Estonian Journal of Ecology, 2011, **60**, 2, 111–131 doi: 10.3176/eco.2011.2.03

Effect of atmospheric circulation types on spring arrival of migratory birds and long-term trends in the first arrival dates in Estonia

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Received 21 December 2010, revised 11 April 2011, accepted 12 April 2011

Abstract. We studied the spring arrival of 42 migratory bird species in Estonia in relation to integrated climatological variables (atmospheric circulation types). We found that all early arrivals were short-distance migrants, which were more directly affected by cyclonic conditions. Those conditions design a tailwind system that favours or hinders the migration of birds to their breeding areas. All late arrivals were long-distance migrants, whose spring arrival took place mostly in anti-cyclonic windless or also eastern or south-eastern wind conditions, i.e. tail- or crosswinds. Our hypothesis that different arrival times of the same species in western (Kuressaare) and eastern (Tartu) Estonia may have been caused by the birds' different circulation type preferences was not confirmed – birds preferred similar types. Differences in the first arrival dates between western and eastern Estonia were related rather to climatic differences as well as differences in flyways and migratory routes. The spring arrival date significantly advanced during the period 1958–2002 in several species from both guilds but the rate and significance of the advances were in general higher in early arrivals than in late arrivals. We concluded that weather conditions and climate change affected the spring arrival of both short-distance and long-distance migrants. Among circulation classifications, the effects on migratory birds were most often detected in the case of classifications with a low number of circulation types (such as SANDRAS or CKMEANSC09), suggesting that birds are generally not waiting for very specific types of circulation. The results indicate that methods of synoptic climatology are useful for studying bird migration phenology and migration patterns, especially at a large scale.

Key words: bird phenology, early arrivals, late arrivals, COST 733, atmospheric circulation types, weather conditions.

INTRODUCTION

Climate is one of the most important ecological factors that affect the activities of many organisms, populations, and species in their annual life cycle (Huntley, 1991; Walther et al., 2002; Root et al., 2003; Aasa et al., 2004; Nõges & Järvet, 2005). Climate appears to directly determine, for example, the timing of particular phenological events in the seasonal development of nature. Favourable weather in spring generally advances the start of the growing season and the timing of animal migration, while adverse weather conditions (freeze, blizzard, anomalously low air temperature, late night frosts, etc.) may delay these and, in birds, can even cause reverse migration (Sokolov & Kosarev, 2003; Newton, 2010). The effects of weather conditions are especially important for migratory birds because they determine the habitat quality, especially the food resources, not only in their breeding areas but also at the wintering and stopover sites. This affects the progression speed and territory acquisition, as well as the timing and success of breeding (Newton, 2004, 2010; Drever & Clark, 2007; Møller et al., 2010). Thus, one of the threshold questions in avian ecology is how weather conditions design migration strategies of species or populations both in the case of spring and autumn migration.

The effect of climate on the spring migration phenology of birds is relatively well studied (e.g., Lehikoinen et al., 2004; Leech & Crick, 2007; Møller et al., 2010). It has been suggested that species generally respond differently to climate. This is most clearly visible in differences between short- and long-distance migrants (Stervander et al., 2005; Hubálek & Čapek, 2008; Palm et al., 2009; Newton, 2010). The former are largely affected by exogenous factors while the latter are more dependent on endogenous ones, which lead to lower correlations with climate variables and thus lower variability in the spring arrival time (Palm et al., 2009). For instance, the wintering population of the Mute Swan *Cygnus olor*, a classical short-distance migrant or 'weather bird' or 'facultative migrant' (Berthold, 1971, 1993), increased considerably in Estonia in the 1980s and early 1990s because of mild winters and almost ice-free conditions in the Baltic Sea (Leibak et al., 1994). In contrast, although the spring arrival of the Eurasian Crane *Grus grus*, a partly short-distance and partly long-distance migrant, has shifted considerably forward in Estonia in the last 50 years due to climate warming (Leito et al., 2006; Palm et al., 2009, 2011), the cranes have not started to winter in Estonia.

Studies of spring migration phenology of birds usually employ single climatological or meteorological characteristics, such as North Atlantic Oscillation (NAO) indices or air temperature (Gordo, 2007). However, most of the biological processes (including bird migration) are driven by a combination of meteorological variables and thus it is advisable to use integrated climatological variables, such as atmospheric circulation types (CTs). The integrated influence of climatic and weather conditions on migration has, however, been poorly treated (Richardson, 1978; Stervander et al., 2005; Gordo, 2007; Newton, 2010).

The main principle of synoptic climatology methods applied in the present study is that the variety of atmospheric circulation can be classified into a relatively small number of CTs (Barry & Perry, 1973; Yarnal, 1993; Huth et al., 2008; Huth, 2010). For instance, classifications of atmospheric circulation elaborated by COST Action 733 'Harmonisation and applications of weather type classifications for European regions' (COST 733, 2010) contain 9, 18, or 27 CTs (Huth, 2010; Philipp et al., 2010). The idea of CT classifications is based on empirical experience of weather forecasters, who noticed that circulation processes share some spatial and temporal variables, such as repeated locations of pressure areas and cyclone trajectories, as well as other variables that describe weather. Such processes that evolve by one scenario follow the same direction for approximately 3–4 days, after which there is a rapid, steep change in circulation conditions (Barry & Perry, 1973; Yarnal, 1993). Therefore, the first classifications of atmospheric circulation were subjective decisions by experienced meteorologists, which described the dynamics of atmospheric processes quite well but were not fully repeatable by other authors even when they used the same initial data and precepts (Yarnal, 1993). Later, several so-called objective (or automated) classification methods have been developed, which use certain mathematical algorithms resolved by the computer. With the same initial data, the time series is identically repeatable by anyone (Yarnal 1993; see also the section 'Atmospheric circulation data').

An important feature of synoptic climatology is a smaller spatial range compared to NAO and other similar indices that describe atmospheric circulation over continents. The CTs usually deal with circulation processes, for example, over the Baltic Sea region. Consequently, the NAO describes the general background of atmospheric circulation but the CTs are more detailed and better adapted for regional or local studies (Yarnal, 1993).

Usually, CTs are formed or calculated on the basis of air pressure data and represent most characteristic positions of high and low pressure systems, frontal zones, etc. that shape our everyday weather conditions (Barry & Perry, 1973; Yarnal, 1993). The basic paradigm of synoptic climatology that the atmospheric circulation determines local meteorological conditions has been proved by numerous studies (Barry & Perry, 1973; Yarnal, 1993; Barry & Carleton, 2001). However, the main advantage of circulation classifications is that CTs allow drawing conclusions on the general state of weather over a study area. For example, we can say that drought and above average air temperatures are typical in summer in the case of a certain anticyclonic CT (i.e. a type with dominating high pressure system over the study area); but the same CT causes below average air temperatures in winter. As radiative cooling and, in some cases, advection of cold Arctic air masses are usual for anticyclonic CTs, night frosts in spring and autumn are connected to those CTs. Thereby CTs are relatively simple but still enough detailed tools for analysing the relationships between climate and other environmental phenomena, such as the migration of birds.

