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Long-term trends in the timing of spring migration of passerines on the Courish Spit of the Baltic Sea

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Abstract: Sokolov, L.V., Markovets, M.Yu., Shapoval, A.P. & Yu. G. Morozov (1998): Long-term trends in the timing of spring migration of passerines on the Courish Spit of the Baltic Sea. Avian Ecology and Behaviour 1:1-21.

An analysis of dates of first captures and mean dates of spring migration in 33 passerine species revealed that the earlier a species migrates through the Courish Spit, the greater is the inter-annual variation in the tuning of passage. The annual fluctuation in mean arrival dates did not depend on the length of migratory route. In early migrants (arriving in April) over the study period (1959-1996) two decades were recorded (1960s and 1980s) when earlier migration prevailed, and two decades with late migration (1970s and 1990s). In migrants that arrive late (in May) only one period with early migration was recorded (1980s), except for the very late migrants in which no trends were found. A comparison of the timing of spring migration in 20 species of migrants with mean monthly temperatures showed a significant relationship between mean arrival date and mean temperature in 12 species that migrate area primarily in April and May. Higher temperatures were associated with earlier migration. In the Willow Warbler *Phylloscopus trochilus* and Icterine Warbler *Hippolais icterina* a similar relationship was recorded in the timing of arrival of the local population. An analysis of temperature change at 10 sites in European Russia (from Smolensk to Kola Peninsula) revealed a similar pattern of inter-annual variation of April and May temperatures over this region. On the basis of our own data and available literature we concluded that over the 20th century long-term trends in the timing of spring bird migration occurred, especially in passerines. These trends were caused primarily by climate fluctuations in the northern hemisphere. Warmings in the 1930s and 1940s, and then in the 1960s and 1980s led to significant shifts in the timing of spring migration towards earlier dates. Conversely, colder periods during the 1950s, 1970s and possibly 1990s, caused later passage. Climate change influenced the migration of species wintering both within Europe and in Africa.

Key words: long-term trends, spring migration, passerines, timing, air temperature.

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1. Introduction

Recently long-term trends in the dates of spring passage have been reported for a number of bird species in Europe. On Heligoland (North Sea) earlier arrival dates were recorded in the 1980s in ten bird species (Moritz 1993). In central England an analysis of the timing of spring migration in 23 species, mainly long-distance migrants, over 50 years (1940-1991) revealed a significant trend towards earlier arrival in some species, and towards later arrival in others (Mason 1995). Some researchers suggested that these trends could be explained primarily by climatic fluctuations in the northern hemisphere (Mason 1977, 1995, Berthold 1994). According to Williamson (1976), a warming which occurred in Europe between 1890 and 1940 influenced the populations and breeding ranges of some British bird species. Some climatologists believe that significant warming occurred from the mid 19th century onwards, especially at higher latitudes of the northern hemisphere (Monin & Shishkov 1979, Borisenkov 1982). Temperature fluctuation was evident, with maximum warming at higher latitudes, in the 1930s and 1940s, leading to drastic changes in the marine fauna over 15-20 years, southern species colonising the northern seas (Berg 1947). The periods of warming in the 1930s and 1940s were recorded in the southern hemisphere as well. In mid 1940s, due to largely unknown causes, the climate of the northern hemisphere began getting colder, whereas in 1960s another period of warming started. According to Mason (1995), in central England a trend towards earlier arrival was recorded in the 1940s and 1960s compared with the 1950s and 1970s when spring temperatures were lower.

If we assume that a further warming due to a human-induced environmental change is expected (Leggett 1990, Schneider 1990, Gorshkov 1995, Johannesson et al. 1995), it may have a significant impact on avian populations (Berthold 1991). With further increases, the mean annual temperature may be expected to reach the values of the 1940s between 2020 and 2060, which would cause a similarly early arrival of migrants (Mason 1995). However, other authors expect a cold spell, not a warm period in the 21st century (John 1979). Lamb (1977) analysed the patterns climate change and suggested that a quasi-periodic process, with periods of 20-25 and 45-55 years playing a role in climate fluctuation in England over the last 290 years.

At the Biological Station Rybachy birds have been captured in Rybachy-type traps since 1958 within a standard period (April to October) every year. This database, collected on the Courish Spit which is well suited for the study of bird migration (Thienemann 1931), allows an analysis of long-term trends in the dates of spring migration. This study may give some new insights on the pattern of arrival of birds (primarily passerines) to their breeding areas, as well as on the influence of external and endogenous factors on this process.

2. Material and methods

Annual trapping of migrating passerines in Rybachy-type traps (description: Dolnik & Payevsky 1976; two or three traps in every spring) has been carried out at the field station "Fringilla" (55°05' N 20°44' E) since 1958. Traps are oriented along the NE-SW axis which corresponds to the main direction of migration in the Baltic region. The trapping was conducted from April 1 until November 1, though in some years it started in late March. All data is computerised and stored with the aid of original software (Morozov 1995, Morozov & Yefremov 1986, 1994, 1995a, b).

The timing of spring migration was analysed in 33 passerine species, including long- and short-distance migrants. In 27 species a special analysis was performed in order to reveal long-term trends in the dates of spring migration between 1961 and 1990. In general, trends over the period between 1959 and 1996 were analysed.

The timing of spring migration was characterized by the mean trapping date in the standard traps during the period between April 1 and June 1. The arrival date of local birds was defined as the date of first capture of birds ringed in the study area in previous years.

Two time intervals were selected: 1961 to 1977 (17 years) and 1973 to 1990 (18 years). Statistical treatment included Spearman's rank correlation (r_s) (Lloyd & Ledermann 1984) and regression analysis. Weather data between 1959 and 1990 was analysed in our study region (Kaliningrad Region), as well as at other sites in European Russia (from Smolensk up to Kola Peninsula) and in Lithuania. Mean monthly air temperatures and mean annual temperatures were included in the analysis.

3. Results

3.1. Timing of spring migration

The analysis of first captures and mean date of spring migration in 33 species showed large inter-annual variation (Tab. 1). It is noteworthy that in early migrants, e.g. in the Great Tit *Parus major* and Blue Tit P. *caeruleus,* a considerable proportion migrate through the Courish Spit in late February and March, i.e. before the beginning of the trapping season (April 1st or late March). Nevertheless, even in these species inter-annual variation in the mean date of spring passage was considerable. The following rule may be found: in early migrants the inter-annual variation of the mean date is larger (Fig. 1). The bulk of species that pass through the Courish Spit in April migrate within Europe, whereas species that arrive in May migrate from Africa. In some long-distance migrants *(Motacilla alba, Phoenicurus phoe-nicurus)* that arrive comparatively early, i.e. in late April, the fluctuation of the mean passage date is significant (Tab. 1).

