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BIRD MIGRATION AND WEATHER: A SHORT-TERM FORECAST FOR THE BALTIC REGION

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Summary

This paper summarizes the results of bird migration research carried out over twenty years in Lithuania applying a whole set of migration investigation methods of which radar proved to be most effective. The results presented in the paper are available for use in solving the bird strike problem while applying short-term forecast of constituents of migration process of various birds (bird spring arrival, take-off, migratory flight en route, as well as formation and movements of bird concentrations during migration and wintering periods). The results obtained may be successfully applied not only in Lithuania but also in a large part of Eastern Atlantic Flyway - Eastern and Central Europe and some countries of Western Europe (e.g. Germany).

Keywords: Birds, Migration, Forecast, Baltic Region, Take-off, Spring Arrival, Staging and Wintering Concentrations

INTRODUCTION

The research into bird migration, concentrations during migration period, wintering concentrations and movements carried out in Lithuania in the last 2 decades may be successfully used in solving the bird strike problem not only in Lithuania but also in neighbouring countries of Central and Eastern Europe. In Eastern Atlantic Flyway birds migrate covering sufficiently large distances outside the boundaries of any one country. Hence, the material collected in Lithuania may find a much wider application - for a large portion of migratory flyway, i.e. the Baltic region. The more so as the material has been collected by two radars, i.e. in a rather large territory.

This paper is the second part of a cycle dedicated to bird migration forecast in the Baltic region. The first part was published in the material of BSCE - 23 Meeting in 1996 held in London and was dedicated to long-term forecast of bird migration, i.e. characteristics which are typical to the Baltic region and recur from year to year (Palakevieius, 1996). Similar works have been earlier published by authors who represent other countries and regions (Bruderer, 1992; McCloud, 1992; Alfiya, 1992; Leshem, 1992; Becker, 1992; Buurma, 1994; Alfiya, 1994, [etc.)] and applied in warning system of bird migration in aviation.

STUDY AREA

Observation of migration was carried out in airports of civil aviation of Lithuania: Palanga (Baltic coast) and Vilnius (continental part). As migrating flocks of birds were registered at the radius of 100 km in the coastal area the radar surveyed migration proceeding over the western part of Lithuania, south-west part of Latvia, great part of the Kuroio Spit and Kuroio Lagoon and part of Kaliningrad Region and Baltic Sea (total area reaching 30 thous. sq. km). The same area was covered by the radar in Vilnius able to survey part of south-eastern Lithuania and Belorus. Besides, the observed in Lithuania migrating birds are starting in territories extending far from observation sites. Also their territories of destination are far from Lithuania. For example, high-altitude migration occurring both above the continental part of Lithuania and the zone of the Baltic coast are formed by take-offs taking place in large territories, sometimes 1000 km long. Thus being observers in Lithuania we are onlookers of the process in its intermediate section in some period of time. Therefore, this information, migration patterns, characteristics may be successfully used for the adjacent territories of Eastern Atlantic Flyway, e.g, the whole Baltic region.

METHODS

The material on *en route* migration was collected from 1974 in spring and autumn in the continental part of the study region and in the coastal zone of the Baltic sea. Observation of migration was carried out by a 24-hour photoregistration of the screens of two radars with length of the wave 10 cm in airports of civil aviation of Lithuania: Palanga and Vilnius. Intensity of bird migration is understood as the absolute number of echoes observed simultaneously on the screen of the radar per certain time unit. Intensity of bird migration over the night (or day) was obtained by summing up the intensities of bird migration during single hour of the night (or day). Thus any change in the intensity of migration in the course of the night (or day) influenced the volume of migration of the whole night (or day). To study the dynamics of nocturnal migration we used a widely accepted division of the night into consequent hours beginning with sunset. Analogically the timing of diurnal migration was done beginning with the local sunrise. Together with radar the following methods have been extensively used: a network of visual observation points throughout the whole territory of Lithuania, mist-nets, moonwatching, records of voices of nocturnal migrants, the method newly discovered in our laboratory, namely, investigation of nocturnal migration in the dispersed electric light of the greenhouses, which has proved to be greatly convenient, valuable and greatly effective. Study of phenology of birds arrival is based on the material of investigation in the environs of Vilnius, Lekeeiai, Puvintas, Kuroio Spit. For comparison, the results of investigation in Estonia and the Ukraine have been processed. Take-off areas were predicted using radar data on main directions and speed of migration during the first day or night after the take-off. It is known that diurnal migration is formed by birds leaving their staging areas at sunrise, whereas nocturnal, during the first hour after sunset (with passerines making the majority of Baltic migrants) or during the last two hours before sunset (waterfowl). Sometimes diurnal migration was the continuation of heavy nocturnal flight. These cases were not taken into consideration. On the basis of the rhythm ("from" and "to") of intensive diurnal and nocturnal flight, possible take-off locations (areas) forming peaks of migration

