A Gaussian (normal) seasonal distribution curve can be fitted as a quadratic function on a logarithmic scale \( \log(\{ \text{expected number on day } x_i \}) = \mu_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 \).

However, the following re-parameterization gave lower autocorrelations in the MCMC simulations: “mean” = \( \tau = -\beta_1 / (2\beta_2) \), “peak” = \( \rho = \beta_0 + \beta_1 \tau + \beta_2 \tau^2 \), and “standard deviation” = \( \kappa = 1 / \sqrt{-2\beta_2} \).
Supporting Online Material

Data

We analyzed banding data collected during spring migration in the period 1980–2004 at the bird observatories of Falsterbo (Sweden), Ottenby (Sweden), Jomfruland (Norway) and Hanko (Finland) (Fig. 1). For Hanko and Jomfruland, we also included observations from standardized counts of migrants (see below). A total of 34 species were investigated (Tables S1–S3; see below for selection criteria), of which 17 were classified as short-distance (wintering north of the Sahara desert, mainly in Europe) and 17 as long-distance migrants (wintering south of the Sahara or in South Asia). For trapping and observation data, care was taken not to include any species for which local wintering or breeding birds potentially could influence our sample percentiles.

For comparison with southern Europe, we used banding data based on standardized mist-netting from the island of Capri (southern Italy). Below we summarize details of the data collection procedures at each observatory.

Jomfruland

Jomfruland Bird Observatory (SJ) is located close to the northern end of the island of Jomfruland, along the outer coastline of southeastern Norway (58°53'N, 9°37'E). We used data on birds trapped in mist-nets during the period April 1–June 15. For some common species with low trapping efficiency or an early migration (i.e. where migrating birds may occur prior to the start of the mist-netting period), we instead used daily observation sums for the period March 18–June 15. From 1990 onwards, the mist-netting protocol has remained unchanged, with the number, positions, and operating hours of mist-nets kept constant. Trapping was performed daily, but the number of nets and/or their hours of operation were...
reduced on days with strong wind and/or heavy rain. Prior to 1990, sampling efforts were less
strictly standardized, but trapping occurred on a daily basis throughout the selected period.
For these early years, care was taken to use only data from the same trapping location as later
years, and we did not include any observation data for years with incomplete coverage before
the onset of mist-netting.

**Falsterbo**

The banding site at the Falsterbo Bird Observatory is situated on the south-westernmost tip of
Sweden (55°23’N, 12°50’E). Standardized mist-netting in spring is performed daily at the
Lighthouse Garden, a small (ca. 1 ha) stand of mixed trees and bushes surrounding the
Falsterbo Lighthouse (S2), within an open field area (golf course). Since 1980, the spring
trapping season started on March 21 and lasted till June 10. Depending on weather conditions
(wind in particular), the daily number of mist-nets used varied, up to a maximum of 21. On
days with heavy rain or very strong winds, all trapping efforts were canceled. The nets were
opened before dawn and controlled every half hour. The daily trapping period lasted at least
four hours and continued thereafter as long as the number of captured birds exceeded ten
individuals per hour. Nets have been positioned at the same location during all years.

**Ottenby**

Ottenby Bird Observatory (56°12’N, 16°24’E) is situated on the southernmost tip of Öland, a
137 km long island, ca.10 km off the coast of south-eastern Sweden. Migratory birds have
been caught according to strictly standardized procedures during 1980–2004 (S3). Birds were
captured in stationary mist nets and in two funnel traps of Helgoland type (S4), every morning
from dawn to 11 am. In case of rain or strong winds only the funnel traps were used. The
spring trapping period was March 15–June 15, and only 14 out of 2,325 trapping days had to be cancelled over the years (all comprised between 15–24 March in the years 1980–1987).

**Hanko**

Hanko bird observatory (59°48'N, 22°53'E) is located on a peninsula in the south-western part of Finland (S5). Data were collected by means of two daily routines: standardized counts of actively migrating birds and counts of resting migratory passerines. For further analysis, we used either one of the methods or the sum of both, depending on the species-specific breeding status in the area, the migratory behavior and commonness in the respective set of data. We used data from the period March 10 to June 15. To avoid bias due to non-randomly missing days early in the season, we excluded some early-migrating short-distance migrants from the analyses (see Tables S1–S3). Standardized migration counts consisted of four hours of continuous observation from sunrise onwards in a tower near the tip of the peninsula. Poor weather conditions (heavy rain and/or very strong wind) occasionally reduced observation activity, but during such weather conditions passerine migration is extremely scarce. Resting migratory passerines were counted along routine walking paths at the small (ca. 12 ha) observatory area at the tip of the peninsula after the standardized migration counts.

**Capri**

The island of Capri (40°33'N 14°15'E) is located in the Tyrrhenian sea, ca. 5 km off mainland southern Italy. During spring, many long-distance migratory birds stop there to rest, mainly for a short time (often only a few hours), after the consecutive crossing of the Sahara desert and of the Mediterranean Sea (S6–S9). Birds were trapped with mist-nets, whose location was kept standardized during the study period (see below), while vegetation structure was affected during few years by a fire event (S8); however, this should not affect changes in the
phenology of migration. The trapping area comprises ca. 2 ha of the dry and bushy vegetation (garrigue and “macchia”) typical of this region of the Mediterranean. Data were collected during the period 1981-2004, although no data were available for the years 1982 to 1985, and for the year 2000, when the coverage was insufficient (S8). Trapping activities were carried out every day (from dawn to dusk) during the selected time period (see below), except in cases of heavy wind or rain; this occurred on average 1.05 days each year, with no temporal trend over the study period (slope = 0.060 ± 0.056 SE). In order to standardize the trapping effort across years (see S8), the data used in this study was restricted to the period April 17–May 15. Since the proportions of the birds arriving outside these dates may vary from year to year, simple percentiles from banding dates may be biased and underestimate the variation in mean arrival dates. We therefore fitted a Gaussian curve in a Poisson regression on the daily banding numbers and used the distribution derived from this analysis to estimate percentiles of the yearly migratory distributions. To be able to account for large extra-Poisson variation in the data, the model was fitted with Bayesian MCMC methods (see Methods).