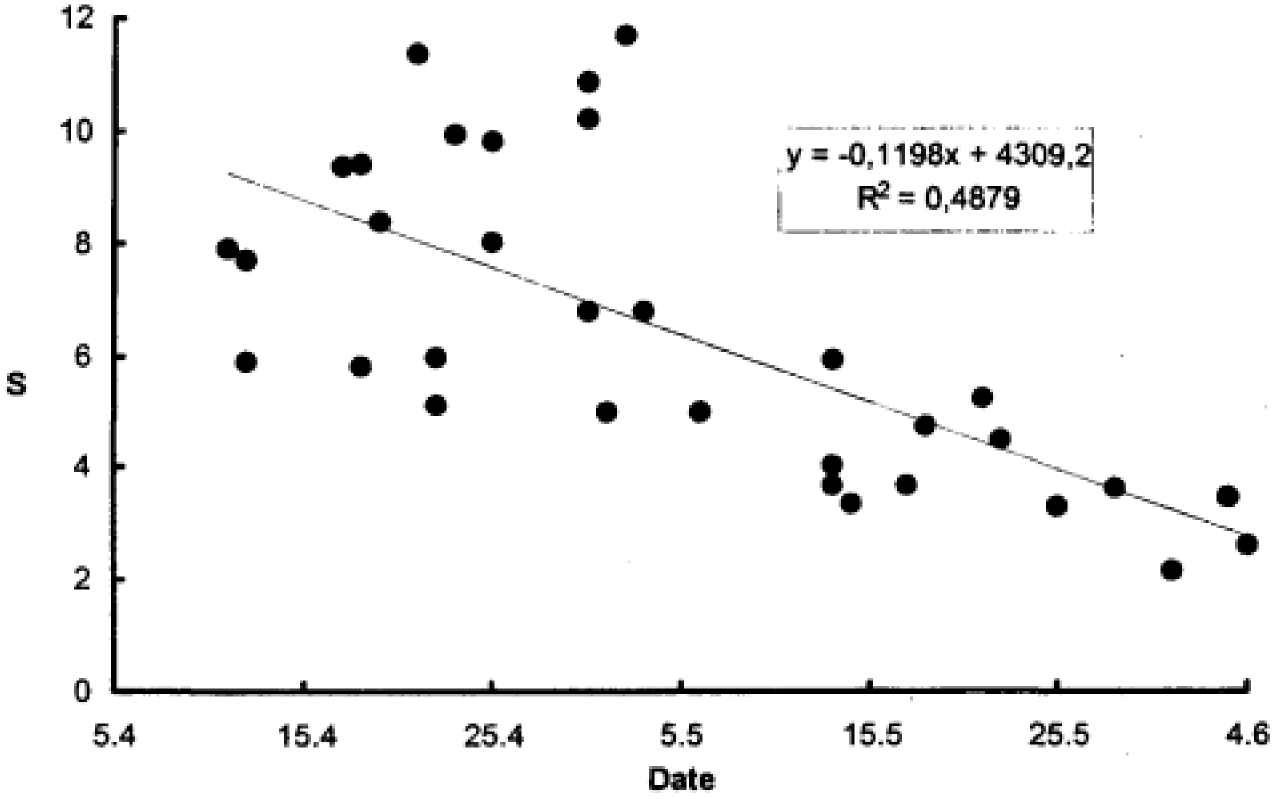
Table 1. Mean dates of spring migration of some passerines on the Courish Spit, 1959-1990.

Species	Date of first catch		Mean date of spring migration		
	Mean	Range	Mean	Range	SD
Parus caeruleus	Mar. 31	Mar. 20 - Apr. 14	April	Mar. 30 - Apr. 29	7.92
Parus major	Mar. 30	Mar. 21 - Apr. 7	Apr. 12	Apr. 2 - May 2	7.69
Regulus regulus	Apr. 2	Mar. 27 - Apr. 11	Apr. 12	Apr. 5 - Apr. 30	5.90
Pyrrhula pyrrhula	Apr. 2	Mar. 22 - Apr. 20	Apr. 17	Apr. 5 - May 10	9.39
Prunella modularis	Apr. 5	Mar. 23 - Apr. 22	Apr. 18	Apr. 8 - May 10	9.40
Troglodytes troglodytes	Apr. 7	Mar. 26 - Apr. 21	Apr. 18	Apr. 10 - May 2	5.83
Anthus pratensis	Apr. 6	Mar. 24 - Apr. 15	Apr.19	Apr. 7 - May 9	8.39
Emberiza schoeniclus	Apr. 6	Mar. 22 - Apr. 29	Apr. 21	Apr. 10 - May 20	11.40
Erilhacus rubecula	Apr. 2	Mar. 30 - Apr. 10	Apr. 22	Apr. 12 - May 3	5.13
Chloris chloris	Apr. 5	Mar. 23 - Apr. 14	Apr. 23	Apr.9 - May 19	9.95
Fringilla montifringilla	Apr. 4	Mar. 22 - Apr. 17	Apr. 22	Apr. 13 - May 9	5.99
Fringilla coelebs	Mar. 31	Mar. 22 - Apr. 7	Apr. 24	Apr.12 - May 16	8.03
Phoenicurus ochruros	Apr. 9	Mar. 30 - Apr. 21	Apr.25	Apr. 10 - May 23	9.82
Cannabina cannabina	Apr. 7	Mar. 24 - Apr. 23	Apr.30	Apr. 10 - May 25	10.89
Carduelis carduelis	Apr. 6	Mar. 23 - Apr. 23	Apr.30	Apr.15 - May 11	6.81
Motacilla alba	Apr. 10	Mar. 26 - Apr. 26	Apr.30	Apr. 13 - May 22	10.22
Phylloscopus collybita	Apr. 10	Mar. 30 - Apr. 30	May 1	Apr.20 - May 9	4.98
Emberiza citrinella	Apr. 4	Mar. 21 - Apr. 19	May 2	Apr. 9 - May 31	11.71
Spinus spinus	Apr. 5	Mar. 21 -Apr. 21	May 3	Apr. 15 - May 19	6.78
Anthus trivialis	Apr. 20	Apr. 8 - May 11	May 6	Apr. 29 - May 18	4.99
Phoenicurus phoenicurus	Apr. 26	Apr.2 - May 10	May 13	Apr. 29 - May 30	5.93
Phylloscopus trochilus	Apr. 19	Apr. 5 - Apr.30	May 13	May 6 - May 21	4.05
Phylloscopus sibilatrix	Apr. 25	Apr. 12 - May 6	May 13	May 3 - May 19	3.69
Ficedula hypoleuca	Apr. 26	Apr. 16 - May 6	May 14	May 3 - May 25	3.36
Saxicola rubetra	May 2	Apr. 17 - May 14	May 17	May 11 - May 27	3.70

Hirundo rustica	May 1	Apr. 15 - May 11	May 18	May 9 - May 29	4.76
Sylvia atricapilla	Apr. 30	Apr. 14 - May 10	May 21	May 13- May 29	5.26
Sylvia curruca	May 1	Apr.14 - May 11	May 22	May 11 - May 31	4.49
Sylvia communis	May 4	Apr.25 - May 14	May 25	May 18 - May 31	3.31
Sylvia borin	May 12	May 5 - May 19	May 28	May 20 - Jun. 4	3.65
Hippolais icterina	May 13	May 4 - May 22	May 31	May 26 - Jun. 5	2.16
Carpodacus erythrinus	May 21	May 8 - May 29	Jun. 3	May 29 - Jun. 10	3.48
Sylvia nisoria	May 18	May 8 - May 26	Jun. 4	May 28 - Jun. 9	2.63

SD — standard deviation

Figure 1. Annual variation of the mean arrival date for spring migrants on the Courish Spit.
S - standard deviation.



The analysis of passage dates in early migrants revealed rather prolonged periods of early and late passage. In the 1960s and especially the 1980s, spring migration occurred comparatively early whereas in the 1970s and the 1990s mostly late passage was recorded (Fig. 2). Over the period 1961 to 1977 a significant trend towards later passage in the 1970s was recorded in many early migrants (Tab. 2). In species that migrate later no such trend was found over this period. Between 1973 and 1990, in both early and late migrants (with the exception of species that arrive very late - Whitethroat *Sylvia communis.* Garden Warbler *S. borin,* Icterine Warbler *Hippolais icterina),* a trend towards earlier passage in the 1980s compared with the 1970s was recorded (Tab. 2, Fig. 2).

Table 2. The tendency to change of mean date of spring migration in some passerines on the Courish Spit (Spearman's rank correlation coefficient: + $p < 0.10$, * $p < 0.05$, ** $p<0.01$, *** $p < 0.001$).

Species	Years 1961-1977	Years 1973-1990
Parus caeruleus	0.44+	-0.40
Parus major	0.04	-0.10
Prunella modularis	0.26	-0.36
Pyrrhula pyrrhula	0.37	-0.51*
Troglodytes troglodytes	0.48*	-0.25
Anthus pratensis	0.57*	-0.66**
Emberiza schoeniclus	0.25	-0.47*
Erithacus rubecula	0.66**	-0.81***
Chloris chloris	0.43+	-0.18
Fringilla montifringilla	0.47*	-0.34
Fringilla coelebs	0.11	-0.72**
Phoenicurus ochruros	0.35	-0.57*
Carduelis carduelis	0.52*	-0.53*
Motacilla alba	0.50*	-0.40
Phylloscopus collybita	-0.30	-0.24
Emberiza citrinella	0.18	-0.34
Anthus trivialis	0.26	-0.22
Phoenicurus phoenicurus	0.01	-0.45+
Phylloscopus trochilus	-0.08	-0.59*
Phylloscopus sibilatrix	-0.57*	0.24
Ficedula hypoleuca	0.06	-0.36
Hirundo rustica	0.25	-0.55*
Sylvia atricapilla	-0.30	-0.17
Sylvia curruca	0.26	-0.56*
Sylvia communis	-0.33	-0.06
Sylvia borin	-0.37	0.58*
Hippolais icterina	0.23	0.24

Figure 2. Changes in the mean arrival date of spring migrants on the Courish Spit.

