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Relationship between irruptions of Long-tailed Tits *Aegithalos caudatus* in the Eastern Baltic and ambient temperature and North Atlantic Oscillation index

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Abstract: Sokolov, L.V., Shapoval, A.P., Yefremov, V.D., Kosarev, V.V., Markovets, M.Y. & Gavrilov, V.V. (2008): Relationship between irruptions of Long-tailed Tits *Aegithalos caudatus* in the Eastern Baltic and ambient temperature and North Atlantic Oscillation index. Avian Ecol. Behav. 14: 35-47.

Analysis of long-term dynamics of numbers showed that frequency of Long-tailed Tit irruptions on the Courish Spit has increased in the last 24 years. In 1957-1980 four irruptive years were recorded (when > 250 individuals were captured), whereas in 1981-2004 12 such years occurred. The mean annual totals in the former period were by an order or magnitude lower than in the latter one (138 vs. 1586, respectively). Autumn numbers were significantly related to NAO index during the preceding winter and spring and to spring air temperatures. In the years following mild winter and spring in the breeding area, significantly more birds were captured on the Baltic coast than after cold years. Spring trapping figures on the Courish Spit were significantly related to the numbers recorded during the previous autumn. On the basis of these data, we conclude that pronounced irruptions of Long-tailed Tits in the Eastern Baltic were recorded after the years when winter and spring were comparatively mild in European Russia. The current climate warming in the Northern hemisphere resulted not only in more frequent irruptions of Long-tailed Tits in the study area, but apparently in the general population growth in this species.

Key words: passerines, Long-tailed Tit, numbers, irruption, autumn and spring migration, temperature, NAO, Eastern Baltic

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1. Introduction

Most authors treat the Long-tailed Tit *Aegithalos caudatus* as a sedentary or partly nomadic species (Dementiev & Gladkov 1954, Cramp & Perrins 1993, Ryabitsev 2001). However, in Northern and Northeastern Europe (Fennoscandia, Karelia, Baltic countries) the Long-tailed Tit behaves as a typical irregular migrant. Its occurrence on migration is subject to significant annual fluctuations (Sokolov et al.

2002). In some years, mass autumn movements of these birds are simultaneously recorded across a huge area of Fennoscandia and Baltic countries (Tischler 1941, Linkola 1961, Hilden 1974, 1977, Lipsberg & Rute 1975, Ehrenroth 1976, Rute & Baumanis 1986). Spring movements are rarely recorded, producing an impression that spring migration is not typical of this species. For example, Rezvyi (1995) believes that autumn movements of Long-tailed Tits are the phenomenon of juvenile dispersal (following the terminology of Noskov 1968), without pronounced spring return migration. However, we have earlier shown that after an autumn irruption of Long-tailed Tits on the Courish Spit on the Baltic Sea, the next year a marked spring passage is usually recorded at the same study site (Sokolov et al. 2002).

In this study, we analyse long-term dynamics of numbers of Long-tailed Tits on autumn and spring passage in several Baltic countries. Our previous publication was devoted to long-term dynamics of the timing of autumn passage of Long-tailed Tits through the Courish Spit on the Baltic Sea (Sokolov et al. 2004). The main aim of this study was to identify environmental factors that are primarily responsible for sharp fluctuation of autumn numbers of this species during passage in the Eastern Baltic.

2. Material and methods

Our analysis is based on long-term captures of Long-tailed Tits in autumn and spring at the field stations Fringilla (55°05´N, 20°44´E) and Rybachy (55°11´N, 20°46´E) situated in the Russian part of the Courish Spit on the Baltic coast. The distance between these sites is ca. 11 km. The annual trapping of birds in performed between late March and late October in large stationary Rybachy-type traps (Payevsky 2000) in Fringilla (1957-2005) and Rybachy (1957-1967), and in mist-nets (Rybachy 1993-2005). In spring 2001, after the strongest irruption on record in 2000, captures in stationary traps were started on 27 February. In different years, a varying number of stationary traps was operated (one to four, on average two), but in the latest 15 years after September 15 only one trap # 5, with its entrance towards the northeast, was open. In spring, one to three traps were operated, oriented by their entrance towards the southwest and the northeast. The traps were located mostly in young and middle-aged plantations of Scots pine (*Pinus sylvestris*). At the Rybachy trapping station since spring 1993, 73 mist-nets with the overall length of 438 m were operated. Due to the flocking behaviour of Long-tailed Tits and their tendency to migrate at daytime at low altitude, their capture efficiency in Rybachy-type traps and mist-nets is high and may reach 55-60% of visually recorded birds (Ehrenroth 1979).

