

TIMING OF AUTUMN BIRD MIGRATION IN CENTRAL SPAIN IN LIGHT OF RECENT CLIMATE CHANGE

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SUMMARY.—*Timing of autumn bird migration in central Spain in light of recent climate change.*

Aims: To examine changes in the timing of migration of 10 migratory bird species (six long-distance and four short-distance migrants) during autumn passage in central Spain, comparing two periods during recent warming over the most part of Europe (1987 - 1990 and 2001 - 2005).

Location: Monte de Valdelatas, near Madrid, central Spain.

Methods: The number of weekly captures in mist-nets from late August to late October between the two studied periods was compared by fitting general linear mixed models.

Results: Long-distance migrants have advanced autumn migration through central Spain in recent years, whereas short-distance migrants have remained at similar passage dates.

Conclusions: Phenological changes observed for long-distance migrants in central Spain are in agreement with results found in other European localities. The phenology of autumn migration has not apparently changed for short-distance migrants. However, other factors associated with recent climate changes, such as the shortening of migration distances and reduction of migratoriness, may have confounded this analysis.

Key words: climate change, long-distance migrants, Mediterranean area, migration phenology, short-distance migrants.

RESUMEN.—*Periodo de migración otoñal de las aves en España central y el reciente cambio climático.*

Objetivos: Examinar los cambios en el periodo de migración de 10 especies de aves (seis migradores de larga distancia y cuatro de corta distancia) durante el paso otoñal a través del centro de España, comparando dos periodos afectados por el calentamiento climático reciente en la mayor parte de Europa (1987 - 1990 y 2001 - 2005).

Localidad: Monte de Valdelatas, cercano a la ciudad de Madrid, España central.

Métodos: Comparamos el número de aves capturadas semanalmente en redes japonesas desde finales de agosto hasta finales de octubre entre los dos periodos de estudio, ajustando modelos generales lineales mixtos.

Resultados: Los migradores de larga distancia han avanzado la migración otoñal a través de España central en años recientes, mientras que las fechas de paso de los migradores de corta distancia no se han modificado de manera apreciable.

Conclusiones: Los cambios fenológicos observados para los migradores de larga distancia en España central se corresponden con los resultados encontrados en otras localidades europeas. Apparentemen-

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te, la fenología de migración otoñal no ha cambiado en el caso de los migradores de corta distancia. Sin embargo, otros factores, que también están relacionados con el cambio climático reciente, como el acortamiento de las distancias de migración o la reducción de la migratoriedad, pueden haber influenciado el análisis.

Palabras clave: cambio climático, migradores de larga distancia, área mediterránea, fenología de la migración, migradores de corta distancia.

INTRODUCTION

Mean global temperature has increased by approximately 0.6 °C over the last century, although warming has not been homogeneous through space and time (IPCC, 2001; Walther *et al.*, 2002; Watkinson *et al.*, 2004). The greatest warming has been registered over land masses of the northern hemisphere, and temporal trends indicate that the temperature has increased at an unprecedented rate since the mid-1970s (Crowley, 2000; Stott *et al.*, 2000). The phenology, physiology and distribution of a broad range of organisms have been already affected by this climate change (Peñuelas and Filella, 2001; Walther *et al.*, 2002; Parmesan and Yohe, 2003; Root *et al.*, 2003).

Migratory birds spend different parts of their annual cycle in separated areas, so they have to face potential variations in climate conditions in both breeding and wintering areas. However, only those climate changes that have fitness consequences are expected to induce an adjustment to the timing of life-cycle stages (*e.g.*, migration, laying, moult). There are a growing number of studies documenting earlier arrival of spring migrants and advancement in laying date as a consequence of increased spring temperatures (Sokolov *et al.*, 1998; Crick and Sparks, 1999; Sparks, 1999; Both and Visser, 2001; Both *et al.*, 2004; Crick, 2004; Lehikoinen *et al.*, 2004; Sparks *et al.*, 2005). However, the potential effects of climate warming on the timing of other life-cycle stages, such as moult and autumn migration, have been investigated less (Coppack *et al.*, 2001; Cotton, 2003; Jenni and Kéry, 2003; Pulido and Coppack, 2004). Available information on