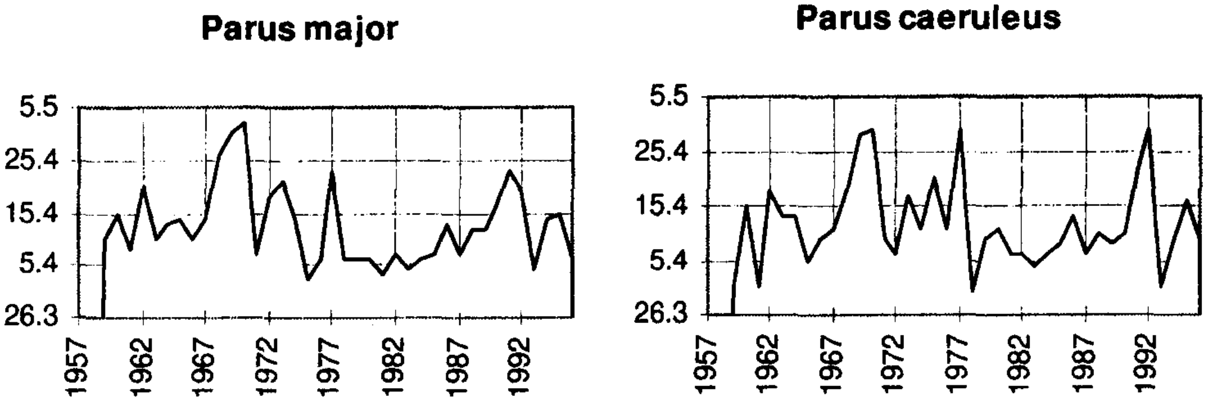
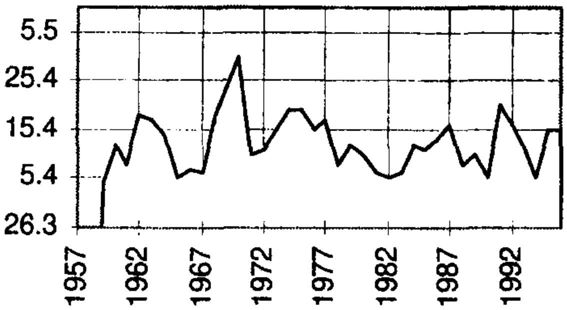
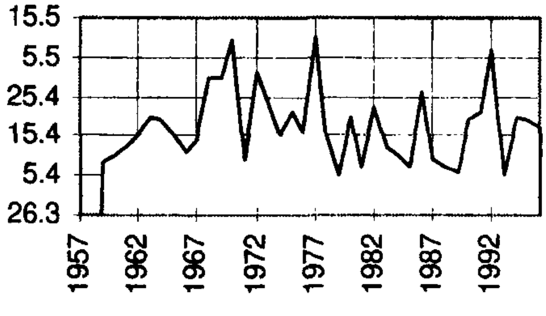


Figure 2. Continued

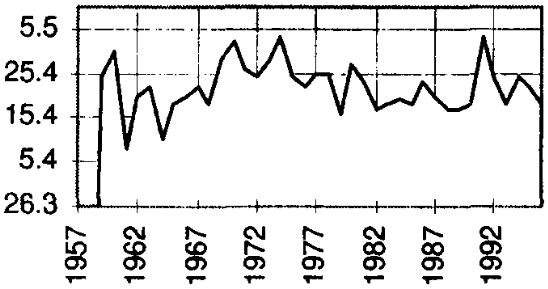
Regulus regulus



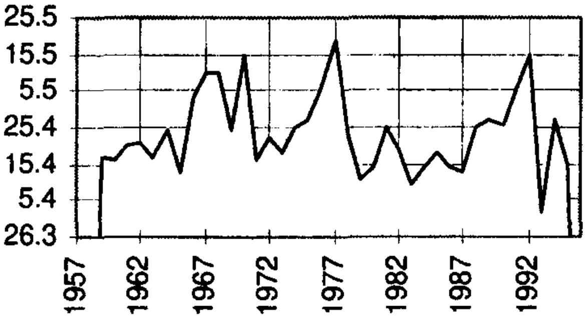
Pyrrhula pyrrhula



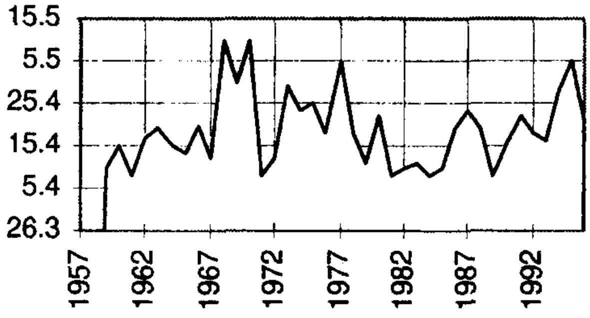
Erithacus rubecula



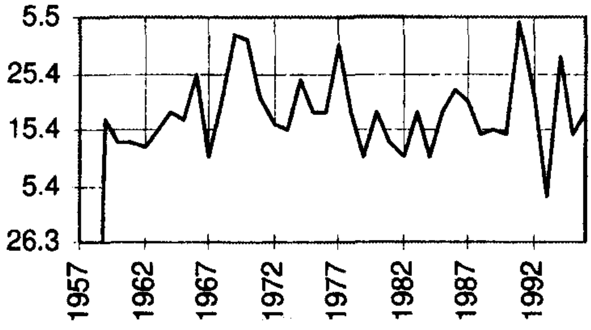
Chloris chloris



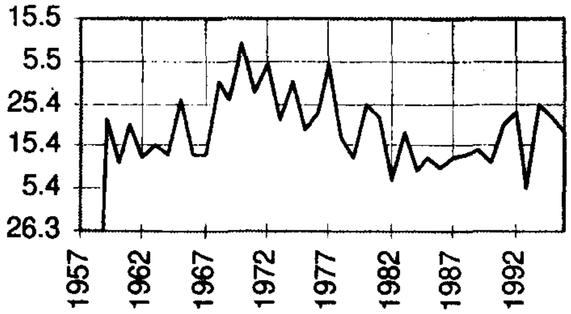
Prunella modularis



Troglodytes troglodytes



Anthus pratensis



Emberiza schoeniclus

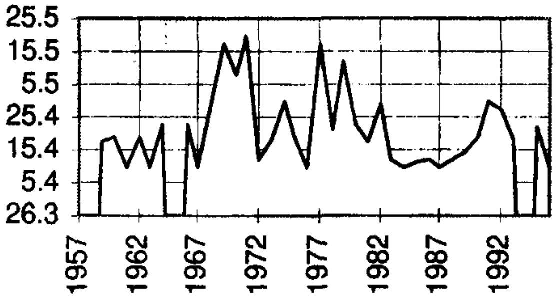
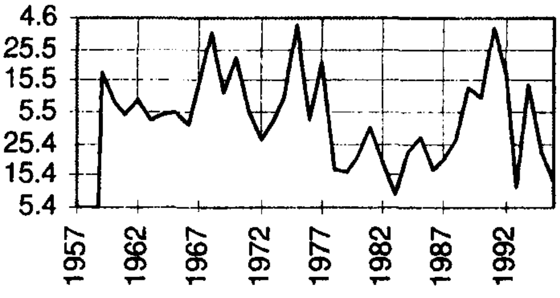
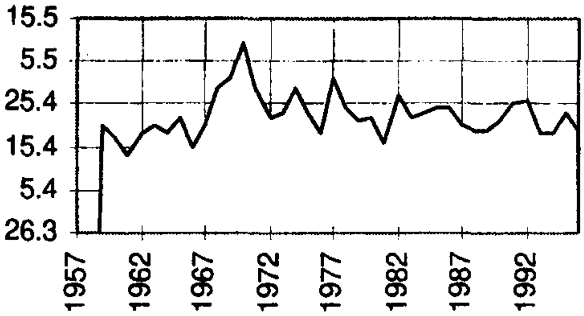


