SHORT COMMUNICATION

First insights into migration routes and nonbreeding sites used by Red-rumped Swallows (*Cecropis daurica rufula*) breeding in the Iberian Peninsula

Joanna B. Wong[1] · Francina Turon[2] · Mario Fernández-Tizón[3] · Steffen Hahn[1]

Abstract

Using EURING data and geolocation, we describe migration routes and the nonbreeding range of Red-rumped Swallows breeding in the Western Palearctic. One bird ringed in southern Spain and recovered in southern Morocco indicates southwestern migration; geolocator data from five birds from central and eastern Iberian Peninsula confirm migration to various nonbreeding sites in sub-Saharan west Africa between Senegal/Mauritania and Ghana. Two swallows showed non-breeding site itinerary by using more than one nonbreeding site per season. Despite wide ranges in departure for autumn (August–October) and spring migration (February–March), all birds arrived at nonbreeding and breeding sites within ± 1-week from each other.

Keywords Hirundinidae · Geolocation · Long-distance migration · Nonbreeding sites · Western Palearctic

Zusammenfassung

Erste Einblicke in Zugrouten und Überwinterungsgebiete von Rötelschwalben (*Cecropis daurica rufula*) der Iberischen Halbinsel. In dieser Studie beschreiben wir Zugrouten und Überwinterungsgebiete westpaläarktischer Rötelschwalben basierend auf EURING- und Geolokations-Daten. Eine Rötelschwalbe, die in Südspanien beringt und im südlichen Marokko wiedergefunden wurde, spricht für einen südwestlichen Zug. Geolokalisation von fünf Vögeln der zentralen und östlichen Iberischen Halbinsel zeigen Überwinterungsorte im sub-Saharischen Westafrika zwischen Senegal/Mauretanien und Ghana. Zwei der getrackten Rötelschwalben nutzten mehrere Überwinterungsplätze pro Saison. Trotz der großen Schwankungsbreite der Abzugszeiten im Herbst (August-Oktober) und im Frühjahr (Februar-März) erreichten die getrackten Vögel ihre Nichtbrut- bzw. Brutplätze innerhalb von 1–2 Wochen.

Introduction

Within the Western Palearctic, Red-rumped Swallows (*Cecropis daurica rufula*; hereafter RRS) have a wide breeding range, spanning across southern Europe towards

✉ Joanna B. Wong
  joanna.wong@vogelwarte.ch

1 Department of Bird Migration, Swiss Ornithological Institute, 6204 Sempach, Switzerland

2 Institut Català d'Ornitologia (ICO), 08037 Barcelona, Spain

3 Instituto de Investigación en Recursos Cinegéticos (IREC) (CSIC-UCLM-JCCM), 13005 Ciudad Real, Spain

the Middle East and parts of Morocco and Algeria (Bird-Life International 2022). Palearctic RRS are migratory, in contrast to mostly resident subspecies that occur in sub-Saharan Africa and southeast Asia (Turner and Kirwan 2020). Despite their widespread distribution, little is known about their nonbreeding range and migratory routes. European populations are presumed to spend their nonbreeding period in Sudan to the Guinean savanna belt across Africa, joining resident African populations in West or Northeast Africa (Turner and Kirwan 2020), although some individuals overwintering in Iberia have also been recorded (SEO/BirdLife 2012). Recent observations of RRS moulting in Morocco have also suggested some birds conduct a short-distance migration within the Western Palearctic (Dufour et al. 2020). During migration, flocks of swallows have been observed crossing the Strait of Gibraltar at peak times in late

September to October (autumn migration), and April (spring migration) (De Juana and Garcia 2015). However, there has been no tracking study conducted on Western Palearctic RRS to confirm these migration patterns (for eastern Asian subspecies, see Heim et al. 2020). Here, we aimed to discern the main nonbreeding sites and general migration routes used by a Western Palearctic population of RRS using ring recoveries and light-level geolocators.

Methods

We searched for ring recoveries using the EURING data set (403 birds from 1961 to 2020, delivery in autumn 2021), wherein either ringing or recovery took place during the non-breeding season (between October and March).

