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Relationship between timing of arrival of passerines to the Courish Spit and North Atlantic Oscillation index (NAOI) and precipitation in Africa

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In the two recent decades, spring arrival of many passerine species is recorded much earlier than in the 1970s in different European countries. It concerns the species which winter within Europe and those wintering in Africa (Moritz, 1993; Mason, 1995; Sokolov *et al.*, 1998; Sparks, 1999; Barrett, 2002; Tryjanowski *et al.*, 2002; Hüppop & Hüppop, 2003). A significant shift of the timing of spring migration towards earlier dates is usually related by the researchers to the current global warming process (Bairlein & Winkel, 2001; Sokolov 2001; Sparks *et al.*, 2001; Forchhammer *et al.*, 2002; Hüppop & Hüppop, 2003).

It is universally accepted that the onset of spring migration in birds is either controlled by the photoperiod, or is governed by an endogenous time programme launched in the breeding area (for species which spend their winter in the equatorial areas, see Dolnik, 1975; Gwinner, 1996; Berthold, 2001). On the basis of this concept, most authors assume that birds start their spring migration each year in the roughly the same species- (or population) specific calendar dates. It is believed that weather conditions of a particular spring have a significant impact on the rate of migratory movements, but not on the time of their onset (Alerstam, 1990; Sparks *et al.*, 2003). European, but not African, weather has been believed to govern the considerable annual fluctuations in the arrival time of long-distance migrants to their breeding grounds (Sparks *et al.*, 2001; Hüppop & Hüppop, 2003).

The aim of this study was to identify environmental factors which could influence not only the timing of arrival to the breeding area, but also the timing of departure from winter quarters during the recent decades. We tested the hypothesis that during the recent two decades, not only arrival dates, but also the onset of spring migration was shifted under the influence of environmental factors related to the global climate

Material and methods

Data on capture dates of passerines in spring on the Courish Spit on the Baltic Sea in Rybachy-type funnel traps in 1959-2002 were analysed. As the main estimate of the timing of migration we used the mean capture date over the period 1.April–15.June. In only some cases was the date of the first capture used. Long-term dynamics of the timing of spring migration was analysed in ten species which mainly winter in Europe and in eight species which spend their winter mainly in Africa.

Of environmental variables which could potentially influence the change of the timing of spring migration in birds, we analysed the following: European mean monthly temperature (for Kaliningrad, Russia and Milan, Italy), North Atlantic Oscillation index (NAOI), mean monthly precipitation (PPT, mm) in Europe and Africa at different latitude. Mean monthly air temperature in winter and in spring from two regions was used, from the area of arrival (Courish Spit, Kaliningrad Region) and from Italy where many passerines breeding on or migrating through the Courish Spit, spend their winter (Payevsky, 1973; Bolshakov *et al*., 2001).

Monthly NAO index is used as an estimate of the meteorological situation in Europe in winter and early spring. NAOI is calculated as the difference between the normalized sea-level pressure at the Azores and Iceland (Hurrell *et al*., 2001). Positive NAOI values are typical of the situation when warm air masses are transported from the west (from Atlantic Ocean) which causes rising air temperature and higher precipitation in northwestern Europe (Hurrell, 1995). By contrast, negative NAOI values are typical of weak westerly winds and thus of lower temperature and precipitation in this part of Europe.

To analyze the level of precipitation in Europe and in Africa, we used the monthly precipitation dataset for global land areas from 1900 to 1998, gridded 5° latitude/longitude (Hulme 1992, 1995; Hulme *et al*., 1998). For each latitudinal zone, we summed the precipitation data for several grid cells and calculated the mean precipitation in the given zone for each month since January until April.

To look for a relationship between the aforementioned parameters, regression analysis and Spearman's rank correlation were used (Lloyd & Ledermann, 1984).

Results

Analysis of long-term monitoring data of arrival dates of passerines on the Courish Spit showed that in six species wintering in Europe and in four species wintering in Africa, a significant shift of spring passage towards earlier dates occurred over the four decades (Fig. 1, Table 2). Generally, the birds arrived much earlier in the 1980s and late 1990s than in the 1970s and partly in the 1960s. In species wintering both in Europe and in Africa, the maximum difference between individual years, as shown by first and by mean capture dates, may be as large as one month (Fig. 1).