Climate data

We used the mean winter (December–March) NAO index (http://www.cgd.ucar.edu/cas/jhurrell/) as a measure of climate fluctuations, because it is known to affect the timing of spring events in Europe (S10). As an explanatory variable, we used the deviations from linear regression of the winter NAO index on year (dNAO). The trend was weakly negative over this time period (slope = –0.052, 95% c.i.: –0.167 to 0.063).

Methods

For each species and year in which at least 20 individuals were trapped/observed at a Scandinavian bird observatory, we estimated the 10\textsuperscript{th}, 50\textsuperscript{th} and 90\textsuperscript{th} sample percentiles. Dates
are given as Julian dates (day-of-year). Note that the estimated percentiles are not, strictly speaking, independent, and fitting a Gaussian curve to the Capri data results in a different statistical dependence between the percentiles.

**Models and statistics**

We tested whether regression coefficients for short- and long-distance migrants differed significantly from each other by constructing a 95% confidence interval for the difference using maximum likelihood and checked whether zero was excluded. To test whether the regression coefficients differed from zero, we checked whether the bivariate 95% confidence region of their means (Fig. 2) excluded zero with respect to the TIME or dNAO axis.

For each species and percentile (10\textsuperscript{th}, 50\textsuperscript{th} and 90\textsuperscript{th}) of the arrival distribution ($S/I$) we fitted a linear mixed-effects model having TIME and the residuals of the regression of NAO on TIME (dNAO) as explanatory variables, ‘observatory’ as a fixed effect and a random between-year variance component in common for all observatories. Note that a unit change in NAO implies an identical change in dNAO, even if the origins of the two scales differ. Thus, we have framed our discussion simply in terms of effects of a change in NAO. Furthermore, to facilitate comparison between the observatories and the banding site on Capri, the mean effects of TIME and dNAO were estimated for the six long-distance migrants for which sufficient data were available both at the four Scandinavian bird observatories and on Capri (see “Estimating mean arrival date in the Capri data by over-dispersed Poisson regression”). Estimates were obtained from a linear mixed model assuming compound symmetry for the year-to-year variation of different species (i.e., same variance for all species and all species equally correlated), and a different residual variance for every combination of species and locations (because the amount of data, and hence measurement error, behind every data point in the analysis vary mainly at this level). The mixed models were fitted with restricted
maximum likelihood (REML) by the ‘lme’ function in the nlme package (S12) of the software R (version 2.1) (S13).

Estimating mean arrival date in the Capri data by over-dispersed Poisson regression

Because data from the Capri banding site did not cover the entire migration period (see Data), mean arrival date at this location was estimated by fitting a Gaussian seasonal distribution curve in a Poisson regression on the daily banding numbers. There is typically large day-to-day variation in banding data of migrating birds (presumably mostly due to local weather conditions), and it is difficult to adequately model this over-dispersion in generalized linear models when using maximum likelihood methods. We therefore used Bayesian MCMC methods implemented in the program WinBUGS 1.4 (S14).

A Gaussian (normal) seasonal distribution curve can be fitted as a quadratic function on a logarithmic scale (log(\{expected number on day \(x_i\)}) = \mu_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 ).

However, the following re-parameterization gave lower autocorrelations in the MCMC simulations: “mean” = \( \tau = -\beta_1/(2\beta_2) \), “peak height” = \( \rho = \beta_0 + \beta_1 \tau + \beta_2 \tau^2 = \beta_0 - \frac{\beta_1^2}{4\beta_2} \), and

“standard deviation” = \( \kappa = 1/\sqrt{-2\beta_2} \).

Two alternative models were considered for modeling the over-dispersion in the data; either a log-normal component of the Poisson parameter (log(\( \lambda_i \)) = \mu_i + \varepsilon_i , where \( \varepsilon_i \sim N(0, \sigma^2) \)), or a stochastic day-effect from a Gamma distribution with shape parameter being 1/scale parameter (\( \lambda_i = e^{\mu_i + \nu_i} \), where \( \nu_i \sim \Gamma(\alpha, 1/\alpha) \), E(\( \nu_i \)) = 1). In the first model, the expected number of ringed birds on day \( i \) is E(\( \lambda_i \)) = e^{\mu_i + \sigma^2/2} . In the latter model, the expected number is E(\( \lambda_i \)) = e^{\mu_i} . The Gamma-model gave somewhat better goodness of fit statistics (see below) and lower DIC (=Deviance Information Criterion) value, and was hence used in the
analysis. The model was fitted for each species separately, and all parameters except $\alpha$ were year-specific ($\alpha$ was constant across years). As estimates of mean arrival dates (see Table s5) we used the medians of posterior distributions of the parameter $\tau$.

To facilitate numerical convergence and eliminate nonsensical parameter values from the posterior distributions, we constrained the parameter space by using uniform and rather vague priors on the parameters $\tau$ (mean passage date) and $\kappa$ (standard deviation in passage date). For $\kappa$ of all years and species, we used a Uniform $(0.25,10)$ prior, meaning that the time elapsed between the 2.5 percentile and the 97.5 percentile of banding dates could take any value between 1 and 40 days. The priors for mean banding date, $\tau$, depended on species and spanned what we considered the maximum reasonable range for that species (Table S4). The peak of the expectation curve, represented by the parameter $\rho$, was allowed to vary between 0 and 10 times the maximum observed daily count of the species, which is essentially an uninformative prior. The prior of the parameter in the Gamma-term accounting for over-dispersion, $\alpha$, was set to an uninformative $\Gamma$(scale = 1/1000, shape = 1000) distribution.