Figure 2. Continued

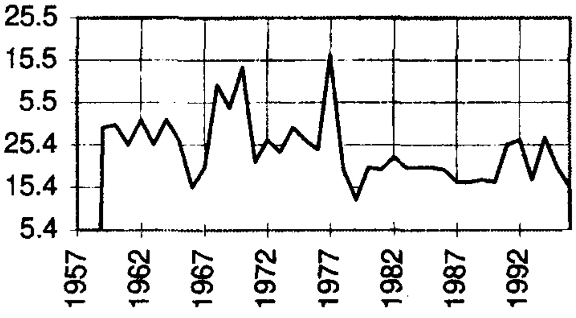
Emberiza citrinella



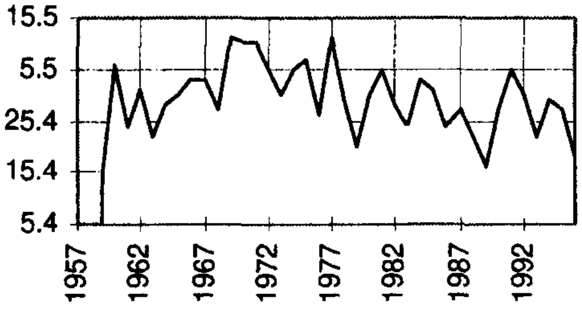
Fringilla montifringilla



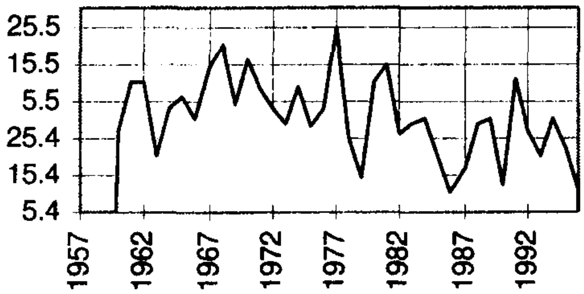
Fringilla coelebs



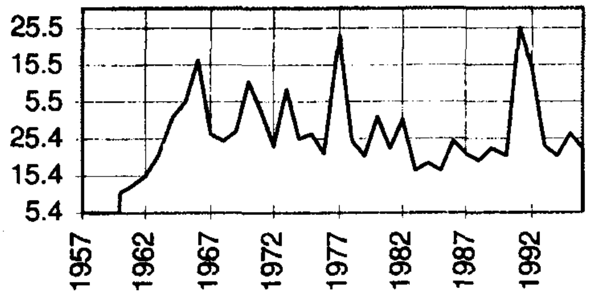
Carduelis carduelis



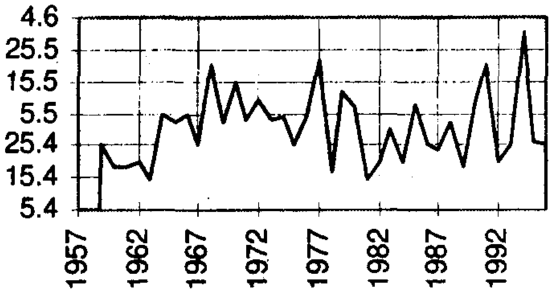
Cannabina cannabina



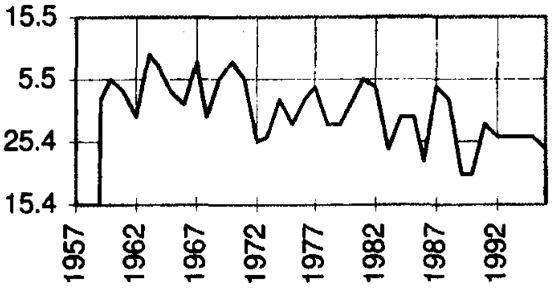
Phoenicurus ochruros



Motacilla alba



Phylloscopus collybita



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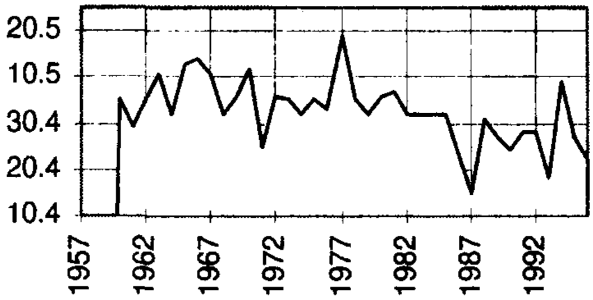
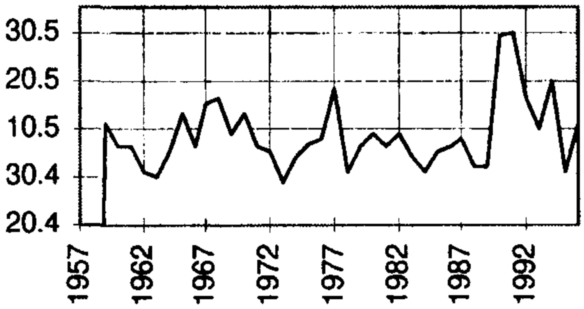
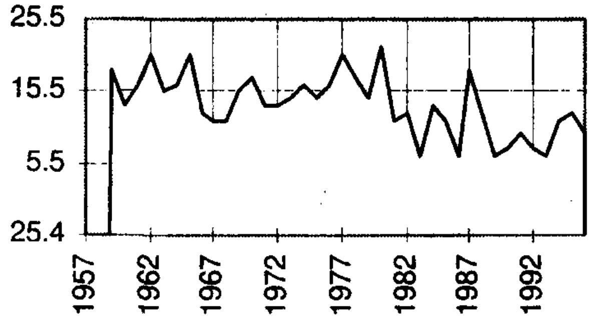
Spinus spinus



