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ORIGINAL ARTICLE

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What affects the magnitude of change in first arrival dates of migrant birds?

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Abstract We analysed which among four factors (mean first arrival date, migration distance, changes in population size, detectability of species) influenced the magnitude of change (regression coefficient) in the first arrival dates of 30 migrant bird species in western Poland during 1983–2003. An examination suggested that several of these factors could be important: the regression coefficient was positively related to mean first arrival date (early species advancing their arrival date more) and negatively with change in population size (species in decline changing less). Moreover, significant differences in regression coefficient were detected between short and long distance migrants and between low detectable and highly detectable species. Undertaking a principal components analysis on the four factors produced an axis explaining 59% of the variance and whose positive values were associated with late arriving, long distance and low detectable species which were more likely to be in decline. However, the multi-collinearity of these factors is a problem that cannot be resolved here and we recommend that further work from different areas is needed to tease apart these effects.

Keywords Climate change · Detectability · Methods · Phenology · Population changes

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Introduction

The timing of when birds return to their breeding area is a key component of studies of the impact of climate change upon bird populations (review in Sparks and Menzel 2002; Sparks et al. 2003; Lehikoinen et al. 2004). One major requirement of studies to identify changes in phenology is access to good long-term data. Because more detailed data are much rarer, the first arrival dates (hereafter FAD) are a commonly used measure in avian phenological studies (e.g. Mason 1995; Butler 2003; Sparks et al. 2003) and have been traditionally used as an indication of the migration timing of birds. It is known that bird species with different migratory distances may react in different ways to temperatures at their breeding grounds (Tryjanowski et al. 2002; Cotton 2003; Sokolov and Kosarev 2003) and, in general, early spring species have advanced most in recent years (Tryjanowski et al. 2002; Cotton 2003; Sparks et al. 2003; Lehikoinen et al. 2004). However, we suspect that the detection of real changes in the migratory timing of birds based on the first bird records in breeding grounds may be influenced by other factors. One factor influencing the chance to detect birds in spring is population size (Sparks et al. 2001; Tryjanowski and Sparks 2001). We predict that when the population size increases the probability of earlier detection should also increase, both because in a larger population the chance of detecting the first arrival increases (statistical reason) and also because competition over territories, nest sites and sexual partner promotes contacts between birds which may increase their individual observability (biological reason). Therefore, FAD should be recorded earlier (for more details on this problem, see Sparks et al. 2001; Tryjanowski and Sparks 2001). Arrival dates are likely to be more accurately recorded in species with large populations. Another potential problem, not yet studied to our knowledge, is the difference in detectability between species. For example, amateurs sending phenological information differ in their knowledge of bird biology and recognise only some of the species. Moreover, some bird species live in frequently visited areas, like water bodies or human settlements, whilst others occur in less frequently visited places such as wasteland or pine forests. Therefore, there is a greater chance of recording early dates with greater accuracy for well-known species, living close to human settlements, such as, for example, white stork (*Ciconia ciconia*), cuckoo (*Cuculus canorus*) or barn swallow *Hirundo rustica*, rather than the less easy to detect and distinguish species like tawny pipit (*Anthus campestris*) or barred warbler (*Sylvia nisoria*) (see also discussion in Tryjanowski and Sparks 2001; Ptaszyk et al. 2003). All of the above mentioned factors suggest that calculated changes in FAD over time can differ between different bird species. Therefore, in multi-species analysis, these additional factors should be taken into account and discussed more carefully.

In this paper, we analyse which factors influenced the magnitude of change in FAD of birds in the Wielkopolska region of western Poland. In contrast to our previous analysis (Tryjanowski et al. 2002), where we focussed mainly on relationships with temperature at local breeding grounds, we discuss other factors influencing reported changes, as well as enlarging on the previously reported study by adding new species and additional years of observation.

Methods

Study area and data sources

Observations on the FAD of 30 migrant bird species were carried out in the western Wielkopolska region (W Poland), c.40 km north of Leszno (51°51′N, 16°35′E). Annual observations from 1983 to 2003 were recorded mainly by one of the authors (S.K.) of this paper, but with occasional help from one to two others. For more details and discussion on the accuracy of methods, see Tryjanowski et al. (2002).

