

# *The History of the Usage of GIS Technologies in Ecological and Faunistic Research*

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**Abstract** — The article provides a brief overview of the historical stages of the development of geographic information systems and describes the experience of their use in ecological and faunistic studies. The examples of using GIS for the ecological, geographical and spatial analysis of different groups of animals are given in this work.

**Keywords** — *geographic information systems, ecological monitoring, fauna, modeling, maps, forecasting, forecasting, zoogeography.*

## I. INTRODUCTION

A special place among modern environmental issue is devoted to the problem of the reduction of biodiversity, one of the fundamental phenomena that characterize the manifestation of life on the Earth. The reduction of biodiversity leads to the destruction of existing ecological relations, the degradation of natural groups and the loss of the biosphere integrity. Studying biodiversity, the researchers are faced with the need to analyze a significant amount of initial information, which creates significant difficulties in the cognition. In this regard, in addition to standard methods, the researchers started to use new methods based on geographic information systems (GIS). "GIS is a system for the management, analysis and processing of spatial-coordinated information for the purpose of its problem-oriented synthesis ..." [1].

With the help of GIS it is possible to connect a large amount of descriptive information that has been accumulated during the research process of biodiversity. The first geographic information systems appeared in the middle of the 20th century in Europe, Canada and the USA and were intended for multifunctional computer mapping and spatial analysis. At the second stage (the stage of state initiatives), a number of large geo-information projects were developed with the help of state funding. The third stage is characterized by

the development of corporate geographic bases created by means of GIS.

The environmental industry plays dominant role in the use of geographic information systems. However, as N.N. Smirnitskaya points out "in Russia, the environmental GIS at regional and local levels are usually used to solve one specific problem (to trace the degradation of flora or fauna, to make a model of the influence and distribution of certain types of chemical pollution using a specific parameter) [2].

## II. RESULTS

In order to use GIS in a particular thematic area, it is necessary, first of all, to formulate a problem that needs to be solved by means of GIS. In environmental resources management GIS technologies allow creating electronic maps reflecting the state of the environment of a territory; to carry out modeling of the phenomena occurring in the environment; to accumulate, to store and to request information on the state of the environment for specific periods of time; to estimate environmental risks for safety management in case of anthropogenic impacts on the environment [3].

Geographic information systems are used in the investigation of the state of specially protected natural areas for collecting, storing and managing the data [4]. Thus, in their study MG. Erunova and A.A. Gosteva based on the use of GIS technologies examined the state of the atmosphere, the level of soil contamination, the state of vegetation, the geographical location of the reserve, the influence of the city on the Stolby and Central Siberian reserves. The GIS ArcGIS was used during the creation of distribution maps of pollution. For the interpolation of the data by space, the Inverse Distance Weighted Interpolation (IDW) method was used [5].

GIS technologies are actively used in urban ecology for monitoring the state of the environment in areas subject to

significant anthropogenic impact. Their use allows providing a systematic approach to the analysis of the level of pollution, multi-variant mapping, and the ability to create new types of electronic maps for making specific business decisions [4].

Despite the fact that geo-information technologies appeared more than 50 years ago, they are penetrating into zoological studies rather slowly. There is a number of scientific works of national and international scientists, reflecting the experience of using GIS technologies for spatial analysis and mapping of different groups of animals. For example I.P. Kokorina in the study of birds' fauna with the use of GIS technology, faced a problem during the mapping of rare species, which is explained by the large number of zero abundance estimations. Zero estimations of abundance on the studied routes are related to the fact that when a person approaches, birds either hide or leave without taking off.

The comparative interpolation method using MapInfo and ArcGis with the analytical modules of Spatial Analyst and Geostatistical Analyst and the application for Arc GIS Typeconvert produced quantitative characteristics of the sections with zero abundance. Interpolation is the process of predicting values for those locations where there are no measured values, using reliable values obtained for other points. Data is transferred from one source set of ranges (key) to another set (target). For each key area, the desired value is assigned to a central point (centroid).

In order to build centroid polygons I.P. Kokorina tested the following interpolation methods: kriging (geostatistical interpolation), spline, moving average value, Inverse Distance Weighted Interpolation (IDW), Delaunay triangulation (TIN), and the construction of Voronoy polygons. According to the author, the most optimal method is the kriging method, with the help of which the surface map "Pre-mining abundance of black grouse on the West Siberian Plain (landscape groups)" was created [6].