As shown by Palm et al. (2009), there is a large interannual variability in the arrival dates of migratory birds in Estonia, especially in the case of short-distance migrants. This suggests that migratory birds are able to accelerate or delay their migration to meet the most favourable circulation conditions. The aim of the present study was to investigate relationships between the spring arrival of migratory birds in Estonia and CTs, and to assess which classifications of CTs or classification methods could be the most suitable for investigating bird migration. We hypothesized that the spring arrival of short- and long-distance migrants is differently related to CTs and that the different arrival dates of birds of the same species in western and eastern Estonia may be caused by regional climate differences and birds' use of different migration flyways and routes. Also, we compared trends in the time series of first arrival dates (FAD; the dates when the first bird(s) have been seen) and changes in the population size of migratory birds to assess the influence of population size on FAD.

MATERIAL AND METHODS

Study area and climate conditions

Estonia is situated in Northern Europe on the eastern coast of the Baltic Sea. Regardless of the relatively small area (45 227 km^2) of Estonia, its climate shows great annual variability because the country is located in the transition region between maritime and continental climates (Jaagus & Ahas, 2000; Jaagus, 2001). The western airflow is the main factor that affects the weather conditions in Estonia. Therefore, the North-Atlantic cyclones dominate the climate, bringing maritime air from the North Atlantic to Estonia and causing remarkably higher air temperatures in winter and somewhat lower temperatures in summer compared with other areas on the same latitude. The direct influence of the Baltic Sea usually appears in the western part of Estonia and becomes noticeably weaker in the central and eastern parts, showing a cooling effect in the warm season and a warming effect in the cold season, as well as a smaller annual temperature amplitude on the coast in comparison with the continent (Jaagus & Ahas, 2000). The importance of maritime and continental air in the weather over the year is generally equal; the continental air plays a more essential role in late winter, spring, and early summer. In winter and spring, there may be a cold air inflow from the Arctic. In this study, we selected two observation areas with different climatic conditions: Kuressaare located in a maritime climate and Tartu in a more continental climate (Fig. 1).

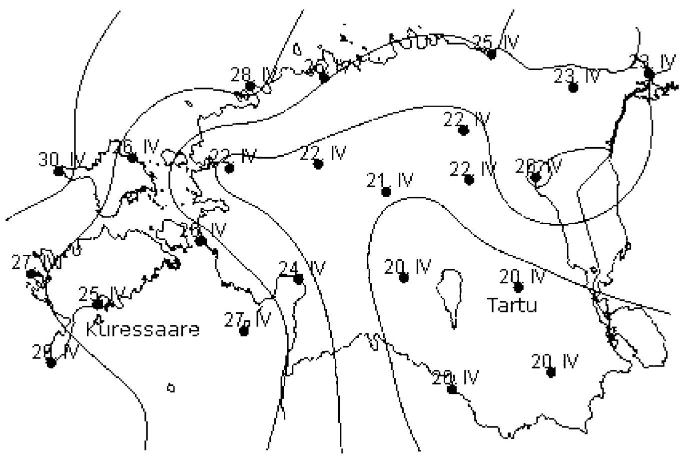

Fig. 1. The start of climatic spring in Estonia (according to Jaagus, 2001). Tartu and Kuressaare are the observation sites used in the present study.

Bird phenology data

We analysed the spring migration phenology of 42 bird species in Tartu and Kuressaare during the period 1958–2002 (Table 1). We used FADs that were recorded by volunteers in an observation network, as described in detail by Palm et al. (2009), who analysed the phenology of migratory birds in Estonia from 1957 to 1996. Here we also added the dates from the same network for the period 1997–2002, which were obtained from the original database of the Estonian Ornithological Society.

On the basis of FADs we divided the analysed bird species into early arrivals (before 10 April) and late arrivals (after 10 April; Table 1). All early arrivals were short-distance migrants, breeding in Estonia and wintering mostly in western and southern Europe and the Mediterranean region. All late arrivals were long-distance migrants, breeding in Estonia and wintering mostly in tropical Africa and Asia. In defining short- and long-distance migrants we followed the traditional classification based on the location of the wintering area and the length of the migratory route (Berthold, 1971, 1993; Newton, 2010). The migration routes and wintering areas of the studied species, breeding and ringed in Estonia, were mostly determined by using ringing recoveries from the Matsalu Ringing Centre in Estonia (Jõgi, 1957; Kumari & Jõgi, 1974; Kastepõld & Kastepõld, 1991; Olavi Vainu, personal communication). As for several species the number of recoveries from Estonia is too small and thus not valid, we additionally used published recovery data from Sweden (Fransson & Pettersson, 2001; Fransson & Hall-Karlsson, 2008) and recovery maps of Finnish birds available on the Finnish Ringing Centre (2010) website.

To relate long-term trends in FADs with population size we used the all-Estonian population trends over the period 1941–2002 (Lilleleht & Leibak, 1993; Elts et al., 2003, 2009). The methods of estimating the population size and population trends are described in detail in (Elts et al., 2003). Population changes (trends) distinguish strong decrease (more than 50%), moderate decrease (10–50%), stable population (no detectable change), moderate increase (10–50%), and strong increase (more than 50%).

Atmospheric circulation data

The FADs of birds were compared with CTs of COST 733 catalogue 1.2, domain 05 (Huth et al., 2008; COST 733, 2010; Philipp et al., 2010). The database consists of a calendar of CTs and the mean sea level pressure (MSLP) maps (see Figs 2–4). The MSLP map makes it possible to determine which weather conditions coincide with the given CT in an area.

One of the aims of COST 733 action was to verify different classification methods. This work led to the formation of a circulation classification catalogue (1.2) consisting of 73 classifications. They represent 22 different classification methods, which, in turn, are united into five families – subjective, threshold-based, PCA methods, based on a leader algorithm, and optimization methods (Appendix). As