We used relatively long chains in the MCMC simulations due to persistent long-legged autocorrelations in some parameters (6 parallel chains of 80,000 iterations with an initial burn-in period of 10,000 iterations and thereafter sampling at every 5$^{th}$ iteration). Convergence was confirmed by the Gelman and Rubin statistic, which compares the within-chain to the between-chain variability of chains started at different and dispersed initial values ($S15$).

Goodness of fit (GOF) was assessed by using Bayesian p-values (comparing the distributions of GOF-statistics computed from both the actual data and from simulated data at every step of the MCMC chain ($S16$). An acceptable fit was verified with respect to the following statistics: deviance, skewness and kurtosis of deviance residuals, correlation
between deviance residuals and day of year ($x_i$), and correlation between the deviance residuals and the fitted expectations $e^{\mu}$. 

**References**


### Supplementary Tables

**Table S1.** Species and observatory specific parameter estimates and variance components when analyzing the early phase of migration (10\textsuperscript{th} percentile) using a linear mixed model with ‘observatory’ as a fixed effect and a random between-year variance component in common for all observatories.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Migration category (SHORT or LONG distance migrant)</th>
<th>Mean date (day of year)*</th>
<th>Variance components (SD units)</th>
<th>Estimates of slope (± SE)</th>
<th>Estimated unexplained between-year variation (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Falsterbo</td>
<td>Ottenby</td>
<td>Jomfru–land</td>
<td>Hanko</td>
</tr>
<tr>
<td>White wagtail</td>
<td>Motacilla alba</td>
<td>SHORT</td>
<td>100.6</td>
<td>107.1</td>
<td>103.0</td>
<td>105.1</td>
</tr>
<tr>
<td>Winter wren</td>
<td>Troglodytes troglodytes</td>
<td>SHORT</td>
<td>90.1</td>
<td>89.7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Hedge accentor</td>
<td>Prunella modularis</td>
<td>SHORT</td>
<td>91.2</td>
<td>89.1</td>
<td>95.8</td>
<td>–</td>
</tr>
<tr>
<td>European robin</td>
<td>Erithacus rubecula</td>
<td>SHORT</td>
<td>95.1</td>
<td>99.7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Common blackbird</td>
<td>Turdus merula</td>
<td>SHORT</td>
<td>86.5</td>
<td>80.3</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Song thrush</td>
<td>Turdus philomelos</td>
<td>SHORT</td>
<td>91.8</td>
<td>94.9</td>
<td>98.0</td>
<td>101.5</td>
</tr>
<tr>
<td>Redwing</td>
<td>Turdus iliacus</td>
<td>SHORT</td>
<td>97.6</td>
<td>90.8</td>
<td>93.6</td>
<td>–</td>
</tr>
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<td>Chiffchaff</td>
<td>Phylloscopus collybita</td>
<td>SHORT</td>
<td>101.6</td>
<td>112.5</td>
<td>108.8</td>
<td>114.7</td>
</tr>
<tr>
<td>Goldcrest</td>
<td>Regulus regulus</td>
<td>SHORT</td>
<td>89.7</td>
<td>99.7</td>
<td>90.4</td>
<td>–</td>
</tr>
<tr>
<td>Blue tit</td>
<td>Parus caeruleus</td>
<td>SHORT</td>
<td>83.5</td>
<td>78.7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Great tit</td>
<td>Parus major</td>
<td>SHORT</td>
<td>82.9</td>
<td>80.1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Chaffinch</td>
<td>Fringilla coelebs</td>
<td>SHORT</td>
<td>89.4</td>
<td>89.8</td>
<td>–</td>
<td>100.4</td>
</tr>
<tr>
<td>Brambling</td>
<td>Fringilla montifringilla</td>
<td>SHORT</td>
<td>-</td>
<td>105.3</td>
<td>–</td>
<td>103.5</td>
</tr>
<tr>
<td>European greenfinch</td>
<td>Carduelis chloris</td>
<td>SHORT</td>
<td>93.4</td>
<td>91.2</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Common linnet</td>
<td>Carduelis cannabina</td>
<td>SHORT</td>
<td>109.5</td>
<td>117.1</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Yellowhammer</td>
<td>Emberiza citrinella</td>
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<td>-</td>
<td>84.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Reed bunting</td>
<td>Emberiza schoeniclus</td>
<td>SHORT</td>
<td>107.2</td>
<td>86.2</td>
<td>92.7</td>
<td>–</td>
</tr>
<tr>
<td>Barn swallow</td>
<td>Hirundo rustica</td>
<td>LONG</td>
<td>137.1</td>
<td>134.1</td>
<td>129.5</td>
<td>–</td>
</tr>
<tr>
<td>Tree pipit</td>
<td>Anthus trivialis</td>
<td>LONG</td>
<td>121.4</td>
<td>122.0</td>
<td>121.7</td>
<td>118.9</td>
</tr>
<tr>
<td>Thrush nightingale</td>
<td>Luscinia luscinia</td>
<td>LONG</td>
<td>132.8</td>
<td>131.6</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Common name</td>
<td>Scientific name</td>
<td>Migration category (SHORT or LONG distance migrant)</td>
<td>Mean date (day of year)*</td>
<td>Variance components (SD units)</td>
<td>Estimates of slope (± SE)</td>
<td>Estimated unexplained between-year variation (SD)</td>
</tr>
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<td>-----------------------</td>
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<td>--------------------------</td>
<td>--------------------------------</td>
<td>--------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Falsterbo  Ottenby  Jomfru-land  Hanko</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bluethroat</td>
<td>Luscinia svecica</td>
<td>SHORT</td>
<td>-</td>
<td>131.3</td>
<td>130.1</td>
<td>2.8 (63 %)</td>
</tr>
<tr>
<td>Common redstart</td>
<td>Phoenicurus phoenicus</td>
<td>SHORT</td>
<td>123.2</td>
<td>125.8</td>
<td>125.4</td>
<td>127.2</td>
</tr>
<tr>
<td>Whinchat</td>
<td>Saxicola rubetra</td>
<td>SHORT</td>
<td>130.0</td>
<td>-</td>
<td>127.9</td>
<td>128.0</td>
</tr>
<tr>
<td>Marsh warbler</td>
<td>Acrocephalus palustris</td>
<td>SHORT</td>
<td>147.8</td>
<td>145.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Eurasian reed warbler</td>
<td>Acrocephalus scirpaceus</td>
<td>SHORT</td>
<td>137.1</td>
<td>141.3</td>
<td>141.7</td>
<td>-</td>
</tr>
<tr>
<td>Icterine warbler</td>
<td>Hippolais icterina</td>
<td>SHORT</td>
<td>140.7</td>
<td>140.9</td>
<td>137.7</td>
<td>-</td>
</tr>
<tr>
<td>Lesser whitethroat</td>
<td>Sylvia curruca</td>
<td>SHORT</td>
<td>123.0</td>
<td>127.0</td>
<td>130.9</td>
<td>133.7</td>
</tr>
<tr>
<td>Common whitethroat</td>
<td>Sylvia communis</td>
<td>SHORT</td>
<td>132.0</td>
<td>133.3</td>
<td>134.9</td>
<td>-</td>
</tr>
<tr>
<td>Garden warbler</td>
<td>Sylvia borin</td>
<td>SHORT</td>
<td>137.6</td>
<td>139.9</td>
<td>140.5</td>
<td>145.7</td>
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<tr>
<td>Blackcap</td>
<td>Sylvia atricapilla</td>
<td>SHORT</td>
<td>120.0</td>
<td>122.0</td>
<td>127.2</td>
<td>133.6</td>
</tr>
<tr>
<td>Willow warbler</td>
<td>Phylloscopus trochilus</td>
<td>SHORT</td>
<td>119.2</td>
<td>123.2</td>
<td>124.3</td>
<td>133.8</td>
</tr>
<tr>
<td>Spotted flycatcher</td>
<td>Muscicapa striata</td>
<td>SHORT</td>
<td>136.9</td>
<td>136.4</td>
<td>138.0</td>
<td>143.4</td>
</tr>
<tr>
<td>Pied flycatcher</td>
<td>Ficedula hypoleuca</td>
<td>SHORT</td>
<td>124.7</td>
<td>124.1</td>
<td>127.9</td>
<td>128.9</td>
</tr>
<tr>
<td>Red-backed shrike</td>
<td>Lanius collurio</td>
<td>SHORT</td>
<td>135.2</td>
<td>135.4</td>
<td>140.0</td>
<td>142.2</td>
</tr>
</tbody>
</table>