changes in the onset of autumn migration has been somewhat equivocal (Bezzel and Jetz, 1995; Gilyazov and Sparks, 2002; Sparks and Mason, 2004). One reason for these sometimes contradictory patterns is that responses differ according to the ecology and life history of a particular species (Gilyazov and Sparks, 2002; Jenni and Kéry, 2003).

Changes in the timing of migration of 10 migratory bird species during autumn passage in central Spain between two periods, 1987 - 1990 and 2001 - 2005, are examined. Recent global warming began in 1976 and has been progressive since then, the rate of warming being greater than at any other time during the last 1000 years (IPCC, 2001; Watkinson *et al.*, 2004). Furthermore, the 1990s seem to have been the warmest decade of the last century (Huang *et al.*, 2000). Therefore, changes in avian migration phenology between these two study periods in central Spain can be expected, as has previously been shown for other European localities (*e.g.*, Cotton, 2003; Jenni and Kéry, 2003). Specifically, it is predicted that long-distance migrants have advanced their autumn passage. This phenological change is probably a consequence of an earlier start and end of the breeding season that presumably enhances bird survival rate during migration and/or wintering (Jenni and Kéry, 2003). Conversely, short-distance migrants winter north of the Sahara and recent climate warming has improved ecological conditions in these areas. Hence, it is predicted that short-distance migrants have delayed autumn migration, or even that individuals from some populations may winter in the breeding grounds. By doing so, they presumably achieve higher survival

rate and/or obtain higher-quality breeding territories by arriving earlier in spring (Jenni and Kéry, 2003).

MATERIAL AND METHODS

Study site and data collection

The study was conducted in the Monte de Valdelatas (40°31' N, 3°40' W), near Madrid, central Spain. Valdelatas is around 300 ha in size (elevation 721 m a.s.l.) and is characterized by holm oak *Quercus ilex* and stone pine *Pinus pinea* forests, and riparian vegetation (see Génova-Fuster, 1989; for a full description of the vegetation). A total of 12 mist-nets (total length 129 m) was set up in four groups 150 - 250 m apart, covering the three main vegetation habitats and an area of approximately 6 ha. Trapping started in 1987 and continued until 1990 when changes in the conservation status of the study area prevented mist-netting activities. In 2001, trapping activities were reinitiated and continued until 2005. During autumn migration (late August to early November), birds were mist-netted weekly, although not all weeks could be covered due to logistical reasons or weather conditions. The number of nets and their position was similar on each occasion. Nets were opened at sunrise and remained open for over 12 hours, although opening time was reduced to 6 hours starting in 2003. However, trapping effort did not change within the season and there was interest in analysing potential within-season changes in the distribution of captures, not between-period differences in total captures, so no correction was made. Birds were marked with a standard numbered aluminium ring.

Statistical analysis

Autumn migration was divided into nine week periods, from the last week of August to

the last week of October, because there was insufficient data for the third week of August and the first week of November for the years 1987 - 1990. Nevertheless, the two main periods of autumn passage across the Iberian peninsula were included in the analyses: September for long-distance migrants and October for short-distance migrants (Cantos, 1992; Tellería *et al.*, 1999). The number of captures for each of the nine weeks, year and bird species were calculated, excluding within-season recaptures. No individuals of long-distance migrants were ever captured during the last week (i.e. fourth week of October) for the years considered, so this week was excluded from the analysis of long-distance migrants. The analyses included six species of long-distance migrants: pied flycatcher *Ficedula hypoleuca* (494 captures), garden warbler *Sylvia borin* (392), willow warbler *Phylloscopus trochilus* (147), whitethroat *Sylvia communis* (115), spotted flycatcher *Muscicapa striata* (90), reed warbler *Acrocephalus scirpaceus* (66); and four of short-distance migrants: blackcap *Sylvia atricapilla* (863), robin *Erithacus rubecula* (386), chaffinch *Fringilla coelebs* (208), and chiffchaff *Phylloscopus collybita* (112). The species were selected following the criteria that they were long-distance or short-distance migrants with more than 50 captures during autumn migration for the period of study. Therefore, the analyses are based on a total of 2873 birds trapped during 56 trapping dates.

