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How consistent are trends in arrival (and departure) dates of migrant birds in the UK?

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Abstract We examine the first arrival and last departure dates of migrant bird species from, respectively, six and three English area bird reports. Of all 145 bird series, 50% demonstrated significantly earlier arrival in recent years, with the average advance over all species being 0.25 days/year or 12 days earlier over 50 years. Thirty percent of 67 series demonstrated significantly later departure, with the average species delay being 0.16 days/year or eight days later over 50 years. There was greater consistency between species in trends in first arrival than in last departure, with species such as sand martin *Riparia riparia* significantly earlier at all six sites while, for example, spotted flycatcher *Muscicapa striata* showed no significant change in arrival at all sites. Significant negative correlations between arrival dates and English temperatures were found for 26% of all series, but temperature effects on departures were less clear. We provide some evidence that trends in arrival dates may be masked by population declines in birds. Since migrant bird populations are in decline generally, this may suggest that the real advance in arrival dates may be greater than that reported here.

Keywords County bird reports · Phenology · Migration · Climate change

Introduction

The return of migrant birds from their winter quarters to their breeding habitat has been of considerable interest to man for many centuries. Historically this return was associated with the arrival of spring and even signalled the start of farming operations (e.g. Lehikoinen et al.

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2004). There are a few examples of documented bird arrival dates going back to the early eighteenth century (Sparks and Carey 1995; Lehikoinen et al. 2004) but these were typically uncoordinated activities. An increase in the recording of bird migration phenology took place in the late nineteenth century, but the volume increased again in the second half of the twentieth century. The emphasis of this activity has been on the arrival of birds in spring. Recording of autumn departure dates (and the arrival and departure of winter residents) has received less attention (e.g. Jenni and Kéry 2003; Sparks and Mason 2004).

In the last five decades, recording of bird migration phenology can broadly be considered to derive from four situations. Firstly, individual recorders acting alone have been known to record bird migration phenology for a considerable number of years (e.g. Jenkins and Watson 2000). Secondly, and providing it starts early enough in the year, groups involved with ringing of birds can produce phenological data as a by-product. Thirdly, dedicated bird observatories, usually set up along migration flyways, will typically obtain phenological data, either through trapping and/or by direct observation (e.g. Hüppop and Hüppop 2003). Lastly, amateur ornithologists in either area or regional groups may coordinate first (and sometimes last) observations of migrants within their area and report these in their own publications (e.g. Mason 1995; Loxton et al. 1998; Bland 1999; Cotton 2003). Our paper involves data collected by this latter group. There is growing interest in the phenological data collected by all these groups. In recent decades there has been a marked increase in temperatures over large parts of western and northern Europe, and in many cases this has been shown to be associated with a tendency for earlier arrival of spring migrants. For instance, Lehikoinen et al. (2004) reported that nearly 40% of approximately one thousand reported series suggested significantly earlier arrival, while only 2% were significantly later. In the main, published summaries of bird migration tend to deal with results from a single location (e.g. Barrett 2002) or a small number of species (e.g. Ahas 1999; Sparks et al. 2005). With the exception of Lehikoinen et al. (2004), who summarised all known published studies available at that time, there has been little attempt to get a consistent picture of bird migration phenology over a large geographic area. The lack of a coordinated approach to examining bird migration phenology is because data are typically not available centrally, not even at the national level. Data are stored independently, in different formats and, in many cases, are not even computerised. Thus, any attempt to summarise all available information, even at a regional level, requires coordination and cooperation between many individuals/organisations. Inevitably, such studies require a large data entry and manipulation component to ensure that data are available in a comparable format for analysis.

First arrival (and last departure) dates can potentially be affected by recorder effort and population changes (e.g. Sparks et al. 2001; Tryjanowski et al. 2005). With the exception of trapping and ringing data, there are no standardised protocols associated with the recording of bird migration phenology. In addition, trapping and ringing schemes can provide the complete arrival (or departure) distribution of a species rather than just the first arrival (or last departure) date. Data on average arrival or passage data derived from trapping at bird observatories are likely to be of the highest quality and should be unaffected by recorder effort or population changes. However, data from such specific locations depend on migrant birds passing over or pausing at a particular point on the migration passage.

In this paper we examine trends in the first arrival and last departure dates of a large number of bird species, as reported in six area bird reports in England. In doing so we look for evidence of consistent patterns of phenological change and temperature responsiveness in summer visitors to the UK.

Methods

Bird migration data

Dates of first records of spring migrant birds were extracted from six UK area bird reports, hereinafter referred to as "sites", as summarised in Table 1. Only those species with at least 20 years of data are included in this paper. Additionally any species only recorded (for 20+ years) at a single site have been omitted. Thirty-three species of bird (see Table 2 for English and scientific names) are thus included in our analysis of first arrival dates. Three of the reports also included dates of last records, and these data have been abstracted as above, resulting in departure information on 23 species (see Table 4). Data on chiffchaff and blackcap appear sparse because these are now regularly seen in winter, particularly in the south, making discrimination of migrating and overwintering birds difficult. In this study, we only present data for these species for Leicester and Wharfedale, which only recorded birds considered to be migrants. It was decided to use a common end year of 2002 for all data sets so that all experienced the same recent period of warming, but a variable start year to benefit from the increased likelihood of detecting trends in longer data series.