*Where mean date is not given, data from this species and observatory has not been included in the analysis.*
Table S2. Species and observatory specific parameter estimates and variance components when analyzing the middle phase of migration (50th percentile) using a linear mixed model with ‘observatory’ as a fixed effect and a random between-year variance component in common for all observatories.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Migration category (SHORT or LONG distance migrant)</th>
<th>Mean date (day of year)*</th>
<th>Variance components (SD units)</th>
<th>Estimates of slope (± SE)</th>
<th>Estimated unexplained between-year variation (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White wagtail</td>
<td>Motacilla alba</td>
<td>SHORT</td>
<td>124.5  129.4  117.0  112.5</td>
<td>0.0 (0 %)  7.6</td>
<td>0.07 ± 0.19  0.31 ± 0.64</td>
<td>0.0</td>
</tr>
<tr>
<td>Winter wren</td>
<td>Troglodytes troglodytes</td>
<td>SHORT</td>
<td>107.2  108.4  -  -  -</td>
<td>1.5 (6 %)  5.8</td>
<td>-0.07 ± 0.12  -0.68 ± 0.45</td>
<td>1.5</td>
</tr>
<tr>
<td>Hedge accentor</td>
<td>Prunella modularis</td>
<td>SHORT</td>
<td>106.8  100.2  103.1  -</td>
<td>4.1 (42 %)  4.8</td>
<td>-0.03 ± 0.14  -0.40 ± 0.53</td>
<td>4.2</td>
</tr>
<tr>
<td>European robin</td>
<td>Erithacus rubecula</td>
<td>SHORT</td>
<td>109.4  112.6  -  -  -</td>
<td>4.7 (74 %)  2.8</td>
<td>0.04 ± 0.15  0.20 ± 0.55</td>
<td>4.9</td>
</tr>
<tr>
<td>Common blackbird</td>
<td>Turdus merula</td>
<td>SHORT</td>
<td>106.0  91.3  -  -  -</td>
<td>1.6 (4 %)  8.1</td>
<td>-0.06 ± 0.17  0.04 ± 0.64</td>
<td>2.4</td>
</tr>
<tr>
<td>Song thrush</td>
<td>Turdus philomelos</td>
<td>SHORT</td>
<td>110.1  111.4  107.6  113.1</td>
<td>3.3 (26 %)  5.5</td>
<td>-0.11 ± 0.12  0.07 ± 0.46</td>
<td>3.4</td>
</tr>
<tr>
<td>Redwing</td>
<td>Turdus iliacus</td>
<td>SHORT</td>
<td>100.7  104.4  103.4  -</td>
<td>3.4 (22 %)  6.5</td>
<td>-0.22 ± 0.16  -1.18 ± 0.58</td>
<td>1.8</td>
</tr>
<tr>
<td>Chiffchaff</td>
<td>Phylloscopus collybita</td>
<td>SHORT</td>
<td>117.0  123.7  119.1  125.6</td>
<td>3.1 (26 %)  5.3</td>
<td>-0.40 ± 0.09  -0.15 ± 0.32</td>
<td>1.2</td>
</tr>
<tr>
<td>Goldcrest</td>
<td>Regulus regulus</td>
<td>SHORT</td>
<td>96.9  112.6  99.7  -</td>
<td>3.1 (24 %)  5.5</td>
<td>-0.06 ± 0.13  0.01 ± 0.48</td>
<td>3.3</td>
</tr>
<tr>
<td>Blue tit</td>
<td>Parus caeruleus</td>
<td>SHORT</td>
<td>91.0  90.5  -  -  -</td>
<td>0.0 (0 %)  5.8</td>
<td>-0.03 ± 0.32  0.05 ± 0.85</td>
<td>0.0</td>
</tr>
<tr>
<td>Great tit</td>
<td>Parus major</td>
<td>SHORT</td>
<td>90.1  87.5  -  -  -</td>
<td>5.1 (71 %)  3.2</td>
<td>-0.07 ± 0.16  -1.12 ± 0.64</td>
<td>4.9</td>
</tr>
<tr>
<td>Chaffinch</td>
<td>Fringilla coelebs</td>
<td>SHORT</td>
<td>105.8  109.4  -  112.4</td>
<td>1.8 (9 %)  5.7</td>
<td>0.13 ± 0.10  -0.49 ± 0.38</td>
<td>1.6</td>
</tr>
<tr>
<td>Brambling</td>
<td>Fringilla montifringilla</td>
<td>SHORT</td>
<td>-  116.9  113.0  -</td>
<td>0.0 (0 %)  4.7</td>
<td>-0.02 ± 0.12  -0.58 ± 0.45</td>
<td>0.0</td>
</tr>
<tr>
<td>European greenfinch</td>
<td>Carduelis chloris</td>
<td>SHORT</td>
<td>118.8  114.0  -  -  -</td>
<td>0.0 (0 %)  10.0</td>
<td>0.39 ± 0.19  1.08 ± 0.77</td>
<td>0.0</td>
</tr>
<tr>
<td>Common linnet</td>
<td>Carduelis cannabina</td>
<td>SHORT</td>
<td>127.5  128.0  -  -  -</td>
<td>1.2 (3 %)  6.5</td>
<td>0.09 ± 0.21  -0.76 ± 1.09</td>
<td>1.2</td>
</tr>
<tr>
<td>Yellowhammer</td>
<td>Emberiza citrinella</td>
