



Migratory connectivity, short steps and loop migration in an alpine population of Whinchats *Saxicola rubetra*

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Abstract

We investigated the migratory strategy of an alpine population of Whinchat *Saxicola rubetra*, a long-distance migratory passerine experiencing severe population declines in Europe. We tracked seven individuals breeding in the French Alps using multi-sensor loggers combining light, accelerometer, and barometric pressure data. Tracked whinchats exhibited an anti-clockwise, loop migration. In autumn, birds migrated westward through France and the Iberian Peninsula, entering Africa near the Strait of Gibraltar and moving south along the western edge of the Sahara Desert. Autumn migration lasted 17–50 days and was characterized by a short step strategy, with numerous short nocturnal flights (mean 9 h) interspersed with frequent, often brief stopovers (on average 15 stops of median duration 16 h). Spring migration followed a more direct, easterly route across the Sahara Desert toward Europe. In contrast, it was faster (12–24 days) and more synchronized, typically beginning with a single, non-stop trans-Saharan flight lasting 37–45 h. These initial spring flights reached the highest of the recorded altitudes (4000–6000 m above sea level), considerably higher than autumn flights, likely facilitating barrier crossing and thermoregulation. Subsequent spring movements involved fewer flights and short stopovers, resulting in a highly accelerated return to breeding sites. Non-breeding ecology revealed flexible strategies. Each individual used one or two main non-breeding sites in West Africa, primarily in Guinea, Sierra Leone, Ivory Coast, Senegal, and Mauritania. Four of seven birds shifted between non-breeding sites at mid-winter, while others remained resident or roamed locally before spring migration. Compared to British breeding populations, alpine Whinchats showed a more spatially aggregated winter distribution, suggesting a moderate degree of migratory connectivity. Conservation implications emphasize the importance of preserving a network of stopover and late-winter fueling sites along the West African flyway, particularly in the context of habitat degradation and climate change.

Keywords Barrier crossing · Long-distance migrant · Migration strategy · Multi-sensor logger · Sahara Desert

Zusammenfassung

Zugkonnektivität, kurze Strecken und Schleifenzug bei einer alpinen Population von Braunkehlchen *Saxicola rubetra*

Wir untersuchten die Zugstrategie einer alpinen Population von Braunkehlchen (*Saxicola rubetra*), eines Langstreckenziehers, dessen Bestände in Europa stark zurückgehen. Hierfür verfolgten wir sieben in den französischen Alpen brütende Individuen

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mithilfe von Multisensor-Datenloggern, die Informationen zu Licht, Bewegungen und Luftdruck erfassten. Die verfolgten Braunkehlchen zeigten einen Schleifenzug entgegen dem Uhrzeigersinn. Im Herbst zogen die Vögel westwärts durch Frankreich und die Iberische Halbinsel, gelangten nahe der Straße von Gibraltar nach Afrika und bewegten sich entlang des westlichen Randes der Sahara nach Süden. Der Herbstzug dauerte zwischen 17 und 50 Tage und zeichnete sich durch kurze Etappen aus, auf denen sich zahlreiche kurze Nachtflüge (durchschnittlich 9 Stunden) mit häufigen, oft kurzen Zwischenstopps abwechselten (im Durchschnitt 15 Stopps mit einer mittleren Dauer von 16 Stunden). Der Frühjahrszug verlief auf einer direkteren, östlichen Route über die Sahara in Richtung Europa. Er verlief schneller (12–24 Tage), synchroner und begann in der Regel mit einem einzigen, ununterbrochenen 37–45 Stunden langen Flug über die Sahara. Diese allerersten Flüge auf dem Frühjahrszug erreichten die höchsten gemessenen Höhen (4000–6000 Meter über dem Meeresspiegel) und lagen damit deutlich über den Flughöhen während des Herbstzugs, vermutlich um das Überwinden von Hindernissen und auch die Thermoregulation zu erleichtern. Der danach folgende Frühjahrszug erfolgte in weniger Flügen und kurzen Zwischenstopps, was eine wesentlich schnellere Rückkehr in die Brutgebiete bedeutete. Im Wintergebiet zeigten sich deutlich flexiblere Strategien. Jedes einzelne Tier nutzte ein oder zwei Hauptgebiete in Westafrika, in erster Linie in Guinea, Sierra Leone, der Elfenbeinküste, Senegal und Mauretanien. Vier der sieben Vögel zogen mitten im Winter zwischen ihren Überwinterungsgebieten hin und her, während die anderen an Ort und Stelle blieben oder vor Beginn des Frühjahrszugs in der Umgebung umherstreiften. Im Vergleich zu britischen Brutpopulationen wiesen die alpinen Braunkehlchen eine räumlich stärker aggregierte Winterverbreitung auf, was auf eine wenig ausgeprägte Zugkonnektivität hindeutet. Aus Sicht des Naturschutzes sei betont, wie wichtig im die Erhaltung eines Netzwerks von Rastplätzen und spätwinterlichen Futterplätzen entlang der westafrikanischen Zugroute ist, insbesondere im Hinblick auf die Verschlechterung der Lebensräume und den Klimawandel.