To test for changes in the distribution of captures during autumn migration between 1987 - 1990 and the 2001 - 2005 periods, two general linear mixed models were fitted, one for each group of migrants. The number of captures (square root-transformed) as the response variable, week and period as fixed factors, and species as a random factor was considered. Because of interest in testing potential shifts in the distribution of captures between the two periods, differences were sought in the interaction between period and week. Statistical analyses were carried out using STATISTICA 6.0 (StatSoft, 2001).

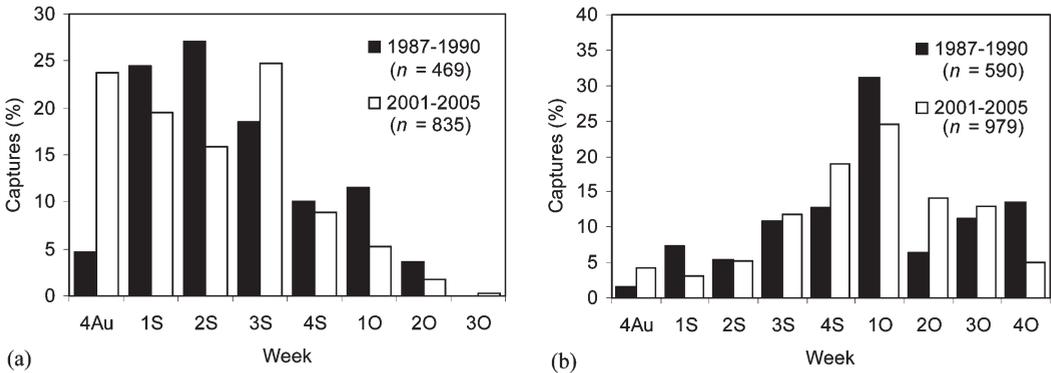


FIG. 1.—Percentage of captures in each week during autumn migration for six long-distance (a) and four short-distance migrants (b) in two different periods at Monte de Valdelatas, central Spain. Total number of captures for each period is indicated. Numbers on abscissa refer to week number (first to fourth); Au = August, S = September, O = October.

[Porcentaje de capturas para cada una de las semanas durante la migración otoñal en seis migradores de larga distancia (a) y cuatro de corta distancia (b) durante dos periodos distintos en el Monte de Valdelatas, España central. Se indica el número total de capturas para cada uno de los periodos. Los números en el eje de abscisas se refieren al número de la semana (primera a cuarta); Au = agosto, S = septiembre, O = octubre.]

RESULTS

At Monte de Valdelatas, migration phenology of long-distance migrants was earlier than that of short-distance migrants (Fig. 1). More birds were captured during the 2001 - 2005 period compared to the 1987 - 1990 period (Fig. 1). This was due to differences in the number of trapping sessions (36 versus 20, respectively), so mean values were usually less accurate for the 1987 - 1990 period (Fig. 2). The distribution of captures for both periods indicated that long-distance migrants have advanced their autumn passage at Valdelatas (week by period interaction: $F_{7,210} = 5.4, P < 0.001$; Fig. 2a). Numbering the nine-week period from one to nine and using mean captures obtained from the general linear mixed model (Fig. 2) as a weighting factor, mean week of passage for long-distance migrants was the beginning of the third week of September (weighted mean: 4.1) during the 1987 - 1990 period, whereas mean passage was at the end of the second week of September (3.8) dur-

ing the 2001 - 2005 period. Conversely, short-distance migrants did not show significant differences in the distribution of captures between both periods (week by period interaction: $F_{8,148} = 1.3, P = 0.28$; Fig. 2b).