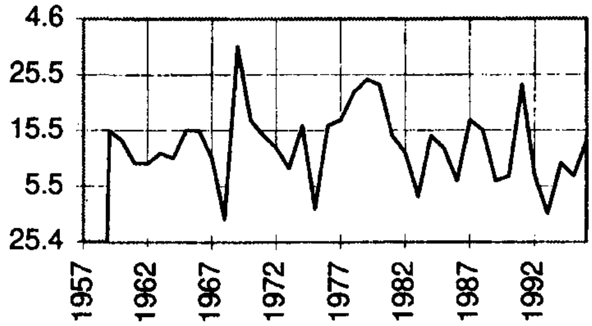
Anthus trivialis



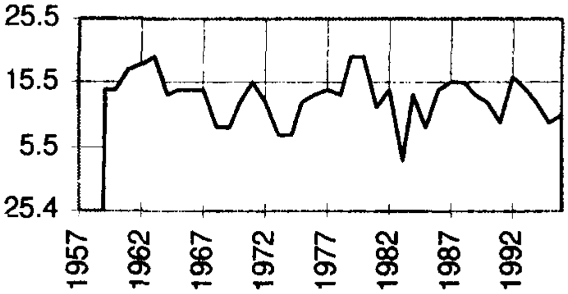
Phylloscopus trochilus



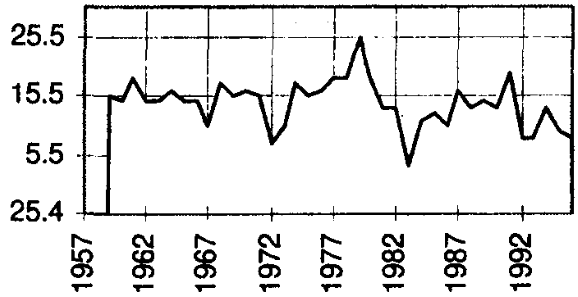
Phoenicurus phoenicurus



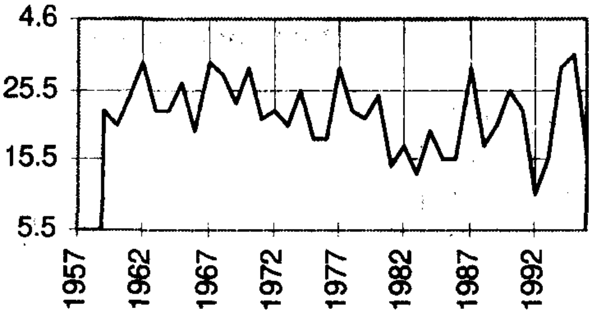
Phylloscopus sibilatrix



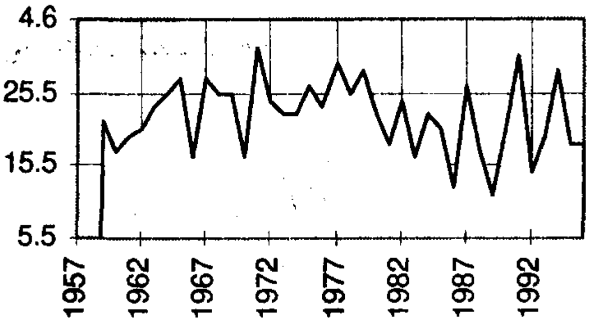
Ficedula hypoleuca



Sylvia atricapilla



Sylvia curruca



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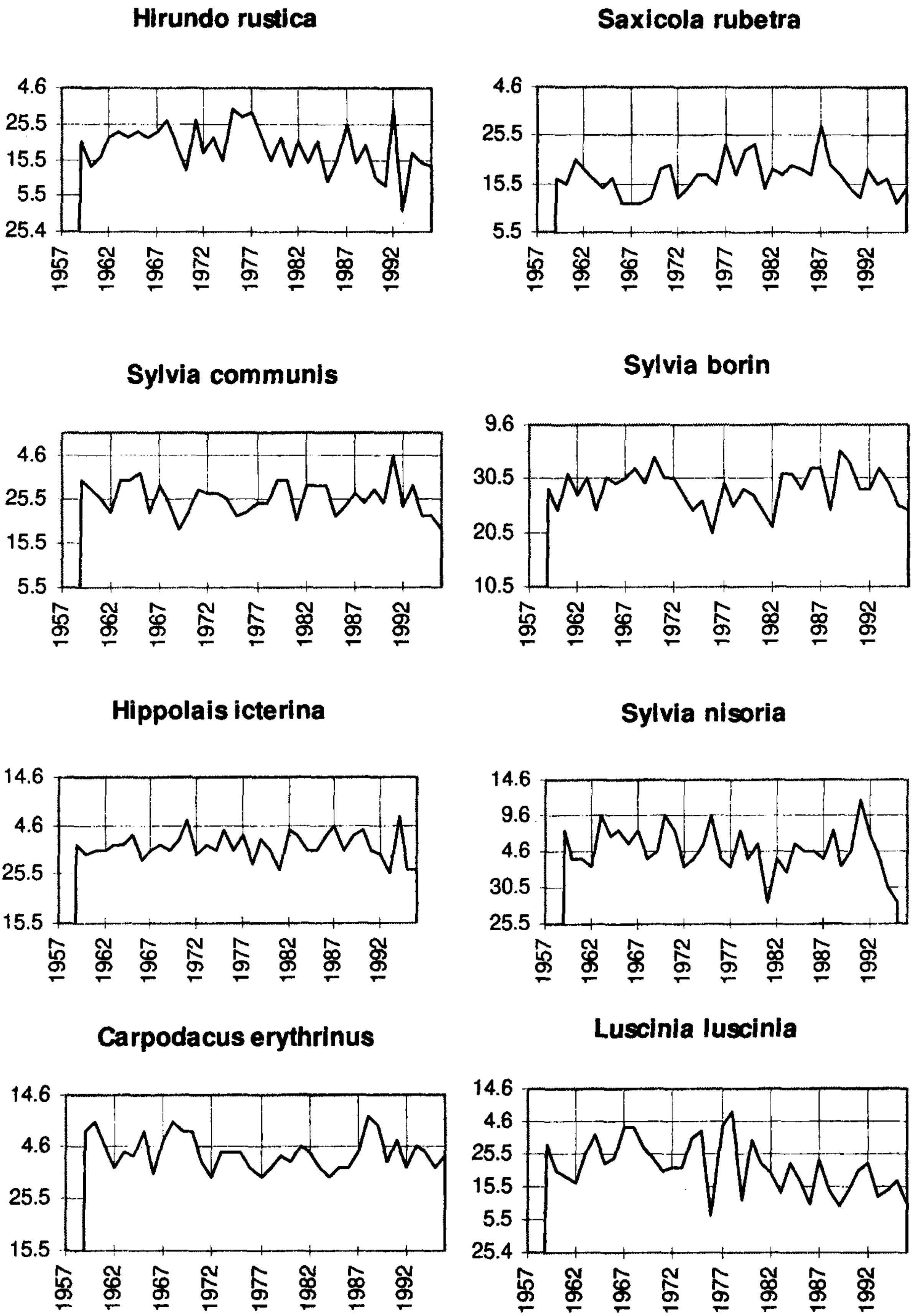


Hirundo rustica

Saxicola rubetra

Sylvia communis

Sylvia borin

Hippolais icterina

Sylvia nisoria

Carpodacus erythrinus

Luscinia luscinia

An analysis of arrival dates of local male Willow Warblers *Phylloscopus trochilus* showed a trend towards earlier arrival in the 1960s and 1980s compared to other years over the period between the 1960s and the 1990s (1961-1971: $r_s = 0.59$; $p = 0.06$ and 1976-1990: $r_s = -0.72$; $p = 0.007$) (Fig. 3). A similar trend was found in females (1976-1989: $r_s = -0.61$; $p = 0.02$). Similarly, male Icterine Warblers arrived in later in the 1970s than in the 1960s (1960-1974: $r_s = 0.72$; $p = 0.006$) and the 1980s (1977-1990: $r_s = -0.40$; $p = 0.14$). In females this trend was weaker (Fig. 3).

Figure 3. First catch of local males and females of some species in breeding area on the Courish Spit.

