3). Significant differences were found between localities and years (two-way ANOVA: locality $F_{1,1976} = 13.88$, $P < 0.0001$, year $F_{8,1976} = 3.37$, $P = 0.001$; interaction $F_{8,1976} = 2.18$, $P = 0.03$). On Cabrera only 4.12% of birds were recaptured more than one day after the initial capture, suggesting that most birds leave the island on the same day as they arrive; likewise, in the Aiguamolls de l'Empordà only 6.4% of birds were recaptured more than one day after initial capture.

Birds stopping on Cabrera stayed from 1 to 7 days, with a median stay of 1 day. Their mean fuel deposition varied from 5.80 to -5.2 g day^{-1} (average $\pm \text{SE} = -0.38 \pm 0.10 \text{ g day}^{-1}$; $t = -3.02$, $df = 79$, $P < 0.005$). Garden Warblers in the Aiguamolls de l'Empordà stayed from 1 to 8 days (median 1 day). Their mean fuel deposition varied from 0.90 to -1.30 g day^{-1} ($0.02 \pm 0.14 \text{ g day}^{-1}$; $t = 0.15$, $df = 19$, $P = 0.89$). We found no differences in body mass between Garden Warblers recaptured and not recaptured more than one

day after initial capture (two-way ANOVA for body mass corrected for wing length: recaptured $F_{1,1976} = 0.16$, $P = 0.69$; locality $F_{1,1976} = 5.76$, $P = 0.02$; interaction $F_{1,1976} = 0.20$, $P = 0.65$).

Discussion

In spring Garden Warbler passage over the western Mediterranean seems to involve a 'direct route' strategy of crossing the desert and sea on a wide front (Grattarola *et al.* 1999). Studies on stopover sites located *en route* provides us with detailed information on the strategies used by migrants. Migration begins in late March, although many birds are still in winter territories during April. Birds reach Britain and Ireland in May (Flegg 2004). The phenology of Garden Warbler over the western Mediterranean shows a peak in the middle of May according to the general pattern for the species, although in the Aiguamolls de l'Empordà this peak occurs before 1 May.

Table 3. Mean wing length, initial mass, change in body mass and rate of change of body mass in migrating Garden Warblers in spring on Cabrera and in the Aiguamolls de l'Empordà
Mitjana de la longitud de l'ala, pes inicial, canvi de pes i proporció de canvi de la massa corporal dels tallarols grossos durant la migració primaveral a Cabrera i als aiguamolls de l'Empordà.

CABRERA

| Sample group | Wing length (mm) | Body mass (g) | Total mass change (g) ^a | Daily mass change (g/day) ^b | Stopover time (days) |
|--------------------|-------------------|-------------------|------------------------------------|--|----------------------|
| Not recaptured | 78.42 (n=1608) | 16.42 (n=1608) | | | |
| Recaptured = 1 day | 78.17 (n=75) | 16.36 (n=75) | -0.47 (sd 1.44) (n=75) | -0.47 (sd 0.90) (n=75) | 1 (n=75) |

^a Body mass at last capture minus mass at first capture / *Massa corporal a la darrera captura menys la massa a la primera captura*

^b Total change in body mass/length of stopover / *Canvi total en massa corporal/durada de l'stopover.*

AIGUAMOLLS

| Sample group | Wing length (mm) | Body mass (g) | Total mass change (g) ^a | Daily mass change (g/day) ^b | Stopover time (days) |
|--------------------|------------------|------------------|------------------------------------|--|----------------------|
| Not recaptured | 79.01 (n=287) | 16.57 (n=287) | | | |
| Recaptured = 1 day | 79.03 (n=20) | 16.57 (n=20) | 0.235 (sd 0.94) (n=20) | 0.02 (sd 0.62) (n=20) | 1 (n=20) |

^a Body mass at last capture minus mass at first capture / *Massa corporal menys la massa a la primera captura.*

^b Total change in body mass/length of stopover / *Canvi total en massa corporal/durada de l'stopover.*

We found some differences in phenology and biometrics between Garden Warblers captured on the mainland and on Cabrera: wing length was shorter and the mean day of capture was later on this island. In fact, later arrival on islands could be related to the hypothesis of delayed spring migration over the western Mediterranean (Barriocanal & Robson 2006): migrants that cross the Mediterranean may do so later than those that choose a continental route due to the pressure to reach breeding grounds. The fact that differences were also found in wing length suggests that some form of differential migration within populations exists, as has been reported by Grattarola *et al.* (1999): an increase in wing length with longitude suggests wide-front movements across the Sahara and Mediterranean rather than a concentration of birds along main routes.

In both study areas we found that birds caught during the first migration pentades had shorter wings than those captured subsequently. This fact could be related to some form of intraspecific differential migration determined by sex, age or geographical origin (Ketterson & Nolan 1983, Ellegren 1991). In the case of the Garden Warbler, there is no sexual dimorphism in wing length (Cramp 1992). Alternatively, long-winged individuals may winter further south than shorter-winged conspecifics. Wing pointedness predicts migration distance (Mönkkönen 1995, Winkler & Leisler 1992) better than wing length *per se*, although more data is needed to test this hypothesis.

Garden Warblers start spring migration weighing more than 30 g (Cramp 1992). After crossing the Sahara birds arriving in North Africa do not refuel and cross the western Mediterranean directly to their breeding grounds (Pilastro & Spina 1997). The mean body mass found on Cabrera and in the Aiguamolls de l'Empordà agrees with the intermediate geographical situation of these studied areas (Bairlein 1991, Grattarola *et al.* 1999), further supporting the idea that no significant re-fuelling takes place between north Africa and southern Europe.

