Warmer springs, laying date and clutch size of tree sparrows *Passer montanus* in Croatia

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Abstract  Global surface air temperatures increased during the past 100 years. Many long-term studies of birds have reported a climatic influence on breeding performance. We analysed long-term changes in first laying date and clutch size for first clutches of sedentary, hole-nesting and socially monogamous tree sparrows *Passer montanus* during 1980–2009 in northwestern Croatia.

Laying date advanced and spring temperature increased significantly during the study. Date of laying was significantly correlated with mean air spring temperature and advanced by 8.6 days during the 30 years period. Laying date was delayed in extremely cold, but not in extremely warm springs compared to years with normal temperatures. These results suggest that current climate change including extreme change does not have negative effects on timing of laying or clutch size. In contrast to laying date, clutch size did not vary systematically during the study period or with mean spring air temperature changes [Current Zoology 57 (3): 414–418, 2011].

Keywords  Climate change, Clutch size, Laying date, *Passer montanus*, Tree sparrow

Global mean surface air temperatures increased during the past 100 years, and an increasing body of evidence suggests that the global climate is changing rapidly (Houghton et al., 2001). Many studies have shown that global warming has increasing influence on plants and animals (e.g. Winkler et al., 2002) and demonstrated their use as sensitive bio-indicators for climate changes (e.g. Parmesan and Yohe, 2003; Root et al., 2003). According to Sokolov (2006), natural selection over hundreds of thousands of years should have provided for the genetic structure of populations that allows their timely restructuring and adaptation to continuously changing environmental factors such as climate. For instance, since 1966 the growing season of plants has advanced by approximately eight days in northern latitudes (Myneni, 1997), seventy percent of the 23 species of butterfly in southwestern United States have advanced their first flight over 31 years by an average of 24 days (Forister and Shapiro, 2003), and amphibian breeding has advanced in United Kingdom by one to three weeks per decade (Beebee, 1995). Recent climate change has influenced birds in several ways. Many studies have documented changes in timing of breeding (e.g. Dunn and Winkler, 1999; Hussell, 2003; Halupka et al., 2008; Dolenc et al., 2009) and arrival dates (e.g. Tryjanowski et al., 2002; Gordo and Sanz, 2006; Kralj and Dolenc, 2008; Dolenc and Dolenc, 2010). Some studies indicated increased brood size (e.g. Hušek and Adamík, 2008; Dolenc, 2009) and increased population size (e.g. D’Alba et al., 2010). Furthermore, several papers reported changes in clutch size (e.g. Järvinen, 1996).

We investigated long-term variation (1980–2009) in dates of breeding and clutch size of the tree sparrow *Passer montanus* to examine breeding phenology in relation to mean spring air temperature and year. Furthermore, we tested if extreme spring temperatures had a differential effect on laying date and clutch size relative to more normal years. Extreme climatic events happen 5% or less frequently as judged from the expected distribution of the climate variable in question (e.g. http://www.emc.ncep.noaa.gov). The exact choice of threshold value in the definition may be somewhat arbitrary, but this has not prevented climatologists from relating the frequency of such events to recent climate change. Because we only had data for 30 years, we used 10% as a threshold value, although other choices produced similar results. We predicted that laying date
would be delayed in extreme years, both when springs are very cold and very warm, because deviations from normal conditions will be experienced as stressful, thus causing a delay in reproduction. The tree sparrow is a sedentary, hole-nesting, socially monogamous and common passerine bird in many parts of Europe and Asia.

1 Materials and Methods

This study was conducted in Mokrice, northwestern Croatia (46°00′N, 15°55′E), 1980–2009. The study area is a mixed farming area with arable land containing small forests (up to 10 ha). The relief is mostly undulating lowland (ca. 140 m above sea level). Dominant deciduous tree species in the area are pendunculate oak Quercus robur and hornbeam Carpinus betulus. Other tree species that occur in low proportion include field maple Acer campestre, narrowleaf ash Fraxinus angustifolia and common elm Ulmus minor. The cover is formed by blackthorn Prunus spinosa and common elder Sambucus nigra. We studied tree sparrow breeding in nest boxes that had the dimensions of approximately 12 cm × 12 cm × 25 cm, the diameter of the entrance hole being 3.2 cm. The birds bred in nest-boxes placed at a height of 2.5–4 m, and all nest-boxes had a sliding top that allowed monitoring breeding events. Contents of nest-boxes were checked at least once every four days and the date of laying was then back-calculated from the number of eggs on the assumption that one egg was laid every day. The number of nests in the sample varied from year to year between 15 and 30 nests (mean = 23.5 nests, total = 705 nests). Females usually lay two or three clutches (rarely one clutch) in a single season (Dolenec et al., 2007). Only first clutches from the pairs that bred in nest-boxes were monitored. Renesting clutches due to nest failure were not included. Dates were expressed as progressive days, where 1 March = 1. All observations from 1980 to 2009 were recorded by the authors (1980–2002, Z. Dolenec; 2003–2009, Z. Dolenec and P. Dolenec).