Table 1. The correlation between mean monthly European air temperatures (T °C) and mean arrival date in 18 species on the Courish Spit, 1959-1998 (Spearman's rank correlation coefficient: $^*p<0.05$, $^{**}p<0.01$)

Species	Mean T °C (Italy, Milano)			Mean T °C (Russia, Kaliningrad)		
	Feb	Mar	Apr	Mar	Apr	May
Short/medium-distance migrants						
Parus major	0.02	0.04	-0.10	0.11	0.09	-0.33*
Parus caeruleus	0.00	-0.08	-0.09	-0.02	-0.11	-0.13
Troglodytes troglodytes	0.03	-0.05	-0.11	-0.11	-0.35*	-0.34*
Erithacus rubecula	0.08	0.14	-0.32*	0.05	-0.27	-0.30
Fringilla coelebs	0.03	-0.03	0.02	0.03	0.07	-0.42**
Carduelis carduelis	0.04	-0.02	-0.21	-0.02	-0.34*	-0.16
Carduelis spinus	-0.15	-0.03	-0.23	-0.03	-0.33*	-0.19
Phoenicurus ochruros	0.21	0.13	-0.37*	0.26	-0.29	-0.24
Phylloscopus collybitus	-0.08	-0.27	0.05	-0.40**	-0.38*	-0.06
Sylvia atricapilla	0.19	0.11	-0.09	-0.10	0.07	-0.41**
Long-distance migrants						
Phylloscopus trochilus	0.06	-0.18	-0.22	-0.30	-0.28	-0.42**
Ficedula hypoleuca	0.19	0.08	-0.07	-0.19	-0.22	-0.35*
Phoenicurus phoenicurus	-0.02	0.10	-0.33*	-0.32*	-0.50**	-0.17
Sylvia curruca	-0.06	-0.06	-0.22	-0.05	-0.23	-0.24
Sylvia communis	0.01	0.18	-0.32*	0.11	-0.31*	-0.19
Sylvia borin	0.04	-0.05	0.03	0.17	0.29	0.10
Muscicapa striata	0.22	0.02	-0.14	-0.14	0.09	-0.13
Hippolais icterina	0.07	-0.21	-0.17	-0.02	-0.15	-0.09

In 11 species a significant negative correlation of the timing of migration with spring air temperatures was found, mainly with April and May temperature in the arrival area, i.e. on the Courish Spit (Table 1). In years with a warm spring, birds arrived to the Courish Spit much earlier than in years with a cold spring. A relationship of arrival dates with spring temperatures in winter quarters (Italy) was found in two species only (Robin *Erithacus rubecula* and Black Redstart *Phoenicurus ochruros*). An analogous relationship was found in two long-distance migrants wintering in Africa (Redstart *Phoenicurus phoenicurus* and Whitethroat *Sylvia communis*).