Table 1. The mean first arrival dates (FAD), standard deviation (SD), and trend (Mann-Kendall test statistic Z) with its significance level of 42 migratory bird species in Tartu and Kuressaare during the period 1958–2002. The column "Z (W)" represents the difference in FADs between Tartu and Kuressaare in days and its statistical significance by Wilcoxon matched pair's signed-rank test. Long-term population trends (Trend) in Estonia for the period 1941–2008 are shown according to Lilleleht & Leibak (1993) and Elts et al. (2009): ++, strong increase; +, moderate increase; 0, stable; –, moderate decrease; −–, strong decrease. Significance levels are indicated as: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Species	Tartu			Kuressaare			Z (W)	Trend
	FAD	SD	Z	FAD	SD	Z		
				Short-distance migrants				
Corvus frugilegus	09 Mar	13.44	–3.76***	12 Mar	13.85	–4.52***	–3.2	+
Sturnus vulgaris	20 Mar	9.81	0.70	13 Mar	8.25	–0.44	6.7***	0
Alauda arvensis	20 Mar	10.90	–1.26	13 Mar	10.77	–0.85	7.5***	–
Vanellus vanellus	25 Mar	9.42	–0.07	19 Mar	8.44	–1.07	6.0***	–
Larus canus	25 Mar	13.46	–5.19***	22 Mar	9.60	–1.04	2.4	0
Buteo buteo	26 Mar	10.08	–3.36***	24 Mar	12.32	–3.52***	1.7	+
Carduelis cannabina	26 Mar	10.48	–1.26	26 Mar	7.99	0.78	0.3	–
Larus ridibundus	28 Mar	8.93	–2.85**	25 Mar	9.16	–3.59***	3.6***	–
Turdus merula	30 Mar	8.93	–0.56	16 Mar	9.32	0.24	14.2***	+
Turdus pilaris	30 Mar	10.83	–3.99***	25 Mar	12.65	–1.20	5.5	–
Anas platyrhynchos	01 Apr	8.90	–2.90**	26 Mar	11.47	–0.74	5.3***	0
Fringilla coelebs	01 Apr	6.05	–0.24	28 Mar	7.50	–0.55	4.2***	0
Falco tinnunculus	01 Apr	10.47	0.36	31 Mar	10.29	0.23	1.6	–
Motacilla alba	04 Apr	6.36	–2.53*	05 Apr	5.01	–1.00	–0.5	+
Anthus pratensis	05 Apr	6.24	–0.51	31 Mar	8.34	–2.61**	4.8**	–
Cygnus cygnus	05 Apr	12.38	–3.06**	21 Mar	11.75	–1.90	14.9***	+
Turdus iliacus	06 Apr	5.91	–1.28	03 Apr	8.20	1.89	2.7	+
Columba palumbus	06 Apr	7.58	–1.86	30 Mar	7.59	0.43	6.6***	0
Turdus philomelos	09 Apr	4.70	–0.71	04 Apr	7.63	1.31	4.7***	0
Grus grus	10 Apr	8.34	–1.19	04 Apr	10.04	–3.91***	6.0**	++
Gallinago gallinago	10 Apr	6.18	–0.33	07 Apr	7.47	–2.66**	2.6	0
Erithacus rubecula	10 Apr	7.91	–1.36	07 Apr	7.31	–0.95	2.6**	0
Numenius arquata	10 Apr	5.22	0.00	10 Apr	5.92	0.32	0.7	0
				Long-distance migrants				
Oenanthe oenanthe	20 Apr	5.62	2.78**	19 Apr	4.53	2.02*	0.6	0
Phylloscopus collybita	22 Apr	5.38	–1.22	24 Apr	4.85	–1.01	–2.0**	0
Anthus trivialis	26 Apr	5.01	–0.59	27 Apr	5.45	0.93	–1.4	–
Jynx torquilla	29 Apr	4.70	–0.74	01 May	4.54	1.07	–2.2*	–
Phylloscopus trochilus	30 Apr	4.58	–3.21**	04 May	3.79	–2.65**	–3.1***	+
Ficedula hypoleuca	30 Apr	4.08	–1.42	04 May	4.89	–1.55	–3.2***	0
Motacilla flava	01 May	5.16	0.79	03 May	7.09	–1.89	–2.0	–
Hirundo rustica	01 May	4.68	–1.48	03 May	4.10	–3.44***	–2.3***	––
Phylloscopus sibilatrix	02 May	4.71	–0.65	05 May	5.36	–1.37	–3.6**	0
Cuculus canorus	05 May	3.26	–0.14	09 May	2.59	1.17	–4.0***	0
Delichon urbicum	07 May	4.98	–2.37*	06 May	5.34	–1.39	0.7	–
Luscinia luscinia	09 May	3.90	–2.15*	13 May	4.93	–4.50***	–3.6***	+
Sylvia communis	12 May	4.21	–2.53*	14 May	4.72	–1.26	–1.6*	++
Muscicapa striata	15 May	4.39	–0.35	16 May	4.80	0.45	–1.0*	0
Hippolais icterina	16 May	4.22	–0.36	20 May	4.49	–2.16*	–3.2***	+
Apus apus	16 May	4.91	–2.84**	22 May	4.58	–1.96	–6.0***	0
Sylvia borin	18 May	4.61	–1.81	20 May	4.78	–2.05*	–2.2**	+
Carpodacus erythrinus	20 May	4.00	0.43	22 May	4.24	–3.99***	–2.2**	++
Oriolus oriolus	21 May	4.36	0.36	22 May	5.07	1.11	–0.4	0

mentioned above, the subjective classifications are based on the decisions of experienced meteorologists; the other four are objective methods. Threshold-based methods are usually automated versions of subjective classifications and define their CTs by declaration of a certain quantified borderline between different CTs in the form of thresholds. Alternatively, the distinction between types can be realized by predefined rules for assignment (Philipp et al., 2010). The PCA methods are based on different principal component analysis procedures (typically S- or T-mode). Leader algorithms (or correlation-based methods by Yarnal, 1993) seek for key (or leader) patterns in a sample of maps that are located in the centre of high density clouds of entities (days) within the multidimensional phase space spawned by the variables, i.e. grid-point values (Philipp et al., 2010). The main idea is to find similarities between predefined and daily CTs, which are expressed in terms of correlations or sums of squares of differences (Yarnal, 1993; Huth et al., 2008). Optimization methods arrange a set of objects (days) within groups (or clusters) in such a way that a certain function is optimized. This function is the minimization of the within-type variability measured as the overall sum of the Euclidean distances between the member objects of a CT and the average of that CT (centroid). Most of the optimization methods used by COST 733 are based on the *k*-means clustering algorithm (Philipp et al., 2010). The basics of synoptic climatology and classification methods were introduced by Yarnal (1993). A detailed description of the classification methods was presented by Philipp et al. (2010).

Three versions of classifications with 9, 18, or 27 CTs were composed by every classification method (Philipp et al., 2010). Circulation types are named after the sequence number of the type in a classification, i.e. they are not comparable by name. For example, type 2 in one classification does not equal type 2 in another classification according to the MSLP map. Altogether about 1300 CTs of the 73 classifications were analysed in the present study. The actual number of types varies according to the classifications, seasonality, etc. Some rare CTs do not occur every year; these are more common for the classifications that contain 27 (or more) CTs. As a general rule, the frequency of those rare CTs is so low (less than 1%) that we assume that they do not affect the output of our study.

According to COST 733, Europe is divided into 11 regional domains (plus one large domain that covers the whole of Europe). All classifications have been recalculated for each domain using specific boundary conditions of the domains. By the division of COST 733, Estonia is located in the centre of domain 05 (COST 733, 2010). As the atmospheric circulation classifications have been generated using air pressure fields of the database of ERA 40 (Uppala et al., 2005), the period under analysis is 1958–2002.

Statistical analysis

For our analysis, we sorted out CTs that occurred on the FAD of each bird species. In addition, we sorted out CTs that occurred on two days preceding the

FAD. We assumed that the birds 'made the decision' to migrate and actually migrated towards Estonia according to the weather conditions during those two days. The frequencies of the CTs on the chosen dates were compared with the long-term frequencies in the spring (MAM). We presumed that birds 'prefer' to migrate in case of such CTs whose frequency exceeds the long-term frequencies most. Similarly, we studied which CTs were avoided by the birds.

Next, MSLP maps for the chosen CTs were studied to determine which circulation conditions correspond to the given types. The map showed which air pressure system – low or high-pressure area – was prevalent in the domain at the time of a given CT. The general wind direction and weather conditions over Estonia can be determined by the position of air pressure areas.

According to the recommendations given on the COST 733 website (COST 733, 2010), the χ^2-test was used to compare the frequencies of CTs on the arrival dates of birds with their long-term frequencies in spring. We assumed that if the CT frequencies differed significantly ($p < 0.05$) from their long-term frequencies, the observed bird species really preferred/avoided certain circulation types in each given classification. Comparison of different classifications of a CT was also conducted using the χ^2-test. We assumed that a classification that had a significant result with a larger number of bird species was better. We used the Mann–Kendall test to calculate trends in FADs and to relate them with changes in population size. The differences in the FADs between Tartu and Kuressaare were analysed with the Wilcoxon matched pair's signed-rank test.