Air temperature is an important parameter that has been shown to be linked to breeding parameters in many birds (e.g. Crick et al., 1997; Dolenec, 2006; Sokolov, 2006). In this study we used the mean of March and April temperatures as the mean spring temperature. We assumed that temperature in this period has probably the most influence on the onset of clutch initiation. We obtained monthly temperatures for March and April in the study period from Maksimir (Meteorological Office in Zagreb), 20 km south of the research area (mean = 9.0 ± 1.41°C, range = 6.5 to 11.8°C).

Because of temporal auto-correlation in life history and temperature data that may render data for individual years statistically dependent, we detrended the time series by subtracting the value in year (i-1) from the value in year (i). This is a standard statistical tool to correct for temporal auto-correlation (Chatfield 1996; Lindström and Forchhammer 2010).

We tested explicitly whether laying date and clutch size in extremely cold and extremely warm years differed from the norm by assigning the three coldest and the three warmest years to the category of extreme years. We used Welch ANOVA for unequal variances to test for a difference in mean of mean laying date and mean clutch size between extreme and normal years, while testing for differences in variance using Levene’s test.

All the other statistics were performed on mean values per year, and tested using Pearson’s correlations with two-tailed P-values. Statistical analyses were performed using the SPSS 13.0 statistical package. Significance was assumed at P < 0.05.

2 Results

2.1 Laying date, clutch size and temperature

During 1980–2009, first-egg laying dates of tree sparrow varied between 31 March and 20 April, mean 13 April (SD = 5.3). Tree sparrow clutches contained 3 to 6 eggs with mean clutch size being 4.9 (SD = 4.4) and modal clutch size 5 eggs.

Laying date advanced significantly during the study (Fig. 1; \( r = -0.56, P = 0.0008, n = 30, \text{ slope } (SE) = -0.29 (0.08) \)). Based on the linear regression slopes, the models indicated that in 2009 tree sparrows laid 8.6 days earlier than in 1980. Mean laying date was significantly negatively associated with mean spring (March–April) temperature (Fig. 2; \( r = -0.58, P = 0.0004, n = 30 \)). Mean spring temperatures increased significantly during the study (Fig. 3; \( r = 0.49, P = 0.0035, n = 30, \text{ slope } (SE) = 0.08 (0.03) \)), indicating a mean increase in spring temperature by 2.5 °C during 1980–2009. An analysis of laying date in relation to year and spring temperature showed significant effects of both variables (year: \( F_{1, 27} = 5.01, P = 0.034, \text{ slope } (SE) = -0.18 (0.08) \); temperature: \( F_{1, 27} = 6.28, P = 0.019, \text{ slope } (SE) = -1.27 (0.51) \)). These findings suggest that temperature is driving the trend.

Clutch size did not change systematically during 1980–2009 (\( r = -0.16, P = 0.20, n = 30 \)). Mean clutch size was not significantly related with the mean spring air temperature (\( r = -0.09, P = 0.39, n = 30 \)).
Time series analysis revealed partial temporal auto-correlation analyses with a time delay of one year of 0.20 for laying date, 0.18 for clutch size and 0.37 for temperature. Only the latter was statistically significant at $P < 0.05$. Detrended laying date was weakly, albeit not significantly related to detrended temperature ($r = 0.30$, $P = 0.06$, $n = 29$), and that was also the case for detrended data on clutch size ($r = -0.14$, $P = 0.52$, $n = 29$).

### 2.2 Laying date and clutch size in years with extreme temperatures

The categorization of years into very cold, normal and very warm years was appropriate because mean temperature in very cold years was two degrees lower than in normal years (Table 1). Likewise, mean temperature in very warm years was more than 2.5 degrees higher than in normal years (Table 1).

