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First evidence of phenological change in a transcontinental migrant overwintering in the Indian sub-continent: the Red-breasted Flycatcher *Ficedula parva*

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We analysed data on the Red-breasted Flycatcher *Ficedula parva* collected in old-growth, oak-hornbeam stands in the primeval Białowieża Forest, Poland during 1973–2002. In this period, the Red-breasted Flycatcher's return to its breeding sites became significantly earlier whilst population size did not change significantly. We show that population size did not influence arrival time in Białowieża. However, arrival time was strongly related to local temperature in April, as well as to March temperature along the migration route and February temperature in the wintering areas. To our knowledge, this is the first demonstration of phenological change in a transcontinental migrant bird species wintering in the Indian sub-continent.

1. 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 (reviews in: 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. It is relatively easy to access such data for arrivals of common and visible bird species, often called harbingers of spring. However, data on many other less easy to detect and rare bird species are scarce. Therefore, a bias probably exists in studies on bird phenology, strongly focused on very well known species, which may limit our knowledge on the functioning of ecological systems. Among the species with limited knowledge on their biology, migratory pattern and, in consequence, phenology is the Red-breasted Flycatcher *Ficedula parva*, a migratory species that overwinters in the Indian sub-continent and breeds across Europe and Asia from the Baltic to the Pacific coasts. Individuals of this species that breed in Poland overwinter in the NW part of the Indian sub-continent and have a long (approx. 5,000 km) migration route that is unusual in that it contains a large longitudinal component and does not involve an equatorial crossing. It experiences a wide range of environments

during its annual cycle. Its arrival time in Poland is similar to birds migrating north from sub-equatorial Africa.

The arrival date of the first bird in the breeding area can be influenced by the size of the bird population that year. Population size effects could be especially important for bird species with a very secret biology and which are not easy to detect in the field (Tryjanowski & Sparks 2001). The Red-breasted Flycatcher belongs to this category of bird and the best method to detect this species is by observation of density-induced activity such as singing males or fights between males during establishment of territories (Cramp & Perrins 1993, Mitrus unpubl. data).

In this paper we examine the first arrival dates of Red-breasted Flycatcher in the Białowieża Forest in eastern Poland. Whilst there have been suggestions that phenological changes are limited to strongly human modified areas this paper examines a species breeding in the last lowland primeval forest complex in Europe. We (1) describe the changes in arrival time of the Red-breasted Flycatcher in the 1973–2002 period, (2) examine the potential relationships between the arrival time and the size of the local breeding population, and (3) identify relationships between time of arrival and air temperature in the breeding site in Białowieża Forest, as well as the temperature on the migration route and in the wintering area.

2. Material and methods

2.1. Study area and study species

The study was conducted during the years 1973–2002 in the primeval stands of Białowieża Forest National Park, eastern Poland (52°42'N, 23°52'E). The data were mainly collected in oak-hornbeam *Tilio-Carpinetum* stands characterised by Hornbeam *Carpinus betulus*, Small-leaved Lime *Tilia cordata*, Pendunculate Oak *Quercus robur*, Norway Maple *Acer platanoides* and Norway Spruce *Picea abies* (Tomiałojć 1991). Many standing and fallen dead trees are present. The Białowieża Forest has a rich bird and mammal community, with elements primeval in character (Tomiałojć 1991, Jędrzejewska & Jędrzejewski 1998).

The Red-breasted Flycatcher is an uncommon species in the old oak-hornbeam stands of the Białowieża National Park at densities up to 1.26 pairs/10 ha (Wesołowski *et al.* 2002). On permanently studied plots (three study plots, total area 79.5 ha) 5–15 pairs occurred per year (mean ± SD = 9.3 ± 0.5), with other Red-breasted Flycatcher individuals recorded during movements between study plots and nests close to the study plots perimeter (up to c. 50 pairs in different years, cf. Mitrus & Soćko 2004).

2.2. Data collection

Observations of the first arrival dates of the Red-breasted Flycatcher males were recorded by a team working on the breeding community of Białowieża forest birds (e.g. Wesołowski *et al*. 2002). Data were collected during standard visits to census birds which were not focused specifically on the Red-breasted Flycatcher. However, this species occurs in the same habitats as other hole-nesting passerines (review in: Tomiałojć & Wesołowski 2004). The intensity of field observation did not differ markedly between study years. Data were not recorded in five of the years (1974, 1975, 1977, 1980, 1990) during the study.

