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Weather conditions and breeding season length in blackbird (*Turdus merula*)

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Abstract. The timing of egg laying by songbirds is known to be strongly affected by local climate, with temperature and precipitation being the most influential factors. However, most research to date relates only to the start of the breeding season: later records and the duration of the whole have not been taken into consideration. In the case of multibrooded species, productivity usually depends on the length of the breeding season. In this work we analysed climatic factors affecting breeding season length of an urban blackbird (*Turdus merula*) population. The study was conducted in two parks in the city of Szczecin, north-western Poland, spanning 14 breeding seasons since 1997. We found that over the study period, the breeding season became shorter as a result of colder springs and possibly because of warmer June-July temperatures. Our study revealed a positive relationship between breeding season length and the mean and mean minimum temperatures in April. Total precipitation in April-July also positively influenced breeding season length. The present survey confirms the influence of temperature and precipitation on the breeding season length of blackbird.

Key words: climate change, temperature, phenology, phenotypic plasticity, urban areas

Introduction

The shift to earlier migration (Ahas & Aasa 2006, Both & te Marvelde 2007) and earlier breeding times has been observed in many birds as a result of climate warming (Goodenough et al. 2010, Donnelly et al. 2012, Sparks et al. 2013). Many studies have shown that the considerable plasticity in the timing of egg laying in songbirds enables them to respond quickly to local weather conditions (Goodenough et al. 2010). Birds start breeding earlier if the pre-laying period is warmer (Bauer et al. 2009, Goodenough et al. 2010). The different phenologies of species could have evolved in response to the influence of genes, photoperiod, temperature and precipitation (Forrest & Miller-Rushing 2010). In the case of songbirds in general and the blackbird (*Turdus merula*) in particular, temperature and precipitation are closely related to the availability of invertebrate prey, mostly earthworms and caterpillars. Earlier breeding benefits individuals with a better breeding territory (Goodenough et al. 2010), increases the possibility of multiple clutches, and therefore enhances the chances of breeding success. On the other hand, earlier breeding heightens the possibility of failure following sudden weather changes in early spring (Katz 2010, Moreno & Møller 2011, Pipoly et al. 2013) as well as possible mismatches between food availability and the need to raise offspring successfully (Miller-Rushing et al. 2010, Sparks et al. 2013). Moreover, nests are less well concealed in the incompletely developed tree canopy, which means that the costs of predation are higher early in the season (Wysocki et al. 2004, Wysocki 2005). These can, however, vary regionally and may be alleviated by the availability of conifers (Mikula et al. 2014). Species with a greater plasticity are thus better fitted to fluctuating climate conditions. For our study, we used data on breeding timing relating to an urban blackbird population (Wysocki 2004a, Wysocki et al. 2004, Wysocki 2005, Wysocki 2006). Since the mid-19th century, the forest population of this species has colonised cities in Western Europe. In north-western Poland this process took place at the turn of the 19th and 20th centuries (Luniak et al. 1990, Evans et al. 2010, Møller et al. 2012, Møller et al. 2014). The population we studied is partly resident, so most individuals leave their territories after breeding (July-August) and reappear between October and December, although some birds do not reappear until just before the next breeding season (Wysocki 2004b). A comparison of the phenology of two different blackbird populations in Poland and the U.K. showed that the Polish population bred later and responded

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weakly to temperature (Sparks et al. 2007). The authors of that paper explained this phenomenon as being an adaptation to a different climate. Moreover, most published studies assessed the timing of only the first brood (Nielsen & Møller 2006, Sparks et al. 2007), because breeding pairs were usually not tracked throughout the breeding season. This is important: in single-brooded species, natural selection promotes one single optimised clutch time, but in multi-brooded species, justified selection of first-clutch timing is weaker because overall fitness can be achieved in subsequent broods. Conversely, this could be considered a trade-off, since chicks from the earlier clutch have better chances of survival than those from later clutches (Newton 1998). We thus monitored all the broods of the target pairs to estimate breeding length. The aim of our study was to find out how temperature or precipitation influence the length of the breeding season.