<td>SHORT</td>
<td>-  98.1  -  -  -</td>
<td>-  -  -</td>
<td>6.4</td>
<td>-0.15 ± 0.30  -0.32 ± 0.89</td>
</tr>
<tr>
<td>Reed bunting</td>
<td>Emberiza schoeniclus</td>
<td>SHORT</td>
<td>128.1  127.6  108.2  -</td>
<td>8.3 (75 %)  4.9</td>
<td>0.23 ± 0.31  1.21 ± 1.07</td>
<td>9.6</td>
</tr>
<tr>
<td>Barn swallow</td>
<td>Hirundo rustica</td>
<td>LONG</td>
<td>-  148.9  147.2  138.9</td>
<td>2.8 (28 %)  4.6</td>
<td>-0.29 ± 0.10  -0.75 ± 0.39</td>
<td>2.0</td>
</tr>
<tr>
<td>Tree pipit</td>
<td>Anthus trivialis</td>
<td>LONG</td>
<td>128.2  131.6  129.1  127.5</td>
<td>3.2 (35 %)  4.4</td>
<td>-0.23 ± 0.11  -0.59 ± 0.41</td>
<td>2.8</td>
</tr>
<tr>
<td>Thrush nightingale</td>
<td>Luscinia luscinia</td>
<td>LONG</td>
<td>137.2  137.8  -  -  -</td>
<td>2.3 (47 %)  2.4</td>
<td>0.04 ± 0.13  -0.10 ± 0.41</td>
<td>2.6</td>
</tr>
<tr>
<td>Common name</td>
<td>Scientific name</td>
<td>Migration category (SHORT or LONG distance migrant)</td>
<td>Mean date (day of year)*</td>
<td>Variance components (SD units)</td>
<td>Estimates of slope (± SE)</td>
<td>Estimated unexplained between-year variation (SD)</td>
</tr>
<tr>
<td>----------------------</td>
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<td>--------------------------</td>
<td>--------------------------------</td>
<td>--------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Falsterbo</td>
<td>Ottenby</td>
<td>Jomfruland</td>
<td>Hanko</td>
</tr>
<tr>
<td>Bluethroat</td>
<td>Luscinia svecica</td>
<td>LONG</td>
<td>135.6</td>
<td>136.5</td>
<td>136.5</td>
<td></td>
</tr>
<tr>
<td>Common redstart</td>
<td>Phoenicurus phoenicurus</td>
<td>LONG</td>
<td>134.4</td>
<td>136.6</td>
<td>134.0</td>
<td>135.2</td>
</tr>
<tr>
<td>Whinchat</td>
<td>Saxicola rubetra</td>
<td>LONG</td>
<td>133.0</td>
<td>-</td>
<td>135.9</td>
<td>135.3</td>
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<tr>
<td>Marsh warbler</td>
<td>Acrocephalus palustris</td>
<td>LONG</td>
<td>149.6</td>
<td>151.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Eurasian reed warbler</td>
<td>Acrocephalus scirpaceus</td>
<td>LONG</td>
<td>146.8</td>
<td>151.4</td>
<td>153.7</td>
<td>-</td>
</tr>
<tr>
<td>Icterine warbler</td>
<td>Hippolais icterina</td>
<td>LONG</td>
<td>149.3</td>
<td>149.0</td>
<td>144.4</td>
<td>-</td>
</tr>
<tr>
<td>Lesser whitethroat</td>
<td>Sylvia curruca</td>
<td>LONG</td>
<td>132.1</td>
<td>136.7</td>
<td>139.6</td>
<td>144.8</td>
</tr>
<tr>
<td>Common whitethroat</td>
<td>Sylvia communis</td>
<td>LONG</td>
<td>140.8</td>
<td>144.4</td>
<td>144.2</td>
<td>-</td>
</tr>
<tr>
<td>Garden warbler</td>
<td>Sylvia borin</td>
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<td>145.2</td>
<td>146.9</td>
<td>148.0</td>
<td>153.5</td>
</tr>
<tr>
<td>Blackcap</td>
<td>Sylvia atricapilla</td>
<td>LONG</td>
<td>132.3</td>
<td>135.2</td>
<td>138.5</td>
<td>147.9</td>
</tr>
<tr>
<td>Willow warbler</td>
<td>Phylloscopus trochilus</td>
<td>LONG</td>
<td>130.8</td>
<td>134.8</td>
<td>135.0</td>
<td>145.2</td>
</tr>
<tr>
<td>Spotted flycatcher</td>
<td>Muscicapa striata</td>
<td>LONG</td>
<td>140.7</td>
<td>144.3</td>
<td>146.4</td>
<td>150.5</td>
</tr>
<tr>
<td>Pied flycatcher</td>
<td>Ficedula hypoleuca</td>
<td>LONG</td>
<td>132.0</td>
<td>133.4</td>
<td>137.6</td>
<td>138.8</td>
</tr>
<tr>
<td>Red-backed shrike</td>
<td>Lanius collurio</td>
<td>LONG</td>
<td>142.6</td>
<td>145.6</td>
<td>150.2</td>
<td>152.5</td>
</tr>
</tbody>
</table>

