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Spring ambient temperature and movements of Coal Tits *Parus ater*

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Analysis of seasonal dynamics of the numbers of *c.* 54,000 Coal Tits *Parus ater* captured on the Courish Spit during 45 years (uninterrupted in 1957-2001) shows three periods of activity: autumn and spring movements and juvenile dispersal. Proportion of adults among the birds which participate in autumn movements is very low, between 0-5.5%, on the average 1.3%. A significant positive relationship was established between autumn numbers of young Coal Tits and mean April temperature in Kaliningrad. A positive relationship exists also between the autumn numbers and the number of young Coal Tits captures during juvenile dispersal. Time of the onset of autumn movements is inversely related to autumn numbers. A strong positive relationship between April temperature and the numbers of Coal Tits during juvenile dispersal exists. Spring ambient temperatures not only govern the timing of breeding but also influence the breeding success which in its turn is crucial for the numbers during autumn movements.

Key words: monitoring of numbers, irruption, migration, juvenile dispersal, Coal Tit, ambient temperature.

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1. Introduction

The Coal Tit *Parus ater* is a small tit inhabiting the whole of Eurasia from Ireland to Kamchatka. It is closely associated with conifers, especially with spruce forests. Adults are sedentary, monogamous (though see Markovets 2001a), they remain within their home ranges with permanent borders. This is typical of European populations, but no data are available on the territorial behaviour of northeastern and eastern populations (Cramp & Perrins 1993). Drastic aperiodic outbursts of Coal Tit numbers were reported many times (Formosov 1965, Löhrl 1977). Coal Tits are especially numerous in irruption years in landscapes which are directing lines of migration: on sea and lake coasts, in valleys and gorges, and on passes (Veromann 1965, Biber 1972, Sheerer 1972, Odintsova 1975, Busse 1994). In such years Coal Tits appear in habitats much different from their usual ones: in arable lands and in towns, in forest tundra and on the islands. They may cross the Gulf of Finland, the Bothnian Bay, the Courish Lagoon on the Baltic Sea or English Channel (Zink 1981).

Various opinions exist on the causes of Coal Tit irruptions. Some authors treat autumn and spring movements of first-year individuals of sedentary tit species as a prolongation of juvenile settlement movements to the new areas, similar to summer juvenile dispersal (Noskov 1968, 1971). Other researchers associate the irregular migration of Coal Tits mainly with the crop of spruce seeds in the year preceding irruption (Formosov 1965, Karelin & Azovsky 1988). A hypothesis has been suggested which explains the irruptions of tits as a consequence of their density-dependent socio-demographic systems (Bardin et al. 1986, Bardin & Rezvyi 1988). The view that the bulk of individuals which participate in irruptions finish their movements in areas unsuitable for their existence and perish, is a quite traditional one (Lack 1954, Wynne-Edwards 1962, Dolnik 1975).

Ambient temperature is one of the primary periodic factors which may govern the dynamics of animal numbers (Ricklefs 1979). For populations of 19 passerines breeding on the Courish Spit, a strong relationship between the timing of breeding and number dynamics and mean monthly temperatures of April and May has been demonstrated (Sokolov & Payevsky 1998, Sokolov 1999). In 21 passerine species migrating through the Courish Spit a significant correlation was shown to exist between the timing of spring and autumn migration and autumn numbers and spring temperatures of the current year (Sokolov et al. 1998, 1999, 2000, Markovets 1999).

The main aim of this study was to test whether a relationship exists between the numbers of Coal Tits during their movements and spring air temperature.

2. Material and methods

The data of long-term captures of Coal Tits in Rybachy-type traps at the Fringilla field station (55°05′N, 20°44′E) of the Biological Station Rybachy (Kaliningrad Region, Russia) in 1957-2001 were used for the analysis. To standardise the data, the analysis of autumn numbers (15 August – 31 October) was done on the basis of captures in one standard trap: # 3 in 1957-1976 and # 5 in 1977-2001. To estimate the numbers of local juveniles, the data on other traps were also used for the period 1 June – 14 August.

The age of Coal Tits was determined by the presence of unmoulted greater coverts (Vinogradova et al. 1976, Svensson 1992) and scull ossification, even though young Coal Tits with all renewed greater coverts have been recorded. Adults were also identified by the lack of colour difference between greater coverts and primary coverts.

As a reference of spring temperatures at the study site we used only the mean temperatures of April in Kaliningrad in 1957-2001. It has been shown elsewhere that the mean temperatures of March, May, June, and July are much weaker related to the autumn numbers of tits (Sokolov et al. 2000). To analyse the relationship, the non-parametric Spearman correlation was applied.