Apart from the data collected in the Russian part of the Courish Spit, we used the data from other parts of Eastern Baltic. The data collected in autumn in Estonia (Kabli station), Latvia (Pape station), and Lithuania (Ventes Ragas and Neringa stations) have been kindly provided by the colleagues from the respective countries. Kabli (58°01´N, 24°27´E) is located 398 km to the northeast of Fringilla; Pape (56°11´N, 21°03´E), is located 124 km to the northeast; Ventes Ragas (55°21´N, 21°13´E) and Neringa (55°26´N, 21°05´E) 43 and 45 km to the northeast, respectively (Fig. 1). Neringa station is situated in the Lithuanian part of the same Courish Spit. All data on captures of Long-tailed Tits in the Eastern Baltic are summarised in Tab. 1.

To study the relationship between the autumn numbers of Long-tailed Tits at different Eastern Baltic site and the weather factors, we used the following standard meteorological parameters: NAO (North Atlantic Oscillation) index and mean air temperature in different regions of Russia and Baltic countries. NAOI is calculated as the difference between the normalized sea-level pressure at the Azores and Iceland (Hurrell et al. 2001). Positive NAOI values indicate a weather in Europe during winter and early spring when warm air masses move from the Atlantic and cause higher temperature and precipitation in northwest Europe (Hurrell 1995). To the contrary, negative NAOI values indicate weaker westerlies and thus lower temperature and precipitation in this part of Europe. Monthly NAO indices are archived at the National Oceanic and Atmospheric Administration's Climate Prediction Center website (www.cpc.ncep.noaa.gov/data/teledoc/nao.html).

In order to link the bird data with climate, we used the best source of spatially explicit large-scale data available. These data are provided by CRU (Climate Research Unit; CR2.0 (New et al. 2002). This is gridded dataset of monthly temperature (0.5 × 0.5 degrees). Mean monthly air temperatures were averaged across European Russia between 53°-60°N and 30°-60°E.