Table 1 Information on the data sets used in this paper

Area	Approximate centre of area	Source	Duration	No. of species		Completeness (%)
				Arrival	Departure	
Sussex	51.0°N 0.3°E	Sussex Bird Report	1960–2002	31	–	95
Bristol	51.4°N 2.6°W	Proceedings of the Bristol Naturalists' Society, Somerset Bird Report	1947–2002	23	21	94/83
Essex	51.8°N 0.6°E	Essex Bird Report	1950–2002	30	23	85/84
Leicester and Rutland	52.6°N 1.0°W	The Birds of Leicestershire and Rutland	1954–2002	23	–	96
Sheffield	53.4°N 1.4°W	Birds of the Sheffield Area	1973–2002	24	23	99/97
Wharfedale	54.0°N 2.0°W	Wharfedale Naturalist Society Annual Review	1947–2002	14	–	88

The number of species does not include those with less than 20 years of data and/or which were only recorded at a single location

The sites are arranged in order of increasing latitude. The final column refers to how complete the species–year combinations of arrival and departure data sets were

Temperature data

The data used here are monthly mean Central England Temperatures obtained from the UK Met Office website (http://www.met-office.gov.uk/research/hadleycentre/CR_data/Daily/HadCET_act.txt). Spanish monthly mean temperatures for years up to 2000 were obtained from the Climatic Research Unit website (http://www.cru.uea.ac.uk/~timm/climate/index.html).

Detectability, population status and population size

Because observations of birds may be biased by their detectability, changing population status or population size (Sparks et al. 2001; Tryjanowski et al. 2005), trends in phenology were examined in relation to these three features. Detectability in a species was classed as low or high, population status was scored from –2 (rapid decline) to +2 (rapid increase), and population size was scored on a log basis 1(<1,000), 2 (<10,000), etc. Allocation of species scores was undertaken by HQPC based on quantitative assessments (using information from Baillie et al. 2006; Gregory et al. 2002; Baker et al. 2006) or expert judgement where insufficient data existed. Values used in this paper are summarised in the "Appendix".

Analysis

Trends in dates were investigated using regression on year, and the resulting regression coefficients estimate the average change in days per year over the length of the series. Pearson correlation has been used to examine the relationship between dates and monthly mean Central England Temperatures for the month in which the mean date occurred and the preceding two months.

Results

Trends in first arrival dates

Table 2 summarises the trends and their significance in the first arrival dates at all sites. Of the 145 series, 127 (88%) advanced their arrival and 72 (50%) were statistically significantly earlier. In contrast, there were only 3 (2%) significantly later arrivals. The overall mean trend per species equates to an advance of 0.25 days/year. Trends were significantly stronger (more negative) for Sussex and Sheffield than for Bristol, Essex and Wharfedale (Tukey's test following ANOVA). All series for blackcap, chiffchaff, hobby, little ringed plover, reed warbler, and sand martin were significantly earlier and, at the other extreme, none for common sandpiper, ring ouzel, spotted flycatcher and turtle dove were significant. An ANOVA on site and species accounted for 64% of the variation in trend values reported in Table 2; with species accounting for 47% ($P < 0.001$) sequentially after fitting site. A consistency in species differences in trends across sites is thus apparent. Restricting this ANOVA to trends in the 1973–2003 period for the ten common species yields similar figures of 68 and 56%, respectively.

Relationships between first arrival dates and UK temperatures

Table 3 summarises correlations between arrival date and the temperatures of the three calendar months up to and

