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DISTRIBUTION, PHENOLOGY AND CONDITION OF AQUATIC WARBLERS *ACROCEPHALUS PALUDICOLA* MIGRATING THROUGH PORTUGAL

DISTRIBUCIÓN, FENOLOGÍA Y CONDICIÓN DEL CARRICERÍN CEJUDO *ACROCEPHALUS PALUDICOLA* MIGRANDO EN PORTUGAL

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SUMMARY.—We show that the low number of aquatic warblers *Acrocephalus paludicola* ringed in Portugal is explained by the low ringing effort, and that Portugal is an important country for its migration. Most of the seven sites where the species was detected are recognized for their biological importance and protected. There seemed to be a decline in the number of birds caught, particularly of juveniles, which might be associated with a decline in breeding success. All aquatic warblers were captured in August and September, showing a peak at the end of August, and adults migrated significantly earlier than juveniles. Both age classes significantly increased in body condition during the season. The potential non-stop flight range varied substantially between individuals: some birds would be able to migrate to the wintering quarters without refueling, but the low flight range of many individuals suggests that some fueling takes place in Portugal.

RESUMEN.—Se muestra que la escasa cantidad de carricerines cejudos *Acrocephalus paludicola* anillados en Portugal se debe al escaso esfuerzo anillador, y que Portugal es una localidad importante para la migración de esta especie. La mayoría de los siete lugares en donde la especie fue detectada se encuentran protegidos y son reconocidos por su importancia biológica. Se aprecia un declive en el número de aves capturadas, particularmente juveniles, que podría estar asociado a un descenso en el éxito reproductor. Todos los individuos fueron capturados en agosto y septiembre, mostrando un pico de capturas a finales de agosto. Los adultos migraron significativamente antes que los juveniles, y ambos grupos de edad mejoraron su condición corporal significativamente durante la estación. Las posibilidades de vuelo sin escalas variaron de manera sustancial entre los individuos, así algunas aves serían capaces de migrar ininterrumpidamente hasta sus cuarteles invernales, pero la baja distancia de vuelo de muchos individuos sugiere que algún reabastecimiento ocurre en Portugal.

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The aquatic warbler *Acrocephalus paludicola*, hereafter AW, is a long-distance migratory passerine that breeds in fen mires from Poland to Russia and winters in sub-Saharan Africa. This habitat specialist has declined substantially in numbers and range since the early 1900s, currently having a global population of 12.000 - 20.000 birds, and is the only globally threatened passerine that occurs in continental Europe (AWCT, 1999; BirdLife International, 2004).

The population decline and current conservation status seems to have been caused mainly by habitat loss at the breeding quarters, due to changes in hydrological regimes, abandonment, and other management practices (AWCT, 1999), where intensive studies have been carried out (e.g. Tanneberger, *et al.*, 2008). However, factors that influence population dynamics may also occur at other periods of the annual cycle, both at the population and at the individual levels (Norris and Marra, 2007), and so it is crucial that this species is also studied during the non-breeding season. Indeed, a major wintering site was recently discovered in northern Senegal, as a result of research using indirect methods (Pain, *et al.*, 2004; Walther, *et al.*, 2007), where some potential important threats were identified (AWCT, *pers.com.*). However, nothing is known about the habitat changes at stopover sites during migration. In fact, the identification of the major sites used during migration, as well as the migration strategy of this species, has only recently been the subject of detailed research (Atienza, *et al.*, 2001; Robles and Arcas, 2004; Jubete, *et al.*, 2006; Julliard, *et al.*, 2006; Schäffer, *et al.*, 2006).

Ringing studies and occasional observations have shown that this species is a scarce, but regular, migrant through western Europe and West Africa, being particularly common in France, Morocco, The Netherlands, Belgium, southern Britain, and Spain during the autumn migration, and occurring further east during the spring migration; and that these birds fatten up in France (Julliard, *et al.*, 2006; Schäffer, *et al.*, 2006). With the exception of the number of ringed birds published by Atienza, *et al.* (2001), virtually nothing is known about the occurrence of AWs in Portugal, even though it is expected that a considerable number of birds migrate through this country due to its geographical location. In addition, the migration strategy of this species is still largely unknown. Here, we review all the Portuguese records of AWs, assess the importance of Portugal for the migration of this species, and describe the phenology, distribution and body condition, comparing with data published elsewhere.