No data are available on the timing of departure from the wintering area. The size of the breeding population of Red-breasted Flycatchers in each year, as well as other breeding birds, was estimated by the combined mapping technique. Every year, at least ten visits were made to each plot between 10 April and 25 June. A plot was checked by proceeding along marked lines, 100 m apart (although a line could be temporarily left for side-penetration when necessary). The censuses were performed by 4–7 experienced people (Wesołowski *et al.* 2002). Moreover, the majority of nests were recorded by following females during nest construction, searching sites where birds were frequently seen, and following adults when they were feeding nestlings (Mitrus & Soćko 2004).

To improve understanding on Red-breasted Flycatcher phenology in relation to age and body condition, males were mist-netted in 2000–2003. Each bird caught (n = 70) was aged by plumage (according to Svensson 1992) and ringed. Flattened maximum wing chord and tail were mea-

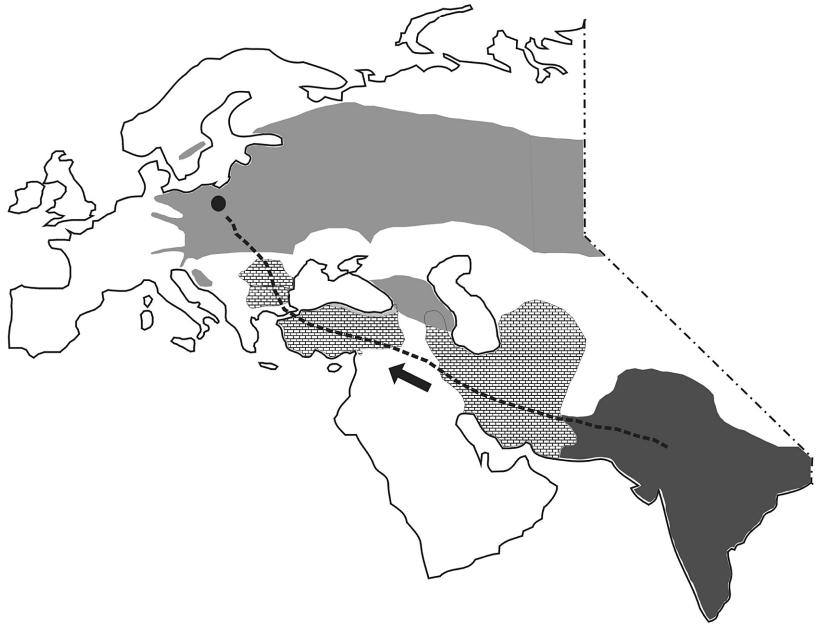

Fig. 1. Schematic map of regions that are presumed relevant for the migration route of the Red-breasted Flycatcher (line with arrow). The breeding range is indicated in grey and the study site in Białowieża Forest with a circle. The wintering grounds (India and Pakistan) are indicated in black and the areas that were chosen to represent the migration route (Iran and Black Sea coast countries) are hatched.

sured using a wing-ruler (± 1mm), and body mass was determined with a Pesola 30-g (± 0.25 g) spring balance.

2.3. Climate data

Local meteorological data were obtained from the weather station at Białowieża, situated 1 km south of the study plot. The first Red-breasted Flycatchers males usually arrived in the Białowieża Forest during the last ten days of April and the beginning of May (see Results). The mean temperatures during April (to approximate the influence of more general temperature effects) for 1973–2002 were therefore used in the calculations. For analysis, dates were converted to days after 31 March, so that 1 April was day 1 and so on. Temperature data for the wintering area and along the migration routes for the period 1973 to 2000 was based on individual countries and was obtained from Mitchell *et al.* (2002; available at www.cru.uea.ac.uk/~timm/climate/index.html).

Because details of Red-breasted Flycatcher wintering area and migration route are poorly known (Cramp & Perrins 1993), we used data from three regions to broadly represent these zones (Fig. 1). The average for India and Pakistan mean February temperatures was used to represent the wintering area, mean March temperatures for Iran were used to represent the first part of the migration route, and the average of Turkey, Bulgaria and Romania April temperatures (henceforth called Black Sea coastal temperatures) used as a second part of the migration route.

2.4. Statistical analyses

All statistical analyses were applied according to the recommendations of Sokal and Rohlf (1995) and were conducted using MINITAB v.13 (Minitab Inc. 2000). For linear regression, we reported the regression's slope b (± 1 SE) and test statistics for the full model (F value and R^2). For multiple linear regression, we reported the regression coefficient and test statistic for this coefficient (t-test).