Birds were distinguished according to their migratory distance (Table 1): 9 species wintering mainly in Western Europe and the Mediterranean basin and 21 species wintering south of the Sahara (i.e. tropical migrants, see also Tryjanowski et al. 2002).

Information on changes in population size were gathered from previously published papers which partly covered the study area (Tryjanowski 1995, 2000; Tryjanowski and Bajczyk 1999; Tryjanowski and Sparks

Table 1 Basic biological and phenological data on analysed bird species. *Dist* type of migrant (*S* short distance – European, *L* long distance – African), *Pop* changes in local population size (*D* declining population, *S* stable, *I* increasing population), *Det* detectability (*L* low detectability, *H* high detectability), mean first arrival dates (*FAD*) and standard deviation (*SD*), trend of FAD (per annum change) and its statistical significance. Species are arranged in FAD order

Species	Dist	Pop	Det	Mean FAD	SD (days)	Trend (1983–2003)
Skylark *Alauda arvensis*	S	d	H	February 12	14.0	−0.557
Lapwing *Vanellus vanellus*	S	d	H	February 23	12.3	−1.091**
Pied wagtail *Motacilla alba*	S	s	H	February 28	14.4	0.023
Woodpigeon *Columba palumbus*	S	i	H	March 7	15.1	−1.874***
Song thrush *Turdus philomelos*	S	s	H	March 14	7.0	−0.662**
White stork *Ciconia ciconia*	L	s	H	March 18	8.8	−0.435
Black redstart *Phoenicurus ochruros*	S	s	H	March 21	8.6	−0.066
Chiffchaff *Phylloscopus collybita*	S	s	H	March 27	8.3	−0.431
Serin *Serinus serinus*	S	s	H	March 31	11.2	−0.123
Barn swallow *Hirundo rustica*	L	s	H	April 3	5.2	−0.380*
Yellow wagtail *Motacilla flava*	L	d	L	Apr 5	9.2	0.458
Willow warbler *Phylloscopus trochilus*	L	s	L	April 6	6.3	−0.068
Blackcap *Sylvia atricapilla*	S	s	L	April 9	10.2	−0.681
Wheatear *Oenanthe oenanthe*	L	s	L	April 9	8.8	−0.553
Lesser whitethroat *Sylvia curruca*	L	s	L	April 16	4.3	0.249
House martin *Delichon urbica*	L	d	H	April l8	7.6	−0.604**
Whinchat *Saxicola rubetra*	L	d	L	Apr 19	6.6	0.344
Wood warbler *Phylloscopus sibilatrix*	L	s	L	April 22	8.0	−0.346
Redstart *Phoenicurus phoenicurus*	L	i	L	April 23	5.9	−0.636***
Whitethroat *Sylvia communis*	L	d	L	April 23	4.5	−0.072
Nightingale *Luscinia megarhynchos*	L	s	H	April 24	3.8	−0.362**
Cuckoo *Cuculus canorus*	L	s	H	April 26	4.0	−0.334*
Turtle dove *Streptopelia turtur*	L	d	L	April 27	5.0	−0.480*
Ortolan bunting *Emberiza hortulana*	L	d	L	April 28	3.2	−0.274
Tawny pipit *Anthus campestris*	L	d	L	April 29	6.1	0.620*
Golden oriole *Oriolus oriolus*	L	s	H	May 2	4.9	−0.467
Spotted flycatcher *Muscicapa striata*	L	s	L	May 4	4.1	−0.351
Red-backed shrike *Lanius collurio*	L	s	L	May 5	2.5	−0.254**
Icterinae warbler *Hippolais icterina*	L	s	L	May 8	3.8	−0.153
Barred warbler *Sylvia nisoria*	L	d	L	May 9	2.7	0.128

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; $P < 0.1$

2001), a local faunistic monograph (Bednorz et al. 2000) and our unpublished data (Kuzniak and Tryjanowski, unpublished data). Because methods of assessing population change varied, we have refrained from calculating a population change index but instead divided species into three broad groups (Table 1); those with a declining population in the study area (10 species), those with stable populations (18 species), and those whose population increased (2 species).

Another potential trait influencing FAD is detectability of the bird on the breeding grounds. Species were divided into two groups, with low detectability (16 species) or with high detectability (14 species) according to our personal experience, and after discussion with a local birdwatchers' club and from information received from other researchers.

Mean FAD was calculated as a simple average of all the FADs during the study period.