RESULTS

We found large differences in the spring arrival of the studied bird species between western and eastern Estonia (Table 1). While short-distance migrants arrived in Kuressaare up to a week earlier than in Tartu, long-distance migrants arrived in the reverse order. Significant differences between the observation areas were detected in 27 species. Although the difference in the arrival dates between Tartu and Kuressaare was large in some cases, we found that the same species chose the same or very similar atmospheric circulation conditions in both areas (Appendix). The short-distance migrants (i.e. early arrivals) came to Estonia mostly from the south-west by tailwinds from the western and south-western direction. The circulation situation where a strong low-pressure area was located in the north-west from Estonia and there was a low- and high-pressure area border over or near Estonia (Fig. 2) was common for early arrivals. On the other hand, they avoided those CTs in whose case the high-pressure area was prevalent in the domain – the high-pressure area was located above the centre of the domain or in the north-west of the centre (Fig. 3).

The spring migration of late arrivals (i.e. long-distance migrants) showed almost opposite relationships with CTs. In general, the spring arrival of long-distance migrants was more associated with anticyclonic, i.e. windless, or also

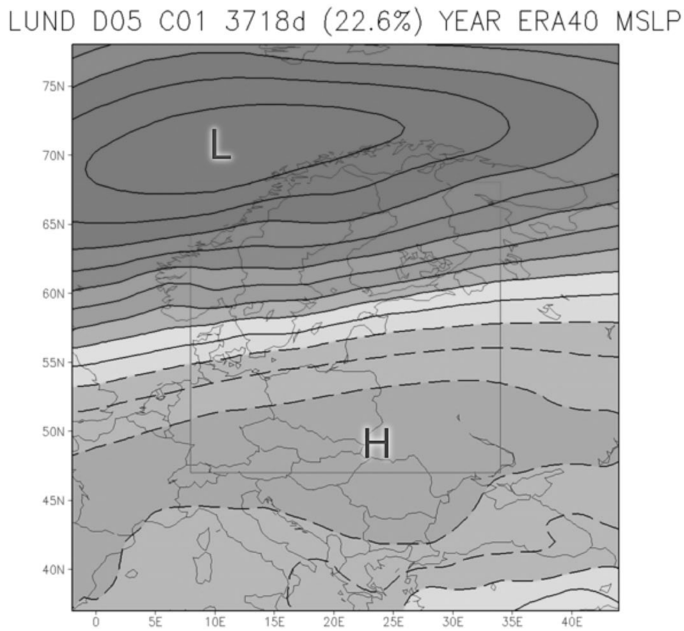

Fig. 2. Type map for circulation type 1 of the classification LUND.

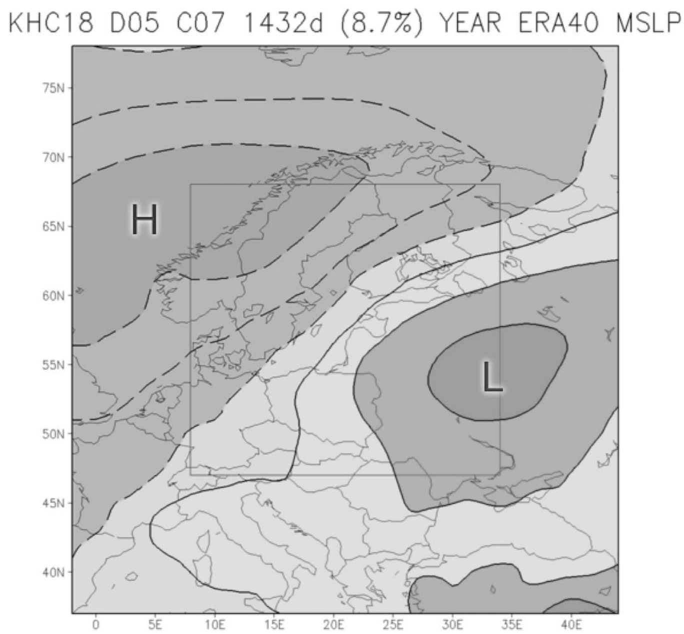

Fig. 3. Type 7 of the classification KHC18.

eastern or south-eastern wind conditions. These wind conditions mean tail- or sidewinds for long-distance migrants. The high-pressure area covered either the centre or the northern or north-eastern part of the domain (Fig. 4). Late arrivals tended to avoid those CTs in whose case cyclones dominated. However, the set of preferred (avoided) CTs in the case of the late arrivals was more dispersed than in the early-arriving species (Appendix).

In early arrivals the 'preferred' CTs for arriving in Tartu and Kuressaare coincided in 25.4% of the cases and, depending on the species and classification, this percentage ranged from 0% to 65.2%. In long-distance migrants the values were 29.3%, and from 0% to 68.4%, respectively. The average coincidence in the avoided CTs was 31% in short-distance migrants and 23.8% in long-distance migrants.

Assuming that the best classification should be associated with the largest number of species, the classifications CKMEANSC09 and NNW stand out (see Appendix). However, in 67% of the cases the 'preferred' CT was also the most frequent type in spring. Hence, we analysed whether the frequency division of CTs represented in arrival dates differed significantly from the frequency of such types in spring. This was significant in 40.7% of the 6132 cases (i.e. 42 species × 73 classifications × 2 observed locations; χ^2-tests; $p < 0.05$), with the classifications SANDRAS and CKMEANSC09 producing good results

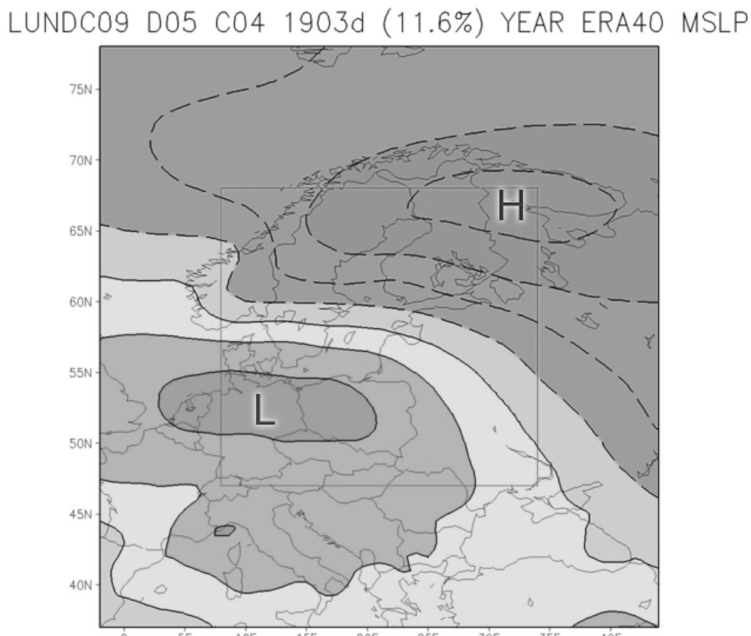

Fig. 4. Type 4 of the classification LUND9.

(significant differences in >90% of the cases). Additionally, the classifications ESLPC09, EZ850C10, HBGWL, NNW, SANDRASC09, SANDRASC18, and SANDRASC27 revealed significant differences in at least 75% of the cases (see Appendix).

