

Date of breeding of the starling *Sturnus vulgaris* in New Zealand is related to El Niño Southern Oscillation

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Abstract: Weather and climatic conditions may impact on the timing of breeding in birds. We examined changes in the laying date of the starling *Sturnus vulgaris* at Lower Hutt, New Zealand in the period 1970–2003 and investigated possible relationships with the El Niño Southern Oscillation (ENSO). Laying dates (expressed both as first and modal dates for the local population) were significantly delayed over the study period, i.e. starlings tended to lay later. The timing of breeding was non-linearly related to ENSO, with early laying associated with both low and high values of ENSO. We suggest that changes in laying dates varied with food availability, which fluctuated according to climatic events.

Key words: birds, climate effects, ENSO, long-term studies, timing of breeding.

INTRODUCTION

Researchers are seeking evidence of the impacts of global large-scale climatological changes on bird distribution, reproduction and phenology (Walther *et al.* 2002; Sparks *et al.* 2003; Lehikoinen *et al.* 2004).

Published work has not only examined the impacts of rising local temperatures on phenological events, including earlier date of breeding (e.g. Crick & Sparks 1999; Sparks *et al.* 2003; Dunn 2004), but also those of large-scale climate indices, such as the North-Atlantic Oscillation (NAO, Ottersen *et al.* 2001; Hüppop & Hüppop 2003; Sokolov & Kosarev 2003; Almaraz & Amat 2004; Kanušćák *et al.* 2004) or El Niño (Grant *et al.* 2000; Nott *et al.* 2002; Almaraz & Amat 2004). Recently, climate change research in ecology has embraced the use of climate indices, derived from large-scale atmospheric patterns, in long-term, retrospective studies. These atmospheric patterns modify local temperatures and precipitation, two extremely important influencing factors in ecological systems (Ottersen *et al.* 2001; Forchhammer & Post 2004). Since over a dozen indices have been derived, even the simple task of selecting one to use in ecological research has become complicated (Stenseth *et al.* 2003; Forchhammer & Post 2004).

El Niño is a natural feature of the global climate system. Originally it was the name given to the periodic development of unusually warm ocean waters

along the tropical South American coast and out along the Equator to the dateline, but now it is more generally used to describe the whole 'El Niño – Southern Oscillation (ENSO) phenomenon', the major systematic global climate fluctuation that occurs at the time of an 'ocean warming' event. El Niño and La Niña refer to opposite extremes of the ENSO cycle, when major changes in the Pacific atmospheric and oceanic circulation occur (see, for example, Stenseth *et al.* 2003). During El Niño, New Zealand tends to experience stronger or more frequent winds from the west in summer, typically leading to drought in east coast areas and more rain in the west. In winter, the winds tend to be more from the south, bringing colder conditions to both the land and the surrounding ocean. In spring and autumn, south-westerly winds are more common. La Niña events have different impacts on New Zealand's climate. More north-easterly winds are characteristic, which tend to bring moist, rainy conditions to the north-east of the North Island, and reduced rainfall to the south and south-west of the South Island (more in: Kidson & Renwick 2002).

However, to test the links between bird population traits and climate indices good long-term data are required and analysis of such data can sometimes explain previously unpredictable evolutionary changes (Grant & Grant 2002). Changes in avian life-history traits resulting from climate change have mainly been postulated and tested in the Northern Hemisphere (e.g. Winkler *et al.* 2002; Tryjanowski *et al.* 2004). Although recent rapid changes in climate were postulated for Australia and New Zealand as well (Houghton *et al.* 2001; Walther *et al.* 2002), to the best

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of our knowledge no long-term changes in the breeding date of birds in Australasia have been documented (see also Parmesan & Yohe 2003; Dunn 2004).

Therefore, in this paper we present an analysis of the laying dates of the starling *Sturnus vulgaris* collected during long-term studies conducted in Lower Hutt, New Zealand.

We focus on the timing of breeding because these data already exist and because timing of breeding strongly influences other life-history traits in birds generally (Rowe *et al.* 1994; Winkler *et al.* 2002; Dunn 2004) and in starlings in particular (Flux & Flux 1981; Källander & Karlsson 1993; Christians *et al.* 2001; Smith 2004). Moreover, our goal was to examine changes in breeding date in relation to air temperature at the breeding site as well as to a large scale climatic factor (ENSO index). We predict (i) according to global changes starling should start egg laying earlier in recent years; and (ii) timing of egg laying could be modified by large-scale atmospheric patterns, expressed by ENSO.