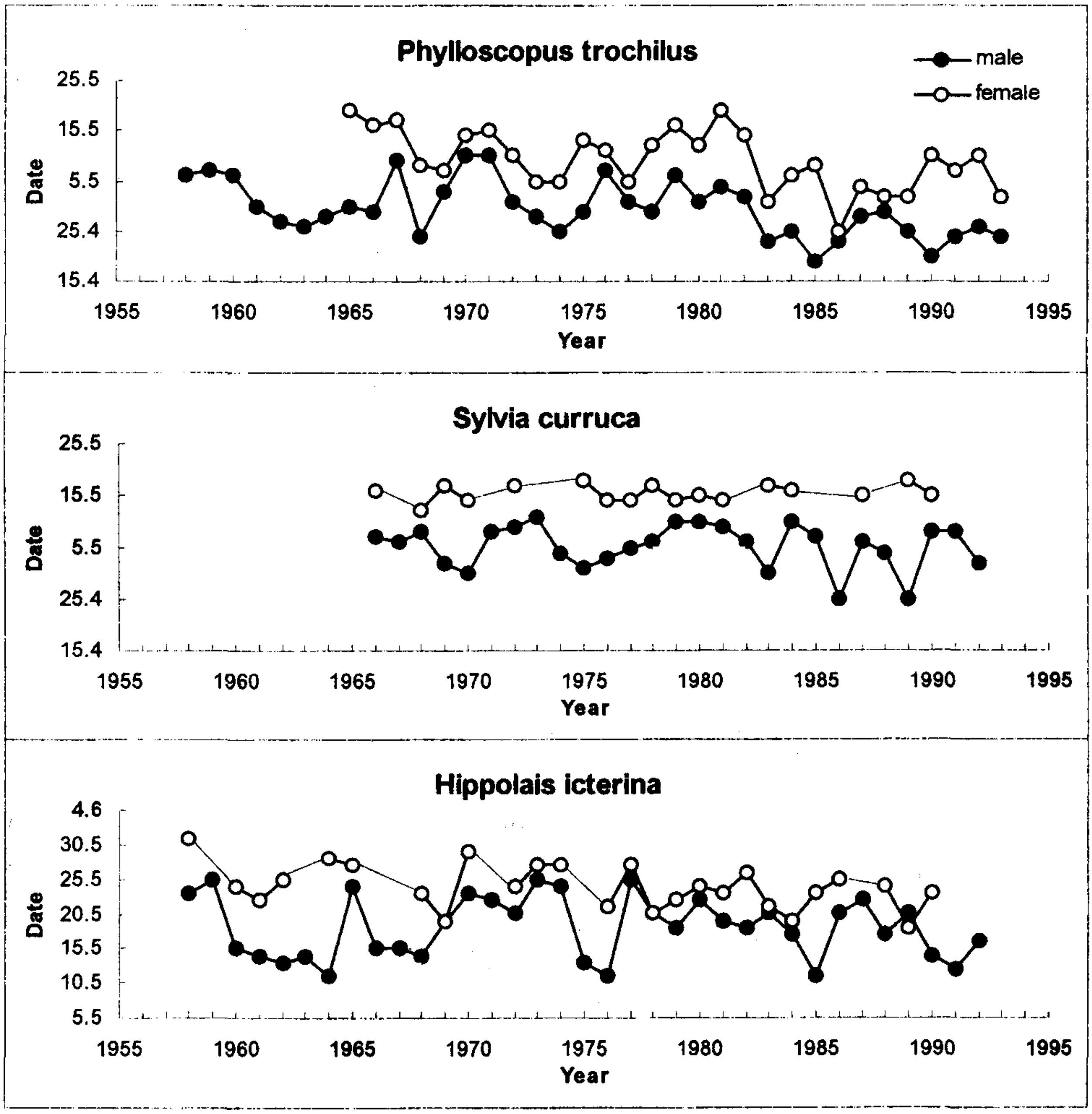
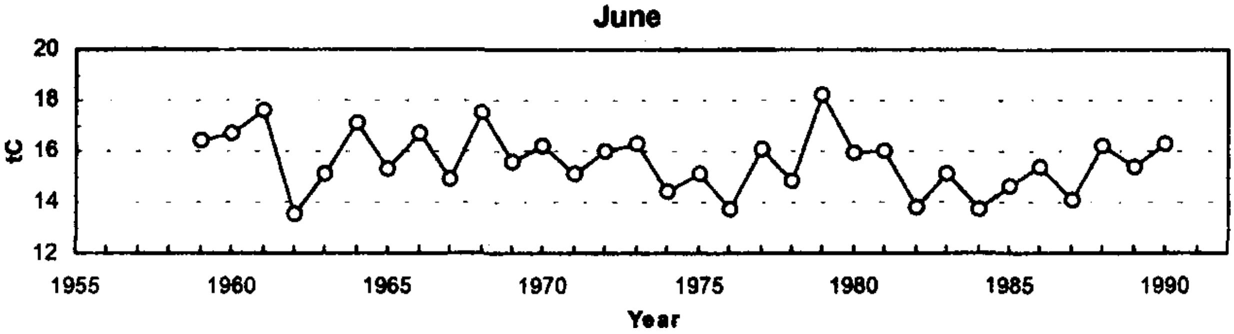


Figure 4. Continued



Mean temperatures in our region were well correlated with similar data from various Russian sites (from Smolensk up to Kola Peninsula) and from Lithuania both in April and in May (Tab. 3). In these spring months similar weather conditions dominate a large area, at least from Byelorussia and Poland up to Finland and Kola Peninsula.

Table 3. Correlation between mean April and May air temperatures in different regions of North-West Russia and the Baltic States (1980-1990). Spearman's rank correlation coefficient: * $p<0.05$

Region	1	2	3	4	5	6	7	8	9	10
1. North Karelia.		0.83*	0.77*	0.86*	0.82*	0.62*	0.78*	0.54	0.58	0.74*
2. South Karelia, Petrozavodsk.	0.32		0.93*	0.92*	0.87*	0.75*	0.84*	0.74*	0.78*	0.92*
3. Leningrad Region, Sviritsa.	0.36	0.45		0.97*	0.93*	0.82*	0.89*	0.85*	0.92*	0.95*
4. Estonia.	0.32	0.81*	0.80*		0.95*	0.77*	0.85*	0.77*	0.86*	0.90*
5. Pskov Region, Velikie Luki.	0.35	0.75*	0.83*	0.97*		0.85*	0.81*	0.77*	0.83*	0.94*
6. Lithuania.	0.72*	0.36	0.35	0.51	0.53		0.87*	0.87*	0.82*	0.90*
7. Courish Spit.	0.63*	0.22	0.17	0.36	0.39	0.96*		0.77*	0.78*	0.87*
8. Kaliningrad.	0.19	0.64*	0.68*	0.87*	0.91*	0.61*	0.54		0.95*	0.83*
9. Kaliningrad Region, Baltysk	0.14	0.74*	0.53	0.85*	0.86*	0.58	0.53	0.94*		0.86*
10. Smolensk Region	0.75*	0.62*	0,60	0.78*	0.82*	0.89*	0.80*	0.74*	0.73*	

Right part of table: data on April temperature; left part of table: data on May temperature.

The comparison of the timing of spring migration with mean monthly temperatures showed that in species that arrive to our area primarily in April, a significant negative relationship between the mean passage date and April temperature exists. Under higher temperatures birds pass the Courish Spit earlier (Tab. 4). The most obvious shift towards earlier migration was recorded in 1983, when April temperature increased drastically (Fig. 4). In 1987 low temperature in April caused later passage in these species.

In species that arrive primarily in May, a significant negative relationship between the timing of migration and May temperature was recorded (Tab. 4). No significant correlation between the mean passage date and March temperature was found in the earliest migrants (Great Tit, Blue Tit, Robin *Erithacus rubecula).* In the latest migrants (Whitethroat, Garden Warbler, Icterine Warbler) no relationship was found either with May or with June temperatures (Tab. 4). Not only passage, but also arrival of local birds is correlated with spring temperature (Tab. 5).

Table 4. Correlation between mean arrival date and spring temperatures in some passerines on the Courish Spit, 1959-1990 (Spearman's rank correlation coefficient: + p < 0.10, * p<0.05, ** p<0.01, *** p< 0.001)

Species	t° C April	t° C May
Parus caeruleus	-0.10	
Parus major	-0.01	
Emberiza schoeniclus	-0.34+	
Erithacus rubecula	-0.35*	
Fringilla coelebs	-0.03	-0.37*
Phoenicurus ochruros	-0,56**	-0.35*
Motacilla alba	-0.26	-0.23
Phylloscopus collybita	-0,58**	-0.06
Emberiza citrinella	-0.14	-0.22
Anthus trivialis	-0.42*	-0.34+
Phoenicurus phoenicurus	-0.68***	-0.30
Phylloscopus trochilus	-0.30	-0.72***
Phylloscopus sibilatrix	0.17	0.04
Ficedula hypoleuca	-0.26	-0.60***
Hirundo rustica	-0.13	-0.50**
Sylvia atricapilla	-0.01	-0.60***
Sylvia curruca		-0.35*
Sylvia communis		-0.05
Sylvia borin		0.13
Hippolais icterina		0.07

Table 5. Correlation between first catch date and spring temperatures in some local birds on the Courish Spit (Spearman's rank correlation coefficient: + p<0.10, *p<0.05, ** p<0.01)

Species	t° C April		t°C May	
	male	female	male	female
Phylloscopus trochilus	-0.48**	-0.38*	-0.06	-0.06
Hippolais icterina	-0.31 +		-0.32+	

4. Discussion

The majority of early arriving migrants belong to species that spend their winter within Europe. The bulk of migrants that arrive from May onwards is composed of species that spend their winter in Africa or in India, e.g. Scarlet Rosefinch *Carpodacus erythrinus* (Payevsky 1973). It has been suggested that smaller variation in the timing of spring migration in long-distance migrants compared to short-distance migrants, is explained by the fact that in the former the onset of migration is under endogenous control, and thus constant between years (Dolnik 1975, Curry-Lindahl 1975, Berthold 1984, Gwinner 1996). However, we found large variation in mean dates of spring migration in some long-distance migrants as well. It seems more probable that in early migrants significant fluctuation of the timing of spring migration is caused by the dependence of the migration pattern on the unpredictable weather which dominates in early spring. Some long-distance migrants that migrate during this period are also subject to weather which may differ from year to year. The onset of spring migration from the African winter quarters may indeed be stable from year to year, being under endogenous control.