Statistical analysis

The FADs for species have been compared to year (to determine trend) using standard regression and correlation techniques. The resulting coefficient is an unbiased estimate of the change that has occurred, and is of greater interest to us, in this instance, than its statistical significance. The latter is influenced by, among others, series length and year-to-year variability. To examine how mean FAD (expressed in Julian date), migration distance (short or long distance), change in population size (-1 = decline, 0 = stable, 1 = increasing) and detectability of the bird on the breeding grounds (low detectability or high detectability) influenced the regression coefficient of FAD over time we used ANOVA on the 30 regression coefficient values, 1 per species. Since the investigated factors were correlated, they were reduced by principal components analysis (PCA) and the first principal component was examined in relation to the regression coefficients in FAD.

All statistical analyses were applied according to the recommendations of Zar (1999) and were conducted using MINITAB v.13.

Results

Twenty-four of the 30 migrant bird species showed negative regression coefficients of FAD against year (i.e. earlier arrival) in Wielkopolska region, of which 10 were statistically significant. Only 6 species (1 significant) showed a trend towards later arrival. There are significantly more negative regression coefficients than would be expected by chance (binomial test, $P = 0.0014$).

The earliest arriving migrants had more variable FAD in comparison to later arriving species (correlation between mean FAD and SD of FAD, $r = -0.867$, $P < 0.001$, $n = 30$).

A univariate examination suggested that several of the investigated factors may be important (Fig. 1). Regression coefficient was positively correlated with mean FAD ($r = 0.40$, $P = 0.030$) and was related to change in population size (polynomial ANOVA $F_{2,27} = 6.20$, $P = 0.006$) suggesting FADs were getting more early for early arriving species and those whose populations were stable or increasing. Significant differences in regression coefficient were detected between short (mean -0.61 days/annum) and long distance (mean -0.19 days/annum) migrants ($F_{1,28} = 5.75$, $P = 0.023$) and between low detectable (mean -0.13 days/annum) and highly detectable (mean -0.53 days/annum) species ($F_{1,28} = 6.22$, $P = 0.019$). An added complication is the interrelatedness of the explanatory factors, for example long distance migrants tend to arrive later and be of lower detectability.

Both forwards-selection and backwards-elimination stepwise regressions resulted in a model containing two variables; population change (negative, $P = 0.033$) and detectability (negative, $P = 0.040$) in an overall model ($F_{2,27} = 6.09$, $R^2 = 31.1\%$, $P = 0.007$). Residuals from this model satisfy normality requirements ($P = 0.46$). Hence the magnitude of the advance in arrival date seemed to be affected most in detectable birds with stable or improving populations.

Undertaking a principal components analysis on the four possible effects produces a first PC axis explaining 59% of the variance whose positive values are associated with late arriving (loading 0.59), long distance (loading 0.58), low detectable species (loading -0.53) and which, to a lesser extent, are more likely to be in decline (loading -0.19). Regression coefficient is positively correlated with this axis ($r = 0.51$, $P = 0.004$, Fig. 2), once again suggesting that all considered factors are likely to be influencing changes in FAD.

Discussion

There is an increasing body of evidence from across Europe that migrant birds are returning earlier and we discussed this in our previous paper based partially on the same data set (Tryjanowski et al. 2002). Our enlarged data set has shown a clear pattern of migrants arriving earlier in Central Europe, especially during the last two decades (Zalakevicius and Zalakeviciute 2001; Tryjanowski et al. 2002; Hüppop and Hüppop 2003; Sparks et al. 2003; Lehikoinen et al. 2004).

Some earlier papers reported that short distance migrants have more plasticity and therefore they benefit more from global warming and arrive earlier and earlier to the breeding grounds (Cotton 2003; Sokolov and Kosarev 2003). A further complication is that migration distance and time of arrival are not independent; short-distance migrants tend to be the earliest arrivals. Some short distance migrants are increasingly wintering further north, and this may soon become a feature of species such as skylark (*Alauda arvensis*) and woodpigeon (*Columba palumbus*) in our study area of western Poland. We do not think that the data we used contain

