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Informational and analytical system for monitoring migration of migratory birds in Northern Kazakhstan

I A Zuban¹, I R Kassimov² and K S Zhadan¹

¹ Biology department, North Kazakhstan state University named after M. Kozybayev, 86 Pushkin street, Petropavl, 150000, Kazakhstan

² Information and communication technologies department, North Kazakhstan state University named after M. Kozybayev, 86 Pushkin street, Petropavl, 150000, Kazakhstan

E-mail: zuban_ia@mail.ru

Abstract. Nesting and stopping sites between nesting and wintering periods are of great importance for birds. The disappearance of these places as a result of human activity, the destruction of wetlands for use in agriculture does not allow birds to feed during the flight, which causes the death of birds during migration. The article is devoted to observations of migration of migratory birds of Northern Kazakhstan. The purpose of these observations is to track the population of birds, places of mass accumulation of migratory birds, wintering places. Modern satellite telemetry tools are used to monitor the route of movement and the time of stay of birds in certain local zones. Computer processing of data, stored on the server, allows to map the route, analyze, model and predict the behavior of birds during migration.

1. Introduction

Scientific and technological progress, in the original form as we know it, laid the Foundation for the “imaginary” primacy of man over nature and its resources.

Destruction of forests, drainage of swamps under the program for the development of virgin and fallow lands in Northern Kazakhstan, in order to increase the sown area of grain crops from 1954 to the 80s of the 20th century, led to the chronic degradation of these lands and to negative changes in the ecological situation in the vast region [1]. To ensure the development of virgin lands, colossal material and labor resources were involved [2]. The virgin saga was one of the largest projects of the second half of the 20th century, but together with the beginning of intensive consumption of biosphere resources, it served as one of the factors of the problem of a sharp increase in anthropogenic impact on the natural complexes of the region. The negative that is associated with virgin (soil dust storms and the death of pastures) is the result of a short-sighted policy of that time [3].

In the middle of the 20th century, new practical tasks of an applied nature arose before ornithology, which in many respects changed the whole style and direction of its work. Ecological ornithology, the subject of which is the structure and organization of the system of relationships between birds and their environment, is becoming a synthetic field of biology that is involved in solving both environmental and biosphere problems [4]. Among them are international programs such as “Species and its productivity in the areal”, “Global climatic change”, “Biodiversity conservation”, “Ecological monitoring” and many others. The overall goal of these programs is to study, conserve and restore biosphere resources and biological diversity, one of the important components of which are birds [5].



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2. Ecological monitoring in Kazakhstan

The current program for the development of the agro-industrial complex of the Republic of Kazakhstan contains the tasks for the efficient use of water and land resources of the country [6]. The list of measures for environmental protection includes measures that contribute to the stabilization and improvement of the state of ecological systems, conservation of biological diversity, rational use and reproduction of natural resources. At the same time, the environmental protection package includes technological and technical measures that can form information systems in the field of environmental protection and facilitate the provision of environmental information.

Today, new technical tools appear in the arsenal of ornithology. With the help of radar, fundamentally new phenomena in the ecology of birds were established: the heights and speeds of migrations, including nocturnal ones, in different parts of the planet, their daily cycle and their relationship with meteorological factors were determined [4].

Unfortunately, the question of the nature of the migration of birds in Kazakhstan was almost not subjected to a sufficiently detailed experimental study. Until recently, bird ringing in Kazakhstan was carried out at only four points: at the “Chokpak” bird ringing station (Western Tien Shan) in the Astrakhan reserve (Volga river delta, on the Kazakhstan border), in the Naurzum reserve and on the border of Pavlodar and Novosibirsk regions. An analysis of the available information on the movements of birds suggests that most of them are built on the basis of visual observations, which, given the vast territory of Kazakhstan and the small number of observers, cannot provide a complete answer to many questions regarding bird migration and their nesting [7]. Here we approach the activities of ornithologists, whose work is based on monitoring and its results.

According to V.S. Nikolaevskiy “Biological monitoring is determining the state of living systems at all levels of the organization and their response to environmental pollution. In other words, it is a system for observing, evaluating and predicting changes in the state of biological systems under the impact of anthropogenic influences” [8].

According to N.F. Reimers “Biological monitoring is tracking of biological objects (the presence of species, their state, the appearance of random introducers, etc.) and environmental quality assessment using bioindicators” [8].

In relation to ornithology, the main tasks of ornithological monitoring are:

- finding out the number, density, and species composition of the bird population;
- determination of the concentrations, routes, and timing of their migrations;
- to determine the changes in bird populations, their causes and the identification of sources of impacts.

The construction of any ecosystem model begins, as a rule, with the organization of operational and consistent access to arrays of primary data from field research. The nature and mechanism of summarizing information about the environmental situation and situation when moving along hierarchical levels of the monitoring system is determined using the concept of *an information portrait of the environmental situation*. The latter is a set of graphically represented spatially distributed data characterizing the ecological situation in a certain territory, together with the cartographic basis of the area [9]. At the same time, the process of data collection and processing requires automation in connection with their large volumes for a certain time interval.

