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Reed warblers migrating through Portugal: climatic influence on stopover ecology over the last decade

Pedro M. Araújo*, Luís P. da Silva, Vitor H. Paiva, Jaime A. Ramos

MARE – Marine and Environmental Sciences Centre, Department of Life Sciences, University of Coimbra, 3000-456 Coimbra, Portugal

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A B S T R A C T

The arrival and breeding dates of small migrant birds have advanced throughout Europe. This study evaluates the hypothesis of a faster migration along the migratory route, which should lead to a decrease in stopover duration in staging areas over the last decades. Several climatic predictors were analysed as proxies to understand the stopover ecology of reed warbler *Acrocephalus scirpaceus* migrating through Central Portugal. The minimum stopover duration of migratory reed warblers decreased significantly over the last decade during both the spring and autumn migrations. Warmer conditions en route should increase food availability, increasing the body condition of departing birds and the quality of departing sites en route to Portugal, such that migrants will reduce the stopover duration at Portuguese reedbeds.

1. Introduction

Climate change has advanced the seasons and thus the phenology of many organisms during the last decades (Crick et al., 1997; Parmesan and Yohe, 2003). It is clear that the arrival and breeding dates of small migrant birds have advanced throughout Europe (Cotton, 2003; Hüppop and Hüppop, 2003; Both et al., 2005), which can be explained by earlier departures due to increasing winter temperatures in sub-Saharan Africa (Cotton, 2003) and/or a faster migration due to improved environmental conditions en route (Marra et al., 2005; Visser and Both, 2005). Visser and Both (2005) showed that male pied flycatcher *Ficedula hypoleuca* breeding in Netherlands arrive and breed earlier in years with higher temperatures at the breeding site. Other species such as the reed warbler (*Acrocephalus scirpaceus*) have also advanced their laying dates, although changes in vegetation and insect development due to increases in temperatures in April and May may have a larger effect (Halupka et al., 2008). Furthermore, birds may migrate faster during periods of warm weather (Richardson, 1990; Schaub and Jenni 2001a; Jenni and Schaub, 2003), and this could partly explain their earlier arrival and breeding dates (Visser and Both, 2005). If environmental conditions are improving en route we should detect a decrease in stopover duration in staging areas over the last decades, but this has not yet been investigated. Departure dates from European breeding grounds have also advanced, which is related to the fact that the breeding season starts and terminates earlier (Jenni and Kéry, 2003). This in turn can partly be related to elevated summer temperatures (Cotton, 2003), which directly or indirectly affect the migration, although for reed warblers other factors such as the interspecific competition with great reed warblers *Acrocephalus arundinaceus* (Schaefer et al., 2006) may also be important.

Stopover duration, flight speed, flight duration and fuel deposition rates (Hedenstrom and Alerstam, 1998; Nilsson et al., 2013) are important factors determining overall migration speed in long-distance migrant passerine birds (Schaub and Jenni, 2001a). Moreover, fuelling rates at stopover sites are crucial to determine the overall speed, duration and success of migration (Schaub and Jenni, 2001a). Changes in stopover duration depend on: (i) feeding conditions, (ii) degree of pre-migratory fueling, (iii) feeding behavior, and (iv) stopover time not used for fuel deposition (Nilsson et al., 2013). Therefore, the amount of time a migrant will stay at a stopover site depends largely on the quality of such a site, as was shown by Ktitorov et al. (2010) via radio-tracking of migrant reed warblers. However, the influence of climatic variation on stopover duration has received little attention so far. The relationship between variation in atmospheric parameters and passerine migration parameters, such as stopover duration, is difficult to assess because many factors must be taken into consideration; e.g., in spring birds migrate at a consistently higher speed than in autumn (Fransson, 1995; Bachler et al., 2010; Nilsson et al., 2013). Nevertheless, birds appear to select favourable wind conditions to migrate, and tail winds are crucial for long-

* Corresponding author.
E-mail address: mmiguelinhu@gmail.com (P.M. Araújo).

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distance migrants to overcome large ecological barriers (Liechti, 2006).

Several recent studies found a significant relationship between large-scale weather phenomena such as the North Atlantic Oscillation (NAO) during winter and timing of spring migration (Forchhammer et al., 2002; Hüppop and Hüppop, 2003; Vahatalo et al., 2004). The NAO is characterised by an oscillation in atmospheric mass between the subtropical high-pressure zone of the Azores and the low-pressure zone of Iceland (Ottersen et al., 2001). Positive NAO index values during winter and early spring indicate warm air masses from the Atlantic moving eastwards, leading to higher temperature and precipitation (i.e. rainfall) in northwestern Europe. Negative winter NAO index values indicate weaker westerly winds, leading to a stronger influence of the continental winter high, which brings lower temperatures and less precipitation in Northern Europe (Hurrell, 1995; Ottersen et al., 2001; Stenseth et al., 2003). The use of large-scale climatic phenomena reduces the temporal and spatial variability into simpler measures such as the NAO (Stenseth et al., 2003), but we must bear in mind that the environmental factors sensed by the birds are variations in, amongst other factors, temperature and/or wind conditions (Hüppop and Hüppop, 2003) that are correlated with large-scale climatic indices. There is very little information about the effects of climate change and global warming on a complete migration cycle (Walther et al., 2002), and evidence for a prolonged breeding season and delayed or advanced autumn migration is not clear (Cotton, 2003; Jenni and Kéry, 2003; Visser and Both, 2005; Saino et al., 2011). The influence of environmental parameters on stopover duration, both before and after individuals cross important ecological barriers (Calvert et al., 2009) is particularly important to evaluate the hypothesis of a higher-speed migration. Stopover sites in Portugal are important in this context given their geographical location after (spring migration) and before (autumn migration) the Gibraltar strait and the Sahara desert.

