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Short communication

Short-distance migration of Wrynecks *Jynx torquilla* from Central European populations

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European Wrynecks *Jynx torquilla torquilla* have generally been considered to be long-distance Palaearctic–African migrants that spend the non-breeding season in Sahelian Africa, where they have been reported regularly. Results from tracking individual birds showed that Wrynecks from two Central European populations migrated only relatively short distances to the Iberian Peninsula and northwestern Africa (*c.* 1500 km and 3000 km, respectively), compared with a minimum distance of about 4500 km to Sahelian Africa. Additionally, differences in wing lengths of populations from Central and Northern Europe support the idea of leapfrog migration, populations from Northern Europe being long-distance migrants with a non-breeding distribution in Sahelian Africa.

Keywords: geolocator, long-distance migration, non-breeding, sub-Saharan Africa, tracking, wing length, woodpecker.

Wrynecks *Jynx torquilla* show considerable variation in migratory behaviour at the subspecies level. *Jynx torquilla tschusii* breeding on the Apennine Peninsula and the eastern Adriatic coast, and *Jynx torquilla mauretanica* from the Balearic Islands and northern Africa, are resident, as are southern European populations of the nominate *Jynx torquilla torquilla* (Cramp 1985, Zwarts *et al.* 2009). All other populations of the nominate form are thought to migrate to Sahelian Africa; populations from N/NW Europe migrate via the North Sea coasts and the Iberian Peninsula and populations from NE/Central Europe migrate via the Apennine and Balkan Peninsulas (Cramp 1985, Zwarts *et al.* 2009). Eastern Eurasian populations probably migrate via the Arabian Peninsula to Africa or further east to southern Asia (Priklonskii *et al.* 2005). This is also reflected in morphological features: the resident subspecies *J. t. mauretanica* has a wing length of around 79 mm, *J. t. tschusii* around 84 mm and the migratory nominate form *J. t. torquilla* has a wing length of about 89 mm (Eck & Geidel 1973, Brichetti & Fracasso 2007). Additionally, Eck and Geidel (1973) showed that Wrynecks of the nominate form from Northern Europe and Central Europe have the most pointed, longest wings with a relatively short tail, whereas birds of the subspecies *J. t. tschusii* and *mauretanica* from around the Mediterranean Sea have both short wings and short tails.

The non-breeding areas, i.e. the main areas of residency during the non-breeding period, are thought to include the entire Sahelian savannah belt from Senegal in the west to northern Kenya in the east (e.g. Cramp 1985), based mainly on direct observations of Wrynecks. However, there are few ring recoveries from Africa: two Wrynecks from Sweden and one from Spain have been recovered in Morocco, and one individual from the Czech Republic has been recovered in Libya, suggesting population-specific passage areas and/or non-breeding areas (Reichlin *et al.* 2009, SEO/Birdlife 2012).

There is also indirect evidence for the location of the Wrynecks' non-breeding areas in Sahelian Africa in that changes in the population index of several European breeding populations (including populations from Germany) were negatively correlated with a precipitation index of the western Sahel (Zwarts *et al.* 2009). Additionally, stable isotope analysis of feathers grown during the boreal winter predicted a non-breeding area in the western Sahel zone and western Sudan/Ethiopia for a German population of Wrynecks, and non-breeding areas that include almost the whole of sub-Saharan Africa and, with lower probability, southern parts of the Iberian Peninsula and northwestern Africa for a Swiss population (Reichlin *et al.* 2010). Despite many observations of Wrynecks of unknown origin in Africa (Cramp 1985), population-specific wintering ranges are still unknown. In this study, we determined the non-breeding areas of Wrynecks from two Central European populations in Germany and Switzerland using geolocators.

METHODS

The study population in southwestern Switzerland (46°14′N, 7°22′E) breeds in an intensive agricultural landscape with fruit tree plantations and vineyards. The study population in eastern Germany (52°01′N, 13°04′E) is located in a former military training area, now

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covered with arid and semi-arid grassland and managed grassland with fruit trees. Both populations breed in nestboxes. Wrynecks from both populations belonged to the nominate subspecies *J. t. torquilla*.

During the breeding season of 2011 (May–July), we captured 43 adult breeding Wrynecks in Switzerland and 10 in Germany, either in the nestbox or at the nestbox entrance, and fitted these birds with geolocators. We did not determine sex in the field since Wrynecks are monomorphic and cloacal protuberance did not allow sex discrimination. To compare recapture rates in 2012, we used adult breeding birds that were ringed only as a control group. Geolocators (SOI-GDL1.0 including a 5-mm-long light guide stalk, Swiss Ornithological Institute) were mounted on the birds' backs using a leg-loop silicon harness. The device including harness weighed 1.2 g, corresponding to 3.0–4.0% of adult body weight (average body weight 36.3 g, range 30–45 g, $n = 198$ Wrynecks caught in both study sites in 2011 and 2012).

