ISSN 1062-3590, Biology Bulletin, 2016, Vol. 43, No. 9, pp. 1203–1211. © Pleiades Publishing, Inc., 2016.
Original Russian Text © S.V. Volkov, O.S. Grinchenko, T.V. Sviridova, 2016, published in Zoologicheskii Zhurnal, 2016, Vol. 95, No. 10, pp. 1182–1191.

The Effects of Weather and Climate Changes on the Timing of Autumn Migration of the Common Crane (*Grus grus*) in the North of Moscow Region

S. V. Volkov[a], O. S. Grinchenko[b], and T. V. Sviridova[a]

[a]*Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, 119071 Russia*
[b]*Institute of Water Problems, Russian Academy of Sciences, Moscow, 119991 Russia*
e-mail: owl_bird@mail.ru

Received January 13, 2016

Abstract—A significant correlation between the beginning of the formation of migratory congregation and the ultimate transition of minimal daily temperatures below 10°C was revealed ($r_s = 0.52$, $p < 0.02$). Departure of common cranes from the north of Moscow Region usually occurs between September 15 and October 15, on 28.09 ± 5 days on average. A significant trend for the shift of this event to later dates ($r_s = 0.66$, $p < 0.002$) was apparent from the data collected during 19 years (in 1994–2012). The date of departure of the cranes is affected by the ultimate transition of minimal daily temperature below 0°C ($r_s = 0.64$, $p < 0.003$), the abundance of precipitation ($r_s = 0.49$, $p < 0.03$), and the number of days with precipitation ($r_s = 0.51$, $p = 0.026$). Cranes stayed at the migratory autumn stopover for longer periods during rainy seasons.

Keywords: climate change, autumn migration, phenology, common crane, *Grus grus*

DOI: 10.1134/S1062359016110170

INTRODUCTION

Climate change, and climate warming in particular, can have considerable effects on different stages of the life cycle in birds. Two large areas with positive trends of annual temperature change are located in Eurasia; the rate of annual temperature increase in these areas exceeds 0.4°C per 10 years (Sherstyukov, 2012). One of these areas includes the entire Eastern Europe and the Middle East and extends to the adjacent regions of North Africa. The increase of average daily temperatures and earlier melting of the snow cover during spring in the temperate zone of the Northern Hemisphere promotes an earlier beginning of plant growth and an earlier increase of the activity of insects that serve as the major food source for most bird species (Crick, 2004; Walther et al., 2002; Hansen et al., 2006). An earlier advent of spring brings about an earlier arrival of migratory species (Sokolov et al., 1999; Marra et al., 2005; Sokolov 2006; Jonzen et al., 2006; Zalakevicius et al., 2006; Palm et al., 2009; Tottrup et al., 2010; Volkov et al., 2013), and sometimes enhances the success of breeding in birds (Both et al., 2005; Guillemain et al., 2013). Climate changes in our study area were manifested as the increase of average temperature of some winter and summer months, shift of the dates of transition of the daily temperatures through 0°C and 5°C, and earlier melting of the snow cover. As a result, the arrival time of the common crane changed (Volkov et al., 2013).

It is still unclear whether earlier arrival of the migrating birds leads to a shift of the reproduction period to earlier dates and to a related shift of the beginning of the autumn migration or the latter could be entirely determined by the specific weather and climate conditions in the breeding area. The results of research on this phenomenon are controversial, but a common trend is apparent: birds that migrate over large distances tend to leave the breeding areas earlier than during the first half of the 20th century. On the other hand, birds that migrate over short distances leave the breeding areas later (Cotton, 2003; Jenni and Kery, 2003; Beaumont et al., 2006; Tottrup et al., 2006; Mezquida et al., 2007; etc.).

Climate change can affect the beginning and duration of the autumn migration of birds, as well as the distribution of birds within the wintering range (Sokolov et al., 2001; Austin and Rehfisch, 2005; Sokolov 2006; Grishchenko, 2010). The shift of the wintering areas towards the north (closer to the breeding areas) was observed for the common crane, and the distance of migration was thus reduced (Prange, 2008, 2011). The decrease of the time of migration due to reduction of the distances between wintering sites and breeding sites should presumably lead to an increase in the length of the stay of the birds within their breeding areas.

The main tasks of the present study consisted in the clarification of the following issues: (1) whether the timing of the autumn migration of the common crane through the north of Moscow Region changed within the two past decades and how this relates to weather and climate changes in the study area; (2) the nature of the external factors associated with different stages of migration activity in the common crane; (3) whether the duration of the stay of the common crane in the breeding areas and at the migration stopovers has changed.

MATERIALS AND METHODS

The study area was located in the north of the Moscow Region (in Taldom and Sergiev-Posad districts) in the southern part of the Upper Volga lowland, at the border of the Dubna lowland and the Taldom hills (56°45' N, 37°45' E). The geological structure of the area differs from that of the surroundings, and the same is true for ground and surface water regimen, the composition of soil and vegetation cover, and the considerable diversity of the fauna. Human activity in the area dates back to the distant past; however, a large part of the area is still covered by forests and marshland (Rechan et al., 1993). The most significant economical transformations in the area (drainage engineering, reduction of marshland area, abandonment of villages, and the increase of field size in the middle of the past century, as well as a sharp drop in agricultural activity at the end of the past century) were described in our previous publications (Smirnova et al., 1999; Sviridova et al., 2002, 2006).

The Taldom autumn migration stopover of the common crane was discovered in 1976. Crane censuses at this site were performed since 1982 (Zubakin et al., 1982; Vloshina et al., 1987; Smirnova, 1997; Smirnova et al., 1999; Grinchenko et al., 2001; Grinchenko and Sviridova, 2008), and the field station founded in 1994 enabled more detailed and regular observations during the autumn period. The census procedure of common cranes on the migration stopover consisted in recording of the number of birds that left the night lodgings for feeding sites between 5:00 and 9:00 in the morning and moved back to the night lodgings between 17:00 and 21:00. The birds were counted simultaneously at several stationary observation points (Voloshina et al., 1987). Censuses and mapping of the location of cranes started after the sightings of the first migrating birds in late summer and continued until the departure of all birds.