On the whole, 20 bird species out of the 42 had a negative FAD trend, i.e. their spring arrival significantly ($p < 0.05$) advanced in Kuressaare (11 species) and/or Tartu (13 species) sites during the period 1958–2002 (Table 1). However, in most species the mean FAD and the significance of its trend differed between the sites. Only the Common Buzzard *Buteo buteo* had almost the same FAD value and trend in both Kuressaare and Tartu. Surprisingly, we found a similar number of short- and long-distance migrants with a negative FAD trend. One species, the Northern Wheatear *Oenanthe oenanthe* (a long-distance migrant), had a significant ($p < 0.05$) positive FAD trend in both observation areas, i.e. it had delayed its arrival during the study period.

Among the 11 early arriving bird species that had a significant ($p < 0.05$) negative FAD trend, three species decreased, three species were stable, and five species increased in their national population size during the study period (Table 1). The Eurasian Crane showed the strongest increasing trend. None of the species from this guild exhibited a strong decreasing trend. Among the late arrivals that had a significant ($p < 0.05$) negative FAD trend, two species of the nine decreased, one species was stable, and six species increased. The Common Whitethroat *Sylvia communis*, Garden Warbler *Sylvia borin*, and Icterine Warbler *Hippolais icterina* had a large (more than 50%) population increase and the Barn Swallow *Hirundo rustica* had a large (more than 50%) population decrease during the study period.

DISCUSSION

Migratory birds and CTs

We related the spring migration phenology of birds to the generalized CT that prevailed at their time of arrival. This approach differs from previous synoptic analyses (e.g., Alerstam, 1978; Richardson, 1978) of the effect of different meteorological variables and the variables of particular pressure areas on the migratory flight or a period of a few days before a specific migration movement.

We detected a large annual difference in the FADs of birds in Kuressaare and Tartu, although these places are located on the same latitude (58 °N) and the distance between the two locations is only 250 km. The early arrivals reached Kuressaare up to a week earlier than Tartu (Table 1). Moreover, the earlier the arrival date, the greater was the difference. On the one hand, this result confirms Berthold's (1971, 1993) conclusion that migratory behaviour, including the spring arrival of the early arrivals (so-called 'weather birds'), is particularly difficult to predict, especially when compared with the late arrivals ('calendar birds'). On the other hand, this indicates that there could be factors causing geographical (longitude) differences in the arrival time associated with climate. There is a noticeable difference between the climate in Kuressaare and Tartu, mostly caused by the influence of the Baltic Sea and prevalence of the western airflow. On average, the climatic early spring starts in Kuressaare four days earlier than in Tartu (Jaagus & Ahas, 2000; Jaagus, 2001).

However, our analysis did not reveal differences in the preference of CTs by migratory birds arriving either in Kuressaare or Tartu (Appendix). Still, it must be noted here that the disparity of CTs and inner-type variation is a controversial issue (Yarnal, 1993), i.e., it is difficult to objectively assess how similar or different CTs are. Our results showed that only about a fourth of CTs coincided in the arrival of birds in both Kuressaare and Tartu. Similarly, the average coincidence percentage values in types that birds avoided were also relatively small. It may still be argued that, according to the MSLP maps, other CTs that were represented at the arrival time of migratory birds in Tartu and Kuressaare had a similar division of pressure areas and thus also the direction of main airflows. Based on the MSLP maps, we found that in their migration to Estonia the early arrivals preferred the cyclonic circulation conditions in which western or south-western winds dominated. This suggests that birds arrived in Kuressaare and Tartu in separate waves from different flyways using different cyclones. On the other hand, early arrivals showed their avoidance of the CTs where the high-pressure area was prevalent in Estonia. In such a situation, the birds would have no tailwind support (i.e. western and south-western winds) to minimize the energy expenditure for flight that is important in bird migration (Alerstam & Lindström, 1990; Newton, 2010). Thus, the wind conditions are a really important factor for those species and determine their spring migration to a great extent. In contrast, the night frosts and advection of the cold Arctic air masses connected with anti-cyclones in the early spring depress the migration. The later arrivals migrated to Tartu up to half a week earlier than to Kuressaare. This is concurrent with that, on average, climatic spring (see Fig. 1) starts approximately five days earlier in Tartu than in Kuressaare (Jaagus & Ahas, 2000; Jaagus, 2001). This indicates that the arrival of long-distance migrants is certainly affected by weather conditions but in a different way. According to Palm et al. (2009), the FADs of long-distance migrants are generally weakly correlated with climate variables such as monthly mean air temperature and NAO indices. Only eight species were significantly related to the start of the climatic spring and/or mean April air temperature. Also, our analyses revealed that relatively fewer similar CTs were used by different species of late arrivals, suggesting that those species use various migration strategies.

Still, our results indicate that in general long-distance migrants preferred anti-cyclonic conditions to migrate to Estonia. In these cases there were either windless conditions above Estonia or weak eastern or south-eastern winds (see Fig. 4). Late arrivals seemed to avoid the CTs where cyclones dominated over the domain, while early arrivals preferred such CTs. The analysed long-distance migrants tend to winter either in Equatorial or South Africa and a small part also in Indochina and Asia Minor. The majority of these migrants should arrive in Estonia from the southern or south-eastern directions. The cyclones coming from the west with either head- or sidewinds, typical for Estonia, can be considered unfavourable circulation conditions for most long-distance migrants.

On the other hand, anticyclonic conditions provide some weak tailwind or windless conditions that enable long-lasting continuous migration of long-distance migrants. Also, many of the long-distance migrants fly at night, their flight altitude may be different compared to daytime migrants, and the wind direction may differ from that near the ground (Richardson, 1978; Alerstam & Lindström, 1990; Dinevich et al., 2005; Newton, 2010). In addition, the clear skies or minimal cloudiness occurring in the high pressure areas enable the nocturnal migrants to use the essential stellar orientation (Wiltschko & Wiltschko, 1978; Newton, 2010).

In terms of synoptic climatology, the main question is which classification or family of classification methods give the best results (and which criteria allow us to determine this). As mentioned above, in our study the classifications SANDRAS and CKMEANSC09 performed best: they had statistically significant results for 90% of the species. SANDRAS-method classifications did especially well with all four classifications producing very good results. Among the families of classification methods optimization methods stood out for excellent results. On the other hand, there were very poor classifications that obviously did not describe bird migration, such as the four versions of the WLKC classification method.

A general tendency was that the larger the number of CTs in a classification, the fewer were the significant test results. This indicates that migrating birds were not waiting for some specific type of circulation, but considered more general circulation conditions. However, some bird species may still use specific CTs as well. The chaffinch *Fringilla coelebs*, a short-distance migrant, and the Common Rosefinch *Carpodacus erythrinus*, a long-distance migrant, in whose case a significant χ^2-test result occurred respectively in 78% and 62% of classifications, support this possibility. Some other species (e.g. the Eurasian Crane and the Chiffchaff *Phylloscopus collybita*) did not seem to be directly affected by the circulation conditions.