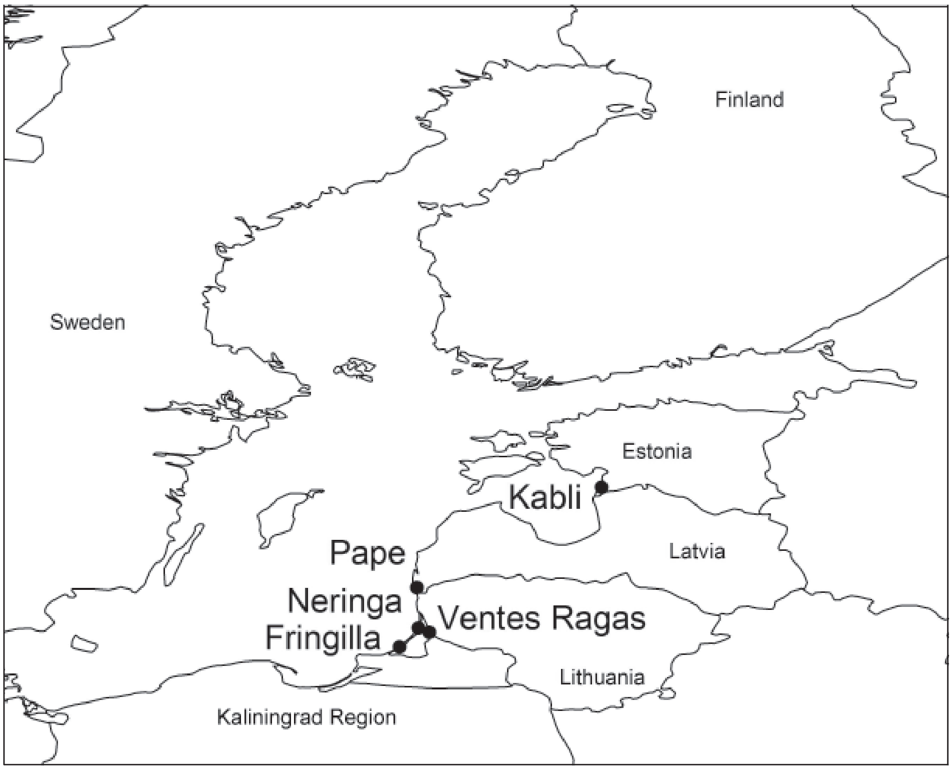

Figure 1. Map of the study area. Dots show the location of the trapping stations.

Table 1. The numbers of Long-tailed Tits captured during autumn and spring passage in the Eastern Baltic.

Year	Autumn						Spring
	Estonia (Kabli)	Latvia (Pape)	Lithuania		Russia (Courish Spit)	Baltic countries	Russia (Courish Spit)
			Neringa	Ventes Ragas			
1957				0	120	120	
1958				0	7	7	
1959				419	950	1369	0
1960				0	0	0	201
1961				0	1	1	0
1962			109	128	260	497	0
1963			0	0	0	0	10
1964			1	10	6	17	1
1965			58	115	48	221	0
1966			652	200	148	1000	44
1967		25	54	0	0	79	9
1968		453	371	208	38	1070	0
1969	171	2233	1460	1125	162	5151	0
1970	1011	404	298	109	8	1830	2
1971	2566	910	1136	89	153	4854	0
1972	1749	1316	1335	570	185	5155	1
1973	5999	2426	1827	1093	470	11815	0
1974	19	0	31	0	0	50	5
1975	1082	653	131	212	41	2119	0
1976	1525	1251	35	2	166	2979	8
1977	8389	1053	1286	139	452	11319	0
1978	444	827	82	76	98	1527	15
1979	64	0	1	0	0	65	12
1980	134	0	0	0	0	134	0
1981	707	68	57	0	41	873	0
1982	1474	269	44	47	23	1857	1
1983	3381	2041	567	1554	819	8362	0
1984	161	55	15	0	6	237	251
1985	6705	5780	1523	4113	1673	19794	0
1986	6795	11033	2508	7893	3841	32070	11
1987	7	1	0	0	12	20	159
1988	204	197	10	40	18	469	0
1989	1495	690	59	456	17	2717	0
1990	2308	1861	327	698	267	5461	0
1991	954	764	109	255	94	2176	0
1992	5213	1961	964	4101	1568	13807	0
1993	4754	1982	770	2920	1035	11461	31
1994	4	0	0	8	0	12	25
1995	378	57	57	399	138	1029	0
1996	4833	4065	1104	4416	3084	17502	25

Table 1. Continued

Year	Autumn						Spring
	Estonia (Kabli)	Latvia (Pape)	Lithuania		Russia (Courish Spit)	Baltic countries	Russia (Courish Spit)
			Neringa	Ventes Ragas			
1997	404	144	17	95	71	731	12
1998	1209	1229	73	1268	1259	5038	0
1999	1315	365	27	478	220	2405	3
2000	10640	22227	604	15443	20910	69824	23
2001			157	5385	1968	7510	931
2002			0	160	95	255	14
2003			241	5046	2605	7892	0
2004					1847	1847	158
2005					3493	3493	196
All years	76094	66340	18100	59270	42868	264667	2148
Mean	2378	1951	431	1261	875	5401	46
S.D.	2802	4164	612	2761	2979	11216	145

The daily dynamics of passage of Long-tailed Tits was estimated as the numbers of birds captured during the daytime (6:00 – 22:00 local time). Regular inspections show that captures never happened during the night. The daily dynamics of captures has been analysed elsewhere (Sokolov et al. 2004).

Statistical analysis was done by the software package SPSS 11.0.