have been established. Cases with high density fiight and maximum migration were treated separately. Meteorological stations entering take-off areas have been marked out.
To elucidate the relationship between migration intensity and weather parameters there were selected 20 meteorological and synoptical variables and tendencies in their change:

- surface air temperature (°C};
- 24h trend in surface air temperature (°C);
- barometric pressure (mb);
- 24h trend in barometric pressure (mb);
- relative humidity (%);
- 24h trend in relative humidity visibility (km);
- cloud amount (scale number);
- low cloud amount (scale number);
- cloud altitude (km);
- cloud type (scale number);
- rain (scale number);
- surface wind direction (degrees);
- surface wind velocity (m/sec);
- 500m air temperature (°C);
- 24h trend in 500m air temperature (°C);
- 500m wind direction (degrees);
- 500m wind velocity (m/sec);
- cold and warm front passage (scale number);
- index of synoptical weather situation (scale number).

The 9 a.m. data were chosen as determinants for diurnal migration, the 9 p.m. data - for nocturnal migration. Index of synoptical situation was used taking into account directions of winds in different parts of cyclone (anticyclone) and directions of bird migrations over the territory of Lithuania.

For the diurnal take-off there were used meteorological data of 9 a.m., for nocturnal of 9 p.m.:

- surface air temperature (°C);
- 24h trend in surface air temperature (°C);
- 48h trend in surface air temperature (°C);
- relative humidity (%);
- barometric pressure (mb);
- 24h trend in barometric pressure (mb);
- 48h trend in barometric pressure (mb);
- cloud amount (scale number);
- low cloud amount (scale number);
- cloud altitude (km);
- wind direction in relation to migration direction (1-360°, scale number); - wind direction 24h prior to the take-off (1-360°, scale number);
- wind direction 48h prior to the take-off (1-360°, scale number);
- wind velocity (m/sec);
- wind velocity 24h prior to the take-off (m/sec);
- wind velocity 48h prior to the take-off (m/sec);
- visibility (km);
- weather (scale number);
- precipitation (mm);
- precipitation 24h prior to the take-off (mm);
- precipitation 48h prior to the take-off (mm).

There was also done the analysis of synoptical weather situation by the surface of the ground in the take-off area.
To make the forecast of the phenology of bird arrival in the study area there was used cluster analysis allowing to statistically reliably single out phenological groups (clusters) of bird arrival which phenophases appear similarly from year to year. The singled out groups as well as relations within them are presented in a form of dendrogrammes. The clusters demonstrate how synchronous is the appearance of birds in every phenological group. To develop the models of the

arrival of separate model bird species in the territory of Lithuania there were used different analyses: linear, exponential, logarithmic and power regression.
To elucidate the dependence of the changes in migration intensity upon weather variables there were used the methods of univariate and multivariate mathematical statistics. Multivariate mathematical statistics is represented by two methods: factor analysis and linear step-wise multiple regression. By means of factor analysis initial variables are changed for a smaller number of more generalized variables - factors. A factor joins the most related variables. The use of the method of linear step-wise multiple regression allowed to develop models for separate processes of migration in the form of equations expressing relations between migration intensity and weather variables under consideration. The equation characterises migratory changes under the influence of the changes in the meanings of each of the parameters acting together.
As the data of migrations are divided into 8 separate patterns of spring and autumn migration occurring in the daytime and night over the continental part of the study region and over the coastal zone of the Baltic Sea, calculations to develop multifactoral models were performed for every pattern separately.