The meteorological data (minimal daily air temperature, average daily air temperature, dates of transitions of average and minimal daily air temperatures through 10, 5 and 0°C, the amount of precipitation, and the number of days with precipitation) were obtained from the Tver meteorological station located in 100 km to the west from the study area. This meteorological station was the only station closest to the study area and with most comprehensive set of data covering the period from the late 1940s till present (see website of the National Climatic Data Center http://www.ncdc.noaa.gov), although the data obtained after the year 1960 were more detailed than earlier data. The meteorological station in Savelovo was operated in 25 km from our study area until the late 1960s, but then it was closed, and the data sets recorded there were incomplete, and therefore we had to use the data collected at the Tver meteorological station. Comparison of the data collected at the above mentioned meteorological stations during the same time intervals revealed good correspondence (98.7%) between the parameters of temperature and precipitation used in the present study (Volkov et al., 2013).

Large-scale oscillations of atmospheric circulation connected between distant areas (long-distance connections) are known to make a considerable contribution to the variability of atmosphere characteristics in the Atlantic-European region (Nesterov, 2013). Various indices are used for quantitative description of these oscillations. The EA/WR circulation index (oscillations in East Atlantic–Western Russia), a variant of the widely used NAO index, is the most appropriate for the characterization of the dynamics of climate change in the study area. The values of this index are available from the website of the NOAA Climate Prediction Center, http://www.cpc.ncep.noaa.gov. Periods with positive EA/WR values correspond to less humid conditions in the European part of Russia and around the Mediterranean Sea, as well as to a decrease of the amount of precipitation below the average level in western Russia and northwestern Africa (Barnston and Livezey, 1987).

Statistica 6.0 software (StatSoft, Inc., 2001) was used for the statistical analysis.

RESULTS

Changes of climatic and weather conditions in the study area in the autumn period. The average air temperature during the period of autumn migration of the common crane (August–October) increased by approximately 1.2°C since the mid-20th century. This trend was statistically significant between 1960 and 2012 ($r_s = 0.47$, $p < 0.001$) (Fig. 1), although a less clear trend was observed during a shorter time interval that corresponded to the time of the present study (years 1994–2012; $r_s = 0.41$, $p = 0.08$).

The greatest changes occurred in September and August that became significantly warmer ($r_s = 0.53$, $p < 0.0001$ and $r_s = 0.36$, $p < 0.01$, respectively). The increase of the minimal daily temperatures was more pronounced ($r_s = 0.48$, $p < 0.04$) than that of the average daily temperatures, this being indicative of stronger changes of night temperatures.

A trend for the increase of the total amount of precipitation between August and October was apparent in 1960–2012 as well ($r_s = 0.25$, $p = 0.09$) (Figs. 1 and 2). This trend was relatively clear, with an approximately

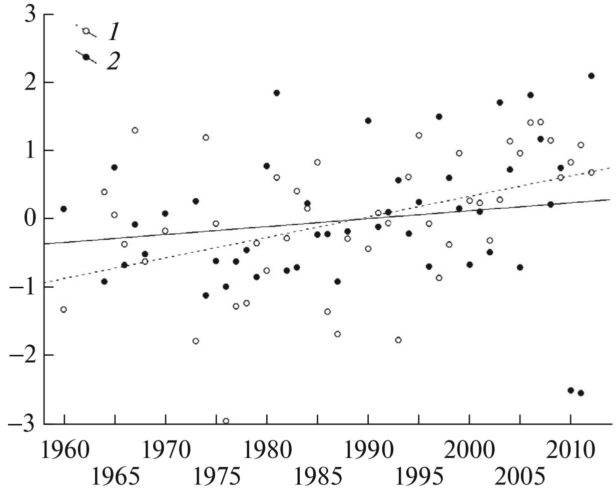

Fig. 1. Trends in the changes of the average daily air temperature (*1*; °C) and of the amount of precipitation (*2*; mm) during the period of migration activity of the common cranes (August–October) in the study area in 1960–2012; $r_s = 0.47$, $p < 0.001$ and $r_s = 0.25$, $p = 0.09$, respectively; standardized data.

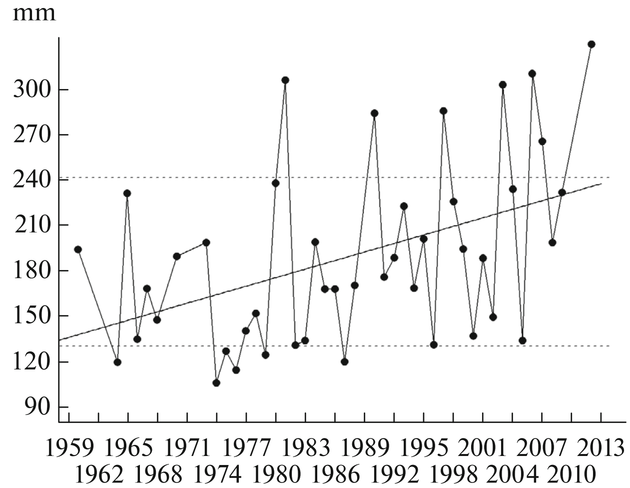

Fig. 2. Changes of the amount of precipitation in the period of existence of the migration stopover of common cranes (August–October) in the study area in 1960–2012; a trend to increase, $r_s = 0.25$, $p = 0.09$.

40-mm increase of the amount of precipitation during the years 1994–2012 as compared to the years 1960–1993 ($t = -2.56$, $p < 0.01$). However, the number of days with precipitation remained almost the same, with 41.8 ± 7.7 days in 1994–2012 ($n = 27$) and 40.3 ± 8.2 in 1960–1993 ($n = 19$). There was no difference between the samples ($p = 0.23$), and no trend was detected ($p = 0.14$).