Introduction

The migration strategies of numerous songbirds have been unravelled using light or multi-sensor loggers, providing new insights on phenology and tracks, including locations and duration of stopovers, and the identification of non-breeding sites (Liechti et al. 2018). Such tracking data also inform on the strategies adopted by small birds to cross geographical barriers (Adamik et al. 2016), especially deserts (Jiguet et al. 2019) and sea expanses too (Dufour et al. 2026). Within migratory passerines tracked with light loggers, the Whinchat *Saxicola rubetra* is one of the species with the most comprehensively documented migration routes (Blackburn et al. 2017, 2018; Burgess et al. 2020; Cresswell et al. 2025).

The Whinchat has a considerable breeding range spanning from western Europe to central Asia, with a non-breeding range extending across the Sahel, east to the Horn of Africa and south to Zambia (Collar and Garcia 2020). Several breeding or non-breeding populations have been tracked to unravel the species migration strategies, especially focusing on migratory connectivity (Blackburn et al. 2017, 2018; Burgess et al. 2020; Cresswell et al. 2025). As one of the most declining passerine birds of European farmlands, Whinchat is a long-distance migrant species of high conservation concern (PECBMS 2025). Understanding its migration ecology is necessary to better target conservation action across the annual cycle (Spina et al. 2022), even though a previous study using capture–recapture data suggested that insufficient reproduction may be the species' main demographic limitation (Fay et al. 2021). With the developments of small tracking devices for passerines, whinchats have

been equipped with light loggers first on African non-breeding grounds, in Nigeria and Liberia (Blackburn et al. 2017, 2018; Cresswell et al. 2025). Recently, whinchats breeding in British upland and lowland have also been tracked (Burgess et al. 2020), again with light-loggers. The general picture obtained from these studies describes an anti-clockwise migration, and the use of multiple non-breeding sites during the winter – at least for birds tagged during the breeding season. These previous studies also reported a weak migratory connectivity, with birds from a similar breeding population spreading across large areas in Africa in winter, or birds from a single African non-breeding site spreading across Europe for breeding. Indeed, Burgess et al. (2020) reported that birds breeding in three British populations wintered across a large region, from Sierra Leone to Nigeria, covering ca. 2000 km in longitude.

In this study, we examined an alpine population of Whinchat, by deploying multiple-sensor loggers to obtain more detailed records of active flights and stopovers. We deployed loggers on breeding birds in pastured grasslands at 1450–1550 m above sea level (a.s.l.) in the French Alps, to document their migration strategy and compare it with previously published information on other tracked populations of the species. The present study yielded data from only seven individuals, a notably smaller sample size compared to previous investigations (Blackburn et al. 2017, 2018; Burgess et al. 2020; Cresswell et al. 2025), but using multiple-sensor loggers provided new detailed information on the migration journeys. Indeed, accelerometer and barometer data allowed a precise description of active migratory flights (duration, altitude a.s.l.),

stopovers (duration) and non-breeding movements. We further discuss the conservation implications of these findings.

Material and methods

Study site, logger deployment and retrieval

All birds were captured using mist-nets between July 2022 and July 2024 at Col des Aravis in Savoie and Haute-Savoie departments, French Alps, and fitted with a metal ring, a color ring (red plastic ring with a white engraved code) and a multi-sensor logger. Captures concerned only breeding adults and occurred during egg laying, incubation or chick rearing periods, targeting birds with clear signs of local reproduction. Birds were captured and handled under regulatory authorizations delivered by MNHN-CRBPO under the program reference PP1190. We used the multi-sensor Intigeo CARP-30Z11-7-DIP manufactured by Migrate Technology (0.6 g with harness and rings). The weight of the tagged individuals varied between 14.6 g and 21.0 g (average $\pm$ s.d. = 16.3 ± 1.2 g), and the tag always amounted to less than 4% of the body mass of the bird. 10 loggers were deployed in 2022 (8 males and 2 females), and 10 in 2023 (8 males and 2 females).

Devices were mounted using a leg-loop harness made with an elastic string (stretch magic) of a 0.8 mm diameter. Loggers recorded ambient light intensity at 5-min intervals, and activity data (via accelerometer) and atmospheric pressure every 20 min.