In general, long-distance migrants had fewer significant preferences than short-distance migrants. This suggests that the migration of long-distance migrants depends to a greater extent on endogenous factors and is less affected by the circulation conditions as also reported in (Newton, 2010). In short-distance migrants a geographical difference is also apparent: they are coming from the western and south-western directions and their migration route to Kuressaare is shorter compared to Tartu because of a longitudinal difference. In long-distance migrants there are no significant differences in the longitude of the migration routes to Tartu and Kuressaare because there is no great latitudinal difference between these geographical points. Also, it must be kept in mind that the migration routes used by a species to arrive in Estonia may be different. For example, the Eurasian

Cranes arrive in West Estonia from the south-west using the West European flyway, while they arrive in East Estonia from the southern directions using the Central and East European flyways (Leito et al., 2006). The cranes arrive in Kuressaare on average six days earlier than in Tartu (see Table 1). Most likely, the cranes from the West European flyway use favourable tailwinds of the western cyclones and the cranes from the eastern flyways use favourable tailwinds of the southern cyclones and anticyclones. In southern anticyclones, the favourable tailwind is additionally supported by good visibility and an upward airflow. Also, the milder late winter and early spring in Kuressaare compared to Tartu (Jaagus & Ahas, 2000) favour the earlier arrival of cranes in Kuressaare.

Trends in FADs

We found that an increasing population size was related to an advanced FAD and a decreasing trend delayed the FAD. Among early arrivals 7 species of 23 decreased, 9 species were stable, and 7 species increased during the study period (see Table 1). Therefore, the FADs of seven species from this guild should have been affected by population size in the direction of advanced spring arrival and another seven species in the direction of delayed spring arrival. However, the change in the FADs of most species should have been minimal because during the study period their population change was only up to 50%. The only exception is the Eurasian Crane, whose population size increased several times in this period (Leito et al., 2006). Therefore, the advance of spring arrival of cranes in Estonia should be to some extent affected by the increased population size, but most likely much more by climate warming in Estonia and all over Europe (Jaagus, 2006; Palm et al., 2009, 2011). This suggestion is supported by the fact that the crane population grew more in western Estonia than in eastern Estonia (Leito et al., 2006) while the mean arrival date advanced significantly in Tartu but not in Kuressaare (see Table 1). Besides, the late winter and early spring in the more continental Tartu became relatively warmer than in the more marine Kuressaare (Jaagus, 2006).

Among late arrivals, 5 species of 19 decreased, 8 species were stable, and 6 species increased during the study period. Considering the strong trends, the FADs of the Common Whitethroat and Garden Warbler may have been affected by the population increase in the direction of an advance of spring arrival and the FADs of the declined Barn Swallow in the direction of a delay of spring arrival. However, of the FADs of these three species only that of the Common Rosefinch advanced significantly in Tartu but not in Kuressaare, and that of the Barn Swallow had a significant advance of spring arrival in Kuressaare and a nonsignificant advance in Tartu (see Table 1). Thus, similarly to early arrivals, the FADs of late arrivals were not markedly affected by the population size but rather by climate change.

Surprisingly, we found a similar number of short- and long-distance migrants who showed a significant negative FAD trend despite a higher variability of the FADs of the early arrivals (see Table 1). We expected, in the light of earlier general findings (Berthold, 1971, 1993; Newton, 2010), that the late arrivals (long-distance migrants) should have no change, or at least a smaller change, in their FADs because of a stronger endogenous determination of the timing of their migration compared to the early arrivals (short-distance migrants). Yet our results showed that weather conditions, particularly atmospheric circulation, affected significantly the FADs of both the short-distance and long-distance migrants.

CONCLUSIONS

We found that, in general, migratory birds preferred or avoided similar circulation types when flying to Kuressaare (West-Estonian Archipelago) and Tartu (East Estonia). Based on the MSLP maps, we can say that the short-distance migrants preferred the cyclonic situation for their arrival, when strong westerly winds prevailed. They generally avoided circulation types where anticyclones dominated. Connections of long-distance migrants with circulation were somewhat weaker, but they preferred the situation when there was a high-pressure area above Estonia and they avoided circulation types with a cyclone dominating.

The spring arrival of migratory birds was somewhat better described by classifications that belong to the optimization method family, especially the methods SANDRAS and CKMEANS. A general tendency was that circulation classifications with up to nine types described migration better than classifications with more types.

There was a similar number of short- and long-distance migrants whose arrival had advanced during the study period despite different population trends and a higher variability of the FADs in early arrivals. Thus, weather conditions and climate change affected the spring arrival of both the short-distance and long-distance migrants. The question how these changes are connected with the changes in the frequencies of CTs requires further research.

To conclude, the method of CTs is adequate for describing bird migration phenology on a regional level and could become even more valuable at a larger scale, such as the size of an atmospheric circulation area.

ACKNOWLEDGEMENTS

The present study was financed by the Ministry of Education and Research of Estonia through Target Funding Projects SF0180127s08 and SF0170160s08 and the Estonian Science Foundation under grant No. 7526. We thank the reviewers and the editor for useful remarks and recommendations improving the manuscript.

APPENDIX

Circulation classifications, circulation types that migratory birds prefer or avoid when migrating to Tartu and Kuressaare, and wind directions (Wd) concurring with the circulation types over Estonia. According to classification methods, the circulation classifications are grouped in families: regular – subjective classifications; bold italic – thresholds; underlined – PCA; bold – leader; italic – optimization. The number in parentheses shows the percentage of the studied migratory birds that gave a statistically significant chi-square test value with the respective classification. In the 'Type' columns, the first figure represents the circulation type in a respective classification and the figure in the parentheses stands for the number of species that prefer (avoid) the given type. WNL refers to windless weather at typical for an anticyclononic situation and ? refers to a situation where the MSLP map did not allow a specific wind direction to be determined

Classification	Short-distant migrants								Long-distant migrants							
	Preferred circulation types				Avoided circulation types				Preferred circulation types				Avoided circulation types			
	Tartu		Kuressaare		Tartu		Kuressaare		Tartu		Kuressaare		Tartu		Kuressaare	
	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd
HBGWL(88.1)	2(8)	SW	2(14)	SW	20(6)	WNL	29(6)	S	29(8)	S	29(7)	S	8(7)	W	2(8)	SW
HBGWT(70.2)	1(13)	SW	1(17)	SW	6(11)	?	6(8)	?	10(11)	S	10(9)	S	1(8)	SW	6(8)	?
OGWL(46.4)	2(6)	SW	2(10)	SW	15(11)	?	15(7)	?	29(7)	SW	25(6)	SE	8(5)	W	2(4)	SW
OGWLSLP(41.7)	2(7)	SW	2(6)	SW	15(7)	NE	15(8)	NE	28(6)	S	28(7)	S	2(5)	SW	8(4)	W
PECZELY(31)	5(11)	S	5(6)	S	10(14)	WNL	10(8)	WNL	5(6)	S	10(8)	WNL	6(6)	S	6(4)	S
PERRET(40.5)	7(6)	SW	7(7)	SW	14(8)	W	20(7)	W	23(7)	S	22(6)	S	14(9)	W	12(5)	?
SCHUEEPP(13.1)	17(4)	W	25(5)	?	6(6)	WNL	6(8)	WNL	10(11)	S	10(10)	W	21(7)	?	25(8)	?
ZAMG(35.7)	13(10)	SW	13(12)	SW	32(11)	W	31(10)	S	32(5)	W	32(5)	W	15(8)	W	15(10)	W
GWT(23.8)	4(9)	SW	3(8)	SW	14(7)	E	14(10)	E	18(4)	S	14(7)	E	1(8)	W	4(7)	SW
GWTC10(38.1)	2(19)	SW	2(12)	SW	8(10)	E	8(10)	E	8(8)	E	8(8)	E	1(6)	W	2(8)	SW
GWTC18(23.8)	4(9)	SW	3(8)	SW	14(7)	E	14(10)	E	18(4)	S	14(7)	E	1(8)	W	4(7)	SW
GWTC26(17.9)	6(8)	SW	6(4)	SW	20(6)	E	20(7)	E	17(3)	NE	20(5)	E	1(4)	W	6(5)	SW
LITADVE(23.8)	6(14)	SW	6(8)	SW	3(9)	E	2(8)	N	5(7)	SW	5(5)	SW	1(8)	NW	1(4)	NW
LITC18(23.8)	11(6)	SW	15(6)	NW	6(12)	E	6(5)	E	9(3)	SW	8(3)	SE	7(4)	S	15(4)	NW
LITTC(15.5)	16(7)	SW	16(7)	SW	9(13)	E	9(8)	E	14(5)	SW	12(3)	SE	10(4)	S	23(3)	NW
LWT2(10.7)	6(8)	SW	23(6)	SW	2(4)	NE	11(4)	SE	2(3)	NE	1(4)	WNL	23(5)	SW	6(3)	SW
LWT2C10(21.4)	4(9)	W	4(10)	W	2(6)	E	5(9)	N	2(5)	E	2(7)	E	4(7)	W	9(4)	W
LWT2C18(13.1)	6(11)	SW	7(6)	W	3(5)	E	3(5)	E	5(3)	S	3(4)	E	1(3)	WNL	6(4)	SW