DISCUSSION

The results indicate that long-distance migrants have advanced the timing of autumn migration through central Spain in recent years when compared with the late 1980s, which is consistent with the first prediction. However, contrary to the second prediction, no delay was found in the autumn migration in short-distance migrants. Despite these findings being in partial agreement with recent evidence for other European sites (Cotton, 2003; Jenni and Kéry, 2003), the limitations of the data are known, so the first discussion is of some potential caveats of the data and then followed by further discussion of the results.

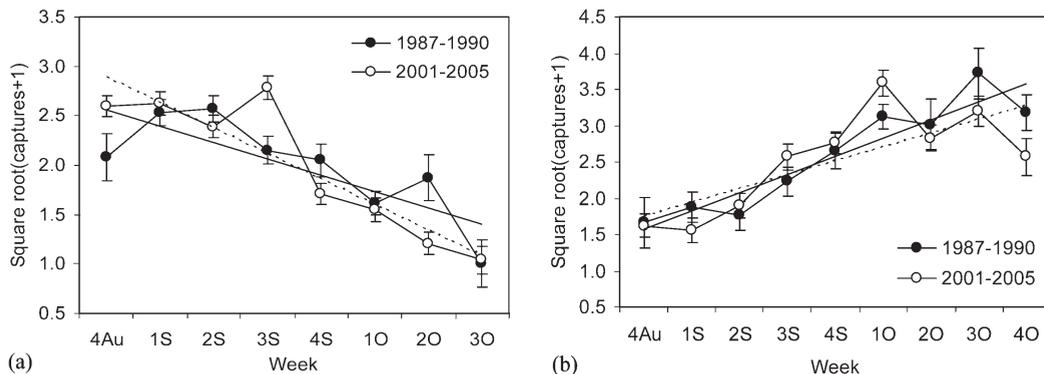


FIG. 2.—Mean weekly captures (square root-transformed; ± 1 se) for six long-distance (a) and four short-distance migrants (b) during autumn migration at Valdelatas, central Spain. The solid lines represent the linear regressions for the period 1987 - 1990 and the dashed lines those for the period 2001 - 2005. Abbreviations for weeks as explained in Fig. 1.

[Capturas semanales promedio (transformadas mediante la raíz cuadrada; ± 1 es) para seis migradores de larga distancia (a) y cuatro de corta distancia (b) durante la migración otoñal en Valdelatas, España central. Las líneas continuas representan las regresiones lineales para el periodo 1987 - 1990 y las líneas discontinuas las del periodo 2001 - 2005. Las abreviaturas utilizadas para las semanas se explican en la Fig. 1.]

Data considerations

Most studies dealing with changes in avian migration phenology have used first arrival or departure dates or various estimations of peak passage dates (Sparks *et al.*, 2001; Lehikoinen *et al.*, 2004). The use of first arrival or departure dates has been considered problematic (Mills, 2005), and estimation of passage dates in banding studies requires frequent banding and considerable sample sizes. For example, Mills (2005) used banding data from three banding stations in North America and estimated passage dates for several quartiles of the seasonal distribution of captures. Similarly, Jenni and Kéry (2003) estimated peak passage of migrants at a location in central Europe using daily captures grouped into 5-day intervals. The weekly banding protocol makes the use of first capture date an unreliable estimator of passage date to assess phenological changes. On the other hand, autumn captures of migrants at the study site did not show the typical unimodal

and symmetrical distribution (i.e., bell-curved). This is probably due to different populations passing with some lag through the study site (Lehikoinen *et al.*, 2004; see also Leal *et al.*, 2004). Therefore, peak passages for each species were not estimated and instead used the full distribution of captures. Given that information for some weeks was lacking for several years, the data was grouped into two periods (1987 - 1990 and 2001 - 2005), making the analyses more conservative to 'atypical' banding dates. This, however, prevented the analysis of inter-annual variations or to explore the effects of other variables, such as temperature or the North Atlantic Oscillation, on migration phenology (Forchhammer *et al.*, 2002; Hüppop and Hüppop, 2003).