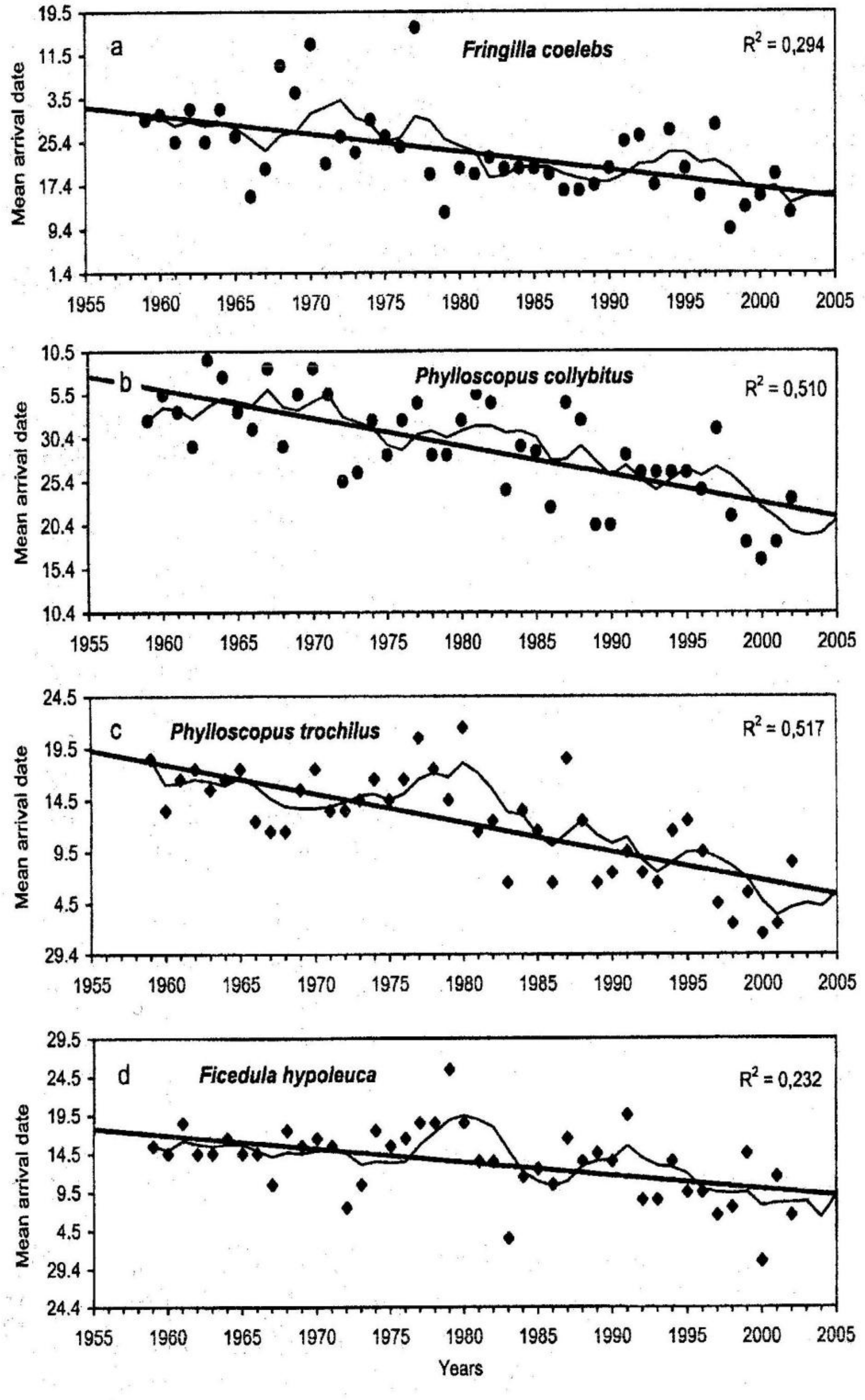

Fig. 1. The change in mean arrival date of a short (a, b) and long (c, d) distance migrants at Rybachy, Russia 1959-2002. Smoothed lines were made on the basis of 5-year intervals

Table 2. The correlation between seasonal NAOI and mean arrival date in 18 species on the Courish Spit, 1959-1998 (Spearman's rank correlation coefficient: *$p<0.05$, **$p<0.01$, ***$p<0.001$)

Species	Year	NAOI				
		Jan	Feb	Mar	Apr	Jan-Mar
Short/medium-distance migrants						
Parus major	-0.28	-0.02	0.03	-0.05	0.28	-0.07
Parus caeruleus	-0.16	-0.13	0.06	-0.30	0.02	-0.15
Troglodytes troglodytes	-0.01	-0.23	-0.26	-0.10	0.10	-0.23
Erithacus rubecula	-0.07	-0.12	0.08	-0.17	0.12	-0.11
Fringilla coelebs	-0.46**	-0.21	-0.09	-0.28	0.25	-0.32*
Carduelis carduelis	-0.35*	-0.28	-0.07	-0.54***	0.24	-0.45**
Carduelis spinus	-0.54***	-0.18	-0.07	-0.42**	0.08	-0.35*
Phoenicurus ochruros	-0.48**	-0.38*	0.01	-0.17	0.17	-0.27
Phylloscopus collybitus	-0.62***	-0.57***	-0.14	-0.52***	0.13	-0.55***
Sylvia atricapilla	-0.62***	-0.21	-0.10	-0.37*	0.26	-0.35*
Long-distance migrants						
Phylloscopus trochilus	-0.64***	-0.38*	-0.26	-0.56***	0.17	-0.58***
Ficedula hypoleuca	-0.41**	-0.27	-0.29	-0.41**	0.20	-0.43**
Phoenicurus phoenicurus	-0.24	-0.35*	-0.05	-0.46**	0.16	-0.39*
Sylvia curruca	-0.29	-0.19	-0.32*	-0.29	0.22	-0.33*
Sylvia communis	-0.31*	-0.08	-0.14	0.05	-0.03	-0.16
Sylvia borin	-0.14	0.07	-0.04	0.08	0.02	0.08
Muscicapa striata	-0.17	-0.13	-0.17	-0.03	0.17	-0.12
Hippolais icterina	-0.49**	-0.37*	-0.31*	-0.29	0.06	-0.40**