A clear trend for a later advent of cold weather in autumn was observed during the study period. In particular, the transition of the minimal daily temperatures to values lower than 5°C and 0°C occurred progressively later in 1994–2012 ($r_s = 0.54$, $p < 0.02$ and $r_s = 0.81$, $p < 0.00002$, respectively). The stable transition of the average daily temperature below 0°C also shifted to a later date ($r_s = 0.55$, p < 0.01). This transition occurred on the 30th of October (± 10.3 days) in 1960–1993 and on the 11th of November (± 11.1 days) in 1994–2012; the difference was significant ($t = -3.77$, $p < 0.0004$). The transition of minimum daily temperatures below 0°C was more significantly shifted to later dates (Fig. 3).

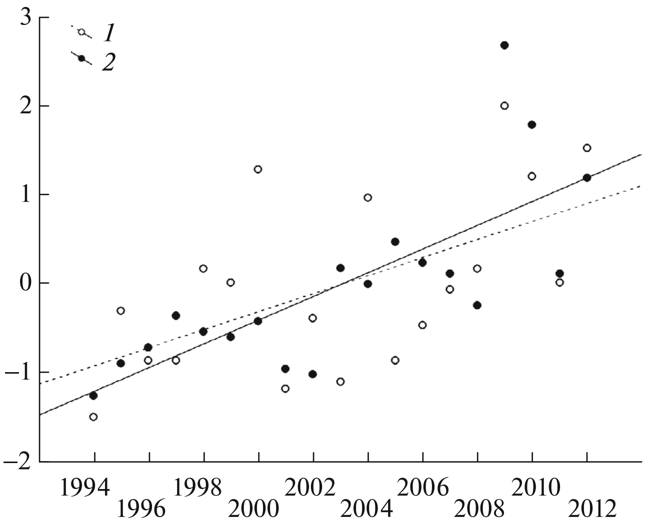

Fig. 3. Trends in the changes of the dates of transition of the average (*1*) and minimal (*2*) daily air temperature to below 0°C in the period of migration activity of the common crane (August–October) in the study area in 1994–2012; $r_s = 0.55$, $p < 0.01$ and $r_s = 0.78$, $p < 0.00002$, respectively; standardized data.

Timing of the beginning of migratory congregation formation. No shifts in the timing of the start of the autumn gathering of the common cranes were identified in the study area in 1994–2012 (no significant change was detected; $r_s = -0.24$, $p = 0.33$). However, there was a significant correlation between the date of the beginning of the formation of migratory congregation and the date of ultimate transition of the minimal daily temperature below 10°C ($r_s = 0.52$, $p < 0.02$) (Fig. 4).

The time of the beginning of the autumn gathering did not depend on the time of arrival of the common cranes in spring ($r_s = -0.22$, $p = 0.36$). Attempts of detecting a correlation between the dates of the beginning of the gathering and climatic indices, average daily air temperature, or the amount of precipitation in August and in the previous minths were unsuccessful. There was no apparent trend in the dates of transition of the minimal daily temperature to values lower than 10°C ($r_s = 0.32$, $p = 0.19$), similarly to the case of

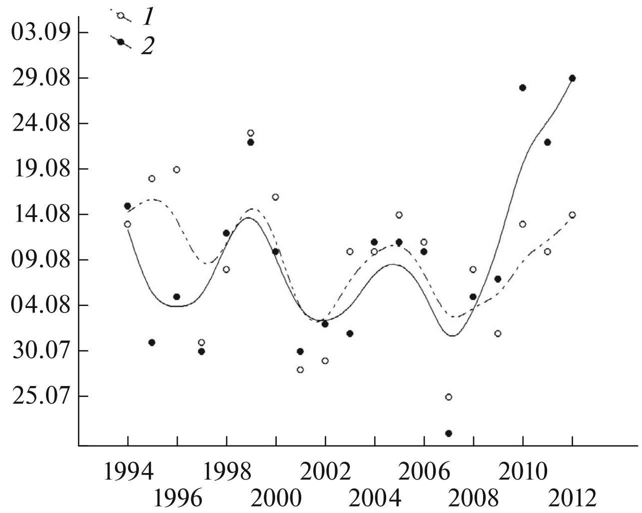

Fig. 4. Dynamics of the dates of the beginning of formation of the autumn gathering of common cranes (*1*) and the transition of minimal daily temperature below 10°C (*2*) in the study area in 1994–2012; the dependence between the events is statistically significant, $r_s = 0.52$, $p < 0.02$.

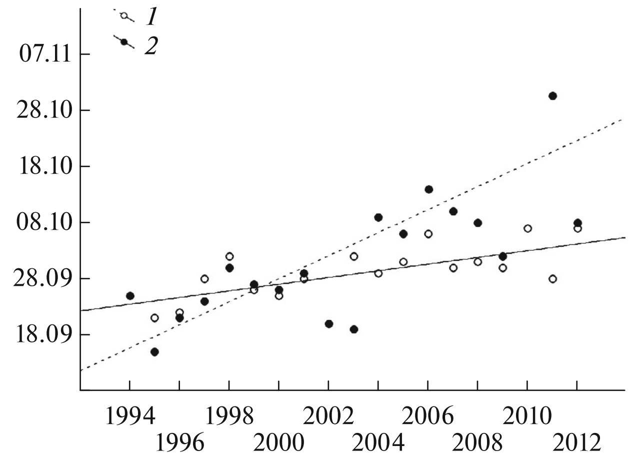

Fig. 5. Changes in the timing of common crane departure (*1*) and the dates of the transition of minimal daily temperature to below 0°C (*2*) in the study area in 1994–2012, $r_s = 0.66$, $p < 0.002$ and $r_s = 0.81$, $p < 0.00002$, respectively.

the dates of the beginning of the formation of migratory congregation.