RESULTS AND DISCUSSIONS

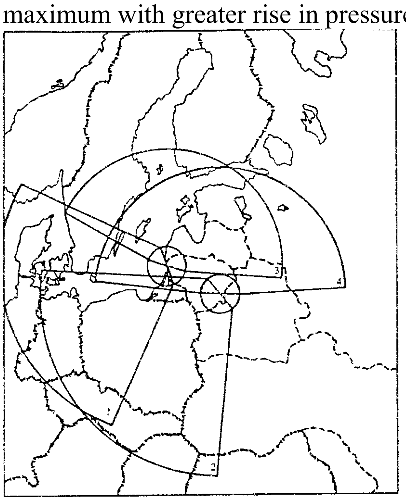
First spring arrival of birds

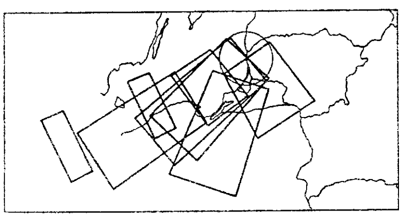
According to our data the arrival to the territory itself appears to be *almost* identical each year, though, the beginning of the process strongly depends on the temperature conditions of the season. For late-arriving species this deviation is significantly large in the beginning of the season of arrival and very minimal at the end of it. For early migrants, the deviation appears to be identical throughout the whole course of bird arrival. Moreover, the difference in time of the beginning of arrival of early species in different years is greater than in late-arriving species. It is noteworthy that in different years the intensity of increase in arrivals varies in early and late migrants, i.e. in early-arriving species the intensity is almost the same both in case of an early and late spring, whereas with late-arriving migrants in case of an early spring the intensity of increase in arrivals is less in comparison with late spring (intensity growth is characterized as more speedy). Variations in the course of arrival in different years depend on temperature conditions and birds' urge towards nest territory.

Migratory take-off

Our studies show that high-altitude migration occurring both above the continental part of Lithuania and the zone of the Baltic coast are formed by take-offs taking place in large territories, sometimes 1000 km long (Fig. 1-3). Though often take-off areas are not so large. Thus the length of the take-off area for diurnal continental migration in spring was 400 km from Vilnius (maximum 900 km) occupying Southern Lithuania, Kaliningrad Region, Northern Poland, Western Belorus and the Ukraine. For diurnal coastal migration in spring, this parameter was 500 (800) km with birds taking off in South-Western Baltic Sea, North-Western and Southern Lithuania, Kaliningrad Region, Northern and Central Poland, Southern Sweden. The take-off area for nocturnal continental migration in spring occupied Southern, Western and Central Lithuania, Kaliningrad Region, South-Western Baltic Sea, Poland, Czech Republic, Hungary, Western Belorus and North-Western Ukraine making 600 (1400) km in total. Analogous migration in the coastal area initiated in the territory of 600 (1200) km occupying central and Southern Lithuania, Kaliningrad Region, South-Western Baltic Sea, North Poland, Southern Sweden, Denmark, Western Belorus.
In autumn, the take-off forming diurnal migration in the continent occupied the territory 400 (1000) km away from the observation site involving Western Russia, Estonia, Latvia, North-Eastern Lithuania, Northern Belorus. For coastal migration, the take-off area made 400 (900) km occupying NorthEastern and central Sweden, South-Western Finland, the Baltic Sea, Western part of Russia and Baltic States, central and Western Estonia and Latvia, North-Western Lithuania. Nocturnal autumnal migration in the continent was formed in staging areas 700 (1000) km away from the observation site. These were western Russia, South-western Finland, Estonia, Latvia, Lithuania, North-eastern Belorus, the Baltic Sea, Sweden. For coastal migration, the take-off occurred 600 (1000) km away and occupied Western Finland, Sweden, Baltic Sea, Estonia, Latvia, Lithuania, Kaliningrad Region, western part of Russia. Both continental and coastal migrations were formed by takeoffs from different territories due to geographical situation of the take-off sites for large scale-migration (land birds, making the majority of migrants in the region, being taken into consideration), as well as due to flight directions of migrants and configurations of the Baltic coast-line in Lithuania