APPENDIX. *Continued*

Classification	Short-distant migrants								Long-distant migrants							
	Preferred circulation types				Avoided circulation types				Preferred circulation types				Avoided circulation types			
	Tartu		Kuressaare		Tartu		Kuressaare		Tartu		Kuressaare		Tartu		Kuressaare	
	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd
WLKC09(9.5)	7(16)	SW	7(11)	SW	9(11)	NW	1(9)	W	7(14)	SW	7(12)	SW	9(6)	NW	9(8)	NW
WLKC18(8.3)	16(11)	SW	16(11)	SW	1(8)	SE	1(9)	SE	7(8)	SW	7(7)	SW	9(5)	NW	18(8)	NW
WLKC28(6)	6(9)	S	20(6)	SW	22(4)	W	5(8)	S	6(6)	S	20(3)	SW	27(3)	W	22(4)	W
WLKC733(7.1)	9(7)	S	39(7)	SW	5(8)	NW	5(9)	NW	9(11)	S	9(9)	S	35(5)	NW	10(4)	W
P27(20.2)	6(6)	S	17(3)	W	22(6)	N	12(5)	S	5(6)	WNL	6(5)	S	16(4)	NW	10(3)	NE
P27C08(44)	8(10)	S	4(10)	SW	1(10)	N	1(9)	N	5(6)	NE	6(10)	SE	4(6)	SW	3(6)	W
P27C16(41.7)	18(10)	S	9(8)	SW	11(11)	E	11(7)	E	11(4)	E	12(5)	SE	7(3)	W	18(4)	S
P27C27(36.9)	27(7)	S	9(7)	SW	11(6)	E	11(12)	E	11(4)	E	11(5)	E	27(3)	S	8(3)	W
PCAXTR(57.1)	9(8)	W	4(10)	SW	3(13)	NE	3(17)	NE	11(7)	S	5(5)	WNL	9(8)	W	9(6)	W
PCAXTRC09(20.2)	4(9)	SW	4(8)	SW	3(14)	NE	6(7)	NE	7(5)	SE	7(7)	SE	1(6)	NW	5(4)	SW
PCAXTRC18(35.7)	6(9)	SW	6(7)	SW	5(12)	NE	5(14)	NE	13(5)	W	5(6)	NE	7(6)	SW	7(6)	SW
TPCA07(10.7)	7(10)	SW	6(6)	W	5(7)	?	2(7)	S	4(9)	WNL	7(10)	SW	6(10)	NW	5(10)	NW
TPCAC09(39.3)	1(12)	W	1(8)	W	4(12)	NE	4(9)	NE	6(11)	SW	5(6)	S	1(7)	W	7(6)	S
TPCAC18(28.6)	1(11)	W	1(7)	W	12(16)	NE	12(13)	NE	12(7)	NE	12(9)	NE	17(6)	W	1(8)	W
TPCAC27(31)	22(7)	W	26(9)	W	12(15)	N	12(9)	N	12(6)	N	12(6)	N	26(4)	W	22(5)	W
TPCAV(16.7)	7(10)	SW	7(6)	SW	4(7)	NW	4(6)	NW	4(11)	SE	7(5)	SW	9(7)	N	9(7)	N
ESLPC09(84.5)	6(11)	W	6(14)	W	2(14)	WNL	1(12)	W	1(9)	W	1(10)	W	6(11)	W	6(12)	W
ESLPC18(60.7)	6(8)	W	11(7)	W	2(18)	WNL	5(10)	E	2(7)	WNL	2(10)	WNL	6(6)	W	8(8)	W
ESLPC27(47.6)	6(7)	W	15(8)	W	2(18)	WNL	2(12)	WNL	2(6)	WNL	2(9)	WNL	6(5)	W	11(4)	NW
EZ850C10(78.6)	4(12)	W	4(15)	W	2(16)	WNL	2(15)	WNL	1(10)	W	1(11)	W	4(11)	W	3(11)	W
EZ850C20(64.3)	9(8)	W	9(10)	W	7(12)	E	7(11)	E	4(6)	S	4(11)	S	9(9)	W	9(13)	W
EZ850C30(60.7)	6(7)	W	14(8)	W	7(8)	E	7(7)	E	3(8)	WNL	3(10)	WNL	11(3)	N	13(7)	S
KHC09(34.5)	5(10)	SW	4(6)	S	7(15)	NE	7(15)	NE	7(9)	NE	3(9)	SE	6(7)	NW	4(6)	S
KHC18(21.4)	1(11)	SW	4(5)	S	7(14)	NE	7(17)	NE	7(5)	NE	7(4)	NE	6(4)	NW	4(4)	S
KHC27(13.1)	1(10)	SW	1(6)	SW	7(10)	NE	7(8)	NE	13(4)	NW	25(8)	E	9(3)	NW	1(4)	SW
LUND(34.5)	1(15)	W	1(17)	W	5(11)	NE	4(9)	E	5(8)	NE	4(9)	E	1(8)	W	1(4)	W
LUNDC09(31)	1(14)	W	1(16)	W	5(10)	NE	4(10)	SE	5(6)	NE	4(9)	SE	1(7)	W	1(4)	W
LUNDC18(25)	1(15)	W	1(16)	W	5(14)	NE	5(11)	NE	5(6)	NE	4(7)	E	1(8)	W	1(8)	W