To address the issue of automating the collection, storage and processing of data, a set of tools is needed, including satellite telemetry tools, data transfer tools and technologies, a computer system for analyzing, processing and forecasting based on the data received.

The computer system, included in the monitoring system, proposed by Yu.A. Israel in 1984 [4], can be represented as an information system. The classic block diagram is shown in Figure 1.

The general scheme of the monitoring system of migratory birds of Northern Kazakhstan can be presented as follows (figure 2).

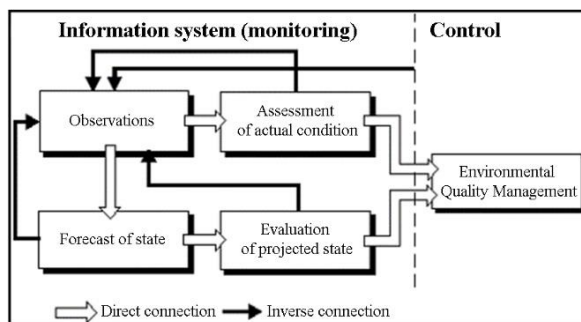


Figure 1. Block diagram of the monitoring system [Israel, 1984].

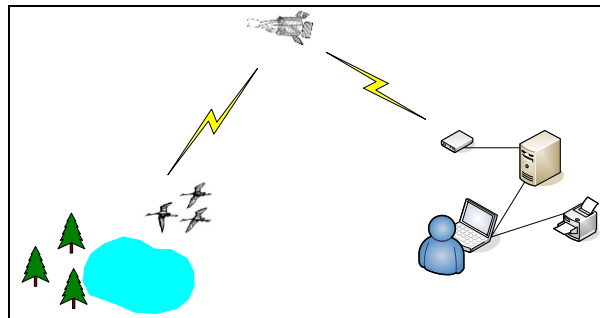


Figure 2. Monitoring system.

3. The architectural content of the monitoring system

Satellite telemetry opens up new possibilities for tracking bird routes and exploring their migration paths, which are unattainable with other methods. Modern trackers allow to get a continuous history of bird movements, providing data on the migration path, speed and duration of intermediate stops during flights. The long period of operation of satellite transmitters⁶ that use solar panels as a power source allows for long-term research, during which it is possible to determine the accuracy of certain migration routes and points of intermediate stops for several years.

In our study, the OrniTrack-N44 solar-powered neck collar [10] was used as a tracker for large species of geese. The GPS-GSM tracker has a waterproof case, equipped with three high-performance solar panels that power the internal lithium-polymer battery with protection against overcharging. Tracker flash memory of 128 MB capable of storing nearly 2,000,000 entries. The record contains the following data: UTC date and time, GPS position, GPS altitude, speed, direction, HDOP, battery voltage, battery charging current, instant acceleration (3 axes), temperature, magnetic field strength (3 axes) [11]. For observations, as soon as possible, 10 birds were equipped with trackers (figure 3).



Figure 3. Equipping a bird with a tracker.

Data from the tracker is collected and stored on the basis of the Glosendas (Global Location & Sensor Data Acquisition Systems) company's servers. The company provides customized solutions for collecting, transmitting, storing and processing data around the world. Tracker data is exported at intervals of 600 to 2073600 seconds by GSM.

Current trends in the development of computer technology make it unreasonable for the labor of each particular ornithologist or group of researchers to develop their own versions of the DBMS, GIS or Expert systems, since there are numerous versions of the appropriate packages and tool environments on the software market that differ only in the set of functions and capabilities, the internal implementation technique and cost [12].

On the Glosendas website, you can select the desired tracker and track movement data. The site allows exporting data values in a territorial context in separate files of the required format to a local

computer or server. In addition, for the visual display of data on a cartographic substrate, the site has a map from Google Maps (figure 4).