and all East Baltic countries. It was especially characteristic of spring passage from the take-off sites in Poland to the continental part of Lithuania.
Approximation of climatic conditions of the take-off showed that birds left their staging areas with air temperature from 6.96±0.77°C to 10.28±1.17°C at night and from 5±0.4°C to 7.1±1.12°C in the daytime (flight with density 3 and density 4 being estimated separately; in 4 scale density of migration) or from 7.74±0.48°C to 8.44±0.52°C at night and from 5.38±0.45'C to 5.48±0.38'C in the daytime (overall estimation). Great difference between spring and autumn take-off was not observed. Nevertheless, 24h-change in temperature showed that in spring birds started migrating with rising air temperature (plus trend being 1.2-3.9 times greater than minus trend): while in autumn, with falling temperature (minus trend being 1.3-6 times greater than plus trend). Similar regularity was observed while analysing 48h-change in air temperature. The day prior to take-off, temperature started decreasing, the lowest temperature being reached during the day of taking-off. The greater temperature increase in spring and the greater temperature decrease in autumn associated with increasing density of the take-off (density 4 in Lithuania). Hence we see that birds left their staging areas on the second day (or night) after air temperature increase (in spring) or decrease (in autumn) with the greatest rise or fall in temperature. Besides, mass character of the take-off in concentration areas of birds and the density of following migration depends upon the value of these trends. Relative humidity varied from 70.5±1.14% to 91.1±0.96%. Minimum take-off tended to occur with higher humidity.
During nocturnal take-off barometric pressure varied from 1005.9t1.23 to 1019.1±1.14 mb. maximum take-off with the following pressure migration of density 4 occurring with higher pressure. During diurnal take-off barometric pressure varied from 994.8±2.79 to 1018.14±1.24 mb. The 24 hour change in barometric pressure showed that in autumn take-off occurred with rising pressure (the sum of plus trends is 1.6-23.6 times greater than that of minus trends), besides, the take-off became maximum with greater rise in pressure (in comparison to migration with density 3 over Lithuania).





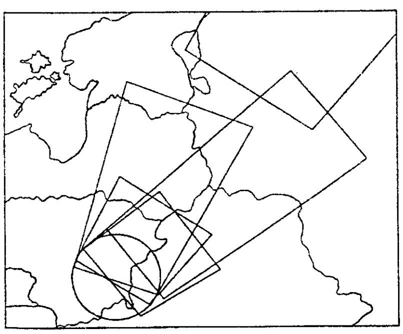


Fig. 1. Staging areas forming large-scale migration over coastal part of the study region (2, 4) and the coastal zone of the Baltic Sea (1, 3)

Fig. 2. Take-off territories of diurnal spring migration over the coastal zone of the Baltic Sea (April 23, 24, 26, 27, 28 and 29, May 2, 'i977)

Fig. 3. Take-off territories of daily continental migration of geese in autumn

The analysis of the 48h change in barometric pressure showed that in almost all migration patterns the majority of plus trends of barometric pressure over minus trends was observed in the day of take-off. This superiority was more significant in cases of maximum take-off in comparison with migration of high density. It needs to be stressed that the increase of barometric pressure was more significant in the day of take-off in comparison with trends of previous 24h periods.
Birds usually left their staging areas with following, following-side and side winds. In 10 migration patterns out of 16, take-off cases associating with opposing and opposing-side winds did not make over 25%. Mean wind velocity during the take-off was rather low and fluctuated from 2.25±0.2 to 3.7±0.28 mps. As a rule, during maximum take-off (migration of density 4 over Lithuania) mean wind velocity was lower.
The take-off of birds usually occurred with good visibility. Over 5 km visibility was observed in more than 70% of all meteorological stations in 10 (out of 16) migratory patterns.
During the take-off day, mean quantity of precipitation in one meteorological station made from 0.02 to 2.9 mm and in all 16 migratory patterns it was less in comparison with the day before (from 0.47 to 5.7 mm). The analysis of 48h change in precipitation showed falling amount of rain in the day of take-off in 14 migratory patterns out of 16 (from 0.1 to 4.6 mm).
As a rule, changes in weather parameters began already 24h before the takeoff. The rise in the frequency of occurrences with the increase of the angle between flight direction and absence of such a regularity with usual direction in a season corroborated the dependence of flight direction upon wind conditions. Birds exert take-off slightly changing their flight direction according to wind direction what occurs to be an adaptation to changeable weather conditions.
The above data show that the take-off of transit migration is conditioned by weather and occurs in concentration places of birds ready for flight when the weather favours migration (on the second day after the improvement of travelling conditions), i.e. with weak following or side winds, clear sky or sparce clouds, increasing or falling air temperature, increasing barometric pressure. Since the take-off occurs in large territories, we suppose that birds wait for favourable travelling conditions and take-off simultaneously. Favourable weather conditions stimulate birds to take-off. Thus the take-off with subsequent migration of high and maximum density is formed by interaction between inner rhythm of avian activity and external conditions of the flight stimulating the take-off itself. On the basis of this, waves of seasonal migration occur.