We used re-captures occurring more than one day after initial capture to calculate changes in body mass in relation to stopover length, even though the Cormack-Jolly-Seber models (Schaub *et al.* 2001) offer a more accurate al-

ternative. However, few Garden Warblers recaptured more than one day after initial capture, as occurs in other passerines during spring migration over the Western Mediterranean (Robson *et al.* 2001), a fact that suggests that most birds depart on the same day of capture. Our data shows a median stopover time of recaptured birds of one day in both stopover sites and just minor changes in body mass, suggesting that re-fuelling does not occur during stopover. This data confirms the idea that both the Aiguamolls de l'Empordà and Cabrera are used just as a resting area before northward travel to breeding areas is resumed. This suggests that from the point of view of energy accumulation this and the other islands stretching across the Mediterranean Sea are not vital stopover points during birds' crossing of this large geographical barrier (Grattarola *et al.* 1999), although they could become so in the event of adverse weather. Moreover, in autumn these stopover sites could be used during the day by birds as resting sites, since flying in high temperatures and turbulent air could result in severe water and/or energy loss (Schmaljohann *et al.* 2007).

The analysis of the differences between Garden Warblers recaptured more than one day after initial capture and the rest of captured birds shows no significant differences in body mass and biometrics. Thus, there are no obvious criteria that might influence the decision to stay for more than a day. However, it is necessary to identify the different factors that make these analyses highly conservative. Firstly, our estimate of stopover length is clearly an underestimation since birds are not captured as soon as they arrive and do not leave the area immediately after release (Schaub *et al.* 2001). Secondly, both wing length and body mass changed according to the year, study season and even day length, and some of these factors have not been allowed for in the analyses.

The islands stretching across the Mediterranean Sea could play an important functional role on the migration route between wintering African territories and European breeding grounds as short stopover sites: the decision taken by migrants to rest is not explained by critical physical conditions (Spina & Pilastro 1999). Our data on Garden Warbler from Cabrera agrees with this pattern, which has already been discussed for other species (Spina

& Pilastro 1999). No differences in body-mass dynamics were found in the analysis of recaptured birds compared with captures from continental locations in the western Mediterranean. The differences in biometrics and phenology between the two localities discussed here could be explained by the presence of populations with different breeding and/or wintering areas and in the future should be studied using DNA and/or isotopic markers (Pain *et al.* 2004, Wink, 2006).

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Resum

Fenologia i dinàmiques de la massa corporal del Tallarol Gros *Sylvia borin* a l'illa de Cabrera (Illes Balears) i als Aiguamolls de l'Empordà (NE península Ibèrica) a la migració primaveral

En el marc del projecte "Piccole Isole" s'ha estudiat la fenologia i les dinàmiques de la massa corporal del Tallarol Gros *Sylvia borin* entre els anys 1993 i 2001 a l'illa de Cabrera i als Aiguamolls de l'Empordà. S'han trobat diferències en el pic de migració de l'espècie que correspon a principis de maig als Aiguamolls i a mitjans del mateix mes a Cabrera. També s'han trobat diferències significatives en les mides alars entre estacions i en ambdues s'ha observat que la longitud de l'ala és més petita a l'inici de la estació migradora. La fenologia entre estacions difereix, depenent dels anys, d'entre un i vuit dies, essent sempre l'arribada més tardana a Cabrera. Ambdues localitats s'utilitzen com un lloc de repòs durant un breu període de temps, tal i com mostra el baix nombre de recaptures de més d'un dia. La mitjana de dies en què els ocells recapturats romanen als indrets de captura és d'un dia, i no es registra cap increment en la massa corporal dels individus, la qual cosa suggereix que no reposten a les zones estudiades. Com ja s'ha constatat en d'altres estudis, les illes mediterrànies no són llocs aparentment vitals d'aturada durant la travessa de la barrera geogràfica que suposa la mar Mediterrània, almenys des d'un punt de vista de l'acumulació d'energia en el Tallarol

Gros. Les diferències fenològiques i biomètriques trobades en aquest estudi podrien correspondre a una forma de migració diferencial de poblacions per la Mediterrània occidental.

Resumen

Fenología y dinámicas de la masa corporal de la Curruca Mosquitera *Sylvia borin* en la isla de Cabrera (Islas Baleares) y en los Aiguamolls de l'Empordà (NE península Ibérica) en la migración primaveral

En el marco del proyecto "Piccole Isole" se ha estudiado la fenología y las dinámicas de la masa corporal de la Curruca Mosquitera *Sylvia borin* entre los años 1993 y 2001 en la isla de Cabrera y en Aiguamolls de l'Empordà. Se han encontrado diferencias en el pico de migración de la especie que corresponde a primeros de mayo en Aiguamolls y a mediados del mismo mes en Cabrera. También se han encontrado diferencias significativas en las longitudes alares entre estaciones y en ambas se ha observado que la longitud del ala es más pequeña al inicio de la estación migradora. La fenología entre estaciones difiere, dependiendo de los años, entre uno y ocho días, siendo siempre la llegada más tardía en Cabrera. Ambas localidades se utilizan como lugar para el descanso durante un breve periodo de tiempo, tal y como muestra el bajo número de recapturas de más de un día. La mediana de días que las aves recapturadas permanecen en los lugares de captura es de un día, y no se registra un incremento de la masa corporal, lo que sugiere que los individuos no repostan en las zonas estudiadas. Como ya se ha constatado en otros estudios, las islas Mediterráneas no son aparentemente lugares vitales desde el punto de vista de acumulación de reservas energéticas durante la travesía de la barrera geográfica que supone el mar Mediterráneo, como mínimo para la Curruca Mosquitera. Las diferencias fenológicas y biométricas encontradas en este estudio podrían corresponder a una forma de migración diferencial de poblaciones por el Mediterráneo occidental.

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