88 adult RRS were trapped using nets at two breeding sites near Ciudad Real (3.95° W, 38.98° N, Castilla-LaMancha) and Maresme (2.69° E, 41.65° N, Catalunya; Table 1). Geolocators (model SOI-GDL2) were attached to 56 birds using leg-loop harnesses (3.5% of average swallow body mass of 20.4 g). Tags were deployed in June–July 2019 and 2020. Two birds with geolocators were recaptured in 2020, while three were recaptured in 2021 (total recapture rate of geolocator birds with and without device: 9%, controls: 25%).

To estimate geographical positions from retrieved geolocators, we analyzed the light data using the packages *TwGeos* (Lisovski et al. 2016) and *SGAT* (Wotherspoon et al. 2013) in R version 4.0.5 (R Core Team 2021) following Lisovski et al. (2020). Using the 'threshold method' and a light-level threshold of 1 (log-scale), we first distinguished times of sunrise and sunset (i.e., twilights) with *TwGeos.* Twilights within 14 days of the equinoxes were deleted. Median reference solar zenith angles were derived from either in-habitat calibration while birds were at their breeding colony, or

Hill-Ekstrom calibration based on the light readings at a stationary non-breeding site (Table S1 in Supplement). The latter was used if calibration at the breeding site was not possible (i.e. due to shading of the tag producing erroneous twilights). We then distinguished the movement from stationary periods based on strong changes in consecutive times of sunrise, sunset, midday, and midnight, signifying a probable change in location. Stationary periods were defined as stops lasting more than 2 days.

Next, we used SGAT's Group model to group similar twilight times to a single location using the mergeGroups function. SGAT follows a Bayesian framework, estimating the most likely positions of birds based on the twilight error distribution, the flight speed distribution (gamma distributed; shape: 2.2, rate: 0.08), and a land mask which gives locations on land a higher prior. We ran a 'modifiedGamma' model for 1000 iterations to initiate the model, and then tuned the model for 5 runs with 300 iterations to include final assumptions and priors. Finally, we ran the model for 2000 iterations, which produced the most likely median tracks and their 95% confidence intervals.

Departure/arrival at the breeding site was defined as the respective last or first date recorded at the breeding colony. The main nonbreeding sites were defined as the sites with the longest uninterrupted stay, and arrival/departure dates were also calculated as the respective first and last dates of stationary activity at the main nonbreeding site.

Results

From EURING records, we found three recoveries during winter in the Iberian Peninsula and a single observation for long-distance migration: a breeding bird ringed in Antequera/Andalusia in 10.07.1999 had been shot on 25.03.2002 near Guelmim, southern Morocco (distance 1034 km, Fig. 1a; Table S2 in Supplement).

Table 1 Departure and arrival dates of five tagged RRS at breeding sites (BS: Maresme: 2.69° E, 41.65° N; Ciudad Real: 3.95° W, 38.98° N) and main African nonbreeding sites (NBS)

Year	BS	ID	Sex	Tag attached	Departure BS	Arrival main NBS	Duration autumn migration	Departure main NBS	Arrival BS	Duration spring migration
2019-2020	Maresme	23FU	male	Jun 9	Oct 16	Oct 29	13	Mar 16	Apr 7	22
	Maresme	23ID	male	Jul 8	Sep 13	Oct 13*	30	Nov 22	-	-
					-	Nov 30	-	Dec 24	-	-
					-	Dec 28	-	Feb 17*	Apr 20	62
2020-2021	Ciudad Real	25LF	male	Jun 10	Aug 24	Oct 11*	48	Dec 9	-	-
					-	Dec 16	-	Feb 19*	Apr 11	51
	Ciudad Real	25NL	unknown	Jun 27	Aug 26	Oct 10	45	Feb 23	-	-
	Maresme	25NI	male	Jun 25	Oct 5	Oct 15	10	Mar 29	-	-
Median					Jun 25	Sep 13	Oct 13	30	Feb 23	Apr 11	51