*Where mean date is not given, data from this species and observatory has not been included in the analysis.
Table S3. Species and observatory specific parameter estimates and variance components when analyzing the late phase of migration (90th percentile) using a linear mixed model with ‘observatory’ as a fixed effect and a random between-year variance component in common for all observatories.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Migration category (SHORT or LONG distance migrant)</th>
<th>Mean date (day of year)*</th>
<th>Variance components (SD units)</th>
<th>Estimates of slope (± SE)</th>
<th>Estimated unexplained between-year variation (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Falsterbo</td>
<td>Ottenby</td>
<td>Jomfru-land</td>
<td>Hanko</td>
<td>Between years (% of total variance)</td>
</tr>
<tr>
<td>White wagtail</td>
<td>Motacilla alba</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>0.0 (0 %)</td>
</tr>
<tr>
<td>Winter wren</td>
<td>Troglodytes troglodytes</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>5.1 (80 %)</td>
</tr>
<tr>
<td>Hedge accentor</td>
<td>Prunella modularis</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>2.4 (10 %)</td>
</tr>
<tr>
<td>European robin</td>
<td>Erithacus rubecula</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>5.9 (90 %)</td>
</tr>
<tr>
<td>Common blackbird</td>
<td>Turdus merula</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>0.0 (0 %)</td>
</tr>
<tr>
<td>Song thrush</td>
<td>Turdus philomelos</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>1.3 (2 %)</td>
</tr>
<tr>
<td>Redwing</td>
<td>Turdus iliacus</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>2.0 (10 %)</td>
</tr>
<tr>
<td>Chiffchaff</td>
<td>Phylloscopus collybita</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>3.1 (14 %)</td>
</tr>
<tr>
<td>Goldcrest</td>
<td>Regulus regulus</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>4.9 (27 %)</td>
</tr>
<tr>
<td>Blue tit</td>
<td>Parus caeruleus</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>0.0 (0 %)</td>
</tr>
<tr>
<td>Great tit</td>
<td>Parus major</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>0.0 (0 %)</td>
</tr>
<tr>
<td>Chaffinch</td>
<td>Fringilla coelebs</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>1.1 (2 %)</td>
</tr>
<tr>
<td>Brambling</td>
<td>Fringilla montifringilla</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>0.5 (1 %)</td>
</tr>
<tr>
<td>European greenfinch</td>
<td>Carduelis chloris</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>5.7 (35 %)</td>
</tr>
<tr>
<td>Common linnet</td>
<td>Carduelis cannabina</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>0.0 (0 %)</td>
</tr>
<tr>
<td>Yellowhammer</td>
<td>Emberiza citrinella</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>6.7 (100 %)</td>
</tr>
<tr>
<td>Reed bunting</td>
<td>Emberiza schoeniclus</td>
<td>SHORT</td>
<td></td>
<td></td>
<td></td>
<td>2.2 (16 %)</td>
</tr>
<tr>
<td>Barn swallow</td>
<td>Hirundo rustica</td>
<td>LONG</td>
<td></td>
<td></td>
<td></td>
<td>2.3 (12 %)</td>
</tr>
<tr>
<td>Tree pipit</td>
<td>Anthus trivialis</td>
<td>LONG</td>
<td></td>
<td></td>
<td></td>
<td>3.5 (56 %)</td>
</tr>
<tr>
<td>Common name</td>
<td>Scientific name</td>
<td>Migration category (SHORT or LONG distance migrant)</td>
<td>Mean date (day of year)*</td>
<td>Variance components (SD units)</td>
<td>Estimates of slope (± SE)</td>
<td>Estimated unexplained between-year variation (SD)</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------</td>
<td>-----------------------------------------------------</td>
<td>--------------------------</td>
<td>---------------------------------</td>
<td>---------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Falsterbo</td>
<td>Ottenby</td>
<td>Jomfru-land</td>
<td>Hanko</td>
</tr>
<tr>
<td>Bluethroat</td>
<td><em>Luscinia svecica</em></td>
<td>LONG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common redstart</td>
<td><em>Phoenicurus phoenicurus</em></td>
<td>LONG</td>
<td>144.2</td>
<td>148.7</td>
<td>143.6</td>
<td>144.7</td>
</tr>
<tr>
<td>Whinchat</td>
<td><em>Saxicola rubetra</em></td>
<td>LONG</td>
<td>139.0</td>
<td></td>
<td>146.2</td>
<td>147.3</td>
</tr>
<tr>
<td>Marsh warbler</td>
<td><em>Acrocephalus palustris</em></td>
<td>LONG</td>
<td>155.1</td>
<td>159.2</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Eurasian reed warbler</td>
<td><em>Acrocephalus scirpaceus</em></td>
<td>LONG</td>
<td>153.5</td>
<td>160.0</td>
<td>161.7</td>
<td>-</td>
</tr>
<tr>
<td>Icterine warbler</td>
<td><em>Hippolais icterina</em></td>
<td>LONG</td>
<td>156.0</td>
<td>157.5</td>
<td>154.6</td>
<td>-</td>
</tr>
<tr>
<td>Lesser whitethroat</td>
<td><em>Sylvia communis</em></td>
<td>LONG</td>
<td>154.0</td>
<td></td>
<td>153.5</td>
<td>157.4</td>
</tr>
<tr>
<td>Blackcap</td>
<td><em>Sylvia atricapilla</em></td>
<td>LONG</td>
<td>148.7</td>
<td>150.5</td>
<td>151.4</td>
<td>156.6</td>
</tr>
<tr>
<td>Willow warbler</td>
<td><em>Phylloscopus trochilus</em></td>
<td>LONG</td>
<td>142.1</td>
<td>146.9</td>
<td>146.0</td>
<td>156.4</td>
</tr>
<tr>
<td>Spotted flycatcher</td>
<td><em>Muscicapa striata</em></td>
<td>LONG</td>
<td>149.1</td>
<td>153.4</td>
<td>157.0</td>
<td>156.5</td>
</tr>
<tr>
<td>Pied flycatcher</td>
<td><em>Ficedula hypoleuca</em></td>
<td>LONG</td>
<td>140.9</td>
<td>142.6</td>
<td>146.0</td>
<td>153.6</td>
</tr>
<tr>
<td>Red-backed shrike</td>
<td><em>Lanius collurio</em></td>
<td>LONG</td>
<td>150.2</td>
<td>152.8</td>
<td>159.8</td>
<td>161.1</td>
</tr>
</tbody>
</table>