Data analysis

We used the threshold method for positioning by light (Hill 1994, Lisovski *et al.* 2012). Sunrise and sunset times were determined using GeoLocator software (Swiss Ornithological Institute unpubl. data). Non-natural sunrises/sunsets, e.g. when entering a nestbox/cavity before sunset and leaving after sunrise, were removed for the calculation of geographical position. We determined non-breeding stationary periods by the ChangeLight function (R package GEOLIGHT 1.02, probability of change = 0.8, minimum stationary period = 3 days; Lisovski & Hahn 2012). Having defined stationary periods, data for individual non-breeding areas were calibrated using Hill–Ekstrom calibration by minimizing the variance of latitudes using a range of sun elevation angles (see Lisovski *et al.* 2012). The site-specific sun elevation angles varied between –3.8° and –6° (mean = –5.2°). We then filtered all outlying positions with distances > 800 km from the median latitude of the respective non-breeding area. For the filtered positions, we applied kernel density estimation using ARCMAP 10.0 (ESRI) with a search radius of 200 km. We calculated kernel densities encompassing 80% and 90% of the maximum density.

Wing length

We gathered data on wing length of nominate Wrynecks from different European breeding sites and on migration. Besides our study sites, we acquired data from breeding populations in Norway (Revtangen Ornitologiske Stasjon, T. Lislevand, pers. comm.) and from a passage site at Ouadâne, Mauritania (Swiss Ornithological Institute, unpubl. data). Data from the Swiss breeding birds consisted only of length of the third primary (P3). We therefore recalculated wing length using a linear regression of wing length against P3 from birds caught in April 2013 in Switzerland using tape-luring (wing length (mm) = 0.876 ± 0.066 (se) × P3 length (mm) + 30.49 ± 4.27 (se), $R^2 = 0.71$, $n = 76$).

RESULTS

Seven Wrynecks from the Swiss population equipped with geolocators were recaptured in 2012 (16.3%). One bird had lost the device. In ringed controls, the recapture rate was 11.8% (mean annual local return rate in period 2002–2009 = 16.1%, range 7.3–32%). For the German population, one individual with a geolocator was recaptured in 2012 (10%). In ringed controls, the recapture rate was 16.7% (mean annual local return rate in period 2009–2011 = 20.7%, range 12–27.6%; mean 2002–2008 = 15.7%). The body mass of Wrynecks returning with a geolocator was not significantly different from the control group (median of 37 g in controls and 36 g for birds with a geolocator, Mann–Whitney Rank Sum Test, control group 2012, $n = 102$, $P = 0.11$).

Birds from Switzerland used non-breeding areas in Portugal ($n = 2$), Spain ($n = 3$) and Morocco ($n = 1$): the single individual from Germany spent the boreal winter in Morocco (Fig. 1a); no bird in our study spent the non-breeding season in Sahelian Africa. The loxodromic distance between the centroid points of breeding and non-breeding areas for the Swiss birds ranged from 1250 to 1950 km, averaging 1500 km, whereas the German Wryneck covered 3050 km (Fig. 1d).

One Wryneck from the Swiss population arrived in the non-breeding area on 6 September, and all others between 2 and 16 October (on average 3 October; Supporting Information Table S1). The Swiss birds subsequently stayed in their non-breeding areas for 141–186 days (Fig. 1c, average 157 days), and departed from the non-breeding areas between 2 and 9 March (average 6 March). The Wryneck from the German population arrived in the non-breeding area on 2 October, stayed there for 166 days, and departed on 15 March.

During the non-breeding period, all individuals sometimes rested in cavities during the night and/or during the day as recorded by unnatural sun events when entering ('evening') or leaving ('morning') the cavity, usually for a few days only (Fig. 1d). However, one Swiss bird and the German bird used cavities more intensively during 76% and 70%, respectively, of the nights in the non-breeding period.

Wing lengths differed significantly between the different populations (Kruskal–Wallis one-way analysis of variance, $H = 296$, df = 4, $P \leq 0.01$; Table 1). The