3. Results

3.1. Arrival time

The first Red-breasted Flycatchers arrived in the study area between 28 April and 11 May (median

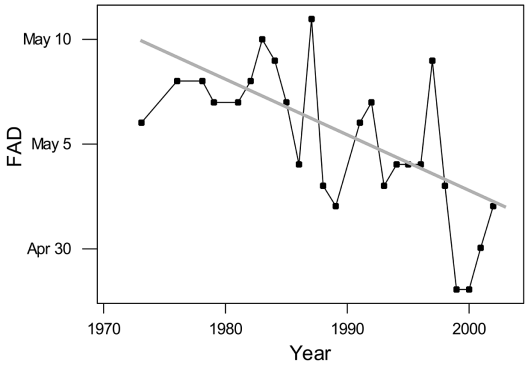

Fig. 2. Yearly first arrival dates (FAD) of the Red-breasted Flycatcher in the study area. The straight line represents the regression line of first arrival date on year.

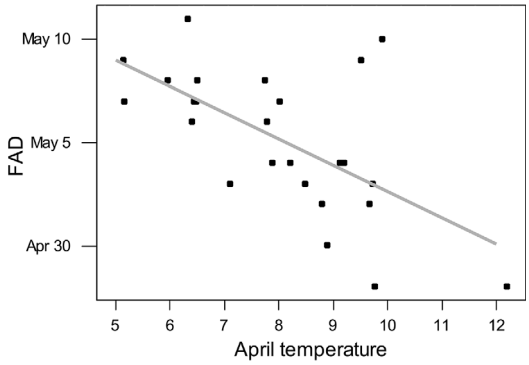

Fig. 3. The relationship between first arrival dates (FAD) of the Red-breasted Flycatcher and mean April temperature (°C) in Białowieża. The line represents the regression line of first arrival date (FAD) on temperature.

= 6 May, n = 25). During the period 1973–2002, the Red-breasted Flycatcher's returned to its breeding sites, on average, eight days earlier (regression of date on year: $b = -0.276 \pm 0.066$, $F_{1,23} = 17.47$, $P < 0.001$, $R^2 = 43.2\%$; Fig. 2). A quadratic term to this regression was not quite significant ($P = 0.063$).

3.2. Population size

The local population size of the Red-breasted Flycatcher varied from 5 to 15 breeding pairs (mean ± SD = 9.3 ± 0.5) over the study period, but without a directional trend (regression of population size on year: $b = -0.078 \pm 0.063$, $F_{1,23} = 1.56$, $P = 0.223$, $R^2 = 5.6\%$). We did not find a significant correlation between the size of the local breeding population and first arrival dates ($r = 0.091$, $n = 25$, $P = 0.671$). Moreover, after fitting the influence of temperature, population size was always a non-significant factor in multiple regression models ($P > 0.8$ in all cases).

3.3. Characteristics of first arrivals

The first arrivals in the study area were males in adult plumage. These trapping data suggest that adult males arrived significantly earlier than young males (9 vs. 14 May, respectively, Mann-Whitney U-test, $z = -3.49$, $n_1 = 149$ (old males), $n_2 = 43$ (young maless), $P < 0.001$). However, there was no evidence that first male arrivals had longer wings, or were in better body condition than subsequent arrivals ($P > 0.67$ in both cases).

3.4. The influence of temperatures

Changes in the temperatures of the selected months/countries are shown in Table 1. Only Białowieża temperatures in April revealed a consistent trend towards warmer conditions, by an estimated 2.9 °C over the 30 years. First arrival dates of males were most significantly related to local temperature in April ($b = -1.27 \pm 0.33$, $F_{1,23} = 14.53$, $P < 0.001$, $R^2 = 38.7\%$; Table 1, Fig. 3). Thus, fine tuning of arrival dates to local conditions (which may also reflect a large continental area as indicated by the significant correlation with Black Sea temperature) was apparent. However, this rate of response is insufficient to explain the eight day advance in arrival. We improved the regression model (beyond local April temperature) by stepwise adding additional variables. Significant additions were the mean February temperature in Pakistan/India ($b = -2.30 \pm 0.58$, $t_{19} = -3.96$, $P < 0.001$) and the Black Sea coastal mean March temperature ($b = -0.70 \pm 0.27$, $t_{19} = -2.64$, $P = 0.016$). In this model, the local effect remained similar ($b = -1.23 \pm 0.25$, $t_{19} = -4.83$, $P < 0.001$) and the overall model fit was very good ($F_{3,19} = 13.57$, $P < 0.001$, $R^2 = 68.2\%$).

Table 1. Summary of temperature data. Coefficients (b) of a regression of temperature against year, and a correlation matrix between first arrival date (FAD) in Białowieża, mean February temperature in India/Pakistan, mean March temperature in Iran, mean April temperature in Black Sea countries and mean April temperature in Białowieża. Correlations in bold are significant at $P < 0.05$.