Seven tagged individuals returned, all of them were recaptured to recover the tag. They concerned 4 males and 3 females (see Table S1). For these seven recaptured birds, body mass was 16.1 ± 0.9 g at deployment and 17.2 ± 2.1 g at retrieval, with no significant differences between deployment and retrieval (paired t-test, $n = 7$, $t = 1.15$, $P = 0.29$). The overall returning rate for tagged birds was 35% (7/20; 75% for females, 25% for males).

During the same tagging years and in the same study site, we captured and ringed another set of 13 adult individuals (one-year-old or older; 8 males and 5 females) which were only color-ringed, to serve as a control group. Of these individuals, 3 (two males and one female) returned to the site during the subsequent year, so with a returning rate of 23%, not dissimilar to that of the tagged birds (chi-square = 0.29, $P = 0.6$). The body mass of these 13 birds was 16.3 ± 1.5 g (range 14.7–20.0 g) at ringing. Table S1 provides details on all individuals color-ringed in this study, with the location of capture, the dates and biometry (at deployment and retrieval time, if pertinent).

Logger data analysis

To reconstruct the migratory journey of the birds, we modelled the trajectory of each track following the approach presented in Nussbaumer et al. (2023a) and using the R package GeoPressureR (version 3.2; Nussbaumer and Gravey 2024). We briefly describe the main steps of the approach and refer the readers to Nussbaumer et al. (2023a) for further details regarding the implementation of the method.

First, we separated stationary periods and flight periods by manually labelling the logger pressure and activity measurements. Stationary periods were characterized by a limited variation in consecutive pressure measurements indicating an absence of change in altitude associated with a limited variation in consecutive activity measurements. We considered a diurnal stop between two consecutive nights of migratory flights as a stopover event. Migratory flights typically displayed a clear drop in atmospheric pressure, corresponding to altitude gain in-flight (ascent) associated with consecutive high activity measurements (which form a plateau of the same duration as the variation in pressure).

Second, we built separate probability maps based on atmospheric pressure and light intensity data (sunrise and sunset times) to estimate the position of each bird during each stationary period. For the pressure-based maps, the time series of the logger pressure measurements during stationary periods were matched with the one-hour atmospheric pressure at surface level from the ERA5 reanalysis dataset (spatial resolution: $0.5 \times 0.5^\circ$) to produce a likelihood map of the logger's position (following the method of Nussbaumer et al. 2023b). The resulting likelihood map included the information of both the temporal variation of pressure and the absolute values of pressure corresponding to the altitudinal range within each grid cell. For the light-based maps, we calculated likelihood estimates following Nussbaumer et al. (2023b). We used an “in-habitat” calibration from the equipment and retrieval periods (as described in Lisovski et al. 2012; Lisovski and Hahn 2012) fitting the distribution of zenith angle with a kernel density estimation. The likelihood maps of twilights belonging to the same stationary period were aggregated with a log-linear pooling.

Finally, we constructed the routes of each bird following a Hidden Markov Model presented in Nussbaumer et al. (2023a). The observation model consisted of the likelihood maps generated from pressure and light data. The movement model used the information of flight duration derived from the labelling and a parametric equation defined as the cubic root of the mechanical power required for the average airspeed computed for a transition, accounting for the different species size and shape (Nussbaumer et al. 2023a). Using this model, we generated (1) the marginal probability map of the position of each stationary period and (2) the most likely migration trajectory of the birds.

Results

Autumn migration

Departures of the seven individuals from the breeding site occurred between 1st of September and 2nd of October—the earliest and latest being females. The duration of the post-breeding migration ranged 17–50 days, and was merely negatively correlated with the departure date ($n=7$, $r=-0.65$, $P=0.055$), with a shortening of migration duration by 0.76 days for each day of delayed departure. From the breeding ground leave to the arrival at the non-breeding stationary location, the post-breeding migration was completed with 13–19 active flights (mean 16 ± 2 flights), whose duration averaged 8.33 ± 5.47 h. The distribution of flight duration identified three kinds of flights. The vast majority of flights (70%) lasted 6–13 h ($n=78$; 9.13 ± 1.77 h), with 26% short flights lasting less than 6 h ($n=29$; 2.94 ± 1.06 h), and finally 4.5% long flights lasting more than 15 h ($n=5$, for five different individuals; 16, 16, 19, 36 and 43 h). All flights occurred during nighttime. Within 105 identified stopovers, 72% lasted less than one day (24 h), 6% lasted between 1 and 2 days, and 3% lasted between 2 and 3 days. The median duration of autumn stopover was 16 h, i.e. individuals generally arrived at a stopover at the end of the night or early morning and departed the next evening.