Individuals 23ID and 25LF used more than one main nonbreeding site; therefore, the arrival date at the first site and departure date from the last site (denoted with an asterisk*) were used in the calculation of the number of days of autumn and spring migration. All other arrival and departure dates from additional nonbreeding sites are shown in gray

During their autumn migration, four geolocator birds flew directly south or southwest from their breeding sites to cross the Mediterranean Sea into Africa, while one bird initially headed west into the interior before travelling south across the coastal Atlantic. Most birds took longitudinally similar (3° W–6° W) southward routes crossing the Sahara Desert (~ 30° N) through Algeria, before routes diverged at ~ 20° N, in which birds headed toward different nonbreeding sites in Mauritania, The Gambia, Sierra Leone, and Liberia (Fig. 1b). Meanwhile, the bird which used the Atlantic crossing also took a more western route, crossing the Sahara at ~ 12° W, but used several nonbreeding sites farther east than other birds, in Guinea, Burkina Faso and Ghana (Fig. 1b). Three birds used a single main nonbreeding site, and two individuals moved through 2–3 sites during the nonbreeding period (Fig. 1b; Table 1). However, the total duration spent at nonbreeding sites was similar for birds using a single (mean: 219 days ± 16) or multiple (mean: 236 days ± 3) sites.

During spring migration, all individuals headed northwest from their last nonbreeding site, crossing the Sahara within 5° W and 15° W longitude (Fig. 1c). Four birds took routes through northern Morocco before crossing the Mediterranean (Fig. 1c). Two individuals from the eastern colony of Catalunya flew directly over the Mediterranean rather than taking inland routes through Spain. Two tags were battery depleted before returning to the breeding site, however, recorded paths showed similar directional patterns as other birds.

RRS's left their breeding site between late-August to mid-October, with a median departure on September 13, but arrived at their main nonbreeding sites within ± 8 days in mid-October (Table 1). Duration of autumn migration varied from 10 to 48 days (Table 1). Spring migration started between mid-February and late-March, with median departure from the nonbreeding site on February 23 (Table 1). For the three birds with recorded arrival, all arrived within ± 7 days of April 11 (median) (Table 1). Spring migration was longer in duration than autumn migration, ranging from 22 to 62 days (Table 1). There were no major spatial or
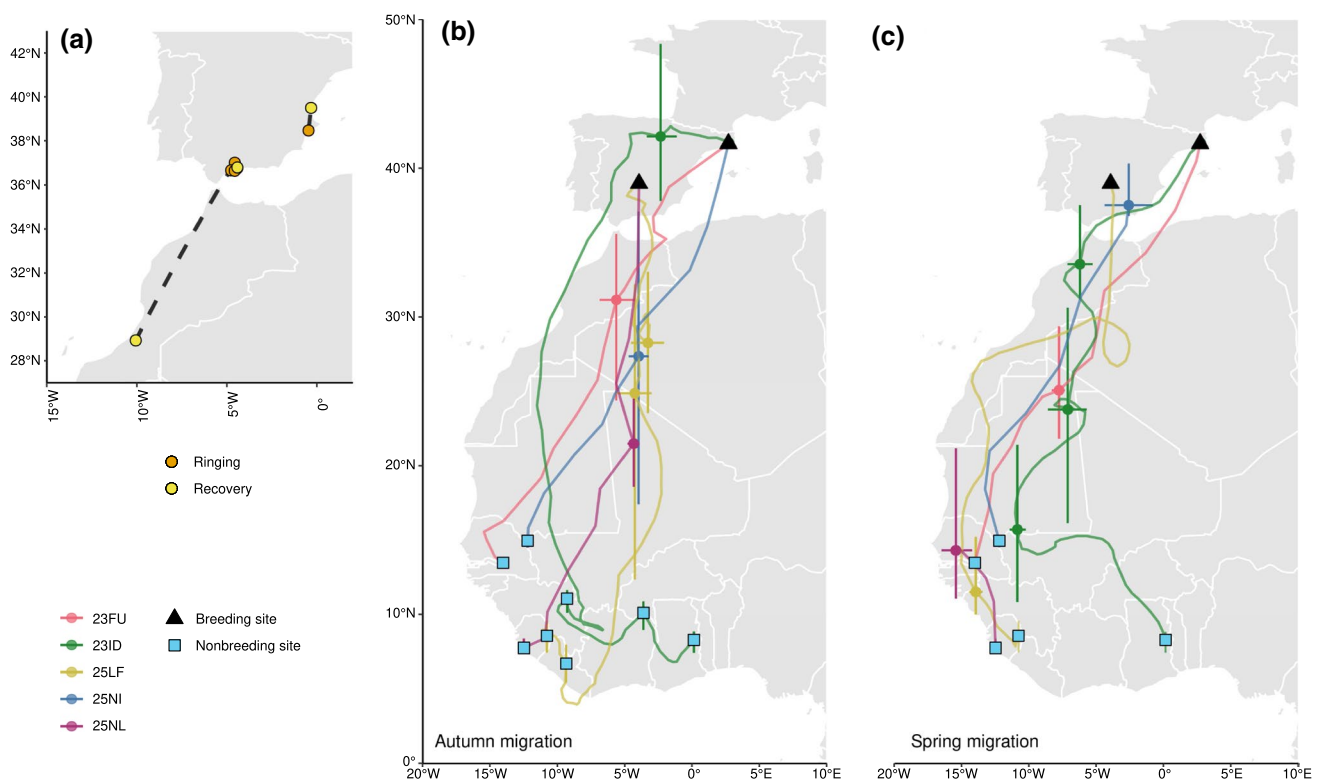