	Regression against year			Correlation			
	b	R^2	P	FAD	India/Pak (February)	Iran (March)	Black Sea (April)
India/Pakistan (February)	0.031	9.9	0.103	–0.327			
Iran (March)	–0.010	0.4	0.763	–0.278	0.121		
Black Sea (April)	0.041	5.2	0.244	**–0.565**	–0.089	–0.111	
Białowieża (April)	0.099	27.6	0.003	**–0.622**	–0.088	–0.037	**0.745**

4. Discussion

The Red-breasted Flycatcher belongs to a secretive group of birds and requires greater taxonomic skills than many readily apparent and easy-to-identify birds recognised by the general public as harbingers of spring (Sparks 1999; Tryjanowski & Sparks 2001). Moreover, it has a limited distributional range in Europe and is limited mainly to old growth forest stands in eastern and central parts of the continent (Cramp & Perrins 1993). Hence, data on the changes in arrival time of this species over the long term, as well as many other aspects of its biology and ecology is lacking (Cramp & Perrins 1993, Byshnev & Stavrovsky 1998). However, its arrival time is very similar to other late long-distance migrants in Central and Eastern Europe (Sokolov *et al.* 1998, Tryjanowski *et al.* 2002) despite having a very different, longitudinally biased migration.

As in many other bird species the first individuals to return to the breeding areas were adult males (review in Morbey & Ydenberg 2001), presumably because there is a strong selection for early arrival time to occupy the best territories. We found no evidence that first arrivals were either larger or in better condition than subsequent arrivals, although this comparison was based on a small sample size.

There is an increasing body of evidence from across Europe that migrant birds are returning earlier (reviewed in Lehikoinen *et al.* 2004). However, data on arrival dates in Europe were limited to species wintering in warmer parts of Europe, or in Africa. To our knowledge, we have revealed the first example of phenological change in a species wintering in the Indian sub-continent and undertaking a long longitudinal migration. Contrary to our expectations, earlier arrival to breeding sites in Białowieża Forest was not influenced by changes in the local breeding population size. We believe this was because data were collected by well trained observers, who paid special attention to this species during bird censuses.

The trend we reported here indicates that the Red-breasted Flycatcher has been arriving earlier, and that arrival time is influenced by temperature. We have shown that arrival times in Poland depend not only on local temperatures but also on temperatures along the migration route and in the wintering area. Huin and Sparks (1998, 2000) showed that the arrival dates of birds in the UK were influenced by both temperatures within the UK and along the migration route through Spain and France. We believe we are the first to show that arrival times are also influenced by temperatures in the wintering areas. The influence of temperature on bird migration will be both direct, through physiological response, and indirect. The indirect impacts result from changes in the flowering and leafing time of trees (e.g. Poulin *et al.* 1992, Sparks & Carey 1995) and in the emergence of invertebrate prey. Both these factors control the abundance of food supply and the potential provision of safe places for nest building in the breeding area. The effect of temperatures along the migra-

tion route and in the wintering area on the date of arrival in Białowieża can probably be attributed to an enhancement of food supplies for this insectivorous species. Differential changes in temperature along migration routes are likely to have complex effects on arrival at breeding sites, and the dependencies and relationships with resident plants and animals which are undoubtedly responding to different cues. The influence of temperatures along the Red-breasted Flycatcher's migration route is apparent and we believe that this study provides firm evidence of climate impacts across a wider geographical range than previously reported.

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Ensimmäinen todiste Intian niemimaalla talvehtivan mannertenvälisen muuttolinnun muuton fenologisesta muutoksesta: pikkusieppo *Ficedula parva*

Analysoimme pikkusieposta, *Ficedula parva* vuosien 1973–2002 välisenä aikana Puolan Białowieżan vanhoista tammi–valkopyökkimetsistä kerätyn aineiston. Tänä aikana pikkusiepon paluumuutto pesimäpaikoilleen aikaistui merkitsevästi, vaikka populaatiokoko ei merkitsevästi muuttunutkaan. Näytämme, että populaatiokoko ei vaikuttanut saapumisajankohtaan Białowieżassa. Saapumisajankohta riippui voimakkaasti paikallisesta lämpötilasta huhtikuussa, muuttoreitin lämpötiloista maaliskuussa ja talvehtimisalueiden lämpötiloista helmikuussa. Tietääksemme tämä julkaisu on ensimmäinen näyttö fenologisesta muutoksesta mannertenvälisellä muuttolinnulla, joka talvehtii Intian niemimaalla.

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