*Where mean date is not given, data from this species and observatory has not been included in the analysis.*
Table S4. Species-specific parameter estimates on Capri.

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean date (day of year)</th>
<th>Standard deviation</th>
<th>TIME (days / year)</th>
<th>dNAO (days / unit)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early phase of migration (10th percentile)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree pipit</td>
<td>106.7</td>
<td>4.2</td>
<td>$-0.05 \pm 0.19$</td>
<td>$0.47 \pm 0.50$</td>
<td>0.07</td>
</tr>
<tr>
<td>Common redstart</td>
<td>109.2</td>
<td>4.1</td>
<td>$-0.23 \pm 0.15$</td>
<td>$-0.06 \pm 0.46$</td>
<td>0.12</td>
</tr>
<tr>
<td>Whinchat</td>
<td>111.7</td>
<td>5.3</td>
<td>$-0.28 \pm 0.18$</td>
<td>$0.86 \pm 0.56$</td>
<td>0.26</td>
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<tr>
<td>Icterine warbler</td>
<td>126.3</td>
<td>3.4</td>
<td>$-0.29 \pm 0.10$</td>
<td>$0.58 \pm 0.29$</td>
<td>0.51</td>
</tr>
<tr>
<td>Common whitethroat</td>
<td>114.8</td>
<td>4.0</td>
<td>$-0.26 \pm 0.13$</td>
<td>$0.75 \pm 0.38$</td>
<td>0.38</td>
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<tr>
<td>Garden warbler</td>
<td>121.6</td>
<td>3.0</td>
<td>$-0.26 \pm 0.09$</td>
<td>$0.34 \pm 0.28$</td>
<td>0.41</td>
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<tr>
<td>Willow warbler</td>
<td>105.5</td>
<td>4.4</td>
<td>$-0.38 \pm 0.15$</td>
<td>$-0.23 \pm 0.45$</td>
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<td>Spotted flycatcher</td>
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<td>4.0</td>
<td>$-0.12 \pm 0.13$</td>
<td>$1.02 \pm 0.40$</td>
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<td>Pied flycatcher</td>
<td>107.5</td>
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<td>$-0.28 \pm 0.16$</td>
<td>$0.76 \pm 0.47$</td>
<td>0.30</td>
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<tr>
<td><strong>Middle phase of migration (50th percentile)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Tree pipit</td>
<td>117.3</td>
<td>3.8</td>
<td>$-0.05 \pm 0.16$</td>
<td>$0.58 \pm 0.43$</td>
<td>0.13</td>
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<tr>
<td>Common redstart</td>
<td>119.9</td>
<td>3.8</td>
<td>$-0.20 \pm 0.14$</td>
<td>$-0.14 \pm 0.43$</td>
<td>0.11</td>
</tr>
<tr>
<td>Whinchat</td>
<td>121.8</td>
<td>4.9</td>
<td>$-0.32 \pm 0.16$</td>
<td>$0.76 \pm 0.48$</td>
<td>0.33</td>
</tr>
<tr>
<td>Icterine warbler</td>
<td>134.9</td>
<td>4.3</td>
<td>$-0.30 \pm 0.14$</td>
<td>$0.64 \pm 0.43$</td>
<td>0.35</td>
</tr>
<tr>
<td>Common whitethroat</td>
<td>125.7</td>
<td>4.1</td>
<td>$-0.28 \pm 0.12$</td>
<td>$0.82 \pm 0.38$</td>
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</tr>
<tr>
<td>Garden warbler</td>
<td>132.2</td>
<td>3.4</td>
<td>$-0.27 \pm 0.11$</td>
<td>$0.46 \pm 0.33$</td>
<td>0.38</td>
</tr>
<tr>
<td>Willow warbler</td>
<td>116.4</td>
<td>3.6</td>
<td>$-0.34 \pm 0.12$</td>
<td>$-0.20 \pm 0.36$</td>
<td>0.34</td>
</tr>
<tr>
<td>Spotted flycatcher</td>
<td>129.9</td>
<td>4.7</td>
<td>$-0.06 \pm 0.17$</td>
<td>$0.94 \pm 0.51$</td>
<td>0.19</td>
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<tr>
<td>Pied flycatcher</td>
<td>117.5</td>
<td>3.9</td>
<td>$-0.23 \pm 0.13$</td>
<td>$0.60 \pm 0.40$</td>
<td>0.28</td>
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<tr>
<td><strong>Late phase of migration (90th percentile)</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Tree pipit</td>
<td>127.8</td>
<td>3.7</td>
<td>$-0.05 \pm 0.15$</td>
<td>$0.73 \pm 0.41$</td>
<td>0.20</td>
</tr>
<tr>
<td>Common redstart</td>
<td>130.6</td>
<td>3.9</td>
<td>$-0.20 \pm 0.15$</td>
<td>$-0.23 \pm 0.45$</td>
<td>0.10</td>
</tr>
<tr>
<td>Whinchat</td>
<td>131.8</td>
<td>4.9</td>
<td>$-0.37 \pm 0.16$</td>
<td>$0.73 \pm 0.47$</td>
<td>0.38</td>
</tr>
<tr>
<td>Icterine warbler</td>
<td>143.5</td>
<td>5.7</td>
<td>$-0.30 \pm 0.20$</td>
<td>$0.67 \pm 0.61$</td>
<td>0.21</td>
</tr>
<tr>
<td>Common whitethroat</td>
<td>136.7</td>
<td>4.4</td>
<td>$-0.30 \pm 0.13$</td>
<td>$0.92 \pm 0.40$</td>
<td>0.45</td>
</tr>
<tr>
<td>Garden warbler</td>
<td>143.0</td>
<td>4.1</td>
<td>$-0.27 \pm 0.14$</td>
<td>$0.57 \pm 0.42$</td>
<td>0.31</td>
</tr>
<tr>
<td>Willow warbler</td>
<td>127.2</td>
<td>3.2</td>
<td>$-0.31 \pm 0.10$</td>
<td>$-0.16 \pm 0.31$</td>
<td>0.36</td>
</tr>
<tr>
<td>Spotted flycatcher</td>
<td>138.7</td>
<td>5.9</td>
<td>$0.00 \pm 0.23$</td>
<td>$0.85 \pm 0.69$</td>
<td>0.09</td>
</tr>
<tr>
<td>Pied flycatcher</td>
<td>127.4</td>
<td>3.6</td>
<td>$-0.19 \pm 0.13$</td>
<td>$0.44 \pm 0.40$</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Table S5. Priors for mean passage dates on Capri. The parameters $\tau$ were constrained to fall within the intervals indicated for each species by using a uniform prior. The range of estimated values of $\tau$ (based on the medians of the posterior distributions over all years) are shown to the right.