3. Results

3.1. Periods of movements

In 1957-2001, a total of 53,978 Coal Tits were captured in Rybachy-type traps. The analysis of the seasonal dynamics of captures (Fig. 1) shows three periods of movements in Coal Tits which may be correlated with autumn and spring movements, and with summer juvenile dispersal. During autumn and spring movements, over 1,362 Coal Tits were recaptured on the Courish Spit that had been ringed during the current year at ringing stations in Lithuania, Latvia, Estonia, Poland and Finland (Bolshakov et al. 2002). Among juveniles trapped between June and mid August, 12 birds had been ringed as pulli on the Courish Spit which makes it possible to define these summer movements as juvenile dispersal.

Long-term dynamics of the numbers of young Coal Tits is shown in Fig. 2. In different years, the numbers captured vary between 3 (in 1970) and 4,551 (1983).

The bulk of moving birds are the youngs. Adults comprised in different years from 0 to 5.5%, on the average 1.3%.

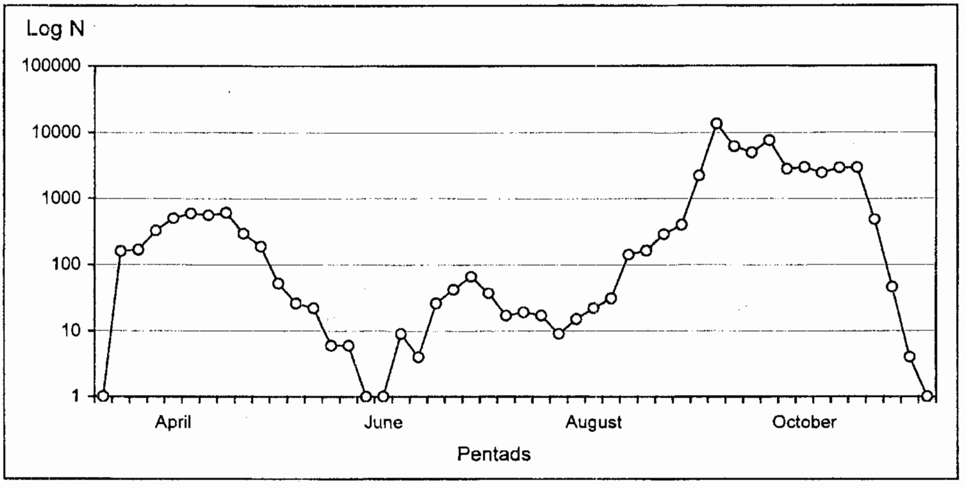

Figure 1. The seasonal dynamics (by standard 5-day periods) of captures of Coal Tits in Rybachy-type traps in 1957-2001.

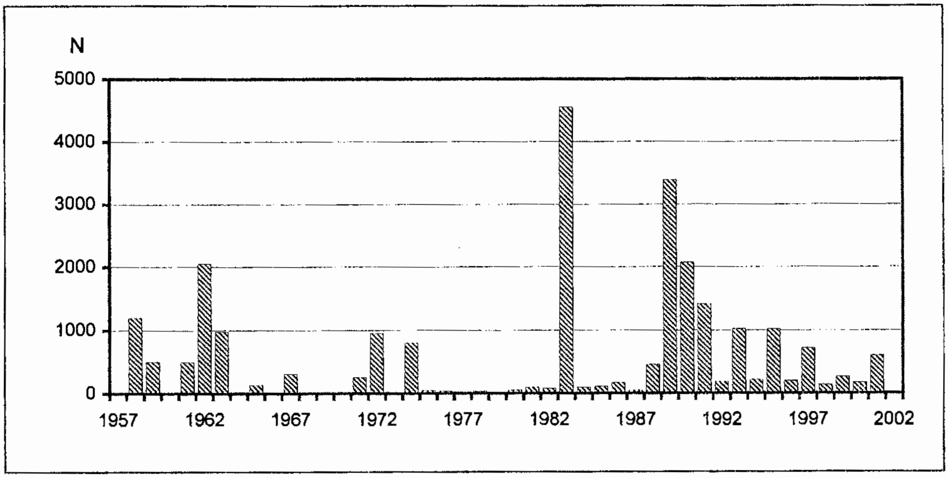

Figure 2. Annual dynamics of captures of young Coal Tits in a single trap in 1957-2001.

3.2. Relationship between autumn numbers and spring air temperature

A significant relationship existed between the autumn numbers of young Coal Tits and the mean temperature of April in Kaliningrad in 1957-2001 (see Table). The autumn numbers are also significantly correlated with the numbers of Coal Tits captured during juvenile dispersal. The onset of autumn movements (first capture after 15 August) was negatively related to autumn numbers (see Table). A strong positive relationship between April temperature and numbers of Coal Tits captured during juvenile dispersal was recorded (r_s = 0.384, p = 0.03).

Table. Relationships between autumn numbers of young Coal Tits, the mean temperature of April, numbers of Coal Tits during juvenile dispersal and the first capture date in autumn (1957-2001). Coefficient of Spearmen's rank correlation is given: *$p < 0.05$, **$p < 0.01$.