Migration *en route*

The method of factor analysis demonstrated that in the coastal zone of the Baltic Sea the intensity of autumnal nocturnal migration correlates with the factors of marked fall in temperature (24h trend) and following (or close to following) wind. In the daytime positive correlation is observed with the factors of following (or close to following) wind and rapid fall in temperature (24h trend); at night a less marked positive correlation is observed with the clear sky (or little cloudiness) and low temperatures; in the daytime negative correlation is observed with stormy weather. Over the continental part of the country the intensity of autumnal migration showed marked positive correlation during both diurnal and nocturnal flights with rapid 24h change in temperature. For nocturnal flight there was observed a less though significantly positive correlation with good weather and following (or close to following) wind; for diurnal - a less marked correlation with high relative humidity and little cloudiness. Table 1, elaborated according to the results of the method of multiple linear step-wise regression, illustrates the contribution of separate weather variables in different models of regression of the dependence of migration intensity upon meteorological and synoptical conditions. The table demonstrates that the most significant contribution in models of autumnal migration is made by the type of clouds, 500 m wind direction, surface wind velocity, visibility, low cloud amount, and surface wind direction. The most marked contribution in the model of spring migration is made by the weather variable of the 500 m temperature; the type of clouds, surface air temperature; rain and relative humidity being left behind. Furthermore, on the basis of multi-dimensional mathematical statistics it was defined that the models of autumnal continental migration are more accurately calculated than the models of coastal migration. Fig. 4 presents theoretical checking of the work of one of the models.

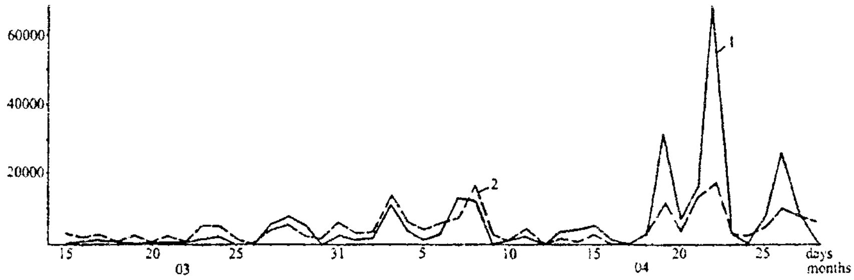


Fig. 4. Forecasting the dynamics of intensity of diurnal spring migration in the continental part of the region, 1975
1 - migration observed
2 - migration predicted by using formulas

Table 1. Contribution of weather variables (in %) to total variance during spring / autumn migration