Spring migration

Initiation dates of the active pre-breeding migration ranged between 2 and 24 April for males, 16 April and 10 May for females, for arrivals back at the breeding location on 25 April–29 May. Consequently, migration duration ranged 12–24 days for males, and 15–21 days for females. From the non-breeding ground departure to the arrival at the breeding site, the pre-breeding migration was completed with 9 to 19 active flights. Actually, it was 9 or 10 flights for all birds that started with a long trans-Saharan flight, and 19 for one male who crossed that barrier in a step-by-step strategy. The total duration of active flights was very similar between individuals and ranged from 96 to 106 h, except for CG366 who performed 113 h of active flights. We identified 6 long flights lasting more than one day, corresponding to the Sahara Desert crossing, in 6 individuals (all but CG366), the duration of these flights being 37, 43 ($\times 3$) or 45 ($\times 2$) hours. The duration of the 64 shorter flights averaged 7.50 ± 2.66 h. Concerning the stopover durations, there was a gradual decrease in the number of stopovers with an increase in duration. Within 63 identified stopovers, 73% lasted less than one

day (24 h), 11% between 1 and 2 days, 5% between 2 and 3 days and between 3 and 4 days, 3% between 4 and 5 and 5 and 6 days. The median of spring stopover duration was 16 h, as in autumn.

Desert crossing

In autumn, we recorded three different strategies of desert crossing, contrasted by the frequency of nocturnal flights prolonged during the daylight. For two individuals, we detected no prolonged flight so no particular flight strategy to cross the Sahara Desert compared to other active migration bouts. Two individuals crossed the Sahara Desert with a single flight covering a night, the following day and the next night, without stopping: 35.66 h in a row for CG309, and 42.66 h for CM811. The other three individuals displayed a more classical nocturnal flight prolonged a few hours during the next morning, with 15.66, 16.0 and 19.33 h of active flight, while the previous and next nocturnal flights did not extend during the daylight. For those five birds with prolonged flights, Sahara Desert crossing started 18 September, 24 September, 2 October, 5 October and 8 October. In spring, 6 out of the 7 birds crossed the Sahara Desert with a single flight covering a night, the following day and the next night, with durations ranging from 42.33 h for CG405 and 45.0 h for CM751. Figure 2 reports the latitude of each individual during the year, with zooms on the active migratory windows. It illustrates the step-by-step desert crossing of most individuals in autumn (except CM811), and the non-stop desert crossing in spring (except the earliest migrant CG366).

Flight altitudes

In spring, the migration started by a first very long flight, lasting more than one day, and reaching the highest altitudes for each individual, between 4000 and 6000 m a.s.l. corresponding to the Sahara Desert crossing (see Fig. 3). In autumn, the whinchats did not reach altitudes as high as in spring, even when crossing the Sahara Desert, most individuals flying between 2500 and 3000 m a.s.l. with only CM811 overpassing 4000 m a.s.l. However, such altitudes were reached by several individuals during their movements above Iberia and North Africa (with CG130, CG309 and CM807 reaching 4000 m a.s.l.).

Non-breeding grounds

Arrival dates on the first non-breeding residency location ranged between 29 September and 31 October, with 4 of the 7 individuals moving to a second non-breeding location in the course of the winter (12 December and 19 January). These movements and changes in latitude during