Table 2 Trends in mean first arrival date calculated for each species and site

		Sussex		Bristol		Essex		Leics		Sheffield		Wharfedale		Mean
		B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	
Wheatear	*Oenanthe oenanthe*	**–0.36**	0.09	**–0.11**	0.05	**–0.19**	0.08	–0.04	0.11	–0.14	0.16			–0.17
Garganey	*Anas querquedula*	**–0.42**	0.15			–0.10	0.19							–0.26
Sand Martin*	*Riparia riparia*	**–0.40**	0.10	**–0.29**	0.07	**–0.41**	0.07	**–0.40**	0.07	**–0.91**	0.15	**–0.40**	0.06	–0.47
Sandwich Tern	*Sterna sandvicensis*	**–0.73**	0.22			–0.09	0.13							–0.41
Chiffchaff	*Phylloscopus collybita*							**–0.31**	0.11			**–0.47**	0.09	–0.39
Little Ringed Plover	*Charadrius dubius*	**–1.07**	0.19			**–0.60**	0.13			**–0.65**	0.21			–0.77
Ring Ouzel	*Turdus torquatus*	–0.26	0.18	–0.02	0.09	–0.28	0.14			**0.36**	0.17			–0.05
Swallow*	*Hirundo rustica*	–0.12	0.17	–0.06	0.08	–0.13	0.08	**–0.37**	0.07	**–0.44**	0.16	**–0.09**	0.04	–0.20
Whimbrel	*Numenius phaeopus*	**–0.70**	0.18			**–1.16**	0.39							–0.93
Willow Warbler*	*Phylloscopus trochilus*	**–0.31**	0.10	–0.02	0.07	–0.02	0.06	**–0.13**	0.06	**–0.57**	0.18	–0.09	0.05	–0.19
Yellow Wagtail*	*Motacilla flava*	**–0.45**	0.10	–0.05	0.06	–0.11	0.07	**–0.17**	0.06	0.25	0.21	0.14	0.09	–0.06
House Martin*	*Delichon urbica*	–0.36	0.19	–0.12	0.07	**–0.15**	0.07	**–0.42**	0.09	**–0.55**	0.18	**–0.17**	0.06	–0.30
Common Sandpiper	*Actitis hypoleucos*	0.05	0.18							–0.28	0.16	–0.08	0.09	–0.10
Tree Pipit	*Anthus trivialis*	**–0.36**	0.07	–0.10	0.07	**–0.29**	0.08	–0.13	0.08	**–0.25**	0.11			–0.23
Blackcap	*Sylvia atricapilla*							**–0.48**	0.12			**–0.33**	0.09	–0.41
Redstart*	*Phoenicurus phoenicurus*	**–0.32**	0.11	**–0.16**	0.07	0.01	0.10	–0.05	0.08	–0.06	0.14	–0.04	0.07	–0.10
Sedge Warbler	*Acrocephalus schoenobaenus*	–0.10	0.07	**–0.15**	0.05	**–0.15**	0.06	**–0.31**	0.06	**–0.65**	0.20			–0.27
Cuckoo*	*Cuculus canorus*	**–0.27**	0.11	–0.01	0.06	0.01	0.07	–0.02	0.08	–0.10	0.27	–0.01	0.04	–0.07
Little Tern	*Sterna albifrons*	**–0.17**	0.07			0.11	0.06							–0.03
Whitethroat	*Sylvia communis*	**–0.26**	0.11	0.05	0.05	–0.08	0.06	**–0.15**	0.06	–0.26	0.16			–0.14
Nightingale	*Luscinia megarhynchos*	**–0.24**	0.10	**0.14**	0.05	**–0.18**	0.07	**–0.39**	0.10					–0.17
Grasshopper Warbler	*Locustella naevia*	–0.01	0.07	–0.04	0.04	–0.12	0.08	**–0.25**	0.06	**–0.54**	0.22			–0.19
Whinchat	*Saxicola rubetra*	**–0.63**	0.19	–0.03	0.08	0.11	0.09	0.01	0.07	–0.01	0.32			–0.11
Garden Warbler	*Sylvia borin*	**–0.40**	0.09	**–0.26**	0.08	0.10	0.06	**–0.18**	0.08	**–0.34**	0.16			–0.21
Hobby	*Falco subbuteo*	**–0.53**	0.08			**–0.66**	0.24							–0.59
Lesser Whitethroat	*Sylvia curruca*	–0.16	0.09	–0.03	0.05	–0.05	0.06	–0.13	0.06	**–0.46**	0.15			–0.17
Pied Flycatcher	*Ficedula hypoleuca*	**–0.37**	0.08	**–0.21**	0.05	–0.09	0.10			**–0.68**	0.21	–0.12	0.07	–0.29
Black Tern	*Chlidonias niger*	**–0.19**	0.08			–0.11	0.13							–0.15
Reed Warbler	*Acrocephalus scirpaceus*	**–0.31**	0.08	**–0.30**	0.07	**–0.28**	0.06	**–0.35**	0.08	**–0.73**	0.18			–0.39
Swift*	*Apus apus*	**–0.25**	0.06	–0.03	0.05	**–0.13**	0.05	–0.10	0.05	**–0.37**	0.07	**0.09**	0.04	–0.13
Turtle Dove	*Streptopelia turtur*	0.02	0.14	0.13	0.08	–0.15	0.08	–0.06	0.05	–0.38	0.21			–0.09
Wood Warbler*	*Phylloscopus sibilatrix*	–0.19	0.11	0.03	0.06	–0.02	0.10	**–0.28**	0.10	**–0.36**	0.12	–0.02	0.07	–0.14
Spotted Flycatcher*	*Muscicapa striata*	–0.20	0.12	–0.06	0.07	0.22	0.11	–0.14	0.08	0.15	0.14	–0.03	0.07	–0.01
Mean		–0.32		–0.07		–0.17		–0.21		–0.33		–0.12		
Mean* species		–0.29		–0.08		–0.07		–0.21		–0.30		–0.06		

In each case, the regression coefficient of day number on year and its standard error are given

Significant results are shown in bold

Ten species (marked with an asterisk) were recorded at each location. Species are arranged in order of mean date, and areas in order of increasing latitude

including the month of the mean arrival date for that species/site combination. Of 435 correlations with temperature, 359 (83%) were negative and 114 of these (26%) were significant. Significant correlations were approximately evenly spread between the month in which the mean date occurred (36), the previous month (41) and two months earlier (37). Only four correlations (1%) were significantly positive. Sand martin, sedge warbler, swallow, tree pipit and willow warbler had a large proportion of significant negative correlations. At the other extreme, pied flycatcher, spotted flycatcher, turtle dove and wood warbler had few significant correlations.