METHODS

Study species and study area

The starling was first introduced into New Zealand from Britain in 1862, with many releases made between 1865 and 1883 and since that period the starling has occurred in the Belmont area (41°10'S, 174°54'E), North Island, New Zealand (Flux & Flux 1981). In New Zealand the starling is a resident species and from the studied population all ring recoveries have been within 20 km of the study area (Flux & Flux 1981; Flux unpubl. data, 2005).

The 1500 ha study area at Belmont ranges in altitude from 250 to 400 m a.s.l. and is entirely covered in pasture closely grazed by sheep.

Starlings nested in some of the 500 boxes built into ventilation shafts of abandoned ordnance storage bunkers. Flux (1987), Flux and Flux (1981) and Thompson and Flux (1991) describe the study area and the history of the Belmont starling population.

Establishing the time of laying

Data on laying dates and some other aspects of starlings' breeding ecology were determined from as many nests as possible (yearly range 50–300). Nest boxes were inspected every two days during the laying period in October each year and were continued to the end of the breeding season. Based on these examinations the date of the first egg laying of each nest was established. From these data we calculated for each year the

earliest first egg date (FED) of the population and the modal first egg date (MoED), i.e. when the peak of egg laying in the population occurred.

Local temperatures and climate indices

Local meteorological data were obtained from the weather station at Wellington, situated 20 km south of the study area. The first starlings nested at Belmont in October (see Results), therefore mean monthly temperatures prior to, and including, October were used in the analysis.

We used values of the bimonthly ENSO index for each year 1970–2003 as an indicator of climatic fluctuation (for reasons for this choice see Stenseth *et al.* 2003; Forchhammer & Post 2004) obtained from <http://www.cdc.noaa.gov/~kew/MEI/table.html>.

Analyses

Dates were converted to numerical values such that 1 = 1st October, etc. and presented as mean \pm SD. Correlation and regression methods were employed using MINITAB v.13 and SPSS for Windows packages.

RESULTS

Laying date

In the study period the earliest first egg date (FED) of the starling varied between 4 and 26 October (mean 16 October). MoED varied between 8 and 31 October (with a mean of 19 October). FED and MoED were strongly positively correlated over the study period ($r = 0.953$; $n = 34$; $P < 0.001$). Differences between MoED and FED were only 3.2 ± 1.5 days, i.e. starlings were synchronized in timing of breeding in the studied population.

Both FED and MoED had a significant or near-significant positive trend during the period 1970–2003 ($r = 0.337$; $n = 34$; $P = 0.051$, and $r = 0.389$; $n = 34$; $P = 0.023$ for FED and MoED, respectively, Fig. 1). Laying appeared to get later until *c.* 1985 and has been stable, or slightly earlier, since.

The influence of temperatures and large scale climate indices on laying date

An examination of Wellington temperatures in October in the 1970–2003 period showed a non-significant trend towards warmer conditions ($r = 0.352$, $P = 0.084$). However, FED and MoED were not

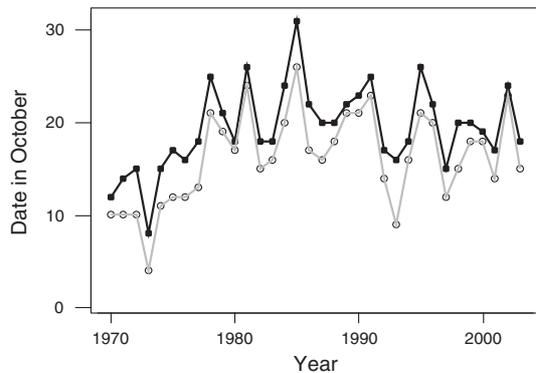


Fig. 1. Variation in the first egg date (grey line, open symbols) and modal egg date (black line, solid symbol) of the starling in the study area.