Fig. 1 A EURING records of four RRS ringed in Spain (orange circles) and their subsequent recovery (yellow circles) ranging from a 3-month (*n* = 1; short-distance), 1-year (*n* = 2; short-distance), and 3-year (*n* = 1; long-distance) period. Note, that two individuals at ~ 5° W were recovered near their ringing site 1-year later (ringing and/or recovery during the nonbreeding season). **B, C** Autumn and spring migration for five RRS (*Cecropis daurica rufula*) from two Iberian breeding sites (black triangles). Tracks shown are based on the most likely modelled tracks per individual, including the main nonbreeding site(s) (blue squares), stopover sites (corresponding coloured circles), and associated 95% confidence intervals*. Note, only the last nonbreeding site is shown in the spring migration for the two individuals which used multiple nonbreeding sites. *Confidence intervals vary per track due to variation in light data quality accompanied by seasonally variable accuracy of geolocation itself (see Lisovski et al. 2012)

phenological differences between birds from the different colonies or across different years of tagging and recapture.

Discussion

Here, we describe the migration routes and main nonbreeding sites used by an Iberian population of RRS. All birds in our tracking study migrated to west Africa and spent the nonbreeding period in sub-Saharan countries between ~7° N and 15° N, in line with the presumed nonbreeding range for this subspecies and the known range of resident African populations (Shirihai and Svensson 2018). The single long-distance EURING record also confirmed a similar directional movement.

Although birds took generally similar routes to cross the Sahara during autumn migration, the variation in nonbreeding sites used in west Africa among RRS from two Iberian breeding populations and different years, suggests that RRS may have low migratory connectivity and low fidelity to the nonbreeding sites. Thus, there must be a non-site-specific driver for nonbreeding site selection in RRS. The use of multiple main nonbreeding sites for two out of five tracked birds suggests RRS may employ a strategy of itinerancy, where birds move between different non-breeding sites presumably in line with fluctuations in site-specific resource availability (Koleček et al. 2018). Itinerancy is characterized by a longer (1–2 month) stop in which remaining at the site is advantageous, compared to shorter refueling stopovers which are simply necessary for continued travel. This strategy has been frequently observed in Africa in line with rainfall patterns and associated food availability (Thorup et al. 2017; Trierweiler et al. 2013), and likely explains the ca. 1–2 month stop per non-breeding site for the two individuals in our study. Despite varied departure dates, all birds also arrived at their main nonbreeding site at similar times. This further suggests that RRS are likely prioritizing arrival in sub-Saharan West Africa by mid-October (Table 1) to coincide with peak rainfall and vegetation periods in the autumn months (Zwarts et al. 2009).