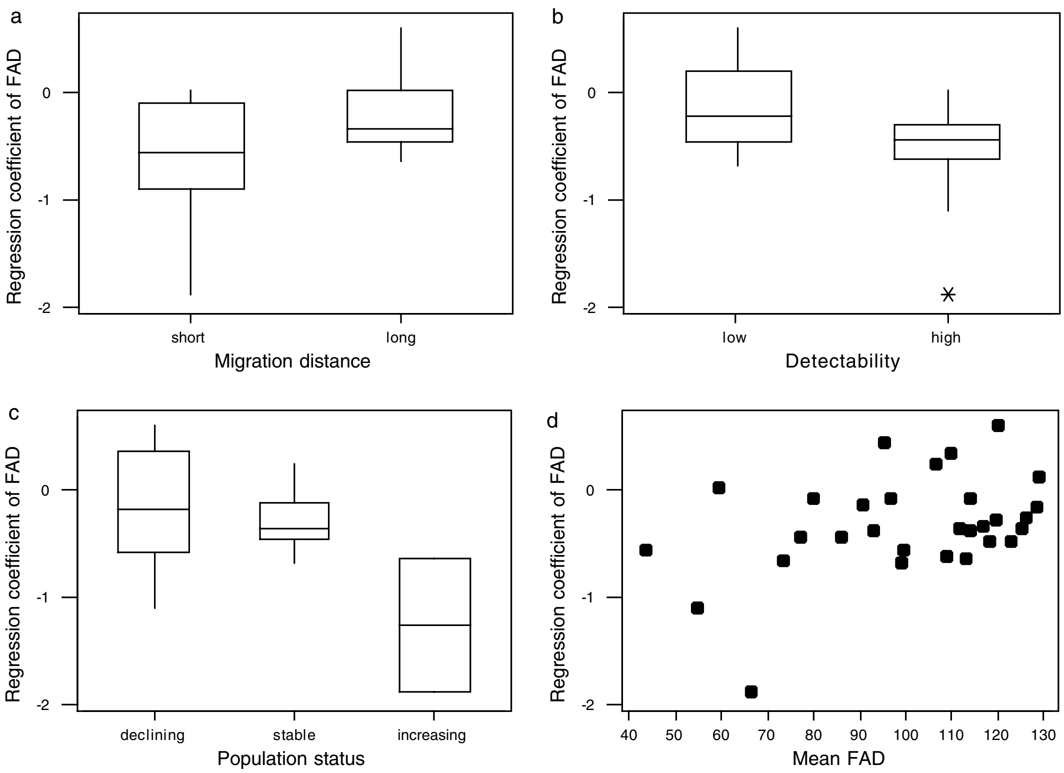

Fig. 1 Influence of **a** migration distance, **b** detectability, **c** changes in population size and **d** mean arrival date on regression coefficient of FAD on year of arrival migrants in western Poland in 1983–2003. The *box plots* used in **a–c** indicate the interquartile range (the *box*), the median (the *horizontal line* within the *box*) and the limits of data (the *vertical lines* and *asterisk* outside the *box*). See text for the significance of these relationships

observations of birds overwintering within the study area. The phenological plasticity in the early species can be seen in the correlation between FAD and their variability (expressed as SD) over the study period.

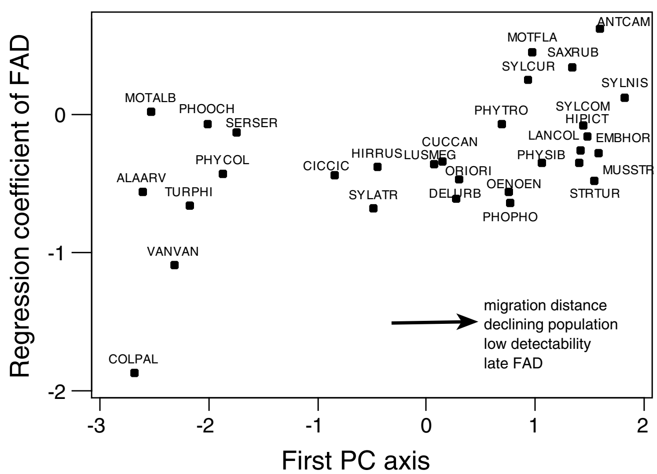

Fig. 2 Graphical presentation of the multiple influence of studied factors on the regression coefficient of FAD of bird species in western Poland in 1983–2003

However, our work suggests that it is not only the difference in migratory distance that has influenced the changes in arrival time to breeding grounds.