3. Results

3.1. Long-term dynamics of the autumn numbers

The autumn trapping figures in Fringilla varied between the years from 0 to 20557. At Rybachy station, the autumn trapping figures varied in 1993-2005 between 0 and 1231. Similarly strong fluctuations of Long-tailed Tit numbers were recorded at other Eastern Baltic sites. However, in Estonia annual variation of the numbers was lower than in other Baltic countries, as shown by the standard deviation (Tab. 1). Correlations of variation in numbers between different sites is very strong (Tab. 2).

Time series analysis showed that frequency of Long-tailed Tit irruptions on the Courish Spit has significantly increased in the recent 24 years ($\chi^2 = 6.0$, df = 1, p = 0.014). In 1957-1980, only four years with an irruption (annual total > 250 birds) occurred, whereas in 1981-2004, 12 such years were recorded (Tab. 1). In the former time period, the mean trapping figure was by an order of magnitude lower (mean = 138) than in the latter period (mean = 1586; Mann-Whitney U-test z = -2.474, p = 0.013).

Table 2. Correlation coefficients between the autumn numbers of Long-tailed Tits at different Eastern Baltic stations (Spearman's rank correlation coefficient: ***p < 0.001).

Station (country)	Pape (Latvia)	Ventes Ragas (Lithuania)	Neringa (Lithuania)	Courish Spit (Russia)
Kabli (Estonia)	0.854***	0.765***	0.797***	0.864***
Pape (Latvia)		0.879***	0.869***	0.932***
Ventes Ragas (Lithuania)			0.736***	0.860***
Neringa (Lithuania)				0.766***

3.2. Long-term dynamics of the spring numbers

The numbers of Long-tailed Tits captured in Fringilla on the Courish Spit in spring varied between 0 and 251. In Rybachy in 1993-2005, spring trapping totals varied between 0 and 745. No significant trend in the spring numbers of Long-tailed Tit has been recorded across the 48 years of study, even though there was a positive tendency since the 1980s (Tab. 1, Fig. 2).

A highly significant positive relationship was found between spring numbers of Long-tailed Tits on the Courish Spit and their autumn numbers in the preceding year at all study sites in Eastern Baltic (Tab. 3). After years with a pronounced irruption in the Baltic area, an increase in the spring numbers was recorded on the Courish Spit (Tab. 1).

Analysis of daily trapping dynamics in spring on the Courish Spit shows that most birds were captured between late March and 12 April. However, the data for 2001 when stationary traps were operated since late February, show that between 12-20 March also considerable numbers were captured. These data suggest that the spring passage of Long-tailed Tits on the Courish Spit occurs mainly in the latter

Table 3. Relationship between the spring numbers of Long-tailed Tits on the Courish Spit and their autumn numbers at different Eastern Baltic station in the preceding year (r_S is Spearman's rank correlation coefficient).

Station (country)	r_S	p
Kabli (Estonia)	0.623	0.0001
Pape (Latvia)	0.626	0.0001
Neringa (Lithuania)	0.526	0.0005
Ventes Ragas (Lithuania)	0.671	0.0001
Courish Spit (Russia)	0.742	0.0001
Baltic countries	0.573	0.0001