Material and Methods

The study was performed in two parks in Szczecin: Zeromski park (53°26′2″ N, 14°33′48″ E) between 1997-2010 and Kownas (53°26′51″ N, 14°32′6″ E) between 1997-2003. The work was done each year from March to August. As our pre-analysis revealed no differences between the parks, the data were pooled. For more details about the parks, see Wysocki (2004b).

The blackbirds, trapped in mist nets, were sexed, aged (Svensson 1992) and ringed with aluminium and colour rings. Information on clutch initiation was obtained by regular nest inspections. The length of the breeding season was calculated as the difference between the laying date of the first egg of the first clutch and that of the first egg of the last clutch for each breeding pair in each year. Where pairs had only one brood, the length was taken to be one day. The dates are given as day of year (DOY).

The length of the breeding season was averaged for each year. The total number of regularly checked pairs was 835 and the mean number for one breeding season was 60. Regression analysis was performed to assess the dependence of breeding season length on three climate variables: mean temperature, mean minimum temperature, and precipitation. Because of the high co-linearity between the climate variables, we performed simple regression for each one. Each of the regression lines was checked for outliers by Cook's distance statistics (observations greater than one were considered as outliers) and, if detected, were excluded (Quinn & Keough 2002).

For each year we averaged temperatures and precipitation for periods from one month to five months between March and July. From the different dependent variables we selected the ones that best explained the variation in breeding season length.

The climate data were obtained from the Szczecin weather station (53°23′42″ N 14°37′21″ E, http://tutiempo.net). Since 2003, spring has been colder than in earlier years ($p < 0.05$; Fig. 1A). On the other hand, early summer temperatures exhibited some increase during the study period ($p < 0.05$; Fig. 1B). The statistical analyses were performed using SPSS software. A 5 % significance threshold was adopted.

Results

During the study period, the breeding season length in blackbirds decreased significantly (Fig. 2A; $r = –0.64$, $F_{1,12} = 8.29$, $p < 0.05$). They started their first broods significantly later over the study period (Fig. 2B; $r = 0.60$, $F_{1,11} = 6.29$, $p < 0.05$), and completed

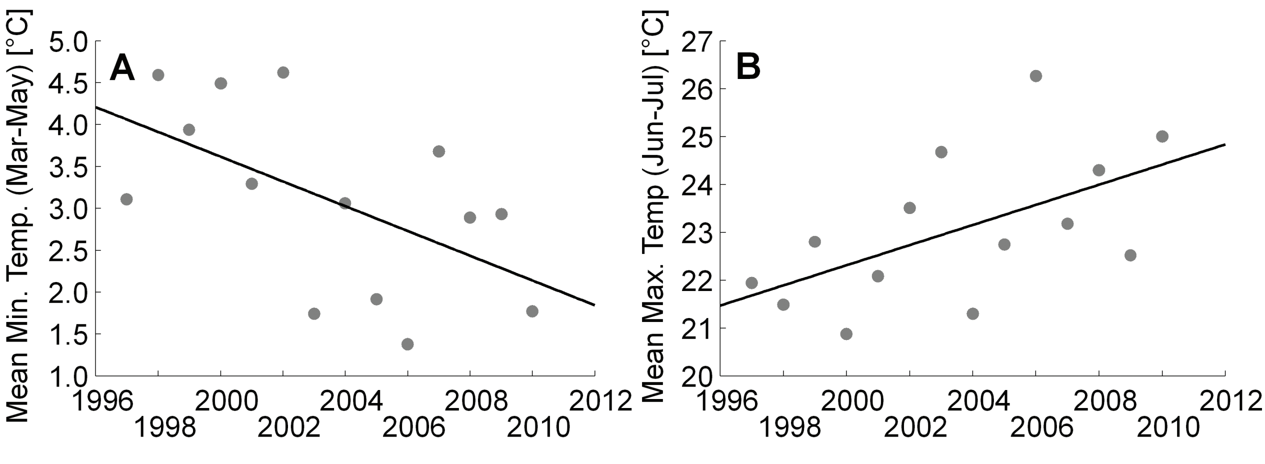
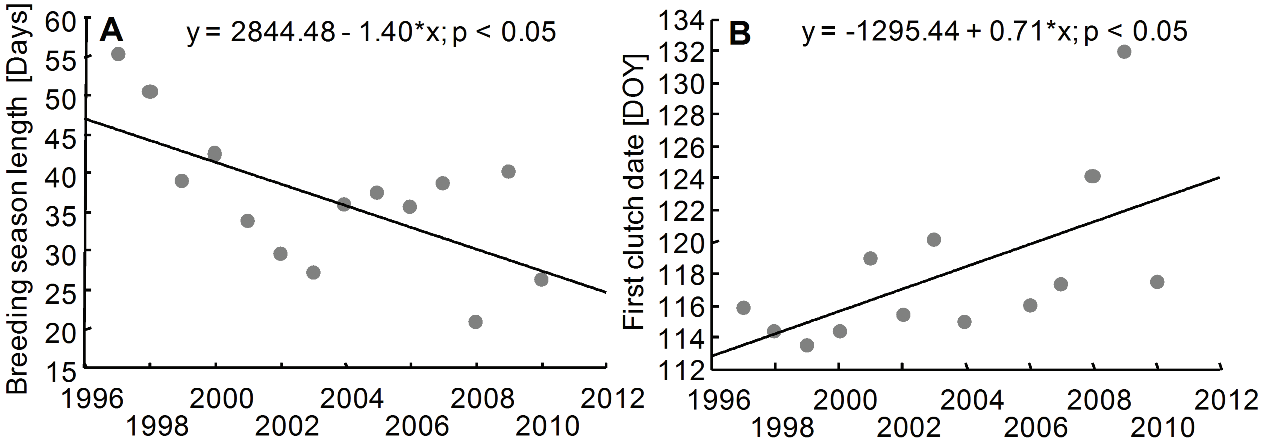