	Mean air temperature in April in Kaliningrad	Date of the first capture of a young in autumn	Number of juveniles captured in summer
Numbers in autumn	0.325*	-0.392**	0.432**

In years when the mean temperature of April exceeded 6 °C, high numbers in autumn (capture total in one trap over 500) were 2.5 times more frequent than in years when the mean April temperature was below this value. The mean number of Coal Tits (903.9) captured in years with the mean April temperature exceeding 6 °C was higher than in years when temperatures were lower (274.6; Wilcoxon rank test: $W = 475$, $z = 2.28$, $p < 0.01$).

The relationship between autumn numbers of Coal Tits and their numbers during next spring is treated in detail elsewhere (Sokolov et al., this volume).

4. Discussion

The relationship between the timing of breeding and spring ambient temperature is well known in tits (Smith 1993, Nager & van Noordwijk 1995, Perrins 1996, Wesolowski 1998). In Coal Tits, the laying of the first egg is significantly related to the temperature of April: the warmer is April, the earlier breeding begins (Löhrl 1977). In another sedentary tit, the Marsh Tit *Parus palustris*, it was also found that laying of the first egg, timing of hatching and breeding success were significantly related to the temperature of April (Markovets 2001b). There are reasons to believe that in April, when most tits begin with nest construction, eggs laying and incubation, similar weather is often established over vast areas in Europe. The climatic conditions of April (mean air temperature and rainfall) are closely correlated in northwestern Russia from Kaliningrad to the Kola Peninsula (Sokolov et al. 1998). Moreover, the mean April temperature in Kaliningrad is significantly related to April temperatures in the eastern areas: in Archangel City ($r_s = 0.496$, $p = 0.041$), Syktyvkar ($r_s = 0.526$, $p = 0.032$), Vologda ($r_s = 0.584$, $p = 0.016$) but not in Kazan ($r_s = 0.402$, $p = 0.098$).

Similar weather conditions of April not only govern the breeding conditions of tits in rather distant regions, but have similar effect on their breeding performance. High April temperature in some years causes early and very efficient breeding.

Breeding performance is undoubtedly related to the numbers of juveniles, both during summer dispersal and during autumn movements. In five species (Great Tit *Parus major*, Blue Tit *P. caeruleus* and three sedentary species: Crested Tit *P. cristatus*, Willow Tit *P. montanus*, and Marsh Tit) a significant relationship between the mean air temperature in April and summer and autumn numbers of youngs was recorded on the Courish Spit (Sokolov 1999, Sokolov et al. 2000, Markovets 1999). A significant negative correlation between the first autumn capture and autumn numbers suggests that in the years with warm spring autumn movements of Coal Tits begin earlier and involve more birds than in the years with cold spring.

Beyond any doubt, long-term dynamics of juvenile tit numbers during their movements, including Coal Tits, is governed by the same factors: early onset of breeding and high breeding success in large areas.

Another problem which is equally intriguing is why it should be the Coal Tits whose autumn numbers vary by an order of three magnitudes. Coal Tits lay the highest number of eggs per pair among all European tits. Second clutches were recorded in at least 50% pairs, and the size of second clutches is also greater then in other tit species. Three clutches per season have been reported (Cramp & Perrins 1993). However all the aforementioned factors cannot enhance the autumn numbers of Coal Tits more than 2-3-fold. We are prone to explain the fantastic (about three orders of magnitude) variation by the vast size of the recruitment areas during irruptions. It is difficult to imagine that high seed crops of spruce which are essential for winter survival of this species (Karelin & Azovsky 1988) form the flow of moving youngs during next autumn. Spruce crops depend on many factors (latitude, weather, age of trees, soil and anthropogenic influence) which cannot be identical over the whole of European Russia. Spring temperatures, to the contrary, may be similar over vast areas. The increasing frequency of Coal Tit irruptions during the recent decade may be related to the global climate change (Perevedentsev et al. 2002). Large weakly fragmented spruce and fir forests of eastern European Russia, the Urals and Siberia are, in our opinion, the natal areas of the bulk of young Coal Tits which are recorded in the Baltic region in the irruption years. Winter density of Coal Tits in coniferous and mixed forests of Eastern European plain is low (1-12 birds · km^{-2}). Only in the forests of the Middle Volga and cis-Urals it reaches 18-29 birds · km^{-2}, and in the southern Urals it may be as high as 36-43 birds · km^{-2} (Preobrazhenskaya & Pankov 2002).

In conclusion, the favourable weather conditions in spring in European Russia, cis-Urals, and possibly in trans-Urals and western Siberia with high mean April temperature (6-8 °C) facilitate early breeding and high breeding performance of Coal Tits and in some years form the great flow of birds moving along the Baltic coasts.

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