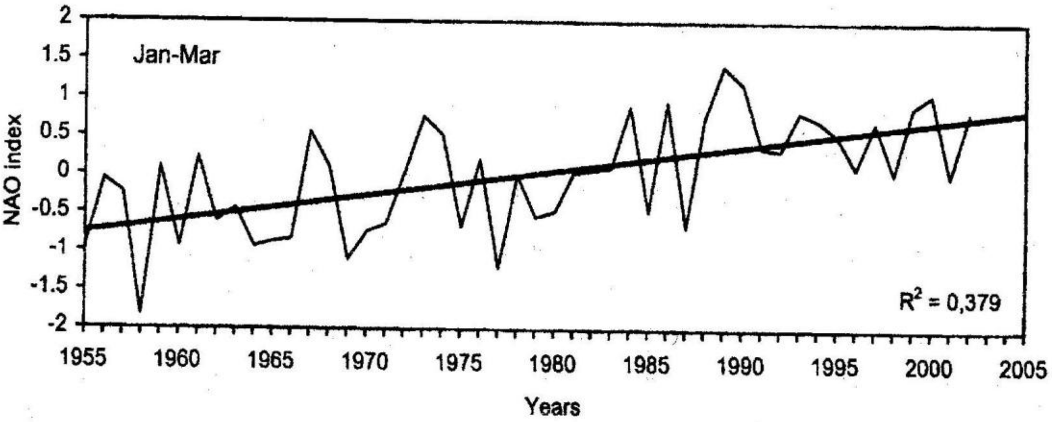

Fig. 2. February to March NAO indices, 1955-2002

Table 3. The correlation between seasonal NAOI and European and African Precipitations (PPT, mm), mean monthly European air temperatures (T °C), 1959-1998 (Spearman's rank correlation coefficient: *p<0.05, **p<0.01, ***p<0.001)

Variables	Month	Year	NAOI				
			Jan	Feb	Mar	Apr	Jan-Mar
Year			0.34*	0.35*	0.42**	-0.05	0.53***
PPT (Europe 52.5° N)	Feb	0.05	0.00	0.37*	-0.13	-0.07	0.07
	Mar	0.24	0.03	-0.16	-0.02	-0.10	-0.11
	Apr	-0.18	-0.21	-0.21	-0.04	0.01	-0.26
PPT (Europe 47.5° N)	Feb	0.04	0.00	0.04	-0.04	-0.11	-0.02
	Mar	-0.15	-0.18	-0.23	-0.41**	0.04	-0.42**
PPT (Europe 42.5° N)	Feb	-0.24	-0.10	-0.44**	-0.18	0.06	-0.28
	Mar	-0.42**	-0.28	-0.30	-0.61***	0.26	0.56***
PPT (Africa 7.5° N)	Feb	-0.29	-0.09	-0.25	0.08	-0.05	-0.15
	Mar	-0.24	-0.20	0.08	-0.31*	0.16	-0.23
PPT (Africa 2.5° N)	Feb	-0.39*	-0.41**	-0.45**	-0.45**	-0.14	-0.54***
	Mar	-0.09	-0.17	-0.03	-0.24	-0.04	-0.20
PPT (Africa 2.5° S)	Feb	-0.17	-0.05	0.00	-0.11	-0.19	-0.07
	Mar	-0.12	-0.26	0.08	-0.28	-0.07	-0.24
PPT (Africa 7.5° S)	Feb	-0.06	-0.07	-0.07	0.05	-0.04	-0.08
	Mar	-0.39*	-0.24	-0.16	-0.21	0.03	-0.28
PPT (Africa 12,5° S)	Feb	-0.18	-0.14	-0.06	0.00	0.00	-0.13
	Mar	-0.45**	0.12	-0.25	-0.08	0.02	-0.11
PPT (Africa 17,5° S)	Feb	-0.04	-0.10	0.08	0.00	-0.06	0.01
	Mar	-0.19	0.09	0.12	-0.09	-0.12	0.08
PPT (Africa 22.5° S)	Feb	-0.02	0.00	0.06	-0.02	-0.02	-0.04
	Mar	-0.06	0.02	-0.03	-0.06	-0.23	0.01
T °C (Russia, Kaliningrad)	Jan	0.15	0.41**	0.13	-0.07	-0.26	0.22
	Feb	0.29	0.40*	0.36*	0.23	-0.14	0.42**
	Mar	0.18	0.30	0.18	0.57***	-0.29	0.48**
	Apr	-0.04	0.47**	0.12	0.28	-0.13	0.40**
T °C (Italy, Milano)	Jan	0.12	0.38*	0.20	-0.18	-0.05	0.09
	Feb	-0.03	-0.04	0.10	0.17	-0.10	0.08
	Mar	0.13	0.14	0.15	0.17	-0.06	0.20
	Apr	-0.27	0.17	-0.02	0.01	-0.17	0.11

A significant negative relationship of arrival dates with NAOI pooled for three months (January–March) was found in ten species out of the 18 studied (Table 2). This relationship was found in both medium- and long-distance migrants. In five species was found a relationship with NAOI of January, in seven species with NAOI of March. Only two species showed a significant correlation with the NAOI of February. In the years with a high NAOI and, correspondingly, warm winter and March (relationship between these parameters is shown in Table 3), early migration was recorded in the species studied. The pooled NAOI for January–March showed a strong positive trend (Fig. 2). The trend of NAOI is most pronounced for March and non-significant for April (Table 3).