Fig. 1. Mean minimum temperature in spring (A) and mean maximum temperature in early summer (B) during the 14 years of this study.



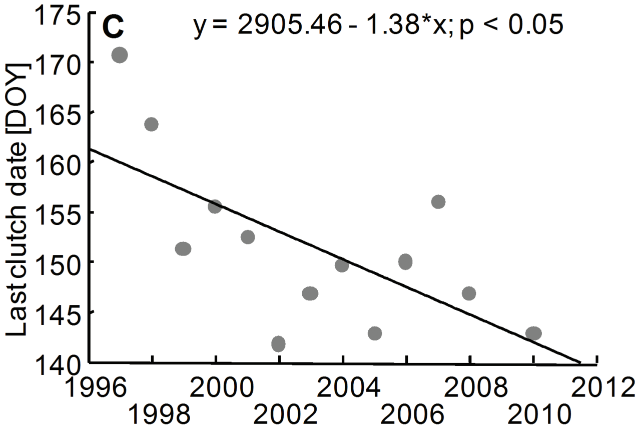


Fig. 2. Trends of mean breeding season length (A), first (B) and last (C) clutch day (DOY – day of year) during the 14 seasons of this study of a blackbird (*Turdus merula*) population.

their breeding season significantly earlier (Fig. 2C; $r = -0.66$, $F_{1,11} = 8.55$, $p < 0.05$).

The breeding season for the whole study period lasted 38 ± 11 days (mean ± SD). There was a significant positive relationship between breeding season length and temperature in two predefined periods: April and April-May (both regression lines significant, $p < 0.05$). However, the mean April temperature better explained the variation of the dependent variable (Fig. 3A; $r = 0.73$, $F_{1,11} = 12.46$, $p < 0.005$). For July and June-July there were negative relationships, albeit non-significant (Fig. 3B showed the better fitted one for June-July; $r = -0.48$, $F_{1,12} = 3.51$, $p = 0.086$). Where the mean minimum temperature was concerned, the best-fitted variable was also the April temperature (Fig. 3C; $r = 0.67$, $F_{1,12} = 8.72$, $p < 0.01$).

Significant positive relationships were noted between breeding season length and the sum of precipitation for June, March-July, April-June, April-July, May-June, May-July, June-July (all $p < 0.05$). Of these variables, the best fit was the sum of precipitation for the April-July period (Fig. 3D; $r = 0.86$, $F_{1.11} = 30.40$, $p < 0.001$).