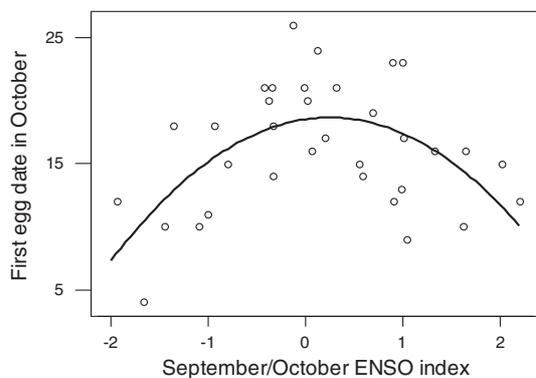


Fig. 2. Relationship between first egg date and El Niño Southern Oscillation (ENSO) index (El Niña years to left, El Niño to right) for September–October. The solid line represents a quadratic fit.

significantly related to local monthly temperatures in the period May–October (all $P > 0.33$).

In FED and MoED, there was strong autocorrelation (with year $n-1$, $P = 0.008$ and $P = 0.025$, respectively). However, even after removing a first order autocorrelation (as a covariate) there was a significant quadratic relationship for both FED and MoED with mean September/October ENSO index (and this was apparent for all bimonthly periods from May/June to November/December). Figure 2 displays this relationship for FED ($F_{3,29} = 7.50$, $R^2 = 43.7$, $P < 0.001$). This suggests that starlings nested earlier at both, El Niño and La Niña, extremes.

DISCUSSION

We expected that, like many other passerines in the Northern Hemisphere (Crick & Sparks 1999; Sparks *et al.* 2003; Dunn 2004) including other starling species (Koike & Higuchi 2002), starlings in New

Zealand should have a tendency to lay eggs earlier in more recent years as global temperatures have increased. But this was not the case. The reason may be that the temperature in the study area in October, when starlings start to breed, increased only very slightly over the study period. Moreover, in contrast to predictions and many previous studies (cited above) our findings support the earlier results by Flux (1987) who reported that the starling in New Zealand had the opposite tendency and have started to lay later in more recent years. One possible explanation is a change in the age structure in the local population with more younger (e.g. second-year) birds which have a tendency to lay later and therefore produce a pattern toward later laying over the study period. However, this is unlikely because: (i) not only has the peak date changed, but also the extreme early dates as well; and (ii) because an examination of the data reveals fewer second-year birds compared to earlier years of the study (Flux 1987 and unpubl. data, 2005). A second possibility is that the starling, as a non-native species to New Zealand, does not properly recognize environmental signals. However, this conflicts with our other finding that the starling's time of breeding is related to ENSO. Why did laying start earlier in extreme ENSO years? The answer may be linked with changes in food supply. Starlings usually collect insects by pedestrian searching among short-grass vegetation (Feare 1984). The most frequent prey of the starling are small species of centipedes, spiders, moths and earthworms (Feare 1984). It is well known that starlings' egg laying date is strongly related to food supply and in years (or experimental situations) when more food resources were available starlings laid earlier (Dunnet 1955; Källander & Karlsson 1993). Therefore, it seems that food availability may change according to weather conditions (described, for example, by the ENSO Index). Although this proposed scenario is speculative, we can imagine how ENSO might influence starlings' time of breeding. Similarly, as in the Americas during El Niño years, productivity of local ecosystems increases, including food supply for starlings (for support of this idea see: Grant *et al.* 2000; Nott *et al.* 2002) and they may lay earlier. On the other hand, during La Niña events, the situation is generally opposite, but strong winds may adversely affect the local sheep population. Many juvenile and adult sheep die during bad weather (Scott 2002; Flux unpubl. data, 2005). Because sheep in New Zealand are raised in the open, dead animals remain on the pastures and are attractive to many invertebrates, which are a good food supply for starlings. In fact, it is frequently observed that starlings eat the abundant maggots from sheep carcasses (Flux unpubl. data, 2005, see also Feare 1984). Hence earlier breeding in starlings may also occur in La Niña years. Paradoxically starlings started laying later in average years.

In conclusion, the results of this study show that laying dates of the starling breeding in New Zealand correlate to large-scale climatic fluctuations (ENSO) and we speculate that they did so via changes in their food supply. Further studies to estimate food supply in a range of years covering both El Niño and La Niña years is necessary to confirm our hypothesis.

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