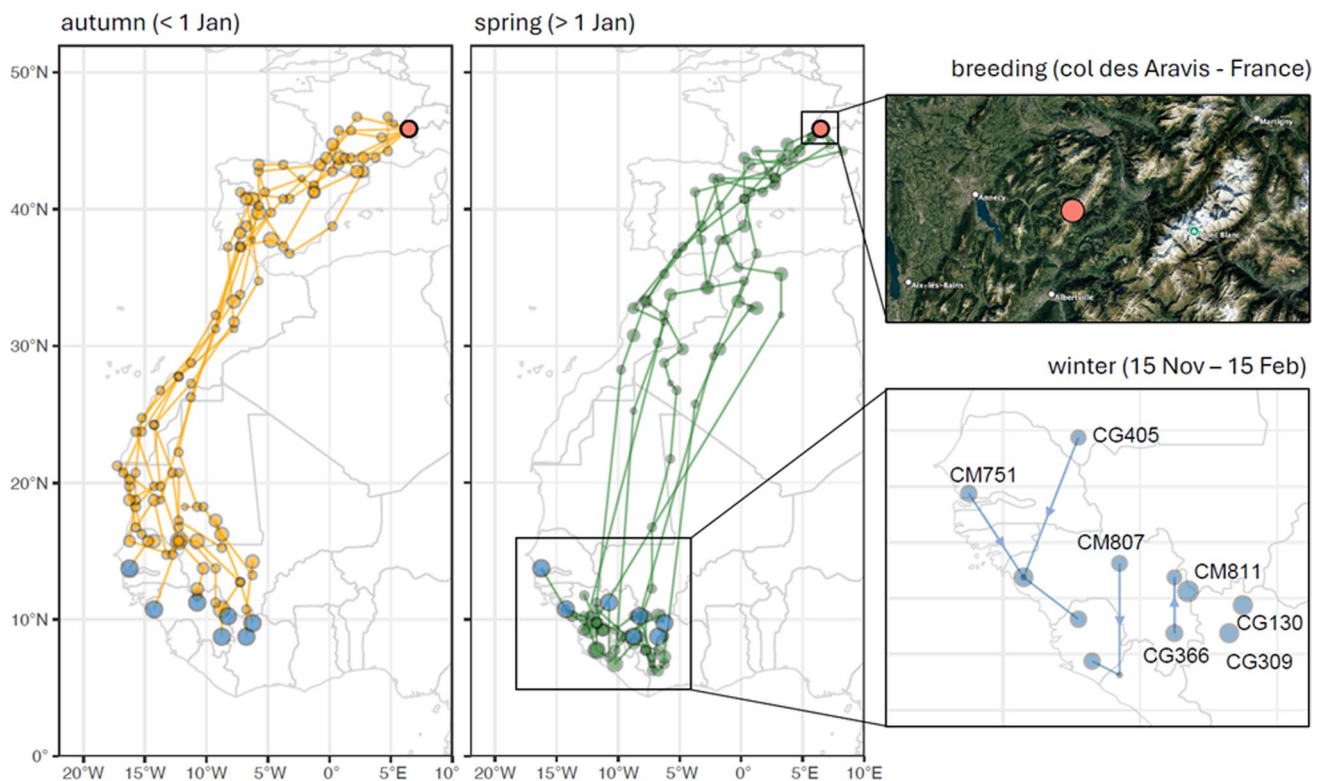


Fig. 1 Migration tracks obtained with multi-sensor loggers for seven whinchats *Saxicola rubetra* breeding in the French Alps at Col des Aravis (red dot), separated in two panels, before 1 January (left, post-

breeding migration) and after 1 January (right, pre-breeding migration). The lower insert reports the non-breeding residency sites as used by each tracked bird

the year are illustrated in Fig. 1 (insert) and Fig. 2, and summarized in Table 1. One female (CM811) used only one non-breeding ground, remaining stationary in south-east Guinea from 20 October to 16 April. Two males used a single non-breeding ground, both in Ivory Coast, before starting to move at the end of March, but without becoming resident. CG130 stayed in Ivory Coast from 26 October to 18 March, then moved to Sierra Leone using 13 different sites on the move, before starting the northwards migration on 23 April. CG309 also stayed stationary in Ivory Coast from 31 October to 22 March, before moving inside Ivory Coast and using 8 different sites before initiating active migration on 24 April. CG366, CM751, CG405 and CM807 moved between a first and a second non-breeding location during the course of the winter. Male CG366 occupied two sites in Guinea 220 km apart (16 October–22 December then 23 December–2 April). Male CM751 occupied one site in Senegal (17 October–17 January) then moved 660 km to Sierra Leone that he left on 19 April. Female CG405 stayed in Southern Mauritania (29 September–11 December) then moved 595 km apart to Guinea (12 December–26 April), before roaming around 26 April–10 May until migration initiation. Female CM807 stayed in Guinea (23 October–12 January) before

moving 400 km to a location in Sierra Leone (14 January–1 May).

On the 1st November, the maximum distance separating two tracked whinchats was 1175 km, while the minimum convex polygon encompassing all seven individuals covered 287,700 km². After the mid-winter relocations of some birds, the same respective values were 885 km and 171,000 km².

Discussion

Anti-clockwise loop migration

The French Alpine Whinchats, like British breeding birds (Burgess et al. 2020), used a westerly route in autumn, reaching Africa near the Gibraltar Strait then descending into West Africa along the Atlantic coast. Westerly autumn migration around the edge of the Sahara Desert has also been shown for other migrant passerines (Lerche-Jorgensen et al. 2017; Ouwehand et al. 2016; Bell et al. 2022; Jiguet et al. 2025; Jiguet et al. 2026). Alpine Whinchats used a direct more easterly route to cross the desert in spring, confirming an anti-clockwise loop migration