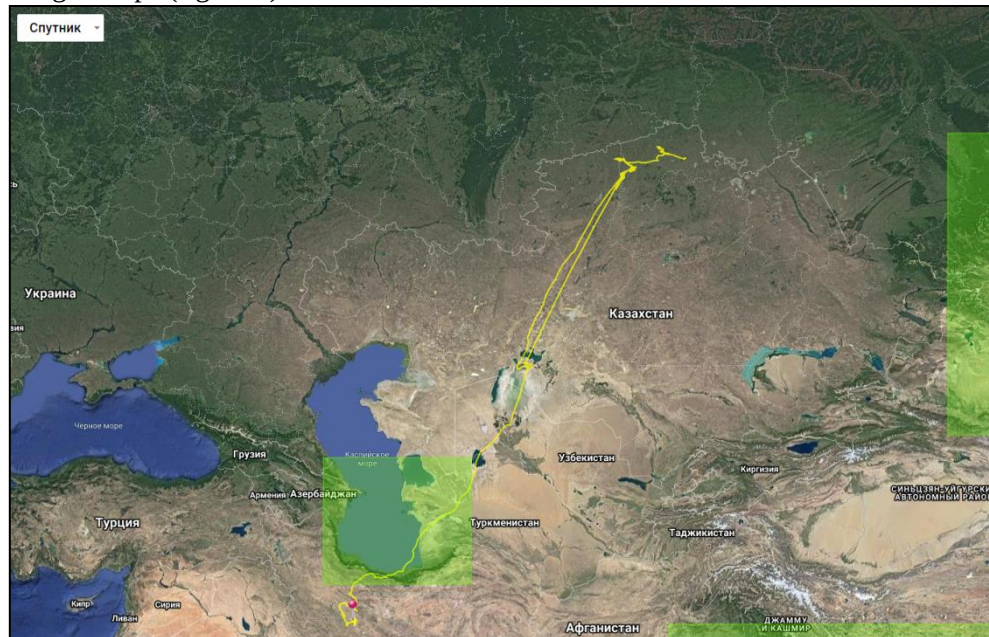


Figure 4. Bird route on the map according to the tracker.

The data stored after export is subjected to primary processing based on algorithms for converting and splitting data into the required format. It should be noted that the data is large. From the moment the first data was transmitted (mid-April 2019) and until mid-January 2020, only 1 tracker data is about 350 MB of information. Moreover, the data for the first 3 months alone represents more than 1,050,000 records in the database (MS Excel 2007 limits the downloaded data file to 92 MB or 1,048,576 records). Processing this amount of data occurs in stages.

Here is a block of code for converting tracker data from a .CSV file for subsequent processing using VBA MS Excel 2007:

```

...
Worksheets("Sheet1").Activate
For i = 1 To 1048576
x = Sheets("Sheet1").Cells(i, 1)
k = Len(x)
m = 1
l = 0
q = 1
For j = 1 To k
y = CStr(Mid(x, j, 1))
If y = "," Then
l = j - 1
j = j + 1
z = CStr(Mid(x, m, j - 1 - m))
Sheets("Sheet2").Cells(i, q) = CStr(z)
m = j
q = q + 1
j = j - 1
End If
Next j

```

Next i

...

After that, the analytical process of data processing based on the available data begins. This process includes data analysis at the sites where the bird spends the longest during nesting and wintering, as well as at feeding sites along the bird. These data can be tracked on the basis of indicators such as time, the position of the bird relative to the spatial coordinates, the coordinates of various waterbodies, etc.

For example, when we enlarge the map, we can see the route of movement, and, therefore, by entering the restrictions and highlight areas for research, to find out the time the bird spent in a given sector of the region (figure 5).

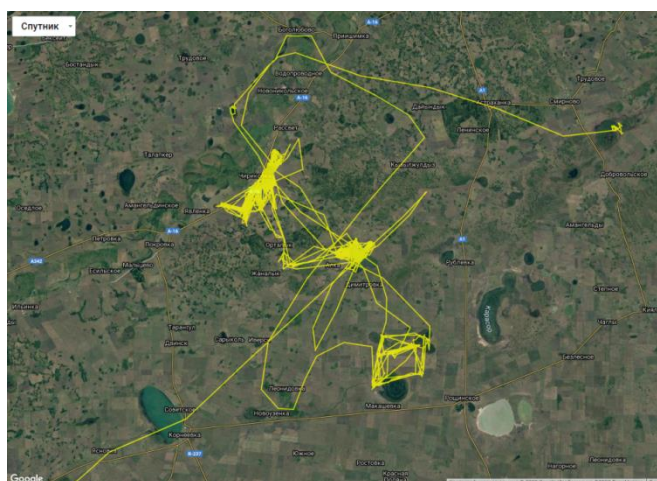


Figure 5. Route for moving a bird in a given region.

A group of analysts is engaged in modeling and mathematical processing of multidimensional observations, based on computer processing of data. The system includes a library of mathematical methods that synthesize a set of decision rules (a team of analysts) to assess the quality of the ecosystem and analyze the cause-effect relationships of this assessment with environmental factors in the region. Subsequently, routes that are most dangerous for migratory birds are identified, a forecast is made on their number. The construction of private and integrated ornithological monitoring maps based on estimated and predicted spatial models is carried out through the systematization, grouping and classification of multidimensional information stored in the database.

4. Conclusion

Obtaining objective data on the status of monitoring species is possible provided that the observations are carried out in the most characteristic habitats typical for each species, allowing them to fully realize their biological potential - to maintain the population size at the optimal level, to occupy the maximum area of the most habitable ecosystem types.

The informational and analytical system is designed to automate the process of collecting, storing, processing and presenting information on the state of the environment of migratory birds of Northern Kazakhstan. The system is the main link in the environmental management system for ornithologists in the northern region of the country.

All this ultimately allows for management decisions to protect the environment and habitats of migratory birds.

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