<table>
<thead>
<tr>
<th>Species</th>
<th>Earliest allowed mean date</th>
<th>Latest allowed mean date</th>
<th>Range in estimated mean date</th>
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</thead>
<tbody>
<tr>
<td>Tree pipit</td>
<td>March 25</td>
<td>May 10</td>
<td>April 21–May 6</td>
</tr>
<tr>
<td>Common redstart</td>
<td>March 10</td>
<td>May 15</td>
<td>April 24–May 6</td>
</tr>
<tr>
<td>Whinchat</td>
<td>April 5</td>
<td>May 20</td>
<td>April 23–May 11</td>
</tr>
<tr>
<td>Icterine warbler</td>
<td>April 25</td>
<td>May 25</td>
<td>May 7–May 21</td>
</tr>
<tr>
<td>Common whitethroat</td>
<td>March 25</td>
<td>May 25</td>
<td>April 29–May 14</td>
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<tr>
<td>Garden warbler</td>
<td>April 15</td>
<td>May 30</td>
<td>May 8–May 17</td>
</tr>
<tr>
<td>Willow warbler</td>
<td>March 15</td>
<td>May 15</td>
<td>April 20–May 3</td>
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<tr>
<td>Spotted flycatcher</td>
<td>April 20</td>
<td>May 25</td>
<td>May 3–May 18</td>
</tr>
<tr>
<td>Pied flycatcher</td>
<td>April 15</td>
<td>May 20</td>
<td>April 19–May 2</td>
</tr>
</tbody>
</table>