Table 3 Correlations between first date and mean Central England Temperature for the month in which mean first date for each species occurred (t_0) and the two previous months (t_{-1} and t_{-2})

	Sussex			Bristol			Essex			Leics			Sheffield			Wharfedale		
	t_{-2}	t_{-1}	t_0	t_{-2}	t_{-1}	t_0	t_{-2}	t_{-1}	t_0	t_{-2}	t_{-1}	t_0	t_{-2}	t_{-1}	t_0	t_{-2}	t_{-1}	t_0
Wheatear	–0.11	**–0.30**	**–0.47**	**–0.28**	–0.21	**–0.46**	–0.21	–0.25	**–0.44**	–0.07	0.03	–0.27	0.02	–0.05	**–0.67**			
Garganey	–0.20	–0.27	–0.25				**–0.43**	**–0.32**	–0.15									
Sand Martin	–0.24	**–0.37**	**–0.63**	–0.20	–0.27	**–0.58**	–0.19	**–0.35**	**–0.59**	**–0.46**	**–0.36**	**–0.57**	–0.16	–0.32	**–0.49**	**–0.27**	**–0.53**	0.00
Sandwich Tern	–0.14	–0.18	**–0.36**				0.28	**0.37**	0.03									
Chiffchaff										–0.09	–0.18	**–0.66**				–0.11	**–0.29**	0.12
Little Ringed Plover	**–0.43**	**–0.34**	–0.06				–0.30	–0.31	**–0.58**				–0.30	**–0.45**	–0.34			
Ring Ouzel	–0.27	–0.13	–0.12	–0.12	–0.19	–0.26	0.08	–0.21	0.23				**–0.41**	–0.26	–0.24			
Swallow	–0.14	**–0.32**	**–0.36**	0.06	–0.11	**–0.35**	–0.17	**–0.45**	**–0.28**	–0.27	**–0.30**	**–0.30**	**–0.57**	**–0.46**	–0.19	**–0.30**	–0.14	0.09
Whimbrel	**–0.37**	–0.31	–0.17				–0.40	**–0.51**	**–0.53**									
Willow Warbler	–0.26	**–0.50**	**–0.53**	**–0.29**	–0.24	**–0.37**	0.07	0.24	–0.15	**–0.31**	**–0.58**	–0.13	**–0.44**	**–0.43**	–0.24	–0.23	**–0.30**	–0.23
Yellow Wagtail	**–0.34**	–0.20	**–0.31**	–0.08	0.06	0.05	**–0.30**	–0.09	**–0.29**	**–0.47**	**–0.43**	–0.19	–0.12	0.16	0.01	0.05	0.13	–0.19
House Martin	–0.14	–0.28	–0.24	0.02	–0.16	–0.21	**–0.33**	–0.27	–0.09	–0.26	**–0.30**	–0.21	–0.26	–0.32	–0.10	–0.03	0.04	0.01
Common Sandpiper	–0.05	0.08	0.21										0.07	0.08	–0.32	–0.14	–0.13	–0.13
Tree Pipit	**–0.40**	**–0.60**	–0.18	–0.15	–0.22	–0.09	–0.09	–0.18	**–0.28**	**–0.33**	**–0.33**	**–0.37**	**–0.46**	**–0.37**	–0.12			
Blackcap										–0.09	–0.16	0.16				–0.28	–0.21	–0.08
Redstart	**–0.41**	**–0.45**	**–0.39**	–0.01	0.08	0.00	–0.02	–0.21	–0.25	–0.21	–0.04	–0.14	–0.21	0.03	–0.17	–0.14	–0.14	**–0.35**
Sedge Warbler	**–0.47**	**–0.46**	–0.08	**–0.44**	–0.17	**–0.32**	**–0.42**	**–0.41**	–0.26	**–0.34**	–0.28	**–0.41**	–0.23	**–0.39**	–0.11			
Cuckoo	**–0.47**	**–0.39**	**–0.33**	–0.07	–0.04	0.12	**–0.33**	**–0.35**	–0.06	0.15	0.07	–0.20	0.10	–0.02	0.22	0.00	**0.27**	–0.01
Little Tern	0.02	0.01	0.03				0.20	**0.37**	–0.18									
Whitethroat	**–0.48**	**–0.50**	–0.09	–0.07	–0.15	**–0.39**	–0.13	**–0.33**	**–0.40**	–0.27	–0.09	**–0.42**	–0.20	–0.25	–0.23			
Nightingale	**–0.43**	–0.25	–0.30	–0.07	**–0.29**	–0.14	–0.10	**–0.30**	–0.22	–0.05	–0.09	–0.09						
Grasshopper Warbler	**–0.38**	**–0.35**	–0.18	–0.13	–0.13	–0.25	–0.30	**–0.42**	–0.17	–0.28	–0.24	–0.09	–0.09	–0.12	**–0.51**			
Whinchat	**–0.34**	**–0.34**	–0.30	0.04	0.02	0.03	0.24	0.20	–0.08	–0.12	0.03	–0.22	**–0.43**	–0.15	–0.04			
Garden Warbler	**–0.36**	**–0.40**	–0.27	–0.14	–0.23	0.06	–0.11	–0.10	–0.14	–0.27	–0.21	**–0.32**	–0.26	–0.14	–0.21			
Hobby	–0.24	–0.17	–0.11				–0.24	–0.06	–0.29									
Lesser Whitethroat	**–0.50**	**–0.52**	–0.02	–0.15	–0.12	–0.20	–0.18	–0.26	**–0.34**	–0.20	–0.06	–0.09	–0.24	–0.15	–0.31			
Pied Flycatcher	–0.23	–0.30	–0.27	–0.12	–0.18	–0.17	–0.07	0.12	0.13				–0.09	–0.28	–0.06	–0.28	–0.16	–0.27
Black Tern	–0.14	–0.19	–0.03				0.17	–0.19	0.06									
Reed Warbler	**–0.43**	–0.22	**–0.46**	**–0.47**	–0.06	–0.23	–0.16	–0.22	–0.14	–0.15	–0.11	–0.18	–0.26	**–0.47**	–0.30			
Swift	**–0.31**	**–0.35**	0.05	–0.15	–0.04	–0.23	–0.05	–0.09	–0.11	–0.21	0.02	–0.16	**–0.46**	**–0.40**	–0.23	0.15	0.16	–0.11
Turtle Dove	–0.13	0.03	–0.08	0.14	0.23	**0.28**	–0.14	–0.01	0.11	0.06	0.26	–0.03	–0.06	0.00	0.06			
Wood Warbler	–0.26	–0.15	–0.23	–0.08	–0.10	–0.08	0.03	–0.07	–0.02	–0.17	–0.21	–0.16	–0.14	–0.23	–0.30	–0.12	0.02	**–0.40**
Spotted Flycatcher	–0.08	–0.06	–0.19	–0.07	0.27	0.14	0.04	–0.02	0.18	0.08	0.05	0.06	0.00	0.16	0.34	–0.16	–0.17	–0.30