According to the Portuguese Rare Bird Committee, no AWs were visually detected in Portugal, and so our analyses are restricted to data extracted from the Portuguese Ringing Centre database and complemented with information provided by individual ringers and ringing centers. Although most of the records were not submitted to the appreciation of the Portuguese Rare Bird Committee, they were obtained or confirmed in the field by experienced ringers (including ourselves), and so we are confident that the identifications and measurements are accurate. A couple of older records were excluded because they lacked information in terms of numbers, location and date, and it was not possible to evaluate the identification (e.g. Henty, 1961). It is noteworthy that most of the ringing effort associated with the capture of AWs took place in major reed beds without the use of tape lures. That is, the records used in this study were not sought by choosing species-specific habitats (wet marshes with diverse low vegetation such as *Carex*, *Juncus*, *Scirpus*) and trapping techniques (with tape lures) that are now commonly used in several sites in France and Spain (Jubete, *et al.*, 2006; Julliard, *et al.*, 2006), but rather constitute accidental capture events at constant effort sites and ringing stations where it is the number of species and captures that are being maximized.

The birds were aged as adult or juvenile according to the amount of feather wear, tongue spots and iris colour (Svensson, 1992). The wing length was measured to the nearest millimeter using the flattened maximum chord technique, the weight was measured to the nearest 0.1 g using Pesola spring balances, and the amount of subcutaneous fat was visually assessed and scored using a 0 - 5 scale.

In order to assess the relative importance of Portugal for the migration of AWs, we calculated the ACROLA index (which is the proportion of AWs relative to all *Acrocephalus* species) and compared with data presented by Julliard, *et al.* (2006) for other countries. This comparison assumes that the total number of captured *Acrocephalus* warblers is strongly correlated with the ringing effort undertaken at the marshlands of different countries. However, as the abundance of sedge (*A. schoenobaenus*) and great reed (*A. arundinaceus*) warblers in Portugal is much more variable between sites and years than the abundance of the reed warbler (*A. scirpaceus*), we compare the relative abundance of AWs between sites and years within Portugal using only the latter species.

The variation in the number of adults and juveniles during the study period was analyzed using Generalized Linear Models (GLM) with Poisson error distribution and log-link function, in which the number of reed warblers caught per year was included as a covariate (to control for annual differences in ringing effort). The annual variation in the proportion of juveniles (which is dependent on breeding productivity) was analyzed using a GLM with binomial error distribution and log-link function, in which the number of juveniles divided by the total number of birds (trials) was the dependent variable (Robinson, *et al.*, 2007).

General Linear Mixed Models (GLMM) were used to analyze the seasonal variation in wing length, weight and fat score, in which "year" was included as a random effect. In the analysis of weight variation, wing length was included as a covariate to control for body size. The predictors initially included in these models were season (number of days from the first of August), age and their interaction, which, whenever non-significant, were excluded from the final model (except if the interaction was significant).

The potential non-stop flight range (Y) was estimated using the equation recently derived by Delingat, *et al.* (2008):

$$Y = 100 * U * \mathrm{Ln}\,(1 + f),$$

in which U is the air speed and f is the relative fuel load $f = (m - m_0)/m_0$. Due to the small sample size, it was not possible to calculate the size-specific lean body mass (m_0) of AWs. Hence, we used the smallest weight measured in Portugal (9.3 g), which still is a conservative estimate of the lean body mass because the similar sized reed warbler often attains weights lower than 9 g. For the flight range calculation, we assumed an air speed of 10 m/s, which is the one expected for small passerines (Alerstam, *et al.*, 2007). Statistical analysis was undertaken in SPSS 16.0 (Mac version), and results are presented as mean ± SE.