The data on the arrival of passerines to central England over nearly 50 years shows that in 20 of 23 species analysed the earliest arrival were recorded in the 1940s and early 1950s (Mason 1995). In 13 species comparatively early arrival was recorded in the 1960s. In the 1980s early arrival was recorded in 20 species. In the 1970s birds were recorded later than in other periods. Thus, our data on the passage through the Courish Spit and the results of Mason (1995) are in good accordance.

The question arises, as to whether such trends in the timing of spring migration can be demonstrated in northern areas. Some information may be obtained from the first records of different birds species in Estonia (Paapskuu, Magi & Meriste 1970-1993) and data on arrival to the Leningrad Region (Malchevsky & Pukinsky 1983). According to the Estonian data, in the 1980s passerines and some non-passerines, e.g. White Stork *Ciconia ciconia* and Wryneck *Jynx torauilla* arrived much earlier than in the 1970s (Fig. 5). Passerines arrived to the Leningrad Region in early 1960s much earlier than in the 1970s, except for 1975 and 1977 when a warm spring caused the early arrival of many species (Malchevsky & Pukinsky 1983). The distinctive song of the Thrush Nightingale *Luscinia luscinia* allows to record its presence very well. The earliest first records in the Leningrad Region over 40 years were in 1950 (May 4), 1960 (May 3), 1962 (May 2), 1964 (May 2), 1975 (May 5), the latest ones in 1953 (May 21), 1972 (May 17) and 1974 (May 24). According to Malchevsky & Pukinsky (1983), a number of species such as the Rook *Corvus frugilegus,* the Reed Bunting *Emberiza schoeniclus,* the White Wagtail *Motacilla alba,* the Tree Pipit *Anthus trivialis,* and the Scarlet Rosefinch arrived in the 19th century much later than in the 20th century. Thus, the mean arrival date of Rooks in Estonia was March 23-24 in the second half of the 19th century and February 27 between 1980-1990. Bulygin & Martynov (1992) compared contemporary arrival dates to the park of the Academy of Forestry (St. Petersburg) and the dates referring to the late 19th century from the data of D. N. Kaigorodov. They showed that the arrival period to this park and in general to the St. Petersburg area became longer, with a shift of 9-11 days towards earlier arrival being recorded in the Rook, Starling *Sturnus vulgaris.* Fieldfare *Turdus pilaris,* and Redwing *Turdus iliacus.* First records of the Greenfinch *Chloris chloris,* Spotted Flycatcher *Muscicapa striata,* Scarlet Rosefinch, Golden Oriole *Oriolus oriolus* occurred a week earlier. These authors showed that arrival dates are well correlated with the seasonal pattern of vegetation and other components of ecosystems.

It is interesting the examine the possibility of long-term trends in the timing of spring migration in short- and long-distance migrants in the Mediterranean area where many species concentrate before moving across Europe. Some information is yielded from the data of Klein et al. (1973). The authors compared the timing of spring migration in the Garden Warbler, a long-distance migrant, and in the Blackcap *S. atricapilla,* a species that winters mainly in the Mediterranean area and northern Africa. No significant trend was found in the Garden Warbler over the period 1953-1969 in southern France (43°25' N 4°40' E), although variation was pronounced (mean passage dates were: 1956 - May 8; 1963 - May 26; 1969 -May 3. In the Blackcap a trend towards later migration was recorded (1955 - March 27,1960 - April 8, 1970 - April 18). In male Blackcaps this trend was stronger than in females (males 0.98 days/year, females 0.68 days/year). The authors suggest that the spring passage of long-distance migrants (e.g. Garden Warbler) is not related to the air temperature, whereas in species migrating within Europe (e.g. Blackcap) a pronounced correlation is recorded.

In this study we have tried to answer the following question: which factors have caused shifts in the timing of spring migration? Among all external stimuli we analysed air temperature as the clearest and easiest to measure meteorological variable. Temperature is also one of major elements of climate (Khromov & Mamontova 1974, Weisberg 1976).

A number of authors believe that other meteorological factors are also important in shaping bird migration, e.g. distribution of air pressure, rainfall, wind, etc. Alerstam (1990) suggested that in spring the most intensive migration in Europe occurs in the high pressure area or to the west of it, before the arrival of a cyclone from the west. He believes that birds may often fly in the warm sector of a cyclone where cloud cover is not complete and no rainfall occurs. Intensive spring migration often coincides with rising air temperature, falling air pressure and decreasing visibility. According to Alerstam (1990), this relationship is secondary, as these characteristic reflect wind and rainfall.

We suggest that air temperature is the best predictor of weather and climate conditions, this opinion being shared by other authors. A dependence between arrival of migrants and the movement of warm isotherms in Russian was suggested by Kaigorodov (1911). In virtually every review devoted to bird migration the influence of temperature has been recognised (Lucanus 1929, Gladkov 1937, Dinesman 1954, Mikheev 1964, and others). In phenological studies this is often referred to as a direct relationship. Other researchers suggest that the influence of temperature shapes migration through foraging (Mikheev 1964, Sema 1989). Temperature influences the availability and abundance of food during migration. These authors suggest that the pattern of temperature change defines the suitable feeding conditions for bird migration.

Migration counts and trapping of migrants using large Rybachy-type traps in Kazakhstan (Pass Chokpak, Western Tien-Sian) between 1966 and 1985 revealed that the beginning of spring migration in early arriving songbirds *(Alaudidae, Sturnidae)* and non-passerines *(Anatidae, Accipitridae, Gruidae, Charadriidae)* coincides with mean daily temperatures of 0°C, whereas mass migration starts at mean daily temperatures of 5-10°C. The dependence between passage and temperature is evident on both weather and climatic levels, the inter-annual variation of the arrival time is lower or equals the variation of the time when a certain temperature is established. The front of migration of early migrants moves in parallel with the isotherm 0-5°C. This dependence is getting weaker along with the season and is hardly detectable in late arriving species (Sema 1989).

Zaiakevicius (1994) concluded on the basis of radar and visual observations of nocturnal and diurnal migrants that the arrival, start and pattern of spring migration occurred under certain conditions - i.e. warm air temperature, high air pressure and slow tail-wind. Birds took off usually on the second day after the rise of temperature. Lewis & Farner (1973) showed in an experiment with the White-crowned Sparrow *Zonotrichia leucophrys* that in spring comparatively low temperature (5.2°C) suppressed nocturnal restlessness in caged birds.

We found a significant negative relationship between the mean date of spring passage of early migrating species and mean April temperature in Kaliningrad Region. In birds that arrive later, a similar relationship was found with mean May temperature. Thus, when higher temperature prevails in spring, earlier passage of passerines is recorded. Mason (1995) found a significant relationship between arrival dates and mean March and April temperatures in 8 migrant species in central England over the period between 1942 and 1991.

When a relationship between the timing of passage and air temperature at a given site is recorded, the question arises as to whether a similar relationship exists in the area from which the birds have arrived? Therefore it is necessary to know if temperature fluctuations occur over a large area. We analysed spring temperatures at 10 sites in European Russia and saw that the long-distance trends in April and May temperatures are similar over a huge area from Smolensk up to Kola Peninsula (Tab. 3). When, at our trapping site in Kaliningrad Region the temperature in April or

May is comparatively high, it is highly probable that it is high over the whole territory. Cyclones, that to large extent characterise the weather in spring in western Russia, may extend to about 1000 km across at the beginning of their development, and to several thousands km in the case of so-called central cyclone (Khromov & Mamontova 1974). The movement of cyclones follows a general westerly direction. The mean air speed of cyclones is about 30-40 km per hour; the air speed of young cyclones may reach 80 km per hour or more.