Significant correlations shown in bold. Order of species and areas as in Table 2

Table 4 Trends in last dates calculated for each species and site

	Bristol		Essex		Sheffield		Mean
	B	SE	B	SE	B	SE	
Wood Warbler			0.41	0.29	–0.13	0.39	0.14
Grasshopper Warbler	–0.14	0.27	0.08	0.37	**0.95**	0.34	0.30
Cuckoo	–0.20	0.17	0.05	0.11	0.09	0.41	–0.02
Pied Flycatcher	**–0.59**	0.25	**0.18**	0.09	0.58	0.98	0.06
Little Ringed Plover			–0.37	0.21	**–0.99**	0.30	–0.68
Sedge Warbler	0.14	0.10	0.03	0.12	0.12	0.31	0.10
Lesser Whitethroat	**0.58**	0.12	**0.40**	0.15	**0.66**	0.21	0.55
Reed Warbler	**0.30**	0.12	**0.46**	0.13	**0.79**	0.31	0.52
Spotted Flycatcher	**0.19**	0.08	0.15	0.11	0.04	0.15	0.13
Swift	**0.34**	0.15	**0.38**	0.16	0.19	0.40	0.30
Tree Pipit	0.14	0.15	**0.61**	0.14	**0.74**	0.34	0.50
Turtle Dove	–0.28	0.31	0.04	0.15	**–0.88**	0.37	–0.37
Garden Warbler	0.04	0.20	**0.37**	0.15	–0.21	0.38	0.07
Whitethroat	0.25	0.14	0.01	0.09	**0.98**	0.26	0.41
Willow Warbler	–0.03	0.13	0.29	0.16	0.26	0.29	0.18
Redstart	**0.55**	0.16	**0.27**	0.12	–0.05	0.36	0.26
Sand Martin	0.07	0.14	–0.12	0.14	–0.04	0.28	–0.03
Yellow Wagtail	0.30	0.19	0.29	0.17	0.10	0.21	0.23
Whinchat	**0.43**	0.15	**0.57**	0.12	0.16	0.25	0.39
Ring Ouzel	0.59	0.30	0.17	0.22	0.61	0.46	0.46
Wheatear	**0.36**	0.09	0.16	0.12	–0.18	0.27	0.11
House Martin	0.01	0.13	–0.01	0.10	**–0.82**	0.21	–0.28
Swallow	0.19	0.13	–0.12	0.12	0.01	0.23	0.03