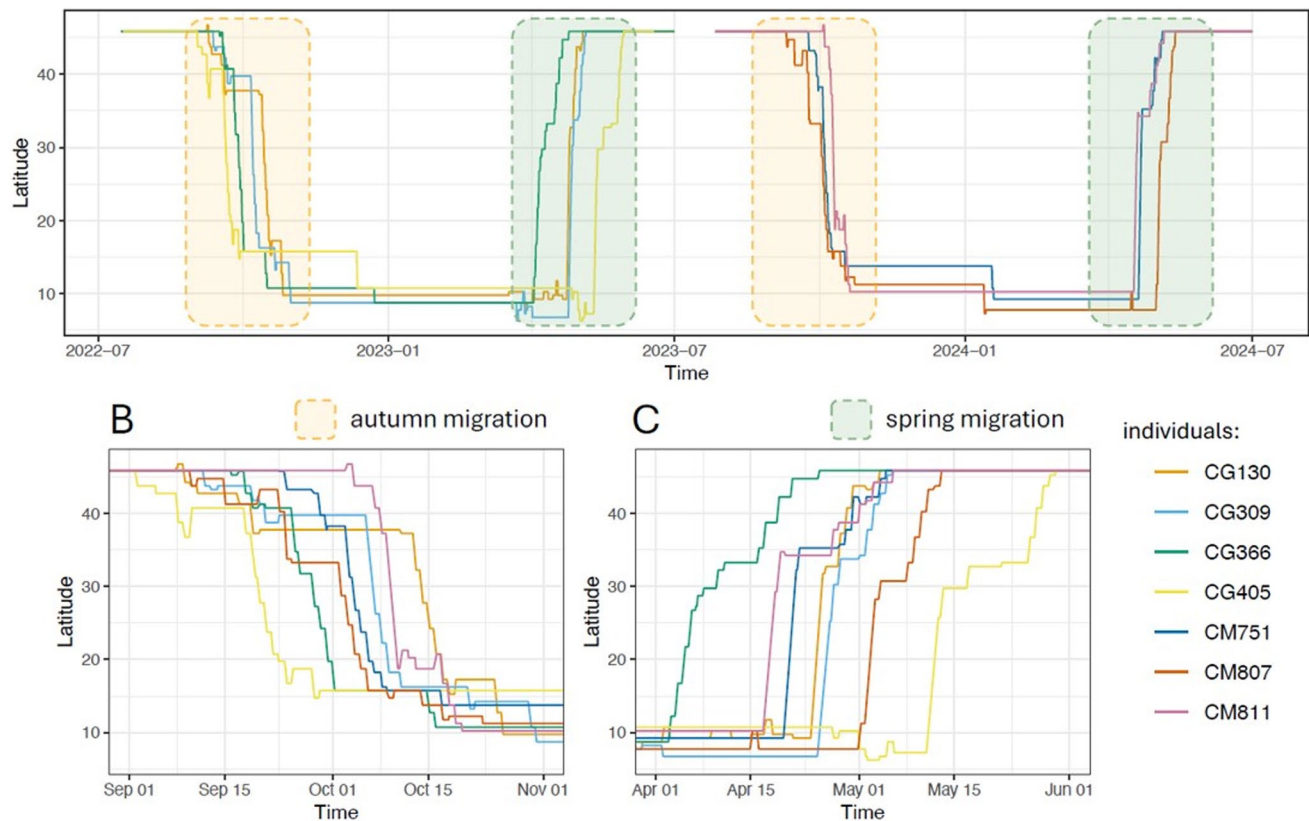


Fig. 2 Variations in latitude for the seven tracked whinchats *Saxicola rubetra* along their annual cycle, with lower inserts focusing on the active migration periods in autumn and spring for all individuals scaled at the same fictive year

Table 1 A summary of stationary periods and movements of the seven tracked whinchats on the non-breeding grounds. Dates correspond to the start of the corresponding period

Individual	Sex	Arrival date	Moving to 2nd site	Roaming	Departure date
CG130	Male	26 October	–	8 March	23 April
CG309	Male	31 October	–	22 March	24 April
CG366	Male	16 October	22 December	–	2 April
CG405	Female	29 September	11 December	26 April	10 May
CM751	Male	17 October	17 January	–	19 April
CM807	Female	23 October	12 January	–	1 May
CM811	Female	20 October	–	–	16 April

(Burgess et al. 2020). This loop migration was however restricted to Africa, and the routes used over continental Europe – France and Spain – were similar in autumn and spring (as found in Tøttrup et al. 2017 or Sjöberg et al. 2025). This pattern, therefore, differs from that of other species, which use markedly different routes in autumn and spring, not only across the Sahara Desert, but also within Europe itself, as observed in songbirds such as the Woodchat Shrike *Lanius senator* (Jiguet et al. 2026) or larger species (e.g., Agostini et al. 2019). Cresswell et al. (2025) also reported a loop migration for birds wintering in Nigeria, and breeding in eastern Europe, but not for birds wintering in Liberia.