Spring arrival at the breeding grounds was also similar, despite variation in departure dates from the nonbreeding sites, and spring migration was longer in duration than autumn migration. This is contrary to most migrating birds which utilize a shorter spring migration and favour an early spring arrival to have better territory or mate selection options (Nilsson et al. 2013). This suggests that for our RRS, conditions in Africa may be more favourable before April than at their Iberian breeding sites. However, further investigation on season- and site-specific environmental conditions with larger sample size is needed before conclusions can be drawn.

Our study provides a first look at the annual cycle of Iberian-breeding RRS using light-level geolocators. Future tracking studies on other Western Palearctic populations would increase understanding of how migration and non-breeding sites used by RRS in west Africa may shift with climate change and fluctuations in rainfall across years.

Declarations

Funding and Competing interests The authors have no competing or financial interests to declare.

References

BirdLife International (2022) Species factsheet: *Cecropis daurica*. http://datazone.birdlife.org/species/factsheet/red-rumped-swallow-cecropis-daurica. Accessed 28 Feb 2022

De Juana E, Garcia E (2015) The birds of the Iberian Peninsula. Bloomsbury Publishing, London

Dufour P, Sallé L, de Franceschi C, Morisot A, Delahaie B (2020) Are Red-rumped Swallows starting to winter in the Western Palearctic? Dutch Bird 42:111–113

Heim W, Heim RJ, Beermann I et al (2020) Using geolocator tracking data and ringing archives to validate citizen-science based seasonal predictions of bird distribution in a data-poor region. Glob Ecol Conserv 24:e01215. https://doi.org/10.1016/j.gecco.2020.e01215

Koleček J, Hahn S, Emmenegger T, Procházka P (2018) Intra-tropical movements as a beneficial strategy for Palearctic migratory birds. R Soc Open Sci 5:171675. https://doi.org/10.1098/rsos.171675

Lisovski S, Hewson CM, Klaassen RHG et al (2012) Geolocation by light: accuracy and precision affected by environmental factors. Methods Ecol Evol 3(3):603–612. https://doi.org/10.1111/j.2041-210X.2012.00185.x

Lisovski S, Wotherspoon S, Sumner M (2016) TwGeos: basic data processing for light-level geolocation archival tags. R package version 0.1.2.

Lisovski S, Bauer S, Briedis M et al (2020) Light-level geolocator analyses: a user's guide. J Anim Ecol 89:221–236. https://doi.org/10.1111/1365-2656.13036

Nilsson C, Klaassen RHG, Alerstam T (2013) Differences in speed and duration of bird migration between spring and autumn. Am Nat 181(6):837–845. https://doi.org/10.1086/670335

R Core Team (2021) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

SEO, BirdLife (2012) Atlas de las aves en invierno en España 2007–2010. Ministerio de Agricultura, Alimentación y Medio Ambiente-SEO/BirdLife, Madrid

Shirihai H, Svensson L (2018) Handbook of Western Palearctic birds. Bloomsbury Publishing, London

Thorup K, Tøttrup AP, Willemoes M et al (2017) Resource tracking within and across continents in long-distance bird migrants. Sci Adv 3:e1601360. https://doi.org/10.1126/sciadv.1601360

Turner A, Kirwan GM (2020) Red-rumped Swallow (*Cecropis daurica*), version 1.0. In: Billerman SM, Keeney BK, Rodewald PG, Schulenberg TS (eds) Birds of the World. Cornell Lab of Ornithology, Ithaca. https://doi.org/10.2173/bow.rerswa1.01

Wotherspoon SJ, Sumner DA, Lisovski S (2013) R Package SGAT: solar/satellite geolocation for animal tracking. GitHub Repository. https://github.com/SWotherspoon/SGAT.

Zwarts L, Bijlsma RG, van der Kamp J, Wymenga E (2009) Living on the edge: wetlands and birds in a changing Sahel. KNNV Publishing, Zeist

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.