Timing of common crane departure. Common cranes usually depart from the north of the Moscow Region between September 15 and October 15, on 28.09 ± 5 days on average. A significant trend for the shift of departure to later dates was observed in 1994–2012 ($r_s = 0.66, p < 0.002$). No correlation between the timing of departure of the birds and the average monthly temperatures in September or October was observed. There were no correlations between this event and the average air temperature in any of the decades or any half of month in September or October. The only positive correlation was found between the date of departure of the common cranes and the average air temperature in the period from September 15th to September 30th ($r = 0.48$, $p = 0.039$). Since the departure of the cranes occurred during the second half of September in more than 60% of all cases (12 years of 19 monitored), the observed correlation is of considerable interest.

A highly significant correlation between the time of the transition of the minimal daily temperatures below 0°C and the date of crane departure was observed ($r_s = 0.64$, $p < 0.003$). The departure took place on average within 5.4 days after the transition of the minimal daily temperature below 0°C, and these events coincided or occurred within 1 or 2 days in almost half of the cases (47.4%) (Fig. 5).

The amount of precipitation also had an effect on the departure of the common cranes: the departure occurred later in rainier autumn seasons as compared to the seasons with less precipitation ($r_s = 0.49$, $p < 0.03$) (Fig. 6). The number of days with precipitation played an important role as well; if there were more such days, the departure of the birds from the Moscow Region started later ($r_s = 0.51$, $p = 0.026$).

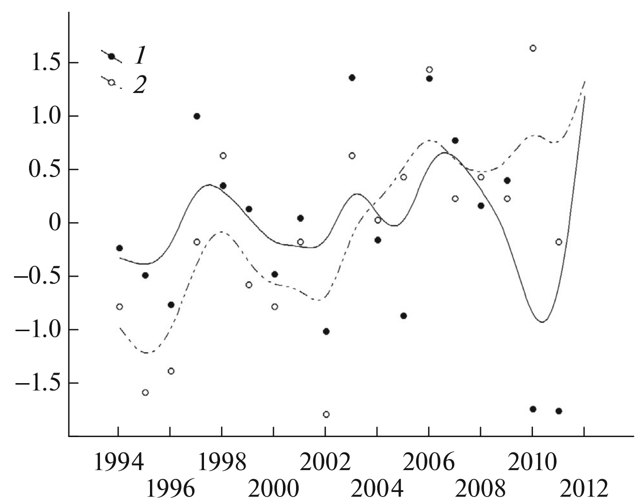

Fig. 6. Dynamics of the amount of precipitation during August–October (*1*), and the dates of common crane departure (*2*) in the study area in 1994–2012; $r_s = 0.49$, $p < 0.03$; standardized data.

No significant correlations between the time of departure of the cranes and the climatic changes, including the circulation indices that characterize the weather changes over large territories were observed for any of the months during which the migratory congregation existed. However, a clear trend was apparent as the data for the time interval from August to October (when autumn migration activity of the common crane takes place) were pooled ($r_s = -0.69, p < 0.002$). Higher values of the EA/WR index corresponded to later

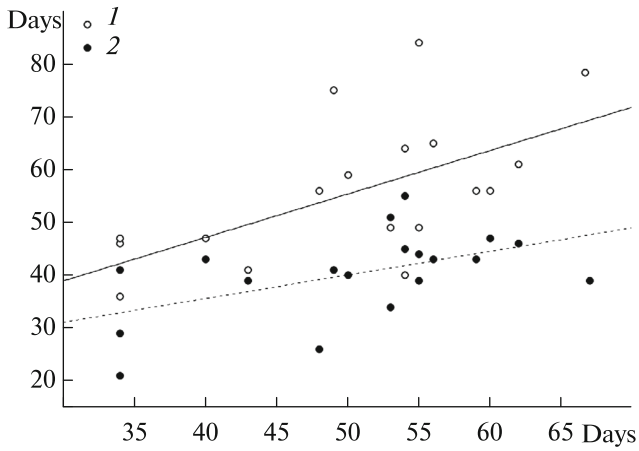

Fig. 7. Dependence of the duration of the autumn migratory gathering of common cranes (*X* axis) on the length of the period with positive minimal temperatures (*1*) and the number of rainy days in August–October (*2*) in the study area in 1994–2012, $r_s = 0.72$, $p < 0.0005$ and $r_s = 0.50$, $p < 0.03$, respectively.

departure of the cranes from the study area; positive values of the index correspond to lower temperature and higher average humidity in the European part of Russia.

Duration of the period of autumn gathering of the cranes. The duration of the autumn stay of common cranes in the study area in autumn increased during the monitoring period ($r_s = 0.57$, $p < 0.012$), mostly due to later departure of the birds ($r_s = 0.54$, $p < 0.018$).

The duration of the existence of the migratory congregation was not correlated to average and minimal daily temperature during various time intervals in August–October. However, the analysis of minimal daily temperature dynamics revealed a correlation between the duration of the stay of the cranes and the duration of the time interval with positive minimal temperatures (the number of days between the dates of transition of the minimal daily temperature to values lower than 10 and 0°C). The increase in the number of days in the above mentioned time interval corresponded to a longer stay of common cranes in the Moscow Region ($r_s = 0.72$, $p < 0.0005$) (Fig. 7).

Precipitation has a pronounced effect on the duration of the stay of cranes in the north of the Moscow Region in autumn as well: the birds stayed in the area for a significantly longer time during seasons with more precipitation. Correlations between the duration of the stay of the cranes in the north of the Moscow Region and the total amount of precipitation in August–October ($r_s = 0.50$, $p < 0.03$), the amount of precipitation in October ($r_s = 0.46$, $p < 0.05$), and the number of rainy days in August–October were detected ($r_s = 0.50$, $p < 0.03$) (Fig. 7).