Discussion

Our results revealed a reverse shift in the timing of breeding compared to other studies of songbirds (Goodenough et al. 2010, Donnelly et al. 2012, Sparks et al. 2013), including blackbirds (Nielsen & Møller 2006, Sparks et al. 2007). We found that the breeding season length became shorter as result of the later start of the first brood and the earlier start of the last brood. Sparks et al. (2007) suggested that animals in Poland exhibited conservative behaviour in order to deal with the local climate and posed the question as to whether these species could modify their phenological response in a period of a rapidly warming climate. On the other hand, the data from that study were collected in western Poland, a long way south of the Baltic coast; the climate of Szczecin experiences a greater influence of the Atlantic, and so is similar to the British climate. Nevertheless, our data indicate that our blackbird population is sensitive to climate conditions. The climatic data from the study period indicate that these changes could be related to the cooler climate since 2003, especially during breeding seasons 2003, 2005-06 and 2010, which were colder than other years. It seems that the higher temperatures in June-July may also be an influential factor, contributing to the shortening of the breeding season.

The mechanism of changes to the timing of breeding could be due to inherited genetic traits assisted by population evolution or could be caused by the phenotypic plasticity of individuals (Lyon et al. 2008). However, there is much agreement that these changes are more likely to be the results of phenotypic plasticity (Van Buskirk et al. 2012), which our study indirectly confirms. Moreover, phenotypic plasticity is a result of natural selection promoting individuals that are able to choose appropriate breeding times during periods when food is plentiful. Different genotypes differ in their responses to environmental cues. The decision to start