Only 67 AWs were captured and three recaptured in Portugal between 1977 and 2008 at seven sites. The three recaptures include one within-year retrap and two birds that were first captured two years previously, all at the same site (see also Catry, *et al.*, 2004). Most birds were captured at Lagoa de Santo André, whereas at the remaining sites only one or two individuals were detected (table 1, figure 1). This is because there has been a ringing station operating at Lagoa de Santo André during the autumn migration since 1977, where a large proportion of the birds ringed in Portugal were caught, particularly in earlier years (Catry, *et al.*, 2004). Other ringing stations located in reed beds are relatively recent, and generally have a lower ringing effort during autumn. When the number of captured reed warblers is taken into account (as a measure of the ringing effort), the difference in the abundance of AWs between the sites is much lower (table 1). Most sites where AWs were detected are recognized for their biological importance and are currently protected either as a Nature Reserve or as a Special Protection Area, though there is no specific management for the benefit of this species. The only site without any protection (Paúl da Tornada) is expected to become a local Nature Reserve in the near future (Helder Cardoso, *pers. com.*). It is possible, however, that most bird ringers choose to undertake their activities in protected areas, where a larger number of birds and species are expected to be captured, and so this distribution might be biased. A detailed survey of all available habitat coupled with standardized ringing effort is needed to further clarify the distribution and abundance of this species in Portugal, and determine priority sites for conservation.

The ACROLA index for Portugal was 0.14, which places this country as the third most important for the migration of AWs, just below France and Morocco (see Julliard, *et al.*, 2006). Therefore, although very few birds were detected during the past three decades, Portugal might be one of the most important countries for the autumn migration of this species. The low number of birds caught seems to be largely explained by a low ringing effort, which is consistent with the fact that only *c.* 15,000 birds are ringed annually in Portugal, whereas in France and Spain, for instance, annual numbers of ringed birds are *c.* 200,000 and *c.* 380,000, respectively (Euring, 2007). However, the ACROLA index should be interpreted with care, as there might be differences in the relative abundance of several *Acrocephalus* species between countries, sites and years; even though the most common species (reed and sedge warblers) have had stable populations (BirdLife International, 2004). The fact that during August

TABLE 1

List of sites where aquatic warblers (AW) were caught in Portugal, relative abundance (percentage of AW/RW) and protection status (for location see figure 1). The number between parentheses refers to recaptures. RW = reed warbler; SPA = Special Protection Area; IBA = Important Bird Area.
[Localidades en las que el carricerín cejudo (AW) fue capturado en Portugal, abundancia relativa (porcentaje de AW/RW) y estatus de protección (para localización ver figura 1). El número entre paréntesis se refiere a las recapturas. RW = carricero común; SPA = Área de Protección Especial; IBA = Área de Importancia para las Aves.]

Site	**AW**	**AW/RW**	**Protection/Importance**
Salreu	2	0.11 %	Natura 2000, SPA, IBA
Paúl da Arzila	2	0.08 %	Nature Reserve, Natura 2000, SPA, Ramsar, IBA
Paúl da Tornada	1	0.04 %	Ramsar
Lagoa de Albufeira	1	0.47 %	Natura 2000, SPA, Ramsar, IBA
Lagoa de Santo André	58 (3)	0.26 %	Nature Reserve, Natura 2000, SPA, Ramsar, IBA
Ria de Alvor	2	0.07 %	Natura 2000
Ludo	1	0.14 %	Natural Park, Natura 2000, SPA, Ramsar, IBA

FIG. 1.—Distribution of aquatic warblers in Portugal.
[Distribución del carricerín cejudo en Portugal.]

2009 J. M. N. caught four AWs at Salreu using a tape lure (which is twice as many as the previous records for this site; see table 1), strongly supports the idea that a much larger number of birds of this species migrate through Portugal, but are being overlooked.

The number of AWs caught in 1977 (when a British expedition was undertaken in Portugal) was far greater than in the remaining years (figure 2). When the number of reed warblers is used as a covariate (as a measure of ringing effort), there is a very significant decline in the number of juveniles during the study period (GLM: b = -0.08 ± 0.02; Wald Chi-square = 8.3; P = 0.004), but not of adults (GLM: b = -0.03 ± 0.03; Wald Chi-square = 1.4; P = 0.231), suggesting that there was a decline in productivity during the study period. However, this is only partially supported by a non-significant decline in the probability of trapping juveniles (GLM: b = -0.04 ± 0.03; Wald Chi-square = 2.4; P = 0.122). Although the vast majority of AWs were caught at a single site, there is no reason to suppose that a local effect would influence one age class and not the other. Hence, despite limitations in our data, we