Our analyses show a strong influence of changes in population size on trends in detected birds' first arrival date. Sparks (1999) suggested the need to investigate the relationship between first arrival date and population size and identified a potential problem with turtle dove (*Streptopelia turtur*) as did Tryjanowski and Sparks (2001) with red-backed shrike (*Lanius collurio*). However, Ptaszyk et al. (2003) tested for potential population size influence on the FAD of white stork and did not detect an effect. The former two species are relatively difficult to detect, but white stork is among the best known and most easily detected species. Therefore, these results, as well as the findings presented in the current paper, suggest that a population size effect on FAD is especially important for (secretive) species with lower detectability.

Interestingly, three species mentioned by Cotton (2003), whinchat (*Saxicola rubetra*), lesser whitethroat (*Sylvia curruca*) and whitethroat (*Sylvia communis*), had a similar pattern of changes in FAD in western Poland, i.e. they did not advance arrival time over the study period (and were even slightly later). Although Polish and English breeding populations differ in migratory routes (via Israel and Gibraltar, respectively) they may be stimulated by the same factors in Africa and hence have a generally declining population over their whole breeding range (Bird Life International/European Bird Census Council 2000) which might have affected changes in their FAD.

A new problem presented here is that changes in FAD may be influenced by differences in detectability between species. Highly detectable species will be recorded with more accuracy and hence with greater likelihood of detection of change when present. Although it is unlikely to affect constant efforts capture data (e.g. Sokolov et al. 1998; Hüppop and Hüppop 2003; Jenni and Kéry 2003; Sokolov and Kosarev 2003), a lot of avian phenological studies derive from observational data of amateurs (Sparks 1999; Sparks and Menzel 2002; Lehikoinen et al. 2004). Such observations can differ not only in timing activity, with a weekend preference, for example (Fraser 1997; Ptaszyk et al. 2003), and weather conditions (Vahatalo et al. 2004), but also in species recognition skills. Therefore, the probability of obtaining very early records of well-known and detectable species can be higher than for more secretive ones (Tryjanowski and Sparks 2001).

Working with multiple-species studies can be advantageous because this minimises a positive publishing bias (e.g. Parmesan and Yohe 2003). However, to pay attention to factors other than just migratory distance can be useful in understanding why avian species differ in their reaction to climate changes. To our knowledge, this is the first paper which suggests the joint influence of several factors on FAD. Some problems were analysed and discussed by Jenni and Kéry (2003) in a study on autumn departure data obtained by mist-netting. Although we present here some criticism of interpretation of changes based on multi-species data, such studies are very necessary to detect a more general pattern of avian phenology changes resulting from climate change.

Zusammenfassung

Was beeinflusst die Größe der Änderung von Erstankunftsdaten bei Zugvögeln?

Für die Erstankunftsdaten von 30 Zugvogelarten in Westpolen in den Jahren 1983–2003 untersuchten wir, welche von vier Faktoren (mittleres Erstankunftsdatum, Zugstrecke, Änderung in der Populationsgröße, Feststellbarkeit der Arten) die Größe der Änderung (Regressionskoeffizient) von Erstankunftsdaten beeinflussten. Eine Untersuchung deutete darauf hin, dass verschiedene dieser Faktoren wichtig sein könnten: der Regressionskoeffizient war positiv korreliert mit den mittleren Erstankunftsdaten (frühe Arten verlegten ihre Erstankunft weiter nach vorn) und negativ mit einer Änderung in der Populationsgröße (Abnehmende Arten ändern ihre Erstankunft weniger). Darüber hinaus wurden signifikante Unterschiede gefunden im Regressionskoeffizienten zwischen Kurz- und Langstreckenziehern und zwischen leicht und schwer feststellbaren Arten. Eine Hauptkomponentenanalyse über die vier Faktoren erbrachte eine Hauptkomponente, die 59% der Varianz erklärte und deren positive Werte assoziiert waren mit später Ankunft, langer Zugstrecke und schwer feststellbaren Arten, die wahrscheinlicher im Rückgang begriffen sind. Die Multikolinearität dieser Faktoren ist jedoch ein Problem, das hier nicht gelöst werden kann, und wir empfehlen, dass weitere Forschung in unterschiedlichen Bereichen nötig ist, um diese Effekte einzeln zu untersuchen.

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