A significant correlation between the duration of the stopover of the cranes in the north of the Moscow Region and the average value of the EA/WR climatic index in August–October (time when the migratory congregation exists) was detected as well ($r_s = -0.76$, $p < 0.0002$). Higher values of the index correspond to shorter duration of the existence of the migratory congregation in the study area; positive values of the index correspond to lower temperature and higher average humidity in the European part of Russia.

DISCUSSION

A large number of studies on global warming and the related ecological effects was published in the recent years, although the opinions on the assessment of these effects vary greatly. Changes in the phenology and migration due to climate and weather fluctuations are unique for each bird species. The majority of studies revealed earlier departure from breeding sites for long-distance migrants (birds that breed and spend the winter at different continents) and an opposite trend for short-distance migrants (Cotton, 2003; Jenni and Kery, 2003; Beaumont et al., 2006; Tottrup et al., 2006; Morozov, 2007; Miller et al., 2015; etc.). The impact of the weather and climate parameters on the dates of departure may be less pronounced for long-distance migrants, because most of these species leave the breeding areas long before the onset of critical weather conditions. However, the departure dates of some warbler species (genera *Acrocephalus* and *Locustella*) from Hungary were shifted to later dates during the time interval between 1987 and 2004 (Miholcsa et al., 2009), although these species are typical long-distance migrants that spend the winter in sub-Saharan Africa. In our opinion all these findings are indicative of complex regulation of the timing of migratory activity in species with different migration strategies.

The current climate change in the European part of Russia is manifested as the increase in average temperatures of certain winter and spring months and an earlier transition of the surface air temperature to values higher than 0, 5, and +10°C in spring (Mirvis et al., 1996; Abakumova et al., 1998; Volkov et al., 2013; etc.). Analysis of meteorological data for the autumn period in the study area revealed considerable changes as well: for instance, the transition of air temperatures to values lower than 5 and 0°C was shifted to later dates, and the values of minimal daily temperature increased significantly. The latter observation is indicative of milder weather conditions during nighttime that is the most critical period for birds, especially the young ones. The duration of the period with positive temperatures in autumn increased in the study area, so that the advent of winter was delayed and the cranes could stay in the breeding areas (and at the migration stopovers) longer. The shift in the dates of departure of the cranes from the north of the Moscow Region showed that the birds used this opportunity.

The formation of pre-migration and migratory congregations before the flight to the south is characteristic of cranes in the Center of European Russia (Prange, 2008; Markin, 2013). These congregations are rather dynamic in the Moscow Region (Smirnova, 1997; Grinchenko and Sviridova, 2008); they are formed by groups of birds that have not bred during the current season, local breeding pairs, and migrating cranes gathered from the adjacent areas. Such congregations are usually (at least in the Non-Black Earth Zone) formed in areas with local breeding populations. The offspring of local birds is capable of flying by the time of the beginning of migratory congregation formation; however, these birds often retain a connection with the breeding territory where they spend the night, regardless of feeding at the same sites as the migrants.

Wintering sites of the common crane are located in western Europe, north and northwest Africa (to the north from Sahara), in the Middle East, and in northeast Africa (to the south from Sahara). The birds from the northern and central parts of European Russia migrate to Turkey, Israel, and northeast Africa, up to 2–4 thousand kilometers from the breeding sites (Markin, 2013), and thus they belong to the intermediate group between short-distance migrants and long-distance migrants. The importance of weather for common cranes during the non-breeding season (migration and wintering) was reported by a number of researchers (Vegvari and Kovacs, 2012; Salvi, 2012; Lundgren, 2012, Nowald et al., 2012; Mingozzi et al., 2013; etc.). For instance, the number of cranes that wintered in France was correlated with the average temperature during the winter months: fewer birds arrived to the area during colder winters (Salvi, 2012). The dependence of the distance between crane breeding and wintering sites on climatic characteristics, and the NAO index in particular, was reported by German researchers; reduction of the median distance from 2041 to 677 km (that is, more than twice) was registered between 1997 and 2006 (Nowald et al., 2012). Recent studies of the autumn migration of cranes in Ukraine revealed a trend to earlier beginning of transit through the country, as well as a trend to later ending of this transit (Grishchenko, 2007).

Research on seasonal migration in a range of species showed that the flight between the breeding areas and the wintering areas takes more time in autumn than in spring (Tottrup et al., 2006, 2012; Litvin, 2014). Birds often spend much time at stopovers and gradually progress to the wintering sites after the weather conditions along the flyways become less favorable. A clear trend for the shifting of the wintering sites of cranes towards the north has become apparent during the recent decades, both in Europe and in the Middle East (Alon, 2001; Prange, 2008, 2011; Filippi-Codaccioni et al., 2011; Nowald et al., 2012; Shanni et al., 2012). On the other hand, there is a clear tendency to displacements of many migratory stopovers from the northern and central regions of European Russia towards the southern regions of European Russia (Ilyashenko and Markin, 2012). Therefore, the distance between breeding and wintering sites of the common crane decreased. Thus, both the delayed onset of cold weather in autumn and the decrease of the length of the flyways enable longer stays of the birds at migration stopovers.

Dates of the beginning of the formation of migratory congregation of the common cranes in the north of the Moscow Region did not change throughout the monitoring period and did not depend on the time of arrival of the birds in spring. We initially assumed that earlier arrival could lead to an earlier beginning of migratory congregation formation in autumn, but this hypothesis proved wrong. Thus, the formation of a migratory congregation (one of the stages of autumn migration activity in the cranes) depends neither on the time of arrival of the birds in spring nor on the time when the nesting period is over, although earlier breeding was followed by earlier migration in a range of passerine bird species (Sokolov, 2006). The beginning of congregation formation is probably largely controlled by the dynamics of the local weather conditions, and especially by the annual features of the shift of the temperature regimen from the "summer" type to the "autumn" type. The ultimate transition of the minimal daily temperatures below 10°C is among the markers of the event mentioned above. This transition of temperature defines the ending of the active vegetation period of most cultivated plants in the temperate climate zone of Russia (Pavlova, 1968); thus, cranes can perceive this transition as an indirect sign of the ripening of cereals that serve as the main food source for the birds during the autumn migration, including the period of pre-migratory congregation formation.