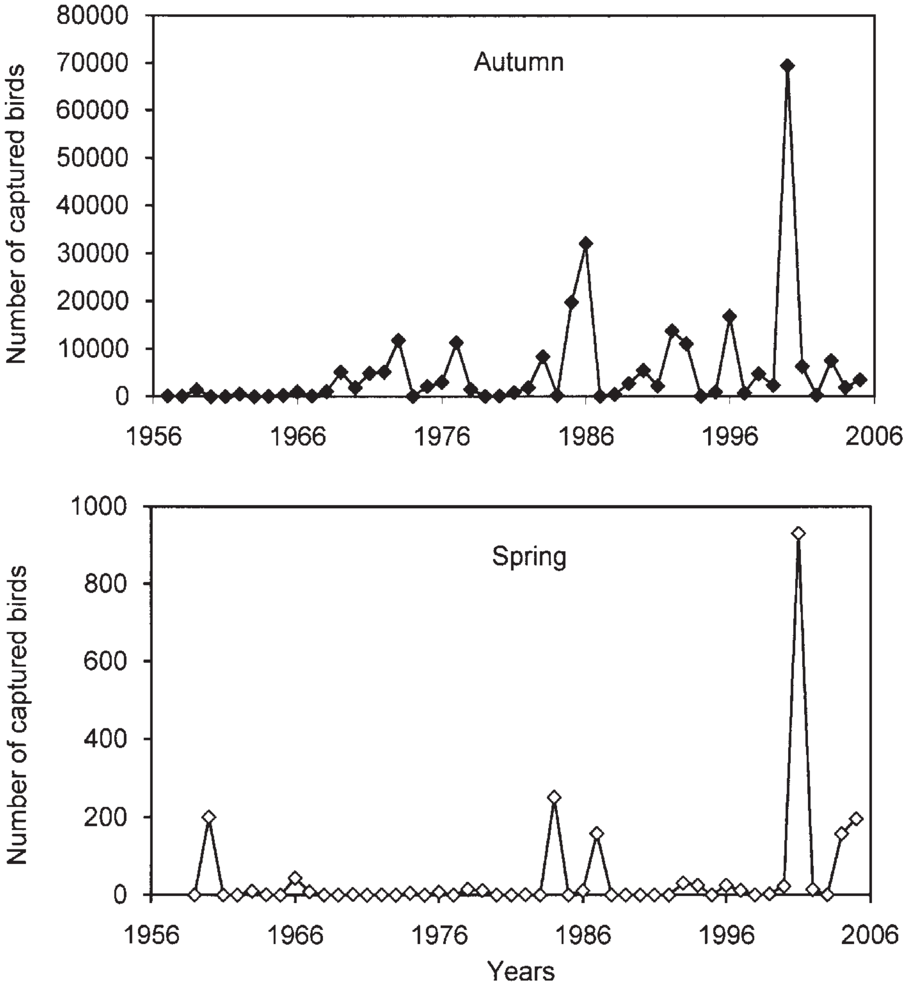

Figure 2. Long-term dynamics of the autumn and spring numbers of Long-tailed Tits in the Eastern Baltic.

half of March and in early April (Fig. 3). The solitary individuals that were captured in early March 2001 in Fringilla may have been wintering birds.

3.3. Relationships between the bird numbers and the weather variables

3.3.1. Relationship between the bird numbers and NAOI

Analysis of relationships between the Long-tailed Tit numbers at the Baltic sites and NAOI for the different seasons showed a significant correlation with the winter and spring period (January – March, Tab. 4). In the years with high NAOI