Table 4. The correlation between European and African Precipitations (PPT, mm) and mean arrival date in 18 species on the Courish Spit, 1959-1998 (Spearman's rank correlation coefficient: *$p<0.05$, **$p<0.01$, ***$p<0.001$)

Species	Latitude									
	52.5° N		42.5° N		2.5° N		2.5° S		12.5° S	
	Mar	Apr	Feb	Mar	Feb	Mar	Feb	Mar	Feb	Mar
Short/medium-distance migrants										
Parus major	-0.10	0.29	0.26	-0.03	-0.09	0.06	-0.16	0.01	-0.20	0.05
Parus caeruleus	-0.01	0.03	0.23	0.17	0.25	0.24	0.16	0.15	-0.28	0.16
Troglodytes troglodytes	-0.02	0.16	0.27	0.03	0.18	0.19	-0.17	-0.07	-0.29	-0.15
Erithacus rubecula	-0.22	-0.10	0.11	0.20	0.18	0.11	-0.09	-0.06	-0.22	-0.03
Fringilla coelebs	-0.26	0.15	0.04	0.25	0.05	0.21	-0.06	0.27	0.01	0.03
Carduelis carduelis	-0.09	0.04	0.12	0.39*	0.08	0.10	-0.23	0.06	-0.28	0.07
Carduelis spinus	0.07	0.20	0.15	0.28	0.08	0.05	-0.09	0.25	-0.11	0.20
Phoenicurus ochruros	-0.01	-0.16	-0.12	-0.04	0.17	0.04	-0.19	0.06	-0.18	-0.11
Phylloscopus collybitus	-0.04	-0.17	0.04	0.40**	0.35*	0.18	0.05	0.31*	0.26	0.16
Sylvia atricapilla	-0.20	0.06	0.18	0.25	0.24	0.00	-0.05	0.07	0.02	0.38*
Long-distance migrants										
Phylloscopus trochilus	-0.09	0.01	0.20	0.52***	0.52***	0.11	0.13	0.16	0.13	0.29
Ficedula hypoleuca	-0.05	-0.06	0.23	0.38*	0.47**	0.01	0.09	0.00	0.15	0.39*
Phoenicurus phoenicurus	-0.04	-0.15	0.31	0.51**	0.32*	0.16	0.04	-0.02	0.03	0.18
Sylvia curruca	-0.07	-0.11	0.25	0.34*	0.34*	-0.04	-0.42*	-0.16	0.00	0.11
Sylvia communis (1st date)	-0.18	-0.22	-0.06	0.33*	0.25	-0.04	-0.03	0.03	0.11	-0.03
Sylvia borin (1st date)	0.24	0.08	0.12	-0.04	0.08	-0.19	-0.28	-0.18	-0.21	-0.01
Muscicapa striata	-0.24	0.14	-0.26	-0.02	-0.01	-0.13	-0.01	-0.06	-0.04	0.13
Hippolais icterina	0.01	0.10	0.14	0.30	0.44**	0.01	0.18	0.03	-0.15	0.10