There were no significant changes in the dates of the beginning of migratory congregation formation in the area, but the departure of cranes from the north of Moscow Region occurred significantly later. Similar trends were observed for this species in other regions of Europe (Grishchenko, 2007; Prange, 2008, 2011; Sarychev, 2011; Salvi, 2012; Mingozzi et al., 2013). In our opinion, the delay of the departure from the north of the Moscow Region is due to the warming of the autumn period, and especially due to shifting of the transition of average and minimal daily temperatures below 0°C to later dates. The ultimate transition of the average daily temperatures to values lower than 0°C currently occurs 11–12 days later than in the second half of the past century.

The present study pointed at the level of minimal daily temperature (that usually corresponds to night-time temperature) as the most important factor for the timing of the departure of cranes from the north of the Moscow Region. The long-term changes of average and minimal daily temperatures during the autumn period were somewhat dissimilar in the study area, with a more pronounced trend towards warming observed for the nighttime. This is the most probable reason for a stronger dependence of the date of departure of the cranes on the minimal (nighttime) daily temperatures. This dependence is quite clear from the biological point of view, since the nighttime is the most risky period for birds (especially for the younger individuals) due to reduced activity and inability to feed in order to compensate for the energy expenses related to thermoregulation. The energy consumption for thermoregulation increases progressively during the autumn season as the night temperatures decrease (Dol'nik, 1995), while the possibility for the compensation of the energy expenses in the daytime remain the same or become poorer as the duration of the daylight period decreases. Thus, the birds are forced to migrate towards the south.

Later departure to wintering sites and the related increase in the duration of the migration stopover may be advantageous for the young birds, since they have more time to increase their fitness before the flight. As a result, the risk of their death on the flyway is reduced. Given the above, the assessment of threshold conditions that make the stay on the flyways or at the breeding areas more favorable than further flight seems of interest as the object of future studies.

The duration of the existence of the migratory congregation in the north of Moscow Region varies. Regardless of the interannual fluctuations, a general trend for longer existence of the stopover is apparent. This increase was accompanied by significant changes in a range of weather and climate characteristics, such as an increase of the average monthly temperature of most of the autumn months, a later onset of the winter season, and the increase of the duration of the period with positive temperatures. All these factors, alone or combined, can affect the time of departure of the birds. It was also found that the congregation of cranes persisted over a longer time during rainier autumn seasons. The latter correlation may indirectly reflect the general increase of the duration of the interval with positive temperatures during the autumn months, since the probability of rain on warm autumn days is higher than the probability of rain on cold days. The mechanism that underlies the impact of the amount of precipitation and the number of rainy days on the duration of the existence of the migratory congregation has not been completely clarified yet. A longer duration of cereal harvesting period, plowing of stubble fields, and sowing of wintering cereals in case of a rainy autumn may provide a putative explanation.

Modern bird species certainly had to adapt to both prolonged cold periods and climate warming periods during evolution; these climate changes could have been even more pronounced than the current climate change. In view of this phenomenon, the current changes in the phenology of spring and autumn migration of cranes can hardly be considered unique, although these changes undoubtedly are of interest as an example of response of migrating species to climate changes. Changes in the location of wintering sites and the flyway patterns, earlier arrival and later departure, and specific combinations of these phenomena turn out to be the first responses of migratory birds to climate changes.

REFERENCES

Abakumova, G.M., Isaev, A.A., Lokoshchenko, M.A., and Sherstyukov, B.G., Tendencies of changes in the climate of Moscow in the late 20th century, in *Priroda Moskvy* (The Nature of Moscow), Moscow, 1998, pp. 39–49.

Alon, D., The Hula Valley: an important stopover site for Western Palearctic birds, in *Wings over Africa: Proceedings of the International Seminar on Bird Migration: Research, Conservation, Education and Flight Safety,* Shefayim, Israel, 2001, pp. 203–212.

Austin, G. and Rehfisch, M.M., Shifting non-breeding distributions of migratory fauna in relation to climatic change, *Global Change Biol.,* 2005. vol. 11, pp. 31–38.

Barnston, A.G. and Livezey, R.E., Classification, seasonality and persistence of low-frequency atmospheric circulation patterns, *Mon. Weather Rev.,* 1987, vol. 115, pp. 1083–1126.

Beaumont, L.J., McAllan, I.A.W., and Hughes, L., A matter of timing: changes in the first date of arrival and last date of departure of Australian migratory birds, *Global Change Biol.,* 2006, vol. 12, no. 7, pp. 1339–1354.

Both, C., Piersma, T., and Roodbergen, S.P., Climate change explains much of the 20th century advance in laying date of northern lapwing *Vanellus vanellus* in the Netherlands, *Ardea,* 2005, vol. 93, no. 1, pp. 79–88.

Cotton, P.A., Avian migration phenology and global climate change, *Proc. Natl. Acad. Sci. U. S. A.,* 2003, vol. 100, pp. 12219–12222.

Crick, H.Q.P., The impact of climate change on birds, *Ibis,* 2004, vol. 146, supp. 1, pp. 48–56.

Dolnik, V.R., *Resursy energii i vremeni u ptits v prirode* (Energy and Time Resources in Free-living Birds), *Tr. Zool. Inst. Ross. Akad. Nauk*, St. Petersburg, 1995, vol. 179.

Filippi-Codaccioni, O., Moussus, J.-P., Urcun, J.-P., and Jiguet, F., Advanced autumn migration of the Common Crane *Grus grus* over Western Pyrenean passes, *Acta Ornithol.*, 2011, vol. 46, pp. 37–45.

Grishchenko, V.N., The phenology of autumn migration of common cranes in Ukraine, *Berkut,* 2007, vol. 16, no. 2, pp. 250–263.

