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Late-arriving barn swallows linked to population declines

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ABSTRACT

Barn swallows (*Hirundo rustica*) are arriving later in the spring than they did 30–40 years ago at numerous sites in Korea. In some cases their arrival times are later by more than 1 month. This result is perplexing as spring activities of plants and animals are generally getting earlier due to warming temperatures. The first arrival dates of swallows are not related to temperature, suggesting that another factor is involved. On the basis of a questionnaire, a large majority of long-term observers are confident that there has been a moderate to severe decline in swallow populations at their field site over the study period. The greatest delays in arrival times are associated with sites with more severe reported declines in population size. Simulations using trapping data of large migratory bird populations from the United States, consisting of hundreds of individuals, suggest that severe population declines of 99% can result in delays of 10–12 days in arrival times. In summary, our results suggest that the large delays in arrival time of Korean swallows are due, at least in part, to severe reductions of more than 99% in what were formerly very large populations. Significant delays in spring phenology over time during a period of climatic warming may indicate population decline, though alternative explanations, such as changes in range or migration path or changing number of broods per season, should also be investigated. Delays in first arrival data can provide a valuable new tool to conservation biologists by indicating declines in a population that would otherwise go unnoticed. This can, in turn, lead to efforts by researchers to verify the dynamics of a population and draw attention to the conservation needs of the species.

1. Introduction

Climate change is already having a notable impact on ecosystems throughout the world (Parmesan, 2006; Rosenzweig et al., 2008; Visser and Both, 2005). One of the most sensitive indicators of climate change is the earlier phenology of spring active species (Both et al., 2010; Gordo and Sanz, 2010; Van Buskirk et al., 2009). Plants are flowering earlier in the spring (Cleland et al., 2007; Primack et al., 2004), migratory birds are arriving earlier (Cotton, 2003; Sparks et al., 2005), and many animals are emerging earlier (Diamond et al., 2011; Parmesan, 2007). These earlier patterns of activity are often strongly correlated with temperature in the late winter and spring, with earlier activity associated with warmer temperatures. Analyses show that the earlier activity over time is due to the overall warming trends that species are experiencing (Amano et al., 2010; Miller-Rushing and Primack, 2008; Parmesan and Yohe, 2003).

In addition to these overall patterns, there are some striking exceptions. There are notable cases in which species are showing later phenologies in the spring despite warming temperatures (Doi, 2008; Gordo et al., 2005). In one well-documented case from Massachusetts, USA the first arrivals of certain bird species in the spring are getting later over time (Miller-Rushing et al., 2008). The later arrival in this case is due to a declining population size. With a declining population size, the range of arrival dates becomes smaller over time, with both a later first arrival and an earlier last arrival over time. The challenges of using first arrival data in climate change research are well known, given that population size can affect the observation of first arrival (Sparks et al., 2001; Lehikoinen and Sparks, 2010). However, first arrival dates are often the only data available on phenology.

In Japan and South Korea, a recent study documents a widespread later spring phenology of certain bird, insect, and an amphibian species at numerous sites across both countries (Primack et al., 2009). A declining population size is considered to be a likely explanation, but only limited information from one site is available on changing population sizes of Korean barn swallows (*Hirundo rustica*) (Lee, 2009). This species is known to be declining in other parts of its range (Møller, 1989), although in Denmark the decline is associated with earlier arrival (Møller, 2008).

It is not clear if changing population size is capable of causing such large shifts in spring phenology for these species. The barn

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swallow is particularly noteworthy, as this species is arriving later over time at the majority of sites in South Korea, but earlier over time at the majority of sites in Japan. Could declining population size really be the cause of these later arrival dates of the barn swallow in South Korea? It is important to know the answer because data on the first arrival of birds in the spring are one of the most widely used indicators of climate change. If bird arrival dates are strongly delayed by changing population sizes it would mean that first arrival dates would have to be used much more cautiously in climate change research. In addition, if there is a link between arrival dates and population size, changes in first arrival dates could potentially be used as an indicator of changes in population size and can serve to inform conservation actions.

2. Materials and methods

The barn swallow has been monitored since 1971 at 53 sites surrounding meteorological observatories maintained by the Korea Meteorological Administration (http://web.kma.go.kr/edu/unv/agricultural/seaso-nob/1173374_1389.html). At these sites, observers have been recording when they see the first swallow each spring using a standard protocol. Weather records on average monthly temperature are also available from these sites. Data obtained from the Korea Meteorological Administration were analyzed using regression analysis to determine if first arrival dates of swallows are changing over time, and changing in relation to spring temperature in the months of March and April, the months preceding and during the main migration period.