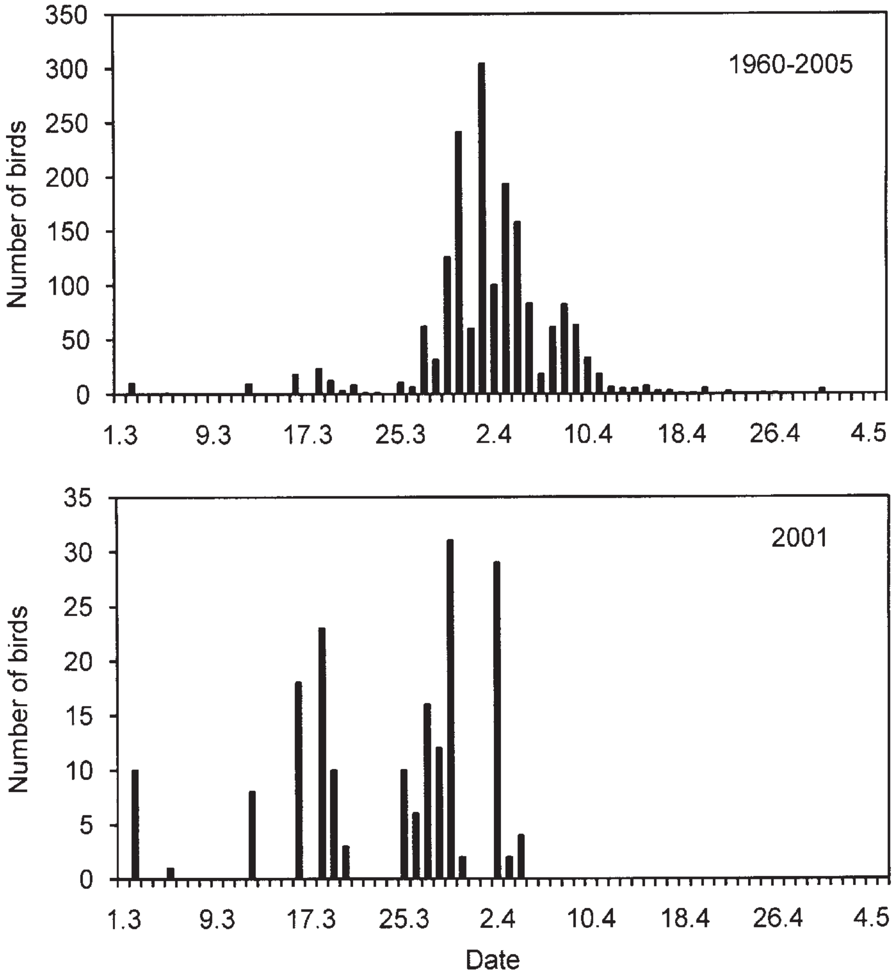

Figure 3. Daily dynamics of spring captures of Long-tailed Tits on the Courish Spit across the whole period of study (1960-2005) and in 2001.

during this period the highest bird numbers were recorded during autumn passage in the Baltic region (Fig. 4).

3.3.2. Relationship between the bird numbers and air temperature

We analysed the relationship between the autumn trapping figures of Long-tailed Tits in the Eastern Baltic and seasonal air temperatures across a large area of European Russia, from the Baltic to the Urals in the east (up to 60°E) and from Syktyvkar (60°N) to the northern border of Kazakhstan (53°N). We found a significant positive relationship between the autumn numbers of Long-tailed Tits and the mean monthly

Table 4. Relationship of the log-transformed numbers of Long-tailed Tits in the Eastern Baltic with NAOI and mean monthly temperature anomalies in European Russia (r is Pearson correlation coefficient: * $p < 0.05$)

Months	NAOI		Temperature °C	
	r	p	r	p
January	0.246	0.088	0.144	0.350
February	0.233	0.108	-0.019	0.902
March	0.214	0.139	0.400	0.007
April	-0.032	0.829	0.351	0.019
May	0.078	0.594	-0.133	0.390
June	0.112	0.442	-0.012	0.940
July	-0.044	0.762	-0.073	0.638
August	0.010	0.946	0.006	0.971
September	0.081	0.581	-0.203	0.187
October	0.120	0.413	-0.196	0.201
Jan.- Mar.	0.332	0.020		

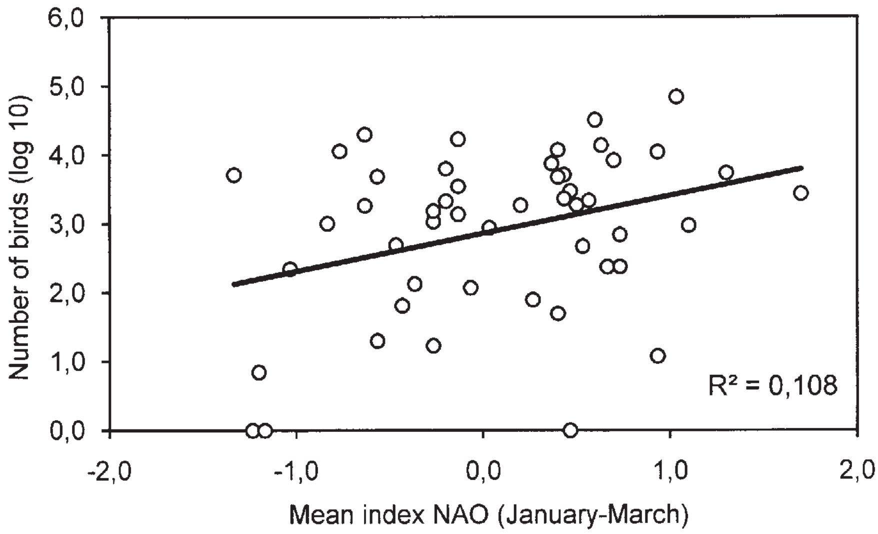

Figure 4. Relationship between the autumn numbers of Long-tailed Tits and winter and spring NAO index values.