Grinchenko, O.S. and Sviridova, T.V., The Common Crane pre-migratory congregation in Dubna (Moscow Region), in *Zhuravli Evrazii (biologiya, rasprostranenie, migratsii)* (Cranes of Eurasia: Biology, Distribution, Migrations), Moscow, 2008, no. 3, pp. 341–347.

Grinchenko, O.S., Smirnova, E.V., Zubakin, V.A., Dylyuk, S.A., Volkov, S.V., et al., Autumn premigratory assemblages of Common Crane (Grus grus) in the Moscow Region, *Ornithologia,* 2001, no. 29, pp. 250–259.

Guillemain, M., Pöysä, H., Fox, A.D., Arzel, C., Dessborn, L., et al., Effects of climate change on European ducks: what do we know and what do we need to know?, *Wildl. Biol.,* 2013, vol. 19, no. 4, pp. 404–419.

Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D.W., and Medina-Elizade, M., Global temperature change, *Proc. Natl. Acad. Sci. U. S. A.,* 2006, vol. 103, pp. 14288–14293.

Ilyashenko, E. and Markin, Y., Changes in the Eurasian crane (*Grus grus*) staging areas distribution in the European part of Russia from 1982 to 2007, in *Cranes, Agriculture, and Climate Change,* Baraboo, WI, 2012, pp. 88–99.

Jenni, L. and Kéry, M., Timing of autumn bird migration under climate change: Advances in long-distance migrants, delays in short-distance migrants, *Proc. Roy. Soc. B,* 2003, vol. 270, no. 1523, pp. 1467–1471.

Jonzén, N., Lindén, A., Ergon, T., Knudsen, E., Vik, J.O., et al., Rapid advance of spring arrival dates in long-distance migratory birds, *Science,* 2006, vol. 312, no. 5782, pp. 1959–1961.

Litvin, K.E., New data on migrations of geese breeding in Russia: A review of the results of remote-sensing tracking, *Casarca,* 2014, no. 17, pp. 13–45.

Lundgren, S., Cranes and climate change in Sweden, in *Cranes, Agriculture, and Climate Change,* Baraboo, WI, 2012, pp. 49–52.

Markin, Yu.M., *Seryi zhuravl' v evropeiskoi chasti Rossii* (The Common Crane in European Russia), *Tr. Oksk. Gos. Biosf. Zap.,* 2013, no. 29.

Marra, P.P., Francis, C.M., Mulvihill, R.S., and Moore, F.R., The influence of climate on the timing and rate of spring bird migration, *Oecologia,* 2005, vol. 142, pp. 307–315.

Mezquida, E.T., Villaran, A., and Pascual-Parra, J., Timing of autumn bird migration in central Spain in light of recent climate change, *Ardeola,* 2007, vol. 54, no. 2, pp. 251–259.

Miholcsa, T., Tóth, A., and Csörgõ, T., Change of timing of autumn migration in *Acrocephalus* and *Locustella* genus, *Acta Zool. Acad. Sci. Hung.,* 2009, vol. 55, no. 2, pp. 175–185.

Miller, R.A., Carlisle, J.D., Paprocki, N., Kaltenecker, G.S., and Heath, J.A., Annual variation in autumn migration phenology and energetic condition at a stopover site in the western United States, in *Phenological Synchrony and Bird Migration: Changing Climate and Seasonal Resources in North America, Studies in Avian Biology*, 2015, vol. 47, pp. 177–191.

Mingozzi, T., Storino, P., Venuto, G., Alessandria, G., Arcamone, E., et al., Autumn migration of common cranes *Grus grus* through the Italian Peninsula: new vs. historical flyways and their meteorological correlates, *Acta Ornithol.,* 2013, vol. 48, pp. 165–177.

Mirvis, V.M., Guseva, I.P., and Meshcherskaya, A.V., Tendencies of change in the time boundaries of the warm and growing seasons in the territory of the former Soviet Union over a long period, *Meteorol. Gidrol.,* 1996, no. 9, pp. 106–116.

Morozov, N.S., Changes in the timing of migration and winter records of the common buzzard (*Buteo buteo*) in central part European Russia: the effect of global warming?, *Zool. Zh.,* 2007, vol. 86, no. 11, pp. 1336–1355.

National Climatic Data Center. http://www.ncdc.noaa.gov/cgi–bin/res40.pl?page=gsod.html.

Nesterov, E.S., *Severoatlanticheskoe kolebanie: atmosfera i okean* (The North Atlantic Oscillation: Atmosphere and Ocean), Moscow: Triada, 2013. NOAA Climate Prediction Center. http://www.cpc.ncep.noaa.gov

Nowald, G., Donner, N., and Modrow, M., Influence of climate change on the wintering site selection of Eurasian cranes, in *Cranes, Agriculture, and Climate Change,* Baraboo, WI, 2012, pp. 55–59.

Palm, V., Leito, A., Truu, J., and Tomingas, O., The spring timing of arrival of migratory birds: dependence on climate variables and migration route, *Ornis Fenn.,* 2009, vol. 86, pp. 97–108.

Pavlova, M.D., *Praktikum po sel'skokhozyaistvennoi meteorologii* (Practical Course in Agricultural Meteorology), Moscow: Kolos, 1968.

Prange, Kh., The common crane in central Europe: breeding, autumn aggregations, migrations, wintering, and protection, in *Zhuravli Evrazii (biologiya, rasprostranenie, migratsii)* (Cranes of Eurasia: Biology, Distribution, Migrations), Moscow, 2008, no. 3, pp. 213–240.

Prange, Kh., Increase in the size of common crane population in Europe and changes along the western European flyway, in *Zhuravli Evrazii (biologiya, rasprostranenie, migratsii, upravlenie)* (Cranes of Eurasia: Biology, Distribution, Migrations, Control), no. 4, 2011, pp. 289–303.

Rechan, S.P., Malysheva, T.V., Abaturov, A.V., and Melankholin, P.N., *Lesa Severnogo Podmoskov'ya* (Forests of the Northern Moscow Region), Moscow: Nauka, 1993.