**Table 1** Tests for annual estimates of reproductive variables for tree sparrows for the three coldest and the three warmest years compared to other years during the 30 years period 1980–2009

<table>
<thead>
<tr>
<th></th>
<th>Temperature April (°C)</th>
<th>Laying date first clutch</th>
<th>Clutch size first clutch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SE) warmest years</td>
<td>11.47 (0.67)</td>
<td>40.00 (2.48)</td>
<td>4.80 (0.12)</td>
</tr>
<tr>
<td>Mean (SE) other years</td>
<td>8.72 (0.22)</td>
<td>43.33 (0.83)</td>
<td>5.01 (0.04)</td>
</tr>
<tr>
<td>Welch ANOVA for means</td>
<td>79.99***</td>
<td>6.42*</td>
<td>1.72</td>
</tr>
<tr>
<td>Levene’s test</td>
<td>4.21*</td>
<td>2.83</td>
<td>0.16</td>
</tr>
<tr>
<td>Mean (SE) coldest years</td>
<td>7.17 (0.75)</td>
<td>48.00 (2.35)</td>
<td>5.04 (0.13)</td>
</tr>
<tr>
<td>Mean (SE) other years</td>
<td>9.20 (0.25)</td>
<td>42.44 (0.78)</td>
<td>4.98 (0.04)</td>
</tr>
<tr>
<td>Welch ANOVA for means</td>
<td>55.24***</td>
<td>18.67**</td>
<td>0.28</td>
</tr>
<tr>
<td>Levene’s test</td>
<td>5.44*</td>
<td>3.04</td>
<td>0.78</td>
</tr>
</tbody>
</table>

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Test statistics are $F$-tests with $df = 1, 28$.
Years with extreme temperatures differed significantly with respect to mean laying date (Table 1). Mean laying date in the three coldest years was significantly delayed by six days relative to normal years, while there was no significant difference in variances (Table 1). Mean laying date in the three warmest years was significantly advanced by three days relative to normal years, while variances did not differ significantly (Table 1). In contrast, there was no significant difference in clutch size between extreme and normal years (Table 1).

3 Discussion

We investigated the response in terms of laying date and clutch size of a passerine bird, the tree sparrow, to increasing spring temperatures. There was a significant increasing trend in spring temperature and an advance in laying date, while clutch size did not change consistently. Extremely cold springs were associated with delayed reproduction, while extremely warm springs were associated with advanced laying dates. In contrast, there was no similar effect on clutch size.

The tree sparrow breeding in northwestern Croatia has responded to increasing spring temperature by advancing timing of breeding. These results are similar to the finding by Nielsen and Möller (2006), who also documented an advance in laying date for the tree sparrow and a range of other species. For example, McCleery and Perrins (1998) showed that changes in mean laying date of the great tit *Parus major* between 1947 and 1997 were linked to shifts in spring temperatures. Data for individual years may not be statistically independent due to temporal auto-correlation. When we considered temporal auto-correlation in spring temperature and laying date by de-trending the data, the significant association between laying date and temperature was no longer significant. This is a cause of concern because only very few studies of effects of climate change have considered problems of temporal auto-correlation in the data.

A consequence of climate change is that more extreme weather conditions occur with increasing frequency (Houghton et al., 2001). How animals cope with such extreme conditions is the main theme of this special issue of Current Zoology. We found not surprisingly that laying was delayed during cold spring, as we had expected. In addition, laying was advanced during very warm springs. In contrast, there were no effects of either extremely cold or extremely warm weather on clutch size. Hence, the response to extreme weather conditions was specific to laying date, and not a general response to all reproductive variables. The fact that laying date was not adversely affected by extremely warm conditions suggests that tree sparrows have not yet encountered environmental conditions that adversely affects their timing of breeding.

Mean clutch size did not vary systematically during the study period or with mean spring temperature. Population studies of some birds have shown increases in clutch size. For example, pied flycatchers *Ficedula hypoleuca* increased clutch size when springs were warmer (Järvinen, 1996). Likewise, Möller (2002) found that warmer springs in Denmark were associated with larger first clutches in the barn swallow *Hirundo rustica*. In contrast, meta-analysis of tits studies (great tit and blue tit *Cyanistes caeruleus*) showed no significant trend of increasing clutch size across the Western Palearctic despite trends towards earlier breeding (Sanz, 2002). It remains unclear why some populations of birds lay earlier, without increasing clutch size (e.g. Winkler et al., 2002), as the population of tree sparrow that we studied, while others show changes in both laying date and clutch size. According to Dunn (2004), one possibility is that birds are optimising the combined date of laying, number of eggs laid and duration of incubation, so young hatch at the peak of food abundance for nestlings.

In conclusion, we have shown increasing spring temperatures and advanced laying dates, but no change in clutch size in a population of tree sparrows. Furthermore, laying date was delayed when springs were unusually cold but advanced when springs were unusually warm, suggesting that extreme weather conditions are not yet detrimental to reproducing birds.

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References

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