Weather variable	Continental		Coastal	
	Diurnal	Nocturnal	Diurnal	Nocturnal
Surface air temperature	4.03/1.63	25.10/1.07	1.27/0.00	0.04/0.50
The 24-hour change in surface air temperature	0.00/0.3	0.00/1.32	2.27/0.10	0.00/0.16
Surface barometric pressure	0.10/1.40	0.15/0.07	0.00/0.50	0.07/0.14
The 24-hour change in surface barometric pressure	0.00/2.31	0.00/0.09	2.01/0.40	0.13/2.41
Relative humidity	6.16/0.00	1.64/0.85	0.04/0.00	0.00/0.20
The 24-hour change in relative humidity	1.77/0.10	1.10/1.30	0.04/0.10	0.37/0.50
Visibility	6.70/12.53	4.92/2.22	0.06/0.50	0.68/0.00
Cloud amount	0.20/0.01	1.87/1.57	0.08/0.00	1.69/0.00
Low cloud amount	0.20/0.08	0.01/0.19	0.10/0.10	0.12/7.70
Cloud altitude	0.20/5.83	0.02/1.21	0.88/0.00	0.44/0.01
Cloud type	34.80/4.39	0.82/25.20	3.22/20.90	14.72/0.02
Rain	1.84/1.31	12.68/2.98	17.67/5.70	3.06/2.37
Surface wind direction	0.63/0.03	0.20/0.00	0.18/9.10	2.92/3.00
Surface wind velocity	0.32/9.93	0.51/0.05	0.67/0.10	0.00/0.01
500 m air temperature	0.10/0.10	0.30/0.00	22.46/0.00	26.54/0.02
The 24-hour change in 500 m air temperature	0.00/0.26	0.02/0.00	0.30/1.40	0.25/0.50
500 m wind direction	1.80/16.27	3.30/11.60	3.79/1.20	0.00/19.60
500 m wind velocity	0.38/0.00	1.98/5.78	0.09/0.30	1.45/1.44
Cold and warm front passage	0.87/0.03	1.08/0.00	0.09/5.21	0.13/3.48
Index of the synoptic weather situation	0.00/0.14	0.10/0.00	0.56/2.30	0.63/0.01
Total	60.10/56.65	55.80/55.50	55.78/47.80	53.24/42.07

Reverse migration

Reverse migration is proved to be characteristic exclusively of the coastal zone especially when spring is comparatively late. According to the investigations of different years, the autumnal reverse migration was rather frequently registered at night. According to the worked-out 4 point scale of flight density, migration may be weak, medium, high and large-scale. Reverse migration was either weak (77% of all cases) or of medium intensity (23%). It is important to note that reverse migration is registered both in the beginning (33.3%) or end (22.3%) of migratory wave as well as during its highest peak (44.4%). The impact of different weather variables on flight density is demonstrated in Table 2. The density of reverse migration was defined to be mostly influenced by the type of clouds (39.5 % of total variance formed by all weather variables included in the model), surface wind velocity (31.2%), 24-h trend in 500 m temperature, surface temperature, total cloud amount, index of synoptical weather situation, cloud altitude, etc. Fig. 5 presents theoretical checking of the work of our model. Nocturnal autumnal reverse migration in the coastal zone of the Baltic Sea occurs in the conditions of clear sky or little clouds, strong wind, rise in the meaning of the

24h trend in 500 m temperature, basically in eastern part of cyclone or western part of anticyclone. These results demonstrate that nocturnal autumnal reverse migration is largely caused by strong head wind (opposed to the general flight direction), what proves the rightness of the hypothesis held by other authors (Able, 1974; Richardson, 1975).

Table 2. Contribution of weather variables (%) to total variance of the model of nocturnal autumnal migration in the coastal zone of the Baltic Sea

Weather variable	Unit of measurement	Total variance (%)
Surface temperature	°C	5.414
24-h trend in surface temperature	°C	0.141
Surface barometric pressure	millibar (mb)	0.037
24-h trend in surface barometric pressure	millibar (mb)	0.018
Relative humidity	%	0.0
24-h trend in relative humidity	%	0.811
Visibility	km	0.472
Coud amount	scale number	3.073
Low cloud amount	scale number	0.626
Cloud altitude	km	2.286
Type of clouds	scale number	28.73
Rain	scale number	0.017
Surface wind direction	in degrees *	0.571
Surface wind velocity	m/s	22.708
500 m temperature	°C	1.304
24-h trend in 500 m temperature	°C	6.824
500 m wind direction	in degrees *	1.079
500 m wind velocity	m/s	0.227
Passage of fronts	scale number	0.245
Index of synoptical weather situation	scale number	2.49
Total		77.073