In recent times, there has been a tendency to combine traditional approaches to the assessment of biodiversity with analysis capabilities offered by geostatistics, fractal geometry, etc. The use of remote-sensed data (RSD) on certain parameters, such as the presence or number of small animals or plants, is difficult due to insufficiently large scale of data and high mobility of animals. In this regard, geoinformation technologies are widely used for the analysis of spatial information, including the assessment of biodiversity and making decisions on its preservation without organizing full-scale studies of animals in nature [7].

A visual form of the results of zoogeographic research is a map of animal population. The study of animals as an object of mapping is always difficult, since they, unlike other components of the geosystem, which are available for direct observation and registration of their changes, have the ability to actively and distantly move, to select the habitats; the majority has a hidden lifestyle and are subject to significant seasonal and annual fluctuations, which makes the study much more difficult [8].

Therefore, during the process of creation of zoogeographic maps, many authors recommend using geobotanical maps.

However the data of geobotanical maps do not always give complete information, and sometimes they significantly differ from the results of the typological classification of animal population. For more accurate identification of the habitat of animals the aerial photographs, forest plans, landscape, topographic and other maps are used.

In order to visualize the structure of the population of faunal complexes, the researchers, using GIS technology, create maps. Thus, V.A. Prelovsky for the fauna of land vertebrates of the South Minusinsk Basin created a series of medium-scale and large-scale maps characterizing the population structure of both the faunal complexes as a whole and individual groups of animals. He created a series of maps: medium-scale maps "Faunistic Complexes of the South Minusinsk Basin" and "Disturbance of the Animal World of the South Minusinsk Basin", large-scale maps of key sections "Mammal population structure of the Lena Key Section" (figure), "Avifauna Population Structure of the Krasnoozersky Key Section".

Additionally, he attracted the satellite images (Landsat, Googlemap.com), forest plans, landscape, topographic maps and land use patterns of the administrative districts of the Republic of Khakassia and the Krasnoyarsk Territory [8]. During the course of the creation of maps, stationary and route data collections, literary data, information from institutions, and collection materials of museums are taken into account.

As many authors point out, maps are the most convenient for visualizing information on biodiversity. They reflect the size of the ranges, the spatial dynamics of species composition.

Not only vertebrate, but also invertebrate animals are used in GIS technology in studies of the spatial distribution.

Thus, I.A. Antonov, I.A. Bashalkhanov et al., in their study of spatial distribution of ants, emphasized that it is GIS that allows for the rapid creation of thematic maps based on incoming data and reflects the current state of research on the territorial distribution of ant nests [9].

Creating the GIS "Landscapes of the Olkhon region and Olkhon Island" the authors used such programs as Excel, MapInfo and SAS Planet. As they noted, the process of fixing of species finding points was automated, now it is possible to quickly receive data from GPS devices directly from the MapInfo software using the GeographicTracker utility [10]. All the points recorded by the GPS navigator are reflected on the digital map [9].

The basis for the primary spatial analysis is digital topographic maps, for the creation of which space images downloaded using the SAS Planet program from one of the map services (for example, Google Maps or Yandex. Maps) are used. Downloading a space image is in the form of so-called tiles - map fragments of 256x256 pixels. The use of GIS technology has allowed a formalized approach to the analysis of the landscape distribution of ants. For the study, a layer was created that contains data on the sites of the 212 registered nests.

As a result, the data on the spatial distribution of a number of species of ants in Olkhon and on Olkhon Island, which coincide with data from traditional ecological studies, was obtained. Drawing the conclusion, the authors note that GIS technologies increase the reliability and deepen the results of spatial analysis.

On the basis of GIS technology, digital models of insect ranges are created. The most convenient is ArcView with ArcViewSpatial and ArcView 3 DAnalyst modules, providing raster and vector modeling, creating three-dimensional contours, performing three-dimensional analysis, modeling spatial and temporal dynamics of insect ranges [11].

GIS tools are created to analyze habitat use by wild animals. Appennino is a tool used to estimate the habitat of animals through a comprehensive analysis. This free tool calculates the habitat use of animals within the framework of a GIS platform for ArcGIS, stores and exports the results of the comparative use of habitats to other statistical software.