temperatures of March and April (Tab. 4, Fig. 5). The highest autumn numbers were recorded in the years when the mean monthly temperatures of March and April in European Russia were significantly above the mean long-term average (Fig. 6). In the years when mass irruptions occurred, high spring air temperatures were recorded not only in European Russia but in many regions of Central and Western Europe. On

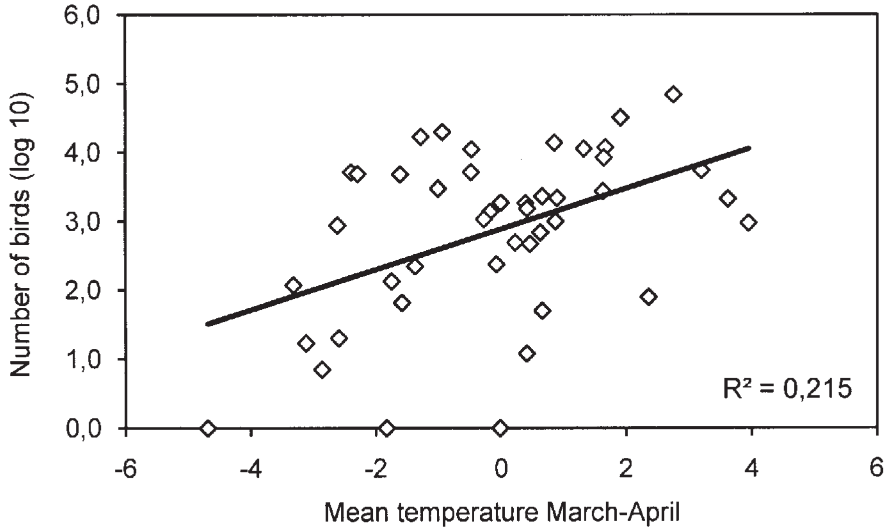

Figure 5. Relationship between the autumn numbers of Long-tailed Tits and the mean spring air temperature in European Russia.

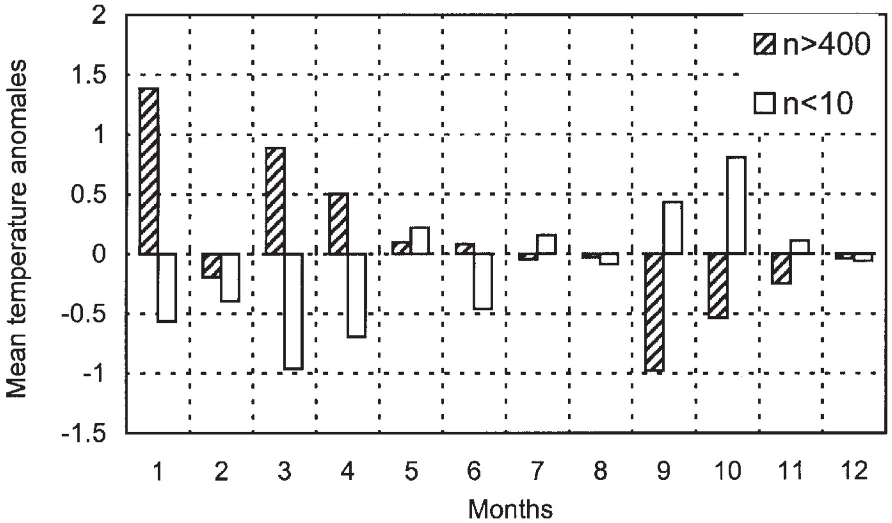

Figure 6. The mean monthly temperature anomalies in European Russia in the years with pronounced irruptions (filled bars) and without irruptions (open bars) of Long-tailed Tits in the Eastern Baltic.

the contrary, in the years with no irruption in the Baltic area, spring air temperatures were low in most of Russia and northern Europe (Sokolov et al. 2004).