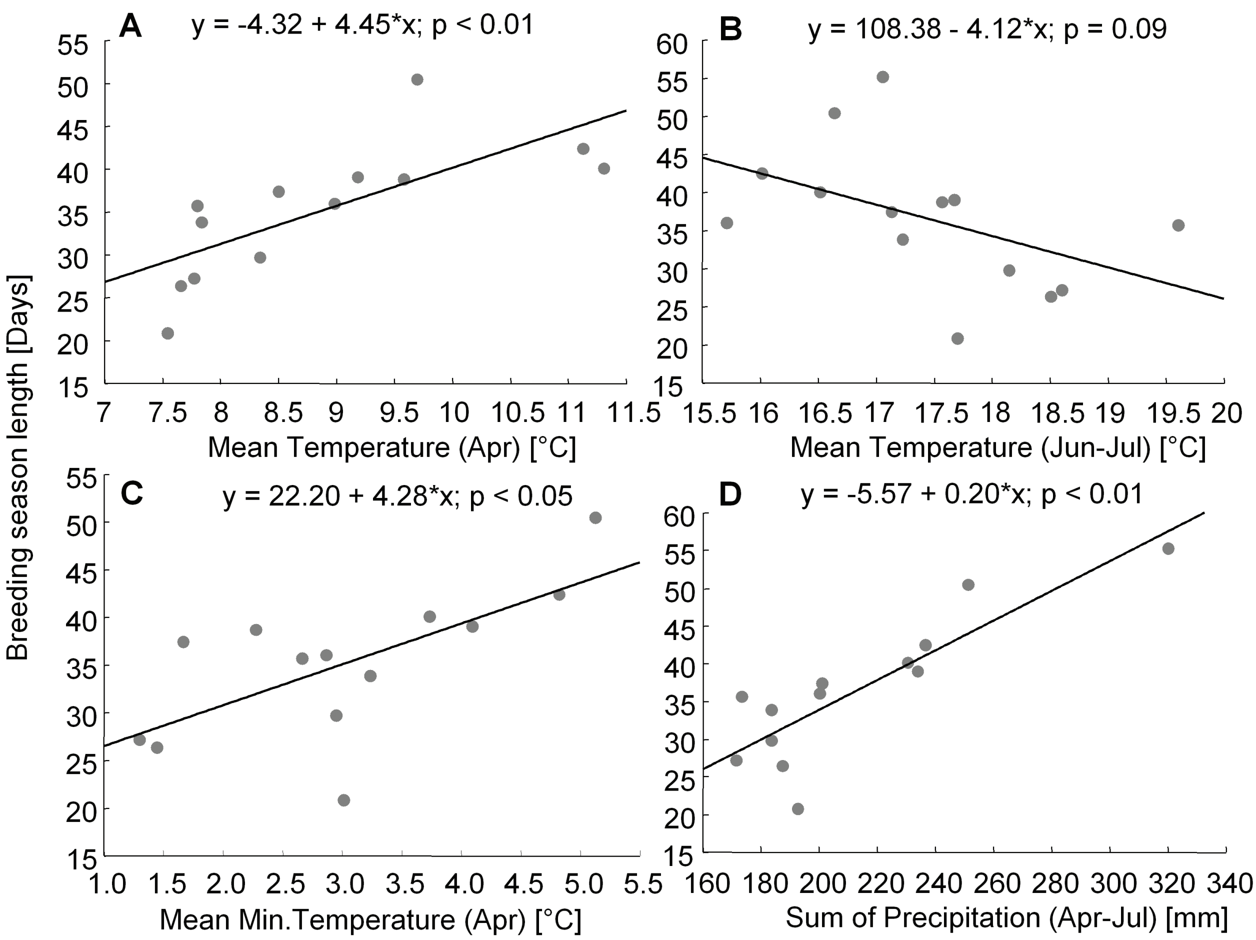


Fig. 3. Linear relationships between mean breeding season length of blackbird (*Turdus merula*) and (A) – mean temperature in April, (B) – mean temperature in June-July, (C) – mean minimum temperature in April, (D) – sum of precipitation in April-July.

breeding is made on the basis of different environmental cues, and it is crucial to understand which are the most important ones (Visser et al. 2010). Some researchers emphasise photoperiod, temperature, precipitation, food abundance and social interactions (Visser et al. 2010). On the other hand, Evans et al. (2012) suggested that genetic differences between rural and urban populations promote sedentary behaviour in blackbirds residing in cities, which could be related to the earlier onset of breeding (Partecke et al. 2004, Partecke & Gwinner 2007) and could also be due to the fact that urban birds have a broader environmental tolerance than rural birds (Bonier et al. 2007, Møller et al. 2014).

Breeding season length was positively influenced by the average temperature in April, which is when most first broods are laid. The most important factor influencing laying date in songbirds is the photoperiod, when the increasing day length acts on gonadal maturation and on the release of hormones (Dawson 2008). However, particular species differ in their first-egg laying date between years, so other factors, especially temperature, must also be important. The phenotypic effect of temperature on the shift in breeding time is related directly to the effect of temperature on fecundity and indirectly to the influence of temperature on the abundance or availability of food (Desrochers & Magrath 1993, Møller 2013). These last two reasons appear to be the most significant if breeding is to be successful, especially if breeding time is to match peak prey abundance. The main food items of insectivorous songbirds are caterpillars. Whilst these are also an important food resource for the blackbird, this species feeds mainly on earthworms, especially at the beginning of the breeding season (Perrins 1998). In addition, the activity of insects – ectothermic animals – depends on the temperature, so warmer spring temperatures could result in an earlier peak of insect numbers. In order to achieve breeding success, the birds would have to adjust their laying time to match the food availability for their offspring (Dunn & Winkler 2008). Precipitation is associated with food accessibility, since the blackbird also feeds on earthworms, which are very abundant after rain (Perrins 1998, Chamberlain et al. 1999). Our study confirmed this, indicating that the overall sum of precipitation was correlated with the duration of the breeding season. The blackbird is a multi-brooded species (Wysocki 2005), so in optimal breeding conditions, these birds can lay up to six clutches per breeding season. We also suggest that breeding season length was related to the average temperatures in June-July, when the last broods were laid. However, the higher temperatures in these months reduce the availability of food, mostly earthworms.

This study of an urban blackbird urban population has clearly indicated a shift of breeding time and breeding season length. Most studies of this phenomenon have revealed an earlier first brood time as a result of climate warming (Nielsen & Møller 2006, Sparks et al. 2007, Goodenough et al. 2010, Donnelly et al. 2012, Sparks et al. 2013). Our study, by contrast, revealed a trend of later first brood timing and earlier last brood timing, which led to a shortening of the breeding season during the study period. We explain this difference as being the result of colder spring and higher summer temperatures.

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