Salvi, A., Eurasian cranes (*Grus grus*) and climate change in France, in *Cranes, Agriculture, and Climate Change,* Baraboo, WI, 2012, pp. 71–76.

Sarychev, V.S., The common crane in the Upper Don basin, in *Zhuravli Evrazii (biologiya, rasprostranenie, migratsii, upravlenie)* (Cranes of Eurasia: Biology, Distribution, Migrations, Control), 2011, no. 4, pp. 303–311.

Shanni, I., Labinger, Z., and Alonet, D., A review of the crane–agricultural conflict, Hula Valley, Israel, in *Cranes, Agriculture, and Climate Change,* Baraboo, WI, 2012, pp. 100–104.

Sherstyukov, B.G., Seasonal features of climate changes in 1976 to 2011, in *Analiz zmenenii klimata i ikh posledstvii* (Analysis of Climate Changes and Their Consequences), *Tr. FGBU VNIIGMI-MTsD,* 2012, no. 176, pp. 3–12.

Smirnova, E.V., Ecological and historical aspects of the formation of seasonal aggregations of the common crane, *Grus grus* L.: the example of the Taldom premigratory aggregation, *Extended Abstract of Cand. Sci. (Biol.) Dissertation,* Moscow, 1997.

Smirnova, E.V., Aksenova, A.B., Sviridova, T.V., Konovalova, T.V., Grinchenko, O.S., and Zubakin, V.A., The staging area of the Common Crane in the light of landscape and land use history in the Moscow Region, *Proc. 3rd European Crane Workshop 1996 and Actual Papers,* Halle–Wittenberg, 1999, pp. 169–171.

Sokolov, L.V., The influence of global warming on timing of migration and breeding of passerine bird in the twentieth century, *Zool. Zh.,* 2006, vol. 85, no. 3, pp. 317–341.

Sokolov, L.V., Markovets, M.Yu., Shapoval, A.P., and Morozov, Yu.G., Long-term monitoring of the dates of spring migration of passerine birds on the Courish Spit, *Zool. Zh.,* 1999, vol. 78, no. 6, pp. 709–717.

Sokolov, L.V., Trop, E.A., Morozov, Yu.G., and Efremov, V.D., Effect of the temperature factor on the long-term fluctuations of the timing of migration, breeding, and dispersal of passerine birds, *Dokl. Biol. Sci.,* 2001, vol. 379, pp. 362–265.

StatSoft, Inc., 2001, STATISTICA (data analysis software system), version 6, 2001. www.statsoft.com.

Sviridova, T.V., Konovalova, T.V., Kol'tsov, D.B., and Zaspa, E.A., 2002. The Eurasian curlew, black-tailed godwit, and northern lapwing in agricultural landscapes of northern Moscow Region (Taldom district), in *Izuchenie kulikov Vostochnoi Evropy i Severnoi Azii na rubezhe stoletii* (Studies of waders of the Eastern Europe and northern Asia at the turn of the centures), Moscow, 2002, pp. 49–57.

Sviridova, T.V., Volkov, S.V., Grinchenko, O.S., Zubakin, V.A., Kontorshchikov, V.V., et al., Impact of farming intesity on birds of agricultural landscapes in the north of Moscow Region, *Razvitie sovremennoi ornitologii v Severnoi Evrazii. Trudy XII Mezhdunar. ornitol. konf.* (Development of the modern ornithology in the Northern Eurasia: Proc. XII Int. Conf.), Stavropol, 2006, pp. 371–398.

Tottrup, A.P., Thorup, K., and Rahbek, C., Changes in timing of autumn migration in North European songbird populations, *Ardea,* 2006, vol. 94, pp. 527–536.

Tottrup, A.P., Rainio, K., Coppack, T., Lehikoinen, A., Rahbek, C., and Thorup, K., Local temperature fine-tunes the timing of spring migration in birds, *Integr. Comp. Biol.,* 2010, vol. 50, pp. 293–304.

Tottrup, A.P., Klaassen, R.H.G., Strandberg, R., Thorup, K., Kristensen, M.W., et al., The annual cycle of a trans-equatorial Eurasian–African passerine migrant: different spatiotemporal strategies for autumn and spring migration, *Proc. Roy. Soc. B,* 2012, vol. 279, no. 1730, pp. 1008–1016.

Vegvari, Z. and Kovacs, G., The effect of climate change on the migratory patterns of the Eurasian crane in Baltic–Hungarian flyway, in *Cranes, Agriculture, and Climate Change,* Baraboo, WI, 2012, pp. 83–87.

Volkov, S.V., Grinchenko, O.S., and Sviridova, T.V., Changes in climate and weather parameters and their correlation with spring arrival of the common crane (*Grus grus*) in northern Moscow region, *Zool. Zh.,* 2013, vol. 92, no. 7, pp. 834–840.

Voloshina, O.N., Zudov, V.E., Krasnova, E.V., Oleksenko, A.I., and Markina, N.V., New data on the autumn aggregation of common cranes in northern Moscow Region, in *Soobshcheniya Pribaltiiskoi komissii po izucheniyu migratsii ptits* (Reports of the Baltic Commission for Studies on Bird Migrations), Tartu, no. 19, pp. 58–63.

Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., et al., Ecological responses to recent climate change, *Nature,* 2002, vol. 416, pp. 389–395.

Zalakevicius, M., Bartkeviciene, G., Raudonikis, L., and Janulaitis, J., Spring arrival response to climate change in birds: a case study from eastern Europe, *J. Ornithol.,* 2006, vol. 147, pp. 326–343.

Zubakin, V.A., Voloshina, O.N., Oleksenko, A.I., and Pancheshnikova, E.E., The common crane in Moscow Region and problems in its protection, in *Zhuravli v SSSR* (Cranes in the Soviet Union), Leningrad, 1982, pp. 75–83.

Translated by S. Semenova