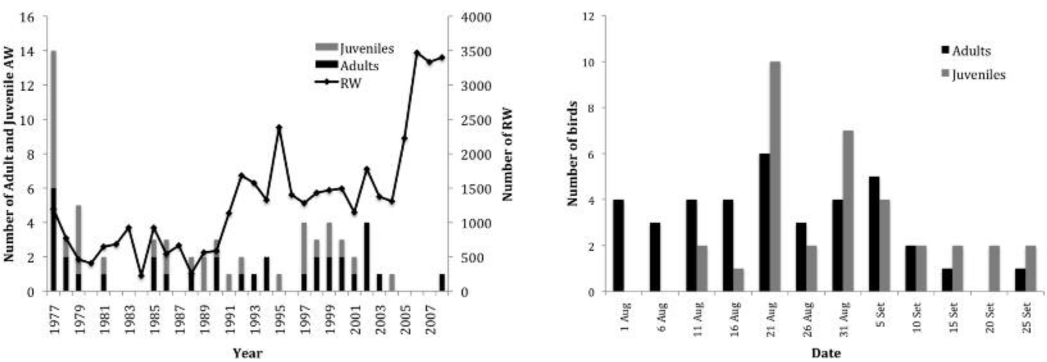

FIG. 2.—Annual and seasonal variation in the number of captures of aquatic warblers (AW) and reed warblers (RW). The number of RW presented for 2008 is an estimate.
[Variación anual y estacional en el número de capturas de carricerín cejudo (AW) y carricero común (RW). El número de RW presentado en 2008 es una estimación.]

found some evidence for a decline in breeding success, and recommend that analysis of productivity is undertaken at sites where a greater number of birds of this species are caught. This result is consistent with the greater decline in the number of juveniles, in comparison with the number of adults, reported by Jubete *et al.* (2006) for La Nava, Spain, although no appropriate statistical analysis were carried out in this study. Interestingly, the proportion of juveniles seems to be much lower in Portugal (49 %) and Spain (41 % at Miño estuary and 57 - 67 % at La Nava; Robles and Arcas, 2004; Jubete, *et al.*, 2006) than in France (96 %; Bargain, 2008), which could be related to differences in migratory strategy between the age classes (see below). However, the relative abundance of the different age and sex classes might be influenced by the use of tape lures (Lecoq and Catry, 2003), which were used at La Nava and in France, and so these comparisons must be interpreted with care.

All birds were captured either in August or September, being generally more abundant at the end of August (figure 2). The peak of migration is two weeks later than the one described for France (Julliard, *et al.*, 2006), and similar to the one in Spain (Atienza, *et al.*, 2001, Jubete, *et al.*, 2006). There is a hint of a double peak in the seasonal variation in abundance (figure 2), as was also found by Atienza, *et al.* (2001), which cannot be explained by the difference in timing of migration between the age classes. It is possible that these peaks represent the passage of different populations, even though we did not find any seasonal variation in wing length classes. This should be further explored with genetic markers and/or stable isotopes.

We found a significant difference between the dates of occurrence of adults and juveniles, with the former migrating 9.0 ± 3.4 days earlier (GLMM: $F_{[1,45]} = 7.1$, $P = 0.01$). This is also apparent in the data presented by Jubete, *et al.* (2006), and is expected for species that do not carry out a complete post-breeding moult (see Neto, *et al.*, 2008).

There was no significant seasonal variation in wing length (GLMM: $F_{[1,30]} = 0.4$, $P = 0.5$), but the weight (GLMM: $F_{[1,28]} = 7.3$, $P = 0.012$) and fat score (GLMM: $F_{[1,18]} = 5.2$, $P = 0.036$) significantly increased with date (figure 3). In addition, juveniles had a greater fat score than adults (GLMM: $F_{[1,18]} = 6.0$, $P = 0.02$) and, surprisingly, slightly longer wings (ANOVA: $F_{[1,53]} = 9.0$, $P = 0.004$), which probably resulted from the greater wear of the old adult feathers (table 2). The increase in body condition with the progress of season has been described before for a number of species (e.g. Neto, *et al.*, 2008), and reflects either a greater fattening rate at the end of the season or simply a lower proportion of lean birds, as the time available for migration decreases. However, no change in body condition with season was found in AWs in France (Julliard, *et al.*, 2006), whereas this was not analysed in Spanish birds. Interestingly, we found that juveniles were in better condition than adults, having significantly greater fat score and a non-significant greater weight, whereas in France adults were heavier than juveniles (Julliard, *et al.*, 2006; see also Robles and Arcas, 2004). These differences in body condition variation between Portugal and France could be the result of a greater migration speed of adults, which probably fatten up faster and depart earlier than juveniles in France, due to their dominance and experience (Lindström, *et al.*, 1990); whereas further south and later in the season, the juveniles might have to fatten up comparatively faster. This would also explain the lower percentage of juveniles captured in the Iberian Peninsula.