Single or multiple non-breeding sites

By looking at the stationary sites used by Whinchat between the post-breeding and the pre-breeding active migration periods, we identified three different movement strategies during the non-breeding period: long-term residency at a single site until migration initiation ($n = 1$), long-term residency until a roaming month before migration initiation ($n = 2$), and a switch from one initial site to a secondary site in the middle of the winter ($n = 4$). This is in line with the use of multiple sites described for British whinchats (Burgess et al. 2020), while this could be more

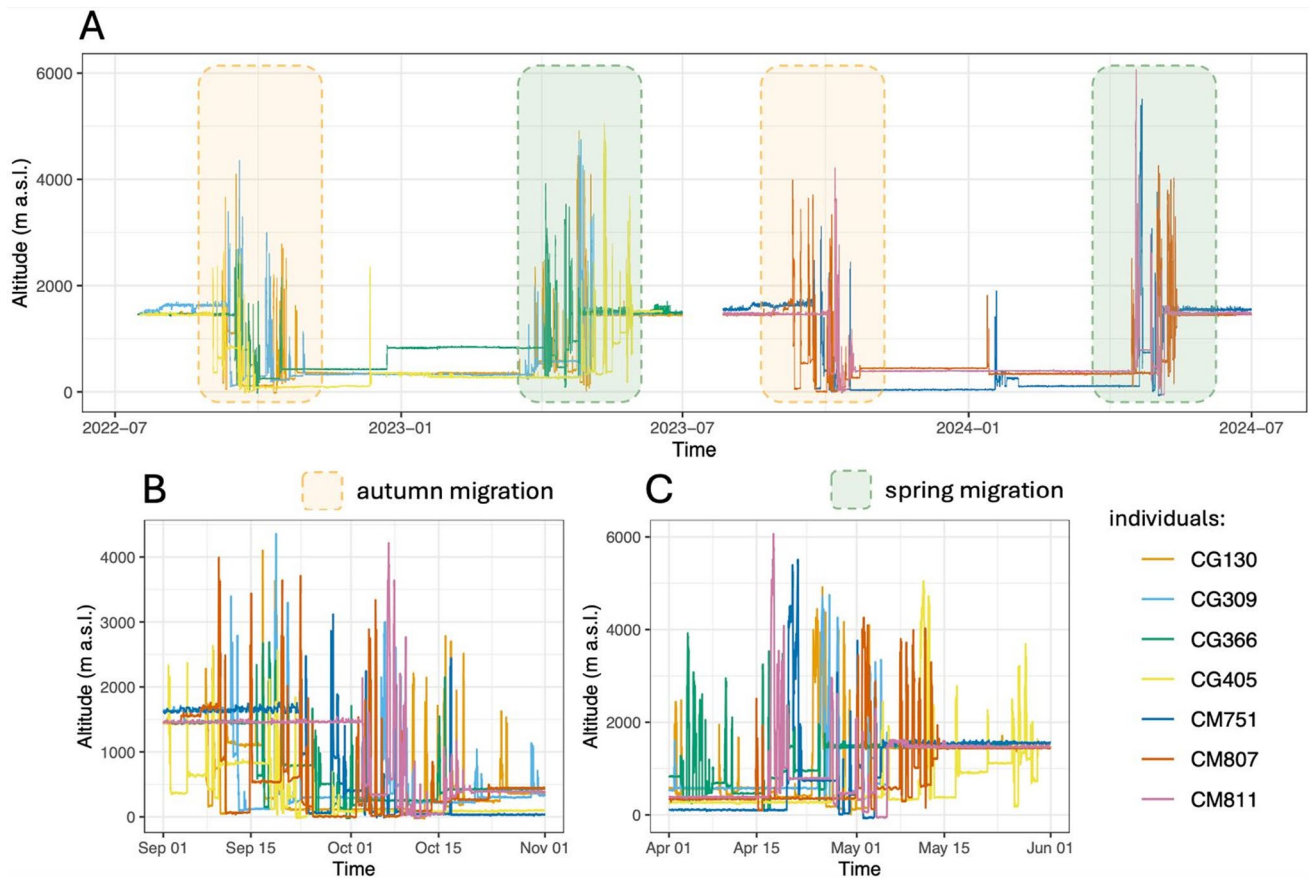


Fig. 3 Variations in altitudes for the seven tracked whinchats *Saxicola rubetra* along their annual cycle, with lower inserts focusing on the active migration periods in autumn and spring for all individuals scaled at the same fictive year

difficult to document from tags deployed and retrieved in winter at fixed non-breeding sites (Cresswell et al. 2025).