In each case the regression coefficient of day number on year and its standard error are given

Significant results are shown in bold

Species are arranged in order of mean date and areas in order of increasing latitude

Trends in last departure dates

Table 4 summarises the trends in last departure dates. Of the 67 series, 50 (75%) involve later departure, of which 20 (30%) are significantly later. There were four (6%) significantly earlier departures. The average trend was +0.16 days/year. Lesser whitethroat and reed warbler were significantly later at all three sites. An ANOVA on site and species accounted for 54% of the variation in trend values reported in Table 4, with species sequentially accounting for virtually all 54% ($P = 0.021$) after fitting site. Some evidence for consistency in species differences in trend across sites is thus apparent. Restricting the ANOVA to trends in the 1973–2002 period produced equivalent values of 62 and 55%.

Relationships between last departure dates and UK temperatures

Table 5 summarises correlations between departure date and the temperatures of the three calendar months up to and including the month of the mean departure date for that species/site combination. Of the 201 correlations, 114 (57%) were positive. Numbers of significant correlations were low; ten positive (5%) and three negative (1%). Correlations for sand martin, wheatear, whinchat and whitethroat were dominated by positive (albeit not usually significant) relationships with temperature, suggesting later departure following warmer weather. In contrast, lesser whitethroat and wood warbler were dominated by negative temperature correlations, again typically not significant.

Factors influencing trends

Regression analysis suggested that trends in spring arrival dates were influenced by population status (Table 6), with declining species showing least advance ($F_{(1,32)} = 5.89$, $R^2 = 16.0\%$, $P = 0.021$). Population size nearly made a significant improvement to this model ($P = 0.054$), but inspection suggested this was driven largely by two species; little ringed plover and whimbrel, recorded from only three and two sites, respectively. Detectability did not significantly influence trends in spring arrival date. None of the three factors significantly influenced trends in autumn departure.

Trend in first dates across species recorded at each location

The mean first dates for the ten species recorded at each location (see Table 2 for names) across the common years 1973–2002 is plotted against year in Fig. 1. A highly significant trend of –0.32 ± 0.04 days/year ($P < 0.001$) is evident. This combined series is most highly correlated with Central England Temperature in March ($r = -0.67$, $P < 0.001$; Fig. 1). However, a stronger correlation with Spanish temperatures in March (note: data were only available up to 2000) was evident ($r = -0.83$, $P < 0.001$, Fig. 1). These results confirm a general trend towards earlier arrival of migrants in the UK driven, at least in part, by temperature. Since temperatures between European countries are highly correlated, it would be difficult to fully separate the influence of (European) migration route and destination temperatures, although logic would suggest that both would be important. The correlation between March Central England Temperature and March Spanish temperature is 0.76 ($P < 0.001$).

Table 5 Correlations between last date and mean Central England Temperature for the month in which mean last date for each species occurred (t_0) and the two previous months (t_{-1} and t_{-2})

	Bristol			Essex			Sheffield		
	t_{-2}	t_{-1}	t_0	t_{-2}	t_{-1}	t_0	t_{-2}	t_{-1}	t_0
Wood Warbler				–0.03	–0.10	0.03	–0.09	–0.02	–0.17
Grasshopper Warbler	0.02	0.17	0.18	–0.10	–0.24	–0.25	0.29	0.32	**0.42**
Cuckoo	–0.11	0.05	–0.11	–0.03	–0.25	–0.07	0.23	–0.02	0.02
Pied Flycatcher	–0.04	–0.19	–0.16	–0.05	0.16	0.00	**–0.44**	0.26	0.40
Little Ringed Plover				–0.29	0.17	0.30	0.21	0.34	0.08
Sedge Warbler	0.17	0.12	–0.07	–0.25	–0.15	–0.16	–0.24	–0.07	0.14
Lesser Whitethroat	–0.10	–0.08	–0.12	0.06	0.02	–0.04	–0.04	–0.10	–0.09
Reed Warbler	0.06	0.11	–0.05	0.19	0.08	0.20	–0.33	0.03	–0.06
Spotted Flycatcher	0.14	0.01	–0.25	0.03	0.01	0.01	–0.07	0.19	0.30
Swift	–0.02	–0.04	–0.24	0.02	–0.11	–0.05	0.03	–0.16	0.11
Tree Pipit	–0.06	–0.09	–0.01	0.16	0.00	–0.10	–0.08	0.19	0.10
Turtle Dove	0.05	–0.10	–0.14	–0.02	–0.03	–0.08	0.17	0.10	0.00
Garden Warbler	0.09	0.02	–0.09	0.12	0.10	–0.09	–0.18	–0.34	–0.17
Whitethroat	0.03	0.15	0.05	–0.02	**0.33**	0.20	0.29	0.14	**0.38**
Willow Warbler	–0.03	–0.01	–0.05	0.17	0.15	0.25	0.12	–0.14	0.02
Redstart	0.02	–0.14	0.18	–0.07	0.18	–0.06	0.14	0.06	–0.03
Sand Martin	0.20	0.15	0.22	–0.08	0.03	0.23	0.03	**0.38**	0.36
Yellow Wagtail	–0.01	–0.01	**0.31**	0.12	0.27	0.04	–0.12	0.05	0.28
Whinchat	**0.31**	0.16	0.11	**0.33**	**0.39**	0.13	0.22	0.35	0.01
Ring Ouzel	–0.15	–0.07	0.01	0.07	–0.20	**0.41**	0.03	–0.19	**0.42**
Wheatear	0.04	–0.02	0.14	0.21	0.19	0.09	0.25	0.07	0.02
House Martin	–0.12	–0.03	0.08	–0.18	0.11	0.06	**–0.40**	**–0.45**	–0.09
Swallow	0.17	0.06	0.19	–0.21	–0.18	0.24	–0.01	0.05	–0.33