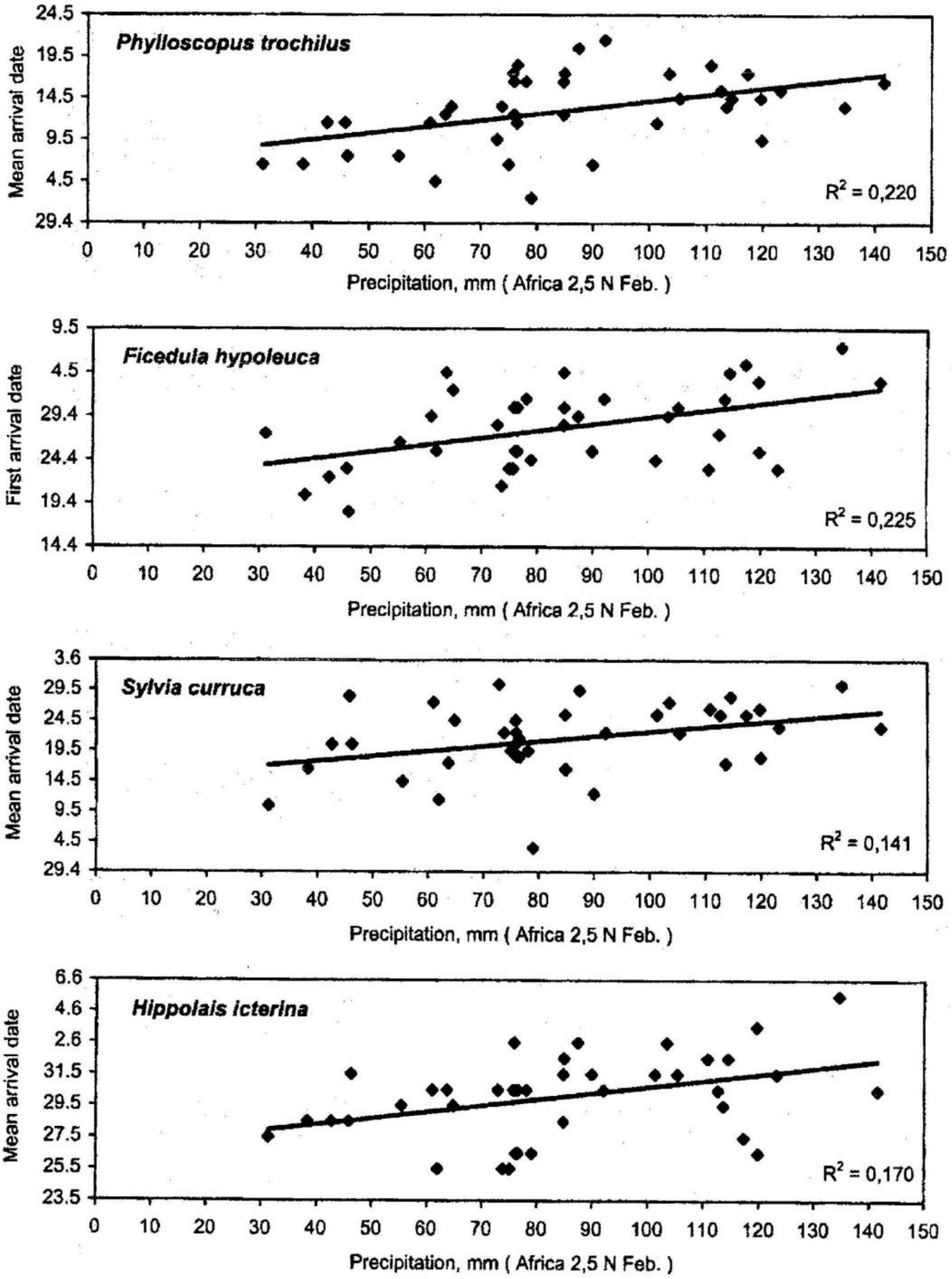

Fig. 3. The relationship between arrival dates of migrants on the Courish Spit and precipitation rate in different regions of Africa