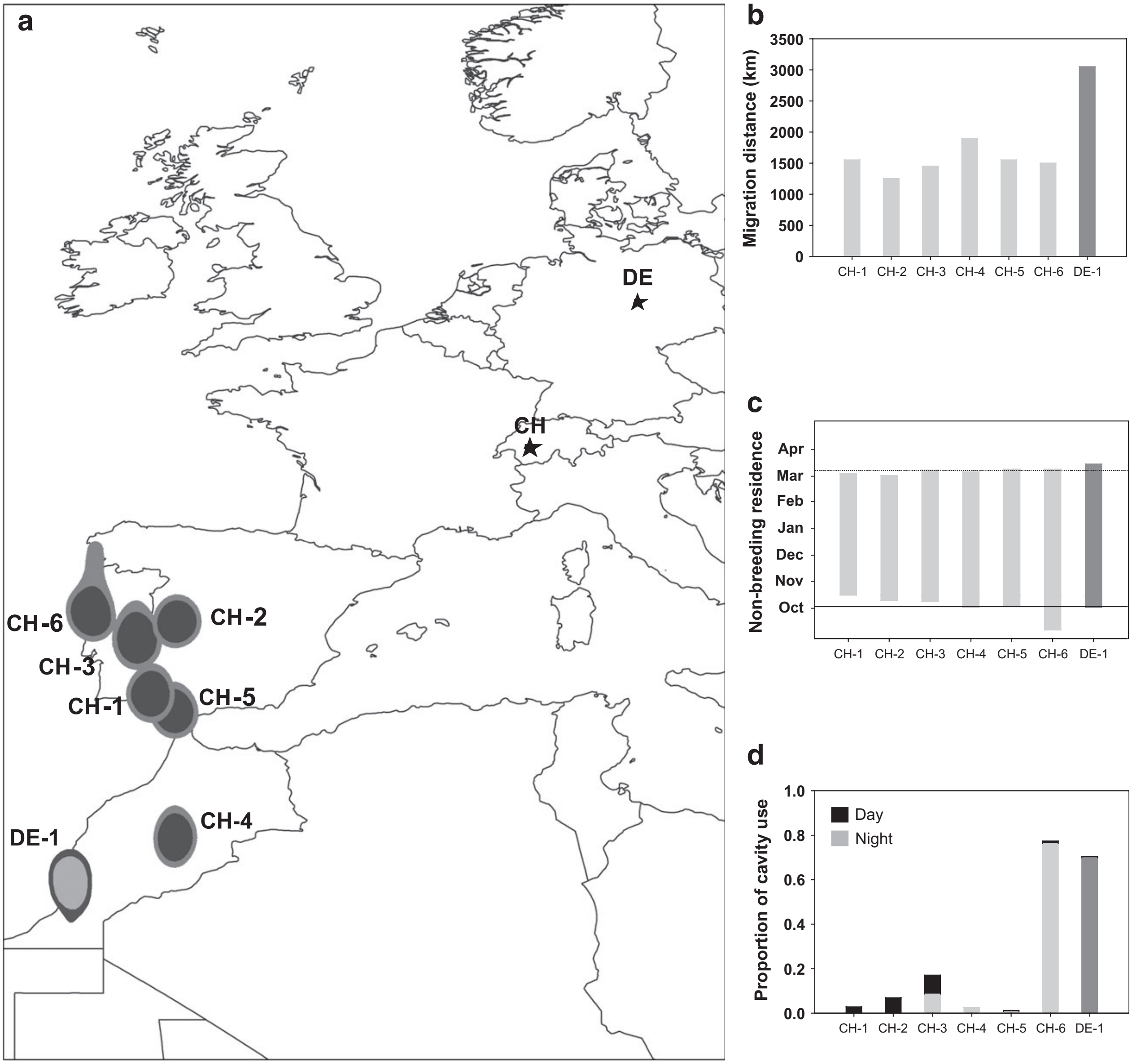

Figure 1. (a) Overview of the non-breeding areas (depicted as 80% and 90% kernel densities) used by the six Wrynecks from Switzerland (CH-x) and one from Germany (DE-1). (b) Loxodromic distances between the breeding and non-breeding areas. (c) Time spent in the non-breeding areas; horizontal lines indicate the mean date of arrival and departure of all seven birds. (d) Proportion of days the birds used a cavity during the non-breeding period divided by day and night.

median wing length of local breeders from Norway was significantly longer than that of breeders from Germany and from Switzerland. Wing lengths of birds from Germany were in turn significantly longer than those from Switzerland. However, wing lengths of birds in Mauritania significantly differed from local breeders from Switzerland and Germany, but not from breeding birds from Norway ($P < 0.05$, Dunn's pairwise comparison test).

DISCUSSION

None of the seven Wrynecks tracked migrated to Sahelian Africa, in contrast to the current understanding of the location of the non-breeding areas of Central European Wrynecks (e.g. Cramp 1985, Reichlin *et al.* 2009). Most birds from the Swiss population spent the boreal winter on the Iberian peninsula; only one bird was located further south in Morocco. The one bird

Table 1. Overview of wing lengths ('WL') of the nominate form *Jynx torquilla torquilla* from different breeding populations and on migration. Median wing length is given with the 25% and 75% percentiles.