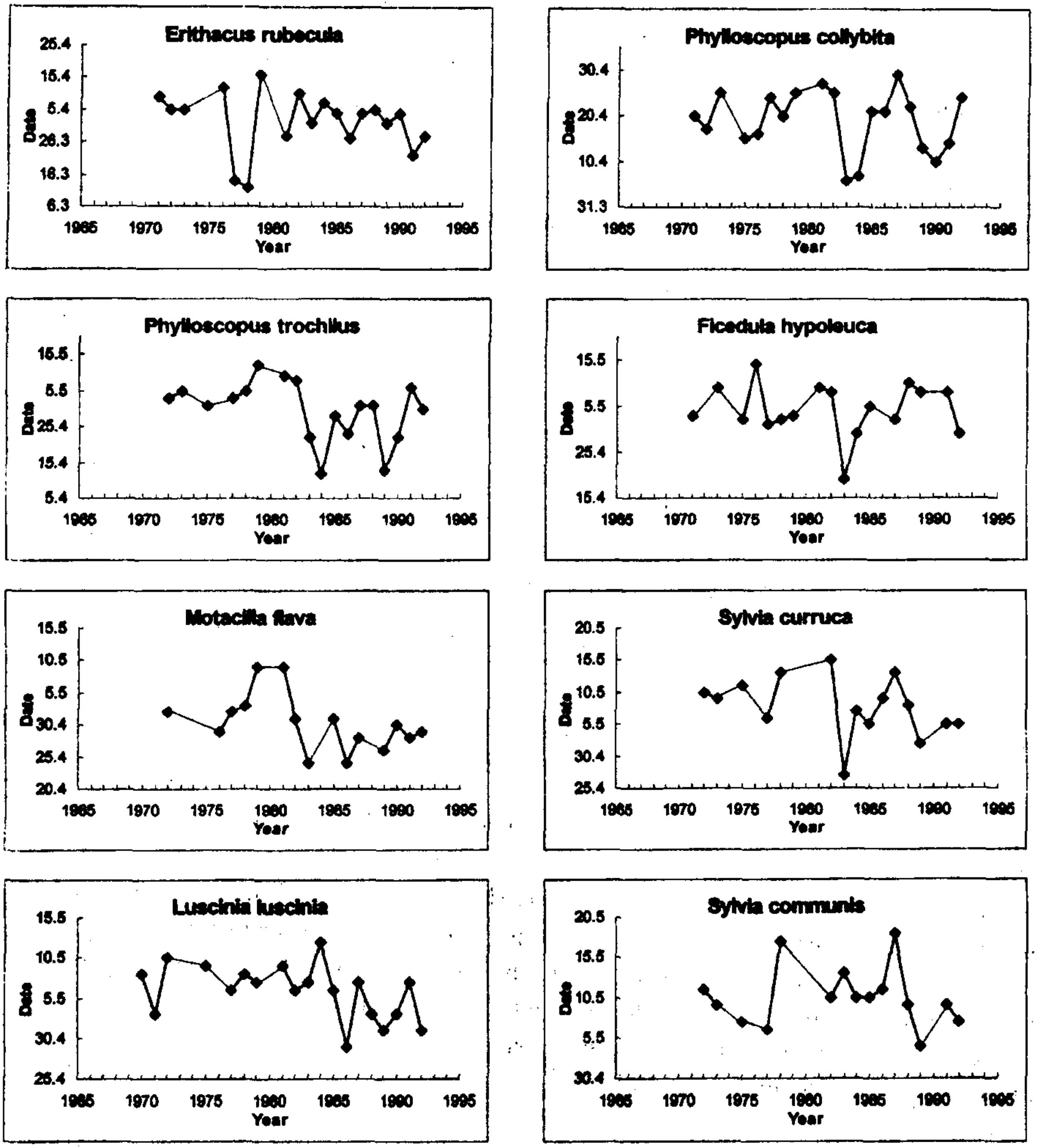


Figure 5. First record of some bird's species in Matsalu reservation, Estonia

According to some authors the arrival isochrone of a number of small passerines in Europe is close to the 8.9°C isotherm (Mason 1995). A relationship between arrival of birds and temperature was also found in Lithuania (Raudonikis 1990). Passerines *(Sturnus vulgaris, Alauda arvensis,* etc.)

and non-passerines *(Ciconia ciconia)* arrived in warm springs earlier and migrated slower than in late springs when they passed later and quicker. Apart from air temperature, phenological events such as the beginning of flowering, opening of leaves and appearance of insects were included in the analysis. No significant relationship between these events and arrival of birds was found. The author believes that such phenological events are strongly dependent upon the local situation, and that bird passage is determined to a great extent by the synoptic situation over a large area to the south of Lithuania, though arrival of birds may be delayed by a cold barrier such as snow or ice in inland waters (Raudonikis 1990).

Minin (1992) studied spatial and temporal variation of phenological events, including the arrival of some birds *(Sturnus vulgaris, Alauda arvensis, Cuculus canorus)* over the huge Russian plain (between 20° and 70° E, 45° and 70° N) on the basis of 'Calendars of Nature' and the database of the Russian Geographical Society. He concluded that with the progress of spring the mean regional variation of arrival dates decreases. The author believes that this is explained by the spring weather over the Russian plain; in late winter and early spring the synoptic situation is very variable which inevitably causes instability in the ecosystems. With the progress of spring, summer type atmospheric circulation is established (insolation increases), and the probability of abnormal synoptic conditions decrease, seasonal events becoming more predictable. More unpredictable are the areas to the north of 60° N, and also the south and south-west of the region. This is caused by general atmospheric circulation. During transitional periods in the north the chances of invasion of the cold air from the Arctic ocean, which interrupts the warming is high. In the south and especially in the south-west Mediterranean cyclones occur. These events make the development of spring conditions in the tundra, north and intermittent taiga, and also in steppe and forest steppe unpredictable, including the timing of arrival of migrant birds. In the eastern part of the Russian plain in early spring the Siberian cyclone results in relative synoptic stability. In the west, Atlantic cyclones periodically enter the Russian plain across the Baltic area. Minin (1992) concludes that general outlines of the timing of spring bird migration are shaped exclusively by climatic influence.

In the Kaliningrad area in spring cold spells occur not infrequently, when cold air enters after a prolonged warm period. This can lead to arrested migration and to reverse migration (Lyuleeva 1967, Payevsky 1985, Alerstam 1990). On the Courish Spit in April up to 30-65 % of birds that have passed to the north may participate in southward reverse migration (Lyuleeva 1967). This author suggested that the reverse migration in spring may be caused by unfavourable weather and feeding conditions in northern areas. These may result from invading cold air from higher latitudes. Such cold spells may occur in Europe in April, May and early June (Khromov & Mamontova 1974).

On the basis of the presented material the following conclusions were derived. In Europe long-term trends in the timing of spring bird migration occurred over the 20th century, especially in passerines. These trends were caused primarily by climate fluctuations in the northern hemisphere. Warmings in the 1930s and 1940s, and then in the 1960s and 1980s led to significant shifts in the timing of spring migration towards earlier dates. Conversely, cold periods during the 1950s, 1970s and possibly the 1990s caused later passage. Climate change influenced the migration of both short distance migrants wintering within Europe and long-distance migrants that spend their winter in Africa. However this does not mean that the onset of spring migration from Africa occurred earlier. Onset of migration is thought to be stable, controlled primarily by endogenous stimuli (Dolnik 1975, Berthold 1993, Gwinner 1996). More likely, the progress of passage within Europe was affected. It has been suggested that unfavourable weather conditions in spring may result in arrested migration (Alerstam 1990, Raudonikis 1990), whereas early and warm spring conditions may be a stimulus to migration in Europe. A similar relationship between timing of spring migration and weather has also been recorded in North America (Temple, Cary 1987, Hagan et al. 1991, Kaufman 1992, Krementz et al. 1994). Radio tracking of *Scolopax minor* during winter and spring migration along the Atlantic coast (Georgia, South Carolina, Virginia) did not reveal a dependence between the onset of spring migration and air temperature, but showed that the progress of migration was affected by temperature (Krementz et al. 1994).

The prognosis of future trends in the timing of spring migration in Europe and in other regions depends on the forecast for future climatic change. If climate in the northern hemisphere is getting milder, then spring migration will occur earlier. A colder climate will result later arrival to breeding grounds.

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