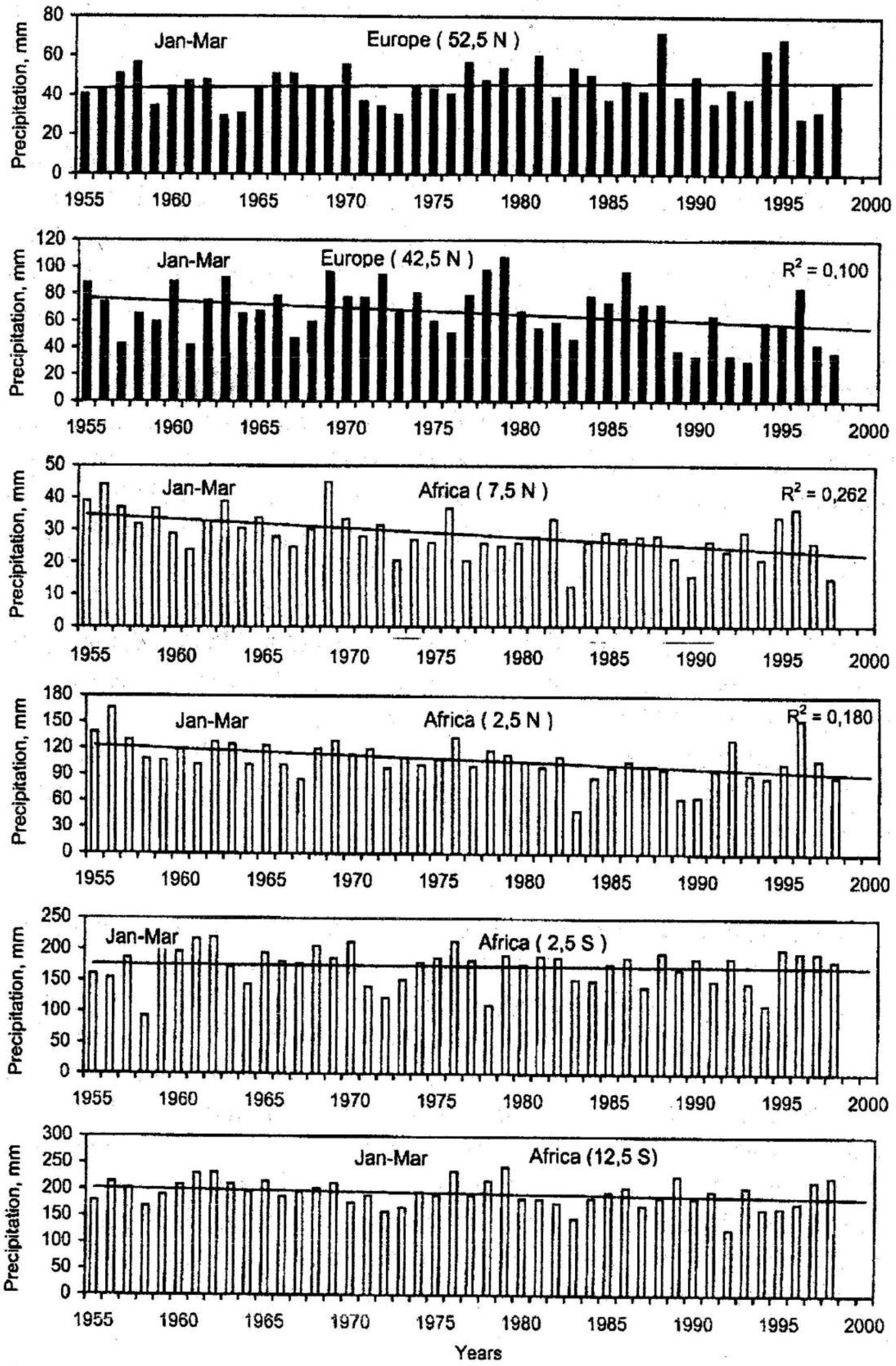

Fig. 4. The change in the mean precipitation rate in different regions of Europe and Africa 1955-1998

Analysis of relationship between arrival dates and precipitation level in Europe and Africa showed a significant positive correlation for the latitude 42.5° N (southern Europe) and for North Africa down to the Equator (Table 4). In the years with low precipitation at these latitudes birds, mainly long-distance migrants, arrive significantly earlier to the Courish Spit than in the years with much precipitation (Fig. 3). An analogous relationship of arrival dates with precipitation in other parts of Africa situated to the south of the Equator was found in only two species of long-distance migrants, Pied Flycatcher *Ficedula hypoleuca* and Lesser Whitethroat *Sylvia curruca*. No significant relationship between arrival dates and precipitation in Europe between 47.5–52.5° N was found (Table 4).

Precipitation in South Europe and Africa (except of the latitudes just south of the Equator and in southern Africa) in January–March showed a significant negative trend, especially in the 1980s (Fig. 4, Table 3). Just in this period, and also in the late 1990s, migrating passerines wintering in Europe and in Africa arrived to the Courish Spit most early (Fig. 1). Correlation analysis showed that precipitation level both in southern Europe and in northern Africa is significantly negatively related to NAOI (Table 3). In the years in high NAOI values and correspondingly with relatively high temperatures in winter and in March, precipitation was abundant both in South Europe and in northern Africa down to the Equator. In northern Europe winter NAOI was, by contrast, positively related to precipitation in winter (Table 3).

Discussion

Several studies suggesting a negative relationship between springtime arrival of birds to Norway and Germany and winter (December-March) NAOI has been published recently (Forchhammer *et al.*, 2002; Hüppop & Hüppop, 2002). This relationship was found not only in species wintering within Europe but also in long-distance migrants which spend their winter in Africa. This brings up the question: why is springtime arrival of birds correlated with winter NAOI values, when the birds, especially the long-distance migrants, are still in their winter quarters? To answer this question, we calculated correlation between arrival dates to the Courish Spit and not only the pooled (January–March) NAOI, but with indices for each month. In several species, long-distance migrants including, a negative relationship was found with indices of individual months (Table 2). Analysis showed that January NAOI is strongly related not only to winter temperatures in Kaliningrad, but also to April temperatures which is, in its turn, significantly correlated with arrival dates to the Courish Spit (Tables 1, 3). Furthermore, winter NAOI values and especially March NAOI show a significant positive trend over time (Fig. 2, Table 3). All this may explain the relationship between winter NAOI values and timing of arrival in Central and Northern Europe found by the authors.