Order as in Table 4. Significant correlations shown in bold

Discussion

This is the first time to our knowledge that such an extensive data set from a single country has been examined for patterns in spring arrival (and autumn departure) date. We have taken data from six area bird reports. In theory this work could be extended to tens of such reports but the workload involved in organising and inputting such data would be substantial. However, we believe that the national coordination of such data could be of considerable interest and importance.

In agreement with many published papers (summary in Lehikoinen et al. 2004), we have found significant evidence for advanced spring arrival dates. The proportion of our series showing significant advances in spring arrival (50%) and significant delays in spring arrival (2%) were similar to those found by Lehikoinen et al. (2004) across Europe. Because we look at data from six sites we can see how consistent the patterns are between species. The strong significance of the species term in our analyses of variance, after fitting a site term, showed that the ordering of species trends showed good consistency between sites. For example, sand martin was significantly earlier at all six sites, whilst spotted flycatcher was not significant at all six sites. Temperatures, even the UK temperatures used here, were correlated with bird arrival. These temperatures will advance the season, providing invertebrate prey for the arriving migrants, and will be positively correlated with temperatures further south.

Table 6 Mean trends in spring arrival date (days/year) for five categories of population status

	Mean trend	SE	*N*
Rapid decline	–0.11	0.03	19
Decline	–0.26	0.05	13
Stable	–0.33	0.11	7
Increase	–0.34	0.16	3
Rapid increase	–0.41	–	1

Trends in autumn departure were biased towards later departure. There were less significant effects and less temperature effects on these than on spring arrivals. Two points should be borne in mind. Firstly that the departure data only relate to three sites, and secondly that autumn departures are unlikely to be as well-recorded as spring arrivals. Consistency in trends for both spring and autumn arrival were apparent from ANOVA, whether or not the data were controlled for a common set of years and species.

The overall mean trends suggest a mean advance of 0.25 days/year in spring arrival and a 0.16 days/year delay

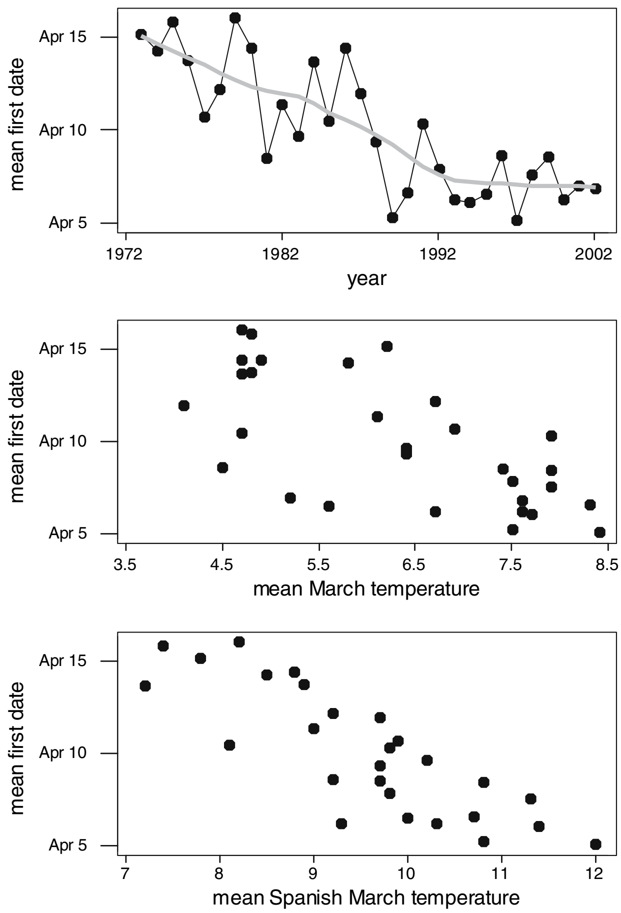

Fig. 1 The mean arrival date of the ten common species (see Table 1 for details) across the six areas for the years 1973–2002 (*top*), plotted against mean Central England Temperature (*middle*) for March, and against mean Spanish temperature for March 1973–2000 (*bottom*)

in autumn migration. Over a period of 50 years, roughly equivalent to the longer studies examined here, this suggests that spring arrives 12 days earlier and departs 8 days later, an extended residency of 20 days. These, however, are average figures, and individual species show very different patterns. One of the most consistent species reported here, the sand martin, has advanced its mean arrival by twice this average (–0.47 days/year), but shows little change in departure (mean –0.03 days/year).