The spatial extent of the 7 non-breeding birds was reduced compared to the values recorded for 22 British whinchats (Burgess et al. 2025): non-breeding minimum convex polygon was $\sim 288,000$ for Alpine birds, contra $\sim 1,206,000 \text{ km}^2$ for British birds, so approx. four times less. Furthermore, the maximum distance observed here between two non-breeding locations of Alpine birds was twice the mean (not maximum) distance for the British whinchats wintering in West Africa (1175 km vs. 652 km, Burgess et al. 2020). There are differences in sample sizes between the two studies, which certainly influence these differences (Burgess et al. 2020), but the non-breeding sites of the whinchats breeding at the Col des Aravis seem to be more aggregated and demonstrate some degree of migratory connectivity. These differences are also likely attributable to the different technologies used, as geolocations estimated from multi-sensor devices combining light and pressure provide substantially higher precision for both identifying movements during the non-breeding period and quantifying them.

Short-step autumn migration

The post-breeding migration lasted 17–50 days, and we identified three types of migratory flights, the most frequent lasting on average 9 h. Shorter flights (less than 6 h) could be repositioning movements, while very long flights (> 15 h) correspond to desert crossings (see Fig. 3). Concerning the stopovers, we can identify two types of durations: long stopovers after desert crossing (4–21 days), and shorter stopovers lasting 1–10 days. Overall, the autumn migration was constituted of short steps, even during desert crossing (except for one individual; see Fig. 3), and the migration duration shortened when the departure date was delayed.

Accelerated spring migration

All birds departed directly from their late-winter non-breeding site, while Risely et al. (2015) reported that most whinchats fatten up locally before the spring migration departure. The spring migration was shorter than the autumn migration, lasting 12 to 24 days, consisting of typically 9 or 10 active flights, the first being a long flight for crossing the

Sahara Desert and lasting more than one day (see Figs. 2 and 3; only one individual made the Sahara Desert crossing in multiple steps—the earliest leaving). Most spring stopovers were short (85% lasting 1 or 2 days), leading to a short spring migration and a rapid return to the breeding site. The distance covered in spring is shorter, which is quite typical for species with loop migration (Tøttrup et al. 2012; Jiguet et al. 2026). The flight altitude reached higher levels, both in 2023 and 2024 (see Fig. 3), with all individuals climbing up to 4000 m a.s.l., and one reaching more than 6000 m a.s.l., which is in line with a non-stop flight to cross the Sahara Desert, and higher altitude during daylight to avoid overheating (Dufour et al. 2026).

Although our sample is small, males also appeared to initiate spring migration earlier than females, which may reflect protandry—a common phenomenon in which males arrive or migrate before females to secure territories and ensure access to mates (Kokko et al. 2006; Briedis et al. 2019; Nakazawa et al. 2023). Risely et al. (2015) reported that males leave the non-breeding sites eight days earlier than females in Nigeria. In contrast, females may time their migration to coincide with peak resource availability, optimizing conditions for successful reproduction. While these observations are consistent with sex-specific migration strategies, caution is warranted given the limited number of individuals tracked in this study.

Conservation implications

The stairway migration reveals the importance of maintaining a network of migratory stopover sites along the flyway, even along the western edge of the Sahara Desert. Any desertification there could impair the step migration strategy of the species. However, the species' migration strategy of Whinchat appears to be quite flexible, with possible adaptations, such as the acceleration of the autumn migration if starting late. The spring migration return is classically accelerated compared to the autumn as for other passerine species showing loop migration (Jiguet et al. 2026). We observed variations around this general pattern, with one (late) direct Sahara Desert crossing in autumn, and one (earliest) stepped Sahara Desert crossing in spring. This flexibility could be advantageous to adapt to a changing world, while the ability to fly at very high altitudes to cross the Sahara Desert should also mitigate the impacts of climate warming for a successful desert crossing (Jiguet et al. 2019; Dufour et al. 2026). In spring, pre-migration fueling is certainly key to a successful desert crossing, which occurred right after leaving the late-winter staging site, while the use of multiple sites during the winter might again offer the possibility to select the optimal sites for fueling to pre-migratory whinchats, and might be related to an optimization of foraging due to seasonal rains (). Altogether, these characteristics do not identify Whinchat as particularly sensitive to climate

change where desert crossing is concerned, compared to other species with low altitude or only nocturnal flights. They might, however, be sensitive to habitat loss and degradation along the autumn migration flyway and on the late-winter fueling sites.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10336-026-02409-1>.

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Data availability The tracking data used in this study are available on Movebank (<https://www.movebank.org/>) under the study ID 886436554.

Declarations

Conflict of interest The authors declare that they have no conflict of interest with the content of this article. The ringing and tagging program was authorized by the French ringing authority CRBPO under the license reference PP1190.

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