* - angle between azimuth of the flight and wind

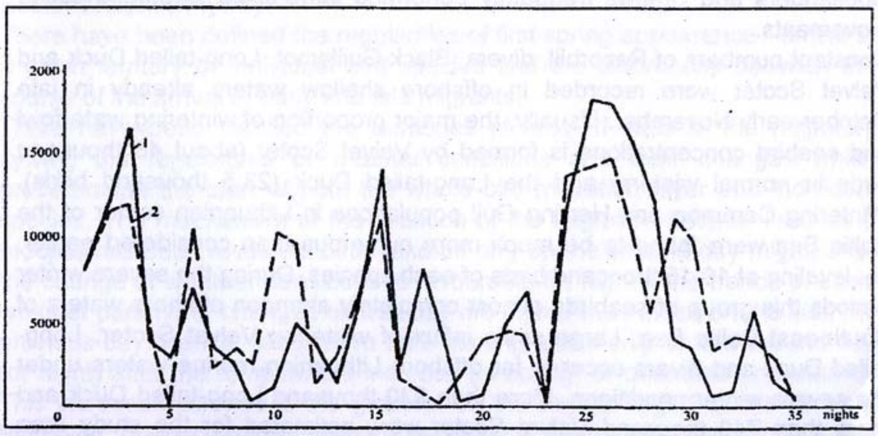


Fig. 5. Forecast of the dynamics of the intensity of nocturnal autumnal reverse migration in the coastal zone of the Baltic Sea:
1 - the flight observed
2 - the flight forecasted with the help of formulas

Staging and wintering concentrations - the source of birds migration and their movements in the region

32 staging waterfowl species are observed in Lithuanian inland waters. However, 3-5 main species comprise 80-90% of all birds observed in staging concentrations. Usually Coot, Mallard and Black-headed Gull are on the top of the list of most abundant species. Only in one of the largest lake of Lithuania - Dusia by their abundance there may be singled out Tufted Duck (in spring), Pochard (in autumn) and Great Crested Grebe (in summer). In all the lakes early spring total waterfowl

concentrations were larger than in late spring-early summer, however, they were smaller than summer waterfowl concentrations formed after postbreeding season. With northern arrivals added summer waterfowl concentrations became the most massive autumn concentrations. Formation of concentrations of separate waterfowl species in spring is determined by climatic situation. In summer and autumn the abundance dynamics of separate years in the same lake is quite similar. Several Lithuanian areas and particularly certain sites of the Kuroio Lagoon, Nemunas river delta area and large lakes of southern Lithuania are of major importance as staging grounds for 14 waterfowl species. The geographical location of these areas is essential, as they are situated on the main Eastern Atlantic Flyway which connects the northern breeding grounds with wintering areas via the coastline of the White and Baltic Sea.

Lithuanian inland wetlands regularly hold about 40 thousand wintering waterfowl. In a relatively small Lithuanian coastal area there are some major resorts of the internationally importance for wintering waterfowl populations. Lithuanian marine waters and the Kuroio Lagoon are particularly important to wintering populations of seaducks and divers. Concentrations of Goosanders and Smews, found in earlier unsurveyed Lithuanian coastal areas, are also particularly high. Like other seaduck species wintering just off the ice-limit, Goosanders and Smews frequently performed large-scale weather-induced movements.

Constant numbers of Razorbill, divers, Black Guillemot, Long-tailed Duck and Velvet Scoter were recorded in offshore shallow waters already in late October-early November. Usually, the major proportion of wintering waterfowl and seabird concentrations is formed by Velvet Scoter (about 48 thousand birds in normal winters) and the Long-tailed Duck (23.5 thousand birds). Wintering Common and Herring Gull populations in Lithuanian sector of the Baltic Sea were found to be much more numerous than considered earlier, i.e. leveling at 10-15 thousand birds of each species. During the severe winter periods this group of seabirds almost completely abandon offshore waters of South-east Baltic Sea. Large scale influx of wintering Velvet Scoter, Longtailed Duck and divers occur in far offshore Lithuanian marine waters under the severe winter conditions. More than 930 thousand Long-tailed Duck and more than 740 thousand Velvet Scoter were estimated for the study area after the Gulf of Riga became covered by ice in mid-February 1994. The coastal and offshore marine waters off Kuroio Spit are of vital importance for wintering populations of the Velvet Scoter and Long-tailed Duck. The main wintering areas of both species in the Eastern Baltic are found just off the average sea-ice limit. It is evident that the extent of the sea-ice distribution and availability of food resources seems to govern their wintering pattern. The other recently obvious important factor influencing bird wintering concentrations is global climate change. With climate change the number of wintering birds lingering closer to their breeding sites tends to increase and in recent years an increasingly large number of wintering birds is observed on Lithuanian Baltic Sea coast and economic zone of the Baltic Sea (Palakevieius, Dvapas, 1997).