Continued overleaf

APPENDIX. *Continued*

Classification	Short-distant migrants								Long-distant migrants							
	Preferred circulation types				Avoided circulation types				Preferred circulation types				Avoided circulation types			
	Tartu		Kuressaare		Tartu		Kuressaare		Tartu		Kuressaare		Tartu		Kuressaare	
	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd	Type	Wd
LUNDC27(15.5)	1(12)	W	1(16)	W	5(12)	NE	4(12)	SE	5(8)	NE	4(6)	SE	1(10)	W	1(9)	W
PETISCO(13.1)	5(10)	W	5(8)	W	3(8)	N	9(11)	NE	6(7)	S	6(7)	S	5(6)	W	2(6)	NW
PETISCOC09(23.8)	3(23)	SW	3(15)	SW	8(12)	NE	8(13)	NE	1(6)	S	8(5)	NE	2(8)	W	2(8)	W
PETISCOC18(17.9)	8(16)	W	8(9)	W	16(8)	NE	16(11)	NE	2(6)	S	16(6)	NE	8(6)	W	3(10)	W
PETISCOC27(14.3)	3(11)	W	7(8)	NW	24(7)	NE	24(9)	NE	2(8)	S	24(6)	NE	3(7)	W	7(8)	NW
CKMEANSC09(90.5)	3(9)	S	8(7)	W	2(21)	WNL	2(19)	WNL	2(15)	WNL	2(16)	WNL	6(9)	W	3(8)	S
CKMEANSC18(64.3)	13(7)	SW	13(9)	SW	7(12)	WNL	7(9)	WNL	1(5)	N	7(5)	WNL	8(4)	S	8(9)	S
CKMEANSC27(61.9)	11(6)	SW	11(6)	SW	5(13)	NE	4(11)	SE	5(6)	NE	4(6)	SE	8(3)	E	13(6)	S
NNW(82.1)	6(14)	S	6(15)	S	8(19)	W	8(13)	W	1(5)	W	8(7)	W	6(16)	S	6(17)	S
NNWC09(33.3)	7(10)	S	6(14)	W	6(5)	W	8(6)	?	4(7)	S	4(9)	S	6(8)	W	6(7)	W
NNWC18(29.8)	16(9)	S	3(9)	W	9(4)	N	9(8)	N	10(7)	SW	10(6)	SW	16(7)	S	3(7)	W
NNWC27(27.4)	25(6)	S	3(5)	W	9(7)	N	14(3)	W	16(6)	SW	19(4)	S	25(8)	S	25(5)	S
PCACA(59.5)	4(18)	S	4(11)	S	1(18)	NE	1(20)	NE	1(10)	NE	1(12)	NE	2(12)	NW	2(12)	NW
PCACAC09(72.6)	9(11)	SW	9(12)	SW	8(22)	E	8(21)	E	8(9)	E	8(14)	E	5(5)	S	9(6)	SW
PCACAC18(61.9)	9(6)	SW	6(5)	WNL	10(13)	N	10(13)	N	17(7)	WNL	10(6)	N	6(7)	WNL	6(8)	WNL
PCACAC27(58.3)	9(8)	SW	11(3)	WNL	8(12)	N	1(8)	E	4(8)	SW	8(5)	N	26(5)	NW	9(6)	SW
PCAXTRKM(44)	8(8)	SW	9(10)	W	3(12)	N	3(11)	N	5(7)	NE	5(7)	NE	9(4)	W	9(8)	W
PCAXTRKMC09(29.8)	5(18)	SW	5(12)	SW	2(15)	NE	2(16)	NE	6(4)	N	7(6)	WNL	1(7)	NW	5(10)	SW
PCAXTRKMC18(31)	7(13)	SW	7(11)	SW	8(16)	NE	8(12)	NE	8(10)	NE	8(8)	NE	7(8)	SW	7(10)	SW
SANDRA(64.3)	5(8)	SW	16(5)	SW	6(10)	E	6(10)	E	2(4)	N	6(7)	E	17(3)	WNL	5(6)	S
SANDRAC09(73.8)	9(9)	W	9(10)	W	3(16)	E	3(17)	E	6(7)	WNL	3(11)	E	9(6)	W	9(13)	W
SANDRAC18(67.9)	10(10)	SW	10(6)	SW	17(9)	N	4(8)	E	6(8)	W	4(6)	WNL	16(4)	WNL	10(6)	SW
SANDRAC27(50)	20(6)	W	25(3)	SW	17(8)	N	17(6)	N	9(7)	E	9(6)	E	1(6)	WNL	22(5)	W
SANDRAS(97.6)	26(6)	SW	26(5)	SW	4(12)	N	4(8)	N	12(11)	S	12(8)	S	10(5)	SE	13(5)	S
SANDRASC09(86.9)	7(8)	W	6(5)	W	1(11)	E	1(21)	E	3(6)	WNL	1(11)	E	8(7)	WNL	6(9)	W
SANDRASC18(75)	2(9)	S	16(4)	SW	1(17)	NE	1(18)	NE	6(6)	SE	1(7)	NE	12(6)	W	11(6)	NW
SANDRASC27(75)	10(8)	SW	19(6)	SW	3(11)	E	3(8)	E	3(6)	E	3(8)	E	13(5)	WNL	10(7)	SW

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Tsirkulatsioonitüüpide mõju rändlindude kevadisele saabumisele Eestis ja pikaajalised trendid lindude saabumiskuupäevas

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Me uurisime 42 rändlinnuliigi kevadist saabumist Eestisse aastatel 1958–2002, seotuna atmosfääri tsirkulatsioonitüüpidega, mis on välja töötatud COST 733 poolt. Tulemused näitavad, et kõik varajased saabujad on lähirändurid, kelle kevadine saabumine seostub tsüklonaalsete tingimustega. Need tingimused kujundavad pärituulte süsteemi, mis soodustab lindude rännet pesitsusaladele. Lähirändurid väldivad tsirkulatsioonitüüpe, mille korral valitseb Eesti kohal kõrgrõhkkond. Hilised saabujad on kõik kaugrändurid, kes saabuvad kevadel enamasti antitsüklonitega seotud tuulevaiksetes, ida- või kagutuuletingimustes, mis kaugrändurite lennumarsruuti arvestades tähendab neile soodsat tagant- või küljetuult. Kaugrändurid väldivad tsirkulatsioonitüüpe, mil valitsevateks on madalrõhkkonnad.

Meie oletus, et samade liikide erinev saabumisaeg Lääne- (Kuressaare) ja Ida-Eestis (Tartu) on põhjustatud erinevatest tsirkulatsioonitüüpide eelistustest, ei leidnud kinnitust. Üldjuhul olid eelistatud samad või sarnased tsirkulatsioonitüübid. Ajalised erinevused linnuliikide kevadisel saabumisel Lääne- ja Ida-Eestisse on ilmselt seotud eeskätt klimaatiliste erinevuste ning erinevate rändeteedega. Paljude liikide, nii lähi- kui kaugrändurite kevadine saabumine aastatel 1958–2002 muutus oluliselt varasemaks, kusjuures varajastel saabujatel olid selle muutuse ulatus ja tõenäosus suuremad kui hilistel saabujatel. Osal liikidest oli suundumus varasemale saabumisele positiivselt seotud populatsiooni kasvuga, ent tähtsaks faktoriks olid ka kliimamuutused.

Tsirkulatsiooni klassifikatsioonide võrdlemisel ilmnes, et väiksema tsirkulatsioonitüüpide arvuga klassifikatsioonid, nagu CKMEANSC09 või SANDRAS, kirjeldavad lindude kevadist saabumist oluliselt paremini. Sellest võib järeldada, et rändlinnud üldiselt ei oota väga spetsiifilisi ilmastikutingimusi. Tulemused kinnitasid ka, et tsirkulatsioonitüüpide meetod, mida me rakendasime rändlindude kevadise saabumise uurimisel, on tõhus ja arendab oluliselt edasi lindude rände sünoptilise analüüsi meetodit. Eriti efektiivne tundub see meetod olevat lindude rändefenoloogia ja ilmastiku vaheliste seoste komplekssel uurimisel suurtel aladel, näiteks Euroopas, mille suurus on lähedane tsirkulatsioonitüüpide ulatusele.