The average fuel load for adults and juveniles was 0.27 ± 0.036 (range 0.32 to 0.73) and 0.35 ± 0.043 (range 0.00 to 0.74), respectively (table 2). This corresponds to an average non-stop flight range (assuming no wind) of 829 ± 96 km (range 114 to 1976 km) and 1051 ± 114 km (range 0 to 1998 km), res-

TABLE 2

Biometrics, condition and flight range of adult and juvenile aquatic warblers captured in Portugal. Data presented is Mean ± SE (Range; n).
[Biometría, condición y rango de vuelo de adultos y juveniles de carricerín cejudo capturados en Portugal. Los datos se presentan como la Media ± ES. En paréntesis el rango y la muestra.]

	Adults	**Juveniles**	**ANOVA test**
Wing length	62.8 ± 0.27 (60 - 65; 29)	64.0 ± 0.29 (61 - 67; 26)	**F = 9.0; P = 0.004**
Weight	11.8 ± 0.33 (9.6 - 16.1; 29)	12.6 ± 0.40 (9.3 - 16.2; 24)	F = 2.2; P = 0.14
Fat	2.1 ± 0.34 (0 - 5; 21)	3.4 ± 0.37 (0 - 5; 17)	**F = 7.7; P = 0.009**
Fuel load	0.27 ± 0.04 (0.0 - 0.7; 29)	0.35 ± 0.04 (0.0 - 0.7; 24)	F = 2.2; P = 0.14
Flight range	1051 ± 114 (114 - 1976; 29)	828 ± 0515 (0 - 1998; 24)	F = 2.3; P = 0.14

pectively. If the typical northern wind that occurs in southern Europe and North Africa during summer/autumn is taken into account, some AWs stopping over in Portugal would be able to reach the wintering quarters in Senegal without replenishing the fuel reserves. The actual percentage of birds that is able to reach the wintering quarters without refueling is greater than the one inferred from the data, because the fuel load at departure was not estimated. In contrast, there is a considerable percentage of individuals that would not be able to fly long distances without refueling, particularly those captured early in the season.

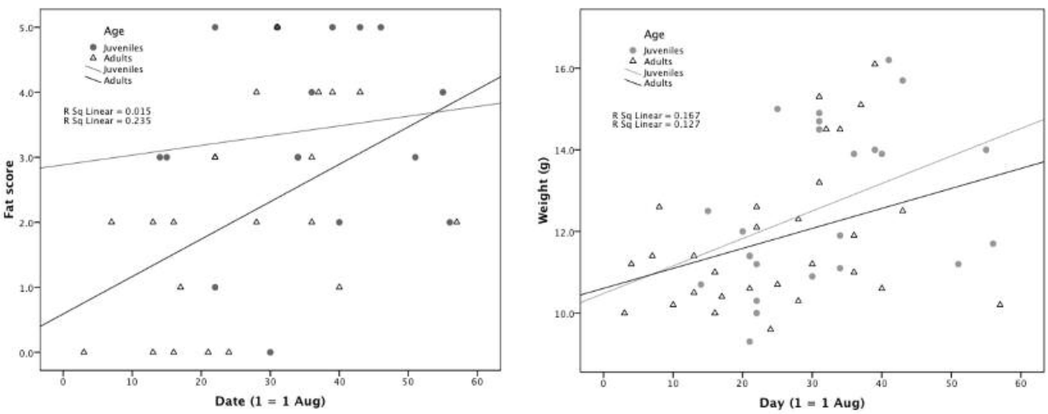

FIG. 3.—Seasonal variation in wing length, fat score and weight of adult and juvenile aquatic warblers. Lines represent linear regressions.
[Variación estacional en la longitud del ala, reserva de grasa, y peso de adultos y juveniles de carricerín cejudo. Las líneas representan regresiones lineales.]

This suggests that at least some birds accumulate fat in Portugal. Data on stopover duration and fueling rates along the migratory route of AWs are needed to clarify its migration strategy and the differences between age classes (e.g. Schaub and Jenni, 2001).

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