The group of authors used the VisualBasic programming language for applications in order to prepare the ESRI ArcGIS 9 utility. The tool was tested on a database of 546 pheasant habitats obtained from a study conducted in Tuscany (Italy). The tool automatically gave the same results as the results obtained when calculating surfaces in ESRI ArcGIS, exporting data from ArcGIS [12].

There are a number of works on modeling and forecasting the spatial distribution of species using GIS technologies. In the work of A.V. Yegoshin the prognostic modeling of the distribution of the Ailanthus highest species (Ailanthus altissima) on the territory of the Sochi National Park, the Caucasus and Teberdinsky State Natural Biosphere Reserves is considered. The modelling was carried out in the MaxEnt environment [23], using bioclimatic variables for 19 WorldClim indicators, represented by a set of raster images (GRID) with a resolution of about 1 km<sup>2</sup>.

The author received a raster map illustrating the suitability of bioclimatic environmental conditions for growing of Ailanthus. According to the results of the analysis, the distribution of this species is influenced by the average annual temperature, the amount of rainfall and the average temperature of the coldest quarter of the year [13]. A similar study was performed by O.V. Kukushkin, I.V. Doronin and Yu.A. Krasilenko. They analyzed the distribution of the juniper *Arceuthobium oxycedri* and its main host *Juniperus deltoides* in the Crimea.

According to the authors, the main role in the formation of the range of these species is played by the annual temperature dynamics, the average temperature of the most humid season and the rainfall of the driest month. In fact, the entire territory of the mountainous Crimea except the highlands (Yayly) enters an area with conditions optimal for the growth of *J. deltoides*. The anthropogenic impact in the historical period significantly narrowed the current distribution of this species at the present time [14]. I.N. Bolotov, A.A. Frolov modeling the area and analyzing the contribution of factors to the climate niche *Parnassius mnemosyne* L. 1758, obtained a forecast of the possible change of area under different climate

change scenarios for the middle and second half of the XXI century.

According to the obtained forecasts, the territory of suitable habitats and climatic optima over the course of a century may shift to the northeast with respect to the present-day range of butterflies; at the same time, an increase in suitable areas is expected in central and northwestern Russia and a decrease in some points of modern climatic optima in central and southern Europe [15].

Geographic informational technologies are actively used in invasive biology, since they make it possible to establish the bioclimatic and ecological-geographical requirements of adventive species, to determine the suitability of the territory for these species, and also to predict their response to climate change. GIS are used in the analysis of the spatial distribution of arthropods that are interesting from the point of view of medicine and related diseases. Their distribution is changing on a global scale due to problems related to natural and socio-economic conditions, border disputes, etc.

GIS provide the ability to quickly and accurately understand local features and possible outbreaks of diseases, as well as the prognosis and eradication of diseases [16]. In order to achieve this, only the corresponding raster cartographic materials are needed, each cell of the raster of which contains information about any environmental parameter, as well as the geographical coordinates of the individuals of the studied objects of living nature [10]. Also A.V. Yegoshin with the help of GIS technologies established the regularities of the spatial distribution of alien species in the south of the Russian Black Sea region, as well as their bioclimatic and ecological-geographical features. The geographical coordinates of the habitats of individuals of the most common adventive plant species were recorded. These data were supplemented by the geographic coordinates of the habitats of alien species presented on the website of the global biodiversity information fund [19].

The raster layers with bioclimatic variables were supplemented with layers containing other ecological and geographical information: the height above sea level, the slope in degrees, the exposure, the degree of development of the territory, the snow depth, the vegetation potential, the net primary productivity, the sum of temperatures of the vegetation period, the soil moisture, as well as the content of organic carbon in it. Further, the author, using the toolkit ArcGIS extracted from the raster layers the values of ecological-geographical and bioclimatic variables at each growing point of the individuals of the studied species. The obtained data were used to calculate the minimum, maximum, average, and median values, as well as the variability of the bioclimatic and ecological-geographical characteristics of the habitats of adventive species.

GIS are used for mapping fish stocks and aquatic habitats for research and management purposes, studying the potential of fisheries in such areas, modeling and predicting changes in aquatic habitats, estimating the number of fish populations in different areas [17].

### III. CONCLUSION

As the result, GIS technologies provide a wide choice of tools and play an important role in environmental management, conservation and monitoring of biodiversity. With the help of GIS, it is possible to receive, operate and store all sorts of space-time data. A geo-ecological mapping allows getting objective information about the state of the environment of the investigated area.

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