Phenological changes

Recent analyses of longer and more complete data sets have demonstrated that Eu-

ropean species of long-distance migrants leave earlier from breeding grounds or have advanced their peak passage in recent decades (Cotton, 2003; Jenni and Kéry, 2003). The present results for six species of long-distance migrants have also shown that trend. In those areas more affected by climate warming, migratory birds are arriving earlier (Crick, 2004; Sparks *et al.*, 2005) and breeding starts earlier (Crick *et al.*, 1997; Crick and Sparks, 1999; Both *et al.*, 2004). Long-distance migrants are single- or double-brooded, so breeding season is also ending earlier as a consequence of climate warming (Cotton, 2003). Moreover, several species do not start the post-nuptial moult until reaching the wintering grounds, south of the Sahara. This suggests that long-distance migrants might benefit from crossing the Sahara as early as possible to take advantage of the benign environmental conditions in the Sahel at the end of the rainy season before continuing their migration further south (Schaub and Jenni, 2001; Jenni and Kéry, 2003; Ottosson *et al.*, 2005). Additionally, some species are known to be territorial during winter (Salewski *et al.*, 2002) and thus individuals arriving earlier at the wintering grounds might obtain higher-quality territories and achieve higher winter survival.

Short-distance migrants, on the other hand, are expected to migrate later in the season with recent warming trends, and a number of advantages of this behaviour has been listed such as attempting more broods or complete pre-migration moult efficiently. This trend of later autumn migration has actually been found for several short-distance migrants in central Europe (Bezzel and Jetz, 1995; Jenni and Kéry, 2003). On the contrary, the results here for central Spain did not show changes in the distribution of autumn captures. Several non-mutually exclusive reasons could explain this result. First, samples sizes were too low to detect a shift in autumn passage. However, the total number of captures was higher for short-dis-

tance than for long-distance migrants, and this analysis includes the species most frequently captured (*S. atricapilla*); although effect size may be smaller for this type of migrants and a more powerful test would be necessary to detect phenological changes. Second, individuals of all but one of the four species of short-distance migrants included in this study winter in the study area. This complicates the separation of later migrants from individuals arriving to overwinter at Valdelatas. Unlike long-distance migrants, the banding schedule did not probably allow complete coverage of the last tail of the distribution of captures of short-distance migrants, at least for some years. For example, two individuals of *S. atricapilla* (a species that did not winter at Valdelatas) were trapped the first week of November in 2003, but as many as 20 individuals during the same week in 2004 (Villarán *et al.*, 2005). This is further complicated by the fact that a shortening of migration distances and a reduction of migratoriness have been reported (Sutherland, 1998; Berthold, 2001; Fiedler *et al.*, 2004), presumably as a consequence of recent climate warming. Therefore, the potential passage of later individuals not included in the analysis or individuals from some populations not passing through the study area in recent years may have made difficult the detection of phenological changes.

In summary, it has been shown that long-distance migrants appear to have advanced their autumn migration through central Spain in recent decades, and that the timing of passage of short-distance migrants has not apparently changed. Given the scarcity of information on the impact of recent climate change on bird populations in the Mediterranean region (Sanz, 2002; but see Sanz *et al.*, 2003; Saino *et al.*, 2004; Gordo *et al.*, 2005; Gordo and Sanz, 2005; 2006; Jonzén *et al.*, 2006), it is hoped that these results will encourage others to analyze similar data sets to further explore bird migration phenology in the Mediterranean given recent climate warming trends.

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