4. Discussion

Analysis of long-term autumn trapping data on Long-tailed Tits from different parts of the Baltic region showed a clear tendency towards more frequent irruptions and higher numbers of birds during autumn passage since the mid 1980s. We have elsewhere shown that in this species mainly the first-autumn birds participate in irregular migration (Sokolov et al. 2004). The strongest irruption was recorded in autumn 2000 when nearly 70 000 Long-tailed Tits were captured in the Baltic countries (Tab. 1, Fig. 1). Assuming that Rybachy-type traps that were mainly used at these sites capture ca. 10% of migrants, at least 700 000 Long-tailed Tits must have passed through the Baltic region in autumn 2000. Therefore, the following questions arise: (1) from which regions of Russia this huge number of juvenile may have originated; (2) which environmental factors facilitated the birth of so many birds.

In this study we tried to identify these regions by the analysis correlations between the autumn numbers in the Baltic countries and winter and spring temperatures that may have facilitated successful breeding of Long-tailed Tits in certain regions of Russia. A significant positive relationship was found between the autumn numbers and spring air temperatures in European Russia (Tab. 4). These data suggest that Long-tailed Tits might have arrived to the Baltic region from a vast area east of the Baltic. This area extends from the Baltic to the Urals (to 60°E) and from Syktyvkar in the north (60°N) to the northern border of Kazakhstan in the south (53°N). The assumption that Long-tailed Tits captured in autumn in the Baltic area may arrive from distant eastern region is supported by the recapture on 7 October 2000 of a juvenile in Ventes Ragas (Lithuania) that had been ringed on 25 June 2000 at the field station Maloye Lebedinoye Lake in Chuvashia (Russia, 56°16´N, 47°18´E; Tikhomirova & Ganitsky 2002). This first-autumn bird covered ca. 1600 km to the west from its natal area. There are good reasons to believe that during the most pronounced irruptions the bulk of birds arrives from the areas rather distant from the Baltic.

The spring trapping numbers of Long-tailed Tits on the Courish Spit are rather low. The first reason for this is that the stationary traps and mist-nets start operations rather late (in the end of March) when a significant part of birds has already passed the Courish Spit. Second, during the return migration in spring, Long-tailed Tits may be less prone to follow the Baltic coast than in autumn and thus are less concentrated on the Courish Spit. It is important to emphasize that the numbers of Long-tailed Tits during autumn passage and return migration in spring are strongly correlated: the more birds are captured in autumn, the more are trapped next spring (Tab. 3). This supports the conclusion we have made elsewhere that irregular, or irruptive, migrants make return migration in spring, like the typical migrants (Sokolov et al. 2002).

What does the positive relationship between the autumn Long-tailed Tit numbers in the Eastern Baltic and NAOI during winter and early spring found by us mean? The positive NAOI values in winter and spring usually suggest that in the given year the winter and the beginning of spring were rather early in the most of Europe and Russia (Hurrell 1995, Sokolov et al. 2003). In such years, first, a higher proportion of birds, both adults and first-years, could have survived and started breeding. Second, breeding of Long-tailed Tits in a large part of their range may have been earlier and more successful (Sokolov et al. 2004). All this should cause a large surplus of juveniles that in autumn migrate towards the Baltic Sea in large numbers. The importance of spring air temperatures is emphasized by significant positive correlations between the autumn numbers of birds in the Eastern Baltic and March and April mean monthly temperatures in different regions of Russia (Tab. 4, Fig. 5). Comparison of spring temperatures averaged across Russia in the years with and without irruptions of Long-tailed Tits showed that in the irruptive years, March and April temperatures were above the 30-years average, and in the non-irruptive years they were below the average (Fig. 6, Sokolov et al. 2004).

Therefore, we conclude that the pronounced irruptions of Long-tailed Tits in the Eastern Baltic occurred in the years when winter and spring were relatively mild in the most part of European Russia. The current climate warming in the Northern hemisphere not only caused an increase in irruption frequency of Long-tailed Tits in the study region but apparently facilitated the general growth of the population numbers.

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