Period	Country	Coordinates	Median WL	25%	75%	Group	*n*	Source
Spring migration	Norway	60°N, 5.5°E	89.5	89	90.9	a	63	I
Breeding	Germany	52°N, 13°E	88.5	87.5	90	b	239	II
			88.0				1	geolocator bird
Breeding	Switzerland	46.1°N, 7.2°E	87.0	85.7	87.9	c	469	III
			87.4	86.3	88.2		6	geolocator bird
Boreal winter	Mauritania	20.9°N, 11.6°W	91.0	89	92.5	a	78	III

Sources are (I) Revtangen Ornitologiske Stasjon (T. Lislevand pers. comm.), (II) D. Tolkmitt (unpubl. data) and (III) Swiss Ornithological Institute. The letters in group (a, b, c) indicate different populations based on differences in wing length. Wings of breeding birds from Norway were significantly longer than wings of breeding birds from Germany and Switzerland, but not significantly different from birds on passage caught in Mauritania (Dunn's pairwise comparison test, $P \leq 0.01$, see text for further information).

from Germany migrated furthest, to southern Morocco. Observations of Wrynecks in these regions and other areas around the Mediterranean Sea are common during the boreal winter. However, they have typically been assigned to the resident subspecies *J. t. tschusii* and/or *J. t. mauretanica*. As it is difficult to distinguish these two subspecies from the nominate form *Jynx t. torquilla* in the field (without having the bird in the hand, see e.g. Brichetti & Fracasso 2007), subspecies assignment might be (partly) erroneous.

Zwarts *et al.* (2009) suggested, based on a correlations of a Sahelian precipitation index and changes in various Wryneck populations, that Wrynecks might winter in Sahelian Africa. Reichlin *et al.* (2010) used a triple stable isotope assignment approach to determine wintering areas of Wrynecks from Germany and Switzerland that partly supported this view. Expected wintering areas for Wrynecks from Switzerland, however, were assigned to West Africa, and with a lower probability, northern Africa, the Iberian Peninsula as well as the Congo basin (figure 3 in Reichlin *et al.* 2010). Wrynecks of the German population were assigned with the highest probability to the Horn of Africa. However, our results did not match the proposed main wintering areas (Fig. 1a).

Zwarts *et al.* (2009) focused their study on the Sahel zone as a wintering area for many species in general, and they probably did not relate conditions of many potential wintering sites to population trends to cross-check for alternative non-breeding strategies in Wrynecks. Similarly, Reichlin *et al.* (2010) determined a very broad potential wintering range for Wrynecks of Switzerland and Germany, mainly due to low geographical differences in stable isotopes in Sahelian Africa. A re-analysis using recently developed isotope cluster approaches (Hobson *et al.* 2012) might give more reliable results.

If the Wrynecks from our study sites migrated to Sahelian Africa, the minimum distance to be covered would have been around 4500 km. The birds from Switzerland covered on average only one-third of this distance, the bird from Germany two-thirds. Wrynecks observed in Sahelian Africa might originate from more northerly populations, e.g. from Scandinavia, and therefore would have to cover much longer distances, supporting the idea of a leap-frog migration (Reichlin *et al.* 2010). This should be reflected in morphological differences in their flight apparatus (e.g. as in Wheatears *Oenanthe oenanthe*, Förschler & Bairlein 2011). Thus, we would expect gradually increasing wing lengths from southern to northern Wryneck populations. We indeed found significant differences in wing length; Scandinavian breeding birds captured on migration in Norway have longer wings than birds breeding in Germany, which in turn are larger than breeding birds from Switzerland (Table 1, $P < 0.001$, Dunn's method of pairwise multiple comparisons). In addition, no significant differences in wing length could be found between these Scandinavian breeders and migrating birds captured in Mauritania. Thus, birds on passage in Mauritania match in size only with the Scandinavian breeders, strongly supporting our idea that Wrynecks breeding in Northern Europe surpass their conspecifics in Central Europe to migrate to Sahelian Africa, whereas populations from Central Europe stay in southern Europe/northern Africa. We furthermore found that at least two Wrynecks spent a considerable amount in cavities overnight (Fig. 1d). This behaviour shows that Wrynecks in their non-breeding areas apparently behave similarly compared with behaviour at the breeding grounds.

Overall, our results shed light on the presumed migration of the Wryneck. The current belief that all individuals of the nominate form *J. t. torquilla* are consistently long-distance migrants should be revised. Yet, there is clearly a need for more information from other Wryneck populations in order fully to support the leap-frog migration hypothesis. Such information is important for conservation, as several European Wryneck populations are declining (PECBMS 2012). Environmental conditions in Africa, such as precipitation patterns in the Sahel zone (e.g. the Sahelian rainfall index, Zwarts *et al.* 2009), are unlikely to affect all European populations, and thus the causes might originate elsewhere.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1. Timing of migration of adult Wrynecks from a Swiss (CH) and a German breeding population (DE).