BIRD MIGRATION MODELLING AND CONTROL: A DYNAMIC BALANCE BETWEEN ENDOGENOUS MECHANISMS AND ENVIRONMENTAL CONDITIONS

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Bird migration research in Lithuania have old traditions. In 1929, by the initiative of T. Ivanauskas a station of bird ringing and watching was set up in Ventės Ragas where up to 1931 the ringing was accomplished by rings of Rossiten production by lighthouse supervisor M. Posingis. Up to the end of 1932, more than 9000 birds have been ringed in Lithuania with 77 recoveries received. At that time Lithuania had 80 bird ringers united by prof. T. Ivanauskas, with another eminent specialist in bird migration investigation in Lithuania A. Vaitkevičius among them. The very first series of reports on ringing presented impressive results on wintering grounds of Lithuanian Starlings, White Storks, Lapwings, Crows, Rooks, Black Storks, Swallows, Rollers and Robins. Thus the first maps of bird migration in Lithuania have been compiled.

Since 1954 bird migration in Lithuania started to be investigated by a visual method. A great amount of work has been done by A. Vaitkevičius in Ventės Ragas and the Nemunas Delta. The accomplished work enabled to determine species composition, abundance in spring and autumn, flight periods and other characteristics as well as to define dependence of flight upon the landscape and changing weather conditions. A still further step, characterized by a new quality in bird migration studies in Lithuania was made in 1974, namely, a Laboratory of Ornithology was created in the Institute of Ecology (formerly Institute of Zoology and Parasitology). Naturally, the methods had to be updated in order to get qualitatively new information. A radar and automatic photo registration of its screen daily and seasonally came in use. The work has been done in Vilnius and Palanga enabling to collect unique information on the scale of diurnal and nocturnal altitudinal bird migration as well as to define its characteristics over the whole territory of Lithuania, a part of Latvia, Byelorussia and Kaliningrad region, the Baltic Sea and Kuršių Lagoon. That permitted to obtain new data on the so far unknown invisible altitudinal bird migration which, according to our knowledge, makes up even 90% of all the birds migrating over the territory of Lithuania. Together with radar the following means have been extensively used: a network of visual observation points throughout the whole territory of Lithuania (Vilnius, Kaunas, Raudondvaris, Obelija, Palanga, Juodkrantė, Ventės Ragas, Rokiškis, Žuvintas, Kartena), mist-nets, moonwatching, records of voises of nocturnal migrants, the method freshly discovered in our laboratory, namely, investigation of nocturnal migrations in the dispersed electric light of the greenhouses, which has proved to be greatly convenient, valuable and greatly effective.

The following statistical methods were used: step-wise linear multiple regression, cluster analysis, as well as linear, progressive, exponential, and logarithmic regression. 20 weather variables were used in analysing the dynamics of migration

density.

Complex studies of many years allowed to elucidate a full species composition of diurnal and nocturnal migrants, a lot of new positions of migration, their characteristics as well as to create a new theory of regulation of seasonal bird migration for the general bird migratory passage and to evaluate the migration regulation specificity in separate bird species.

Before our studies, much attention was paid to mechanisms controlling bird migration. The approach to the problem was two-sided. One school gave a detailed analysis of the influence of weather variables on initiation and course of the flight of separate species as well as a complex of migrants. The other proved the existence of endogenous program controlling migratory behaviour of birds and the influence of circanual rhythms on the dynamics of migration wave, only on some species. Both trends paid much attention to basic investigations of the schools omitting linking aspects. Only some articles pointed out possible endogenous program responses to environmental conditions. For all that, the majority of scientists working on physiology of bird migration thought that natural conditions do not act on endogenous program and are able to change only the tactics of the flight. This appears to be the result of specific conditions of the experiments: almost all of them were carried out with birds in cages. This allowed to mark out the character of manifestation of endogenous programs but correlation between endogenous mechanism and natural conditions was not outlined. Possible means of this correlation were considered by T. Alerstam (1978).

Our works conducted earlier pointed out to the inadequacy of the two trends to the reality, or free flight of migrants in nature.

The first question in studying transit migration over any territory is – what causes the appearance of migration wave in the season and in 24-hour period? Modelling of some species (e. g., Chaffinch in Russia) showed that autumn waves are stimulated by physiological state of a bird; the part of weather being minimal, since waves may also appear under similar constant weather conditions. Due to this theory every bird has its own individual rhythm of migratory state; in flock they synchronise stimulating migration waves. However, owing to some changes in environmental conditions, birds can't be ready for migration exactly at the same time every year. Consequently, year-to-year variations in the appearance of migration waves are inevitable. Moreover, migration wave of a concrete species may be identified only while using a complex of methods because birds fly at various altitudes and can't be detected by visual method only – what was the basis of the theory.

As for the tactics of migration, it for the most part depends upon environmental conditions forming the character of migration, i. e., altitude, species composition, dynamics, direction of the flight, flocking, territoriality, etc. Different year-to-year environmental conditions determine different migratory movements from year to year what proves that migration to a great extent depends upon external conditions, their variability causing much trouble to migration forecasting.