It cannot however be ruled out that the relationship between arrival and March NAOI values is due to the actual impact of western transfer of air masses related to high NAOI values on the birds arriving early in March. This may enhance their movement along the migratory route and also stimulate them to leave their winter quarters in Europe early in the years with high NAOI values. A strong positive relationship between March temperatures and frequency of westerly and southwesterly winds in Surrey (Britain) is suggested by the data of the UK bird observatories (Sparks *et al.*, 2001).

Relationship between arrival dates and spring air temperatures was reported by many authors from different European countries (Mason, 1995; Huin & Sparks, 1998; Sokolov *et al.*, 1998; Askeyev *et al.*, 2002; Barrett, 2002; Gilyazov & Sparks, 2002, Tryjanowski *et al.*, 2002). It comes as no surprise, as migrants are since long ago known to arrive in spring with warm air masses (Kaigorodov, 1911). Cold Arctic air, on the contrary, arrests migration. It however remains unclear whether increasing temperature in spring stimulates departure from European winter quarters. Interannual fluctuations of mean monthly temperatures in southern Europe are quite pronounced. During the recent 50 years, the mean temperature of March varied in Nancy (France) between 1.9–8.8 °C, and in Milan (Italy) between 5.5–11.4 °C. In April, this variation was between 6.6–12.0 °C and 10.9–15.8 °C, respectively. Spring air temperatures are usually strongly correlated in different European countries. For example, Spearman's rank correlation coefficient for the temperature of March is 0.47 ($p = 0.002$) and 0.50 ($p = 0.001$) between Kaliningrad and Milan and Kaliningrad and Nancy, respectively. For the temperature of April, the respective values are 0.49 ($p = 0.001$) and 0.25 ($p = 0.09$). In principle, a bird in its winter quarters may get information of the atmospheric processes (temperature rising or falling) on the basis of mean daily temperature dynamics. A warming may induce an early migratory departure, whereas low temperatures may arrest migration. This is however valid only for species wintering within Europe, but not in Africa where air temperature remains stable and high.

What kind of information, except of photoperiodic or endogenous stimulus from its biological clocks (when wintering near the Equator), can a bird receive in Africa to start migration earlier or later than the average date? The data presented in this paper suggest that it may be precipitation (Fig. 3). In the northern half of Africa down to the Equator, a considerable decrease of precipitation was recorded over the two recent decades during the period (January–March) when long-distance Palaearctic migrants are present there. Indeed, five out of eight long-distance migrants show a significant correlation between arrival dates to the Courish Spit and precipitation in Africa at 2.5–7.5° N where these species spend winter or make stopovers during spring migration, as shown by ring recoveries (Zink, 1973, 1975, 1985). In the years with low precipitation in February at these latitudes, long-distance migrants arrive earlier to the Courish Spit than in the years with much precipitation (Table 4, Fig. 4). This correlation could however be caused by the same reasons as the aforementioned relationship of arrival dates with the pooled NAOI for January–March. February precipitation at 2.5–7.5° N showed a pronounced negative trend over time, as does the timing of arrival of long-distance migrants to the Courish Spit. Similar negative long-term trends may show a chance correlation. However, we failed to find a significant relationship between arrival dates in Europe and March precipitation at 7.5–12.5° S, which also show a negative trend (Table 3). This may suggest that the relationship of arrival dates in Europe and precipitation at certain latitudes in Africa is not capitalising on chance.

Even though we have no firm evidence that precipitation in northern Africa influenced departure dates of some long-distance Palaearctic migrants, we suggest that during the recent two decades, migratory passerines started to depart from winter quarters considerably earlier than they did in the 1970s. This assumption is supported by considerable (up to one month, like on the Courish Spit) interannual fluctuations of the timing of spring passage of passerines in Eilat (Israel) on the border to Egypt (Izhaki & Maitav, 1998; Yosef & Tryjanowski, 2002). As migrants in spring reach Israel early in some years and much later in other years, it can be assumed that they cross the Sahara in different calendar dates in different years. It may be suggested that in drought years which occurred in Africa in the 1980s and partly in the 1990s, long-distance migrants faced shortage of animal and plant food during winter and early spring. This could induce them to depart from their winter quarters early and to migrate towards Europe. Curry-Lindahl (1975) reported that severe droughts during several consecutive years in Africa to the south of the Sahara either force the birds, primarily waterfowl, to leave the usual wintering areas, or cause mass mortality. It may be suggested that migrants were leaving South Europe much earlier in the two recent decades than in the 1970s, because of higher spring air temperatures and considerable reduction of precipitation (Tables 3, 4, Fig. 3).

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