In 2010, a questionnaire was sent to each of the meteorological stations asking the longest serving employees at each station if swallow populations in the area, over the past 40 years, were increasing slightly (up to 25%) increasing moderately (25–50%), increasing a lot (by more than 50%), decreasing slightly (up to 25%), decreasing moderately (25–50%), or decreasing a lot (more than 50%). Respondents were also asked how confident they were with their answers.

Throughout this paper we use the term "population" to describe birds of one species seen in a particular location. In many cases, these will be birds passing through the site on their way north to their breeding grounds. Some biologists prefer the term "cohort" to refer to such a group of birds that migrate through an area and could be heading for different breeding grounds. For these Korean barn swallows, we do not have any information on where they overwinter or where they breed; all we have is the first date of observation at each of the meteorological sites.

We carried out simulations to determine if declines in population size could explain the observed changes in first arrival dates of the barn swallows in Korea. We needed to find a data set in which the arrival dates of a large cohort of individual birds had been recorded at a single site. For this purpose we used the records of trapping of single species of birds at the Manomet Center for Conservation Sciences, in Manomet, Massachusetts, USA (Miller-Rushing et al., 2008). At this site, birds are captured in mist nets as they migrate along the eastern coast of Massachusetts, USA. We used trapping records to simulate how various reductions in population size would affect the first, mean and last arrival dates of each population. We used bootstrapping to simulate a 50%, 75%, 90%, 95% and 99% reduction in population size. Each reduced grouping is the result of resampling the entire dataset one thousand times. We carried out this analysis for the years and species for which there were the greatest number of captures; gray catbird (*Dumetella carolinensis*) for the year 1977 in which 676 birds were captured, and for the white-throated sparrow (*Zonotrichia albicollis*) for the year 1989 in which 408 birds were captured. We used this data because it is what was the best available to us on large numbers of migration dates of individually recorded birds. However, we recognize that these two species have many ecological differences.

3. Results

Across all sites and over 37 years, the average first arrival date is 10 days later. For the 53 sites in Korea, 47 sites show a positive trend over time in arrival dates, meaning that swallows are arriving later with each passing year (Table 1) with 25 sites showing a significant positive relationship. Only six have arrival times that are getting earlier over time, with two of these significant. Two average sites in Korea are Gwangju and Jeongeup which each show significant delays of 10 days (Fig. 1).

Some of the sites show quite dramatic changes in arrival dates with delays of 31, 42, and 45 days over the total time period at three particular sites in central Korea within 20 km of metropolitan Seoul. Consider Gangwha a site showing an exceptionally large change in first arrivals. At this site swallows are now arriving 42 days later than in 1971, and the regression model has an R^2 value of 0.61, indicating that these changes are occurring in a regular manner (Fig. 1). In the 1970s, the first birds arrived in late March, but by the late 2000s, birds were arriving in early to late May. At the Icheon site as well, swallows are arriving 45 days later than in the past ($R^2 = 0.31$). In the early 1970s birds were arriving consistently in early April, but 40 years later, birds are arriving in mid to late May or even in June.

All 53 sites have become warmer during the 1971–2008 period for the months of March and April, with 37 sites showing significant positive warming trends. Most of the values are around 0.040 °C increase per year, with a range of 0.016–0.078 °C per year. Over the 37 year period of the study, this corresponds to an increase in temperature of 0.6–3.7 °C, and an average of around 1.5 °C.

First arrival of swallows is not responding to this warming temperature in terms of earlier arrival dates, in contrast to other phenological studies of other bird species (Sparks and Tryjanowski, 2007; Tryjanowski et al., 2002). The number of sites with arrival dates having a negative correlation with temperature is balanced by almost the same number of sites with a positive correlation. At 28 sites, swallows are arriving earlier in warmer years, with three sites showing a significant trend. However, at 25 sites, swallows are arriving later in warmer years, with one site showing a significant trend.

Responses to questionnaires were received for the 53 sites on changes in the abundance of swallow populations over time. People reported that swallow populations had declined by more than 50% at 27 sites and by 25–50% at 20 sites. Slight declines were reported at an additional four sites. Only two sites reported an increase in swallow populations. At 29 of the sites people reported that they were very confident of their answers, and 19 people reported that they were moderately confident, suggesting that the data of changes in population size may be a reasonable description of changes in population size over time.

An analysis was carried out to determine if the sites that reported the most severe declines in population size, as reported by observers, also had the largest delay in arrival times. Sites were divided into two categories: sites with a reported severe decline of 50% or more in population size in the past 40 years (27 sites), and the rest (26). For the sites with a severe decline, the swallows were arriving on average 13.8 days later over the study period, whereas for the other sites the average delay in arrival over time was 5.8 days. The differences in the means of these two groups are significantly different ($P < 0.001$) using a t-test. This result provides a strong indication that a severe decline in population size is the cause of the later arrival times.