The trends in arrival date, but not departure date, of some species appear to be influenced by other confounding factors apart from climate. As anticipated by Tryjanowski et al. (2005), species in greatest decline, i.e., those with a declining probability of being recorded early, showed least advance in spring phenology. What is interesting is that detection of spring advances was achieved despite the general decline in migrant bird populations (see "Appendix").

We are conscious that we have only briefly touched on the influence of migration route temperatures (e.g. Hüppop and Winkel 2006). This is hampered by limited information on migration routes south of the Mediterranean and, until recently, the limited availability of up-to-date temperatures in these areas. We hope that both of these aspects will be fully addressed in the near future.

We believe that we report here, for the first time, a comprehensive picture of migration phenology over a large scale (England). There can be little doubt from our results that first observations of spring migration are now earlier in the year than they used to, and that temperature strongly influences this. Autumn departure presents a less clear-cut picture, but with the balance towards later departure. We hope that this paper will encourage two related processes: firstly, the collation of data, at least nationally, from all available sources and a thorough investigation of the data when complete; secondly, interrogation of the data to understand species-specific differences in spring and autumn migration, and the causes and consequences of these.

Zusammenfassung

Wie konsistent sind Veränderungen bei der Ankunft (und beim Abflug) von Zugvögeln in Großbrittanien?

Wir untersuchen die früheste Ankunft und den spätesten Abflug ziehender Vogelarten aus sechs bzw. drei Berichtzonen in England. Von den insgesamt 145 Vogelreihen wiesen 50% in den letzten Jahren eine deutlich frühere Ankunft auf, wobei alle Vogelarten durchschnittlich 0,25 Tage pro Jahr oder über einen Zeitraum vom 50 Jahren 12 Tage früher ankamen. 30% von 67 Reihen wiesen einen deutlich späteren Abflug auf, wobei die durchschnittliche Verzögerung pro Vogelart 0,16 Tage pro Jahr oder 8 Tage über einen Zeitraum vom 50 Jahren beträgt. Zwischen den Arten herrscht eine höhere Konsistenz bei der ersten Ankunft als beim letzten Abflug. Arten wie die Uferschwalbe *Riparia riparia* kamen an allen sechs Standorten deutlich früher an, während beispielsweise der Grauschnäpper *Muscicapa striata* an allen Standorten keine wesentliche Veränderung der Ankunftszeit beobachten ließ. Signifikante negative Beziehungen zwischen der Ankunft und den Temperaturen in England ließen sich bei 26% aller Reihen beobachten, allerdings waren die Auswirkungen der Temperatur auf den Abflug weniger eindeutig. Wir können einige Hinweise dafür vorlegen, dass die Entwicklungen bei Ankunftszeiten möglicherweise von Rückgängen in der Vogelpopulation verschleiert werden. Da die Populationen bei Zugvögeln insgesamt rückläufig sind, könnte dies darauf hinweisen, dass die tatsächliche Vorverlagerung der Ankunftszeiten möglicherweise größer ist als hier berichtet.

Acknowledgments We thank all those whose observations contributed to the data reported here.

Appendix

Table 7 Values of detectability, population status and population size used in this paper

	Detectability	Population status	Population size
Wheatear	L	–1	3
Garganey	L	–1	1
Sandwich Tern	H	–1	3
Sand Martin	H	0	4
Chiffchaff	H	1	4
Little Ringed Plover	L	–1	1
Ring Ouzel	L	–2	2
Whimbrel	L	0	1
Swallow	H	0	4
Willow Warbler	H	–2	5
Yellow Wagtail	L	–2	3
House Martin	H	–1	4
Common Sandpiper	H	–1	3
Tree Pipit	L	–2	3
Redstart	L	0	4
Blackcap	H	2	4
Sedge Warbler	H	0	4
Cuckoo	H	–2	3
Little Tern	H	1	2
Whitethroat	L	–2	4
Nightingale	L	–1	2
Grasshopper Warbler	L	–2	3
Whinchat	L	–1	3
Garden Warbler	L	0	4
Hobby	L	1	2
Pied Flycatcher	H	–1	3
Lesser Whitethroat	L	–1	3
Black Tern	H	–1	1
Reed Warbler	H	–1	3
Swift	H	0	3
Turtle Dove	L	–2	3
Wood Warbler	L	–1	3
Spotted Flycatcher	L	–2	3

See "Methods" for details

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