Working in this direction on the basis of data obtained and our experience in migration modelling, a new theory of bird migration was worked out according to which the appearance and the course of migration wave is controlled by dynamic balance between endogenous mechanism initiating the wave (and completely ma-

nifesting itself in weather ideal for flying) and environmental conditions (acting on endogenous program and flight in nature) what conditions the appearance and the course of migration and migratory behaviour of birds. Arisen as an adaptation to the changes in the climate, the whole migratory movement is adapted to seasonal weather.

A very important moment supporting a new theory is a discovery of a new regularity referring to the structure of forecasting models of migration. Modelling of migration dynamics on the basis of the relationship between radar data and weather carried out in many countries gave the results of great exactness, but the model structure for different places was different. It didn't satisfy those who wanted to get a single model suitable for the use in different localities. Why? We knew that different scientists used different methods of gathering and treating the data what complicated the comparison of results. We used the same methods in modelling eight homogenous processes of migration: coastal diurnal and nocturnal migratory movements in spring and autumn and analogous migration processes in the continent. As a result, three weather variables limiting migration intensity were excluded, i. e., cloudiness and temperature, in spring; cloudiness and wind in autumn; and a regularity of the correspondence of model structure to external conditions was established, i. e., migration waves depend on weather veriable as much as it creates more unfavourable conditions for bird flight.

Different environmental conditions of the studied processes of migration suggest different model structures. The practical side of the regularity is important too. Unfavourable pressure of one of the main variables dominating, the prognosis is simplified and built according to only this particular weather variable, e. g., according to wind direction in mountain passes where migration occurs only with following wind; or according to temperature in Lithuania where spring migration occurs with lower temperature than autumn flight. Analogous examples can be found in the works of other authors (Geil, Noer, Rabol, 1974). Their modelling of spring migration with respect to months shows that the main weather variable, temperature, is more relevant in the beginning of migratory season, i. e., March, when temperature is lower and creates more unfavourable conditions for flight (correlation coefficient between the density of diurnal spring migration and temperature is 0.51 in March; 0.21 in April; 0.24 in May; while between the density of nocturnal spring migration and temperature it is 0.55; 0.37; 0.08, respectively).

On the basis of this regularity it should be explained that weather permitting, the flight occurs on the basis of endogenous mechanism. Bird migration depends upon environmental conditions as much as weather creates more unfavourable conditions for flight. In the first case, forecasting can be built according to weather. This dynamic balance between endogenous mechanism controlling migration waves and weather conditions stopping or starting this mechanism working is controlled by ecological conditions establishing the course of migration. The main weather variables may restrict and even stop migratory movement. This can be demonstrated by the worked out logical models for the main weather variables. The models are based on formulae of regression showing the relationship between the importance of a concrete weather in explaining dynamics of the flight and the degree of its unfavourability for migration in the season. The more the flight depends upon a weather variable

is, i.e. the greater its contribution to total variance of migration v. weather model. The tighter the relationship, the less the dependence of migratory dynamics in time upon endogenous program.

A series of works done with radar in summer enabled to detect a strong migration of the Common Scoter to moulting sites over Lithuania at the end of July and in the beginning of August. Visual observation points in Lithuania, Latvia and Estonia have been paralelly used. This migration taking part in high altitudes and mainly at night has not been registered in Lithuania yet. With the help of radar it has been clarified that 2/3 of spring and autumnal migratory passage over Lithuania keep NE-SW direction, and only 1/3 – NNW/NW-SSE/SE. These two large-scale migratory passages meet over the territory of Lithuania. Annually local variability of flight direction under the influence of changes in wind direction and velocity is observed. Within a certain range birds change their migratory direction adjusting themselves to existing seasonal winds. Migratory passages having encountered strong opposite winds form reversal migrations. However, the reasons of these migrations in high altitude and near earth surface can be very diverse.

Species composition in spring and autumn of above 160 species is made in every season. About 3/4 of all birds move at night. In Lithuania there are located lots of stop-over areas used by different migrant species. In the coastal area of the Baltic Sea there are also massive waterfowl wintering grounds serving as staging areas of spring migratory waves.

Apart from the elucidation of migratory characteristics in Lithuania, the following work has been done and modelled: the course of bird spring arrival, take-offs of diurnal and nocturnal bird migrations for upper and lower layers and separate species, the dependence of bird migration intensity on weather conditions: in spring and autumn, in the daytime and at night, over the continental part of the country, the Baltic Sea and sea coast.

The same migratory passsage gives a possibility to perform joint research works, to observe the state of separate species along their migration route, to work jointly in the sphere of the protection of birds, etc. Besides, many practical problems arise in connection with bird migration in aviation, nature protection, medicine and agriculture. Increase in speeds of modern airplanes is the reason for greater danger exerted by birds upon aircrafts. Bird-to-aircraft collisions account for numerous injuries and deaths of people, and damages of aircrafts. The greatest part of collisions occur during seasonal bird migrations.

Furthermore, migrating birds are carriers of arboviruses causing diseases dangerous for the man and domestic animals. The importance of migration is becoming greater in agriculture, hunting and nature protection and management what is connected with some international conventions: Bonn, Ramsar, Biodiversity, Climate change, etc. The role of migrations in the human ecology is also evident.