CONCLUSIONS

Birds migrating by Eastern Atlantic Flyway cover a rather large distance between their breeding sites (migration start sites) and wintering sites (migration destination sites) crossing the borders of the countries of Eastern, Central and Western Europe. Unfortunately, investigations of these migrations in separate countries have been performed on diverse level, in various years and seasons, applying different methods of investigation. The enduring complex investigation of diverse processes in bird migration (diurnal and nocturnal, spring and autumn, over inland territories and the sea) performed in Lithuania applying unified methods of investigation and mathematical-statistical processing is unique in the region and may be favourably used in migration short-term forecast in Europe. This forecast may be adopted in solving the bird strike problem and ensuring the flight safety both in civil and military aviation not only in Lithuania but also in the adjacent countries - Poland, Germany, Russia, over the Baltic sea, Estonia, Latvia, Belorus, Scandinavian countries. It gains weight with NATO enlargement and accession of the associated countries to this organization. The data received reflect the regularities of the dependence of bird migration on environment conditions as well as migration control mechanisms characteristic to whole Eastern Atlantic Flyway.

There have been defined the regularities of first spring appearance - arrival to a given territory of individual bird species and the differences between the course of the arrival of early and (ate migrants. There have been clarified the territories of take-off sites in the migratory flyway, the regularities of weather conditions and their changes, which predetermine the start of both the whole bird migration layer and individual species. The mechanism of the initiation of the migration take-off itself as a process has been revealed: birds take-off only on the second day (night) after the change of weather conditions to favourable for flight if the trends of basic weather parameter changes on that day are higher than those on the first, i.e. previous day. Hence, birds leave their starting areas only on the second day (or night) after the temperature increase (in spring) or decrease (in autumn). This increase/decrease is the greatest on the day (or night) of the take-off. Moreover, mass character of the take-off in concentration areas of birds and the density of the following migration depend upon the level of these trends. The take-off was observed only on the second day after the improvement of travelling conditions. This is a special adaptation enabling birds to choose the most optimal conditions and time for their flight. All this lessens the degree of risk to encounter unfavourable, unexpected and sometimes fatal conditions. For 24h birds wait for still greater improvement of conditions ad interim synchronizing the inner endogenic mechanism - which releases the migratory waves - with the change of environmental conditions. There have been also defined the conditions of bird migration en route which are very significant for the forecast and predetermine not only the periods of migratory waves in the season but also the intensity of these waves - the number of birds over a given territory in a given period of time. The reasons to predetermine the rise and course of reverse migration have been cleared up. The studied connection between the course of various migration stages in separate bird species and weather variables as well as their alterations was determined to have both common and specific features. Hence, spring arrival, take-off and course of migration of all the bird species studied occurred at certain air temperatures (at increasing temperature in spring and dropping temperature in autumn), with high barometric pressure still increasing with weak tailwinds, at clear sky without rain, under good visibility conditions.

Species specificity in bird migration control system is more tangible and of great importance at the beginning of bird migration, i.e, for the dates of first spring arrival, the initiation of migratory flight - take-off. This specificity may vary markedly from species to species depending on the particular selective factors affecting the species. This specificity protects the species against the impact of unfavourable or even disastrous environmental conditions. It must be noted that the very first bird spring arrival to the territory, their migratory take-off is more dependent on weather conditions than the intensity in the migratory flight. These are the stages of utmost importance in the whole process of migration (Leito, 1989; Richardson, 1978, 1990). Birds' strategy to initiate the flight in environmental conditions ideal for migration provides a greater probability to continue migration under conditions favourable for orientation, energy and aerodynamics.

To design bird migration short-term, forecast for the Baltic region, it is advisable to know the situation in a given territory, i.e. where, when and what numbers of birds concentrate during a migratory flight and what movements might be expected. This is of significance not only during the periods of bird migration: due to the change of environmental conditions quite large movements of birds are also observed in winter when birds form concentrations in their wintering sites and their movements are induced by the change in the environment.

In such a way, this paper concludes the cycle dedicated to the forecast of migration in Lithuania and a great part of the Baltic region. Long-term and short-term forecast constitute an indivisible complex which is to be applied both in civil and military aviation in order to cut down the danger of bird strikes, ensure the safety of flights in a rather hazardous part of Europe with one of most intensive Eastern Atlantic Flyway over it.

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