In the present study we used large (winter NAO index) and medium-scale environmental variables (temperature, precipitation and wind speed in North Africa, Central Portugal and Central Europe) because they are likely to reflect better the migratory journey of passerines from Northern Europe through Southern Europe and into Africa, and vice versa. We used 10 years of data from migrant reed warblers in Central Portugal to assess whether minimum stopover duration has decreased both during autumn and spring migrations, and to evaluate the relation of climatic variables with minimum stopover duration and body mass variation during autumn and spring stopover periods. Reed warblers are adequate to examine this aspect because their migration is characterised by short bouts of flight alternating with long stopovers to refuel (Bibby and Green, 1981; Schaub and Jenni, 2001a; Rguibi-Idrissi et al., 2003). We predicted that in years with higher NAO index, stopover duration should decrease during the spring migration due to higher temperature, less precipitation, wind speed and south-westerly winds (Bairlein and Hüppop, 2004; Stervander et al., 2005). During autumn migration, we expected that stopover duration should decrease following warmer conditions in Northern Europe. In relation to medium-scale environmental variables, an increase in temperature and a decrease in precipitation in Central Europe and Portugal should be associated with a decrease in stopover duration. Precipitation inhibits bird flight (e.g. Kerlinger, 1989; Yates et al., 2001), therefore a decrease in rainy days in late summer/autumn will decrease the stopover duration. Selection of favourable wind conditions (e.g. northerly winds) may promote accurate flight, increasing the total migration speed and decreasing the stopover duration along the route (McLaren et al., 2012).

2. Materials and methods

2.1. Study area

Data on minimum stopover duration and body mass variation during the stopover period (hereafter termed body mass variation) of reed warblers was collected in the Paul do Taipal reedbed (40°11′N 008°41′W), Mondego river Valley, Central Portugal between 2002 and 2012. The dense vegetation is dominated by common reed (*Phragmites australis*) with hedges of grey willow (*Salix atrocinerea*). The reedbed vegetation structure remained fairly similar during the long-term study because the areas of open water and mist netting lines were managed and the excess of vegetation was removed.

2.2. Bird sampling

Mist netting sessions were operated every 10 days, following the procedures of constant effort bird-ringing sites (Thomson et al., 2009; Cave et al., 2010), from March to October, 2003–2012, and from June to October in 2002. To strengthen our confidence in the minimum stopover duration estimates, we decided to operate ringing sessions every 5 days for the autumn migration from 2010 to 2012, to assess whether similar values would be obtained as for ringing at 10-day intervals. The mist nets were set before dawn and operated for 5 h after sunrise. In each session 120–240 m of nets were operated. Captured birds were ringed, weighed, aged and sexed according to Svensson (1992). Minimum stopover duration of each individual was determined for each year by calculating the number of days that elapsed from the first capture until the last recapture (Chernetsov, 2012). It was assumed that birds did not leave the site between the first and last capture. To separate breeding birds from migrant reed warblers we considered the entire history of each individual, and if the bird was present during the breeding season it was considered a summer-breeding bird and removed from analysis. Otherwise, it was considered a migratory bird and entered into data analysis. Body mass variation corresponded to the difference in mass between the initial capture of an individual and its final recapture during each migratory season: spring migration = 15 March to end of May, autumn migration = 15 July to end of October. All our birds were in a non-moulting state and we did not detect significant differences in the minimum stopover duration between adults and juveniles ($t_{572} = -1.42$, $p = 0.15$). Our purpose in this study was to compare minimum stopover duration (and not survival) among years and to evaluate its relation with climatic variables, and we did not use Cormack–Jolly–Seber capture–mark–recapture (CMR) methods.

2.3. Environmental predictors

We selected several environmental parameters that were likely to influence the minimum stopover duration of Afro-Palaearctic migratory passerines. Apart from large-scale climatic variables such as the NAO index, we defined climatic variables from Central Europe, Central Portugal and North Africa (see Table S1 and Fig. S1 in the supplementary online Appendix) that are likely to influence minimum stopover duration in Portugal during both the autumn (Europe to Africa) and the spring (Africa to Europe) migrations. Data from Central Europe was used due to the relatively high number of individuals with French, Belgian and Dutch rings captured at our study site ($n = 222$) and reported by Procházka et al. (2013). The NAO index may represent different climatic influences on bird migration and was extracted from https://climatedataguide.ucar.edu/climate-data/hurrell-north-atlantic-oscillation-naoindex-station-based and http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_nao_index/nao.shtml. We used the extended