DEVELOPMENT AND APPLICATION OF RADAR METHODS FOR INVESTIGATION OF BIRD MIGRATION PARAMETERS OVER THE TERRITORY OF BULGARIA

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The aim of the present study is to use radar methods to examine and outline the dynamics of bird migrations over the territory of Bulgaria in the short-term (daily and seasonal) and long-term (long-term) aspect and to indicate the possibilities for application of the obtained data. For the implementation of this goal, the following five tasks were set: 1) Following the 24-hours dynamics of bird migration;2) Establishing the variations in the number of migrants on different days; 3) Establishing the variations in the number of migrants during the different seasons and within each migration season; 4) Following the long-term changes in the course of migrations; 5) Establishing the spatial characteristics of migrations - the main altitude zones and flight directions.

The investigation was based on X-band radar situated in kaliakra protected area and C-band radar in the region of Varna town. The data set used, collected for four consecutive years, is divided into respective parts for autumn and spring migration, as well as day and night migration. Distributed by days, these are 478 days and nights in the spring and 623 days and nights in the autumn, or a total of 1101 days and nights from a four-year period (2014–2017).

Volumetric scanning (in the range of 5 to 25 km from the radar position) and radial velocity data of the objects were applied, thus determining the speed and direction of the moving targets, in this case birds. An algorithm for quantification of birds, developed and tested in a number of previous studies in Europe (Dokter et al.

2011), was applied. For data processing a language and environment for statistical calculations R (R Core Team) were used for analysis and visualization of biological signals from meteorological radars.

The obtained results were presented in a poster and were published and discussed in both articles, attached as appendices to the thesis:

MICHEV, B., ZEHTINDJIEV, P., MARINOV, M. P. AND LEICHTI, F. 2017. Relationship between the intensity of nocturnal migration measured by radar and the anthropogenic mortality of birds. Acta zoologica bulgarica 69 (2): 229-237. SJR:0.217, ISI IF:0.369.

MICHEV, B., ZEHTINDJIEV, P., MARINOV, M. P. AND ZLATANOV, T. 2020. Patterns of Bird Migration Defined by a Weather Radar at Part of the East European Flyway (*Via Pontica*). Acta zoologica bulgarica 72 (2): 263-277. SJR:0.21, ISI IF: 0.354.

MICHEV, B., ZEHTINDJIEV, P., MARINOV, M. P. „Study of bird migration using a meteorological radar

The results obtained on the quantitative characterization of the migration of birds over the territory of Bulgaria by data from meteorological radar allow to draw the following conclusions:

1. Radar data are a valuable and indispensable source of information in the study of the flight of birds over large areas, in a large spatial volume, in round-the-clock observations and differentiation of ecological groups depending on the characteristics of their flight;

2. The radar data of the State Enterprise "Air Traffic Management" (SE ATC) and BirdScan MS1 of the AES GeoEnergy wind farm are most suitable for conducting radar ornithological surveys and for creating a multi-year archive;

3.The intensity of the autumn migration in comparison with the spring one is greater, with the best demonstrated differences in the night migration;

4. The intensity of night migration compared to day migration is statistically significantly higher;

5. The number of migratory birds may vary significantly from year to year, with the highest numbers recorded in spring 2016 and autumn 2014;

6. The main migration flow is concentrated mainly in the zone up to 900 m above sea level;

7. Quantitative information on migration derived from radar data shall be appropriate for use in a monitoring and risk management system for the construction and operation of wind farms and for the security of civil and other flights

8. The species composition of birds killed by moving vehicles and the dynamics of road mortality corresponds to the established by radar flight class "Sparrow-like birds" and to the dynamics of their migration during the same time period;

9. Our radar studies confirm the thesis of Gordo (2007) and other authors about the role of temperature as an essential climatic factor for the phenology and characteristics of migrations;

10. Mortality from vehicles during the flight is among the main negative anthropogenic factors during migration, as the mortality is highest near the places of rest and feeding of birds, near roads. It is necessary to assess the risk of motor vehicles when creating management plans for protected species and for management plans for protected species and protected areas, and appropriate conservation measures can and should be applied to mitigate this factor.

In conclusion, it is possible to state that the conducted studies allowed to obtain a complete, complex picture of the spring (day and night) and autumn (day and night) migration in a key area of the migratory route of the birds *Via Pontica*.