Biodiversity assessment of the Danube region as a tool for the development of protected areas in the region

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Abstract. The paper uses the method of geospatial biodiversity assessment in the Danube region based on an expert evaluation of the distribution of species richness of fish, amphibians, reptiles, birds and mammals. The 10-point grading scale was used to evaluate the number of species in 200 sample plots of the study region. Points from 1 to 10 were separately calculated for the species in each taxonomic group. The analysis showed a close relationship between the Lower Danube floodplain and the small steppe river basins, which together make up a single natural region. A practical testing of the geospatial assessment of the species richness was done for the first time in the Danube region. An important applied result of the research is the opportunity to assess missing elements in the environmental network of the region. This approach will justify the need to designate various types of protected areas, both at the national level (natural reserves) and at the international level (the Emerald network sites and wetlands). The areas could further be used to develop a unified ecological framework, thus contributing to the protection of rare and endangered species of the region.

1. Introduction

The conservation, and moreover the restoration of biodiversity, is one of the global environmental challenges facing humanity. For Ukraine, with its valuable natural regions, such as the Carpathians, Crimea, Danube, Polissia and others, the biodiversity assessment is an initial step in deciding the further conservation strategy.

The Danube region is regarded as one of the valuable regions in terms of biodiversity, but traditionally considered in a narrow aspect, only within the boundaries of the Danube Delta. Based on the centuries-old history of the reciprocal development of the delta, the sea shelf and the mainland, in this paper we consider the Danube region in a broader aspect, taking into

account the past natural connection of the small steppe rivers of the region and the Danube lakes with the unique Danube delta.

The history of biodiversity studies in the Danube Delta has a long tradition [1–3]. Nevertheless, only a few works are dedicated to the biodiversity components of the other areas of the Danube region [4, 5].

Until recently, biodiversity assessment was based on the absolute values of the number of species and their abundance, as well as on various indices of species abundance and biodiversity in general. However, the possibility of using geospatial biodiversity assessment has significantly expanded the practical application of the obtained data. Nowadays, the methods of geoinformation systems are widely applied for biodiversity analysis all over the world [6–11]. As a result, these approaches significantly increase the effectiveness of protected area planning [12–14].

The *purpose* of this research is a spatial assessment of the biological diversity of the Danube region by the example of zoological taxa and the development of a methodological approach for such work.

2. Study area, material and methods

We consider the Danube region as a combination of the small steppe river basins, the left tributaries of the Danube in the lower reaches, and a chain of their final reservoirs (the Danube lakes, which used to be estuaries): Kahul, Kartal, Kuhurlui, Yalpuh, Katlabuh, Kytai and adjacent areas of the Lower Danube (figure 1). The region is studied within the administrative boundaries of Ukraine, so the basins of some small steppe rivers are not fully included. As the runoff of such small rivers as the Kohylnyk and Sarata affects Zhebrianska Bay with its rich flora and fauna (the Danube avandelta), their basins and Sasyk Reservoir are included in this natural region. The total study area covered 975,425 ha. The region is characterised by complex ecological relationships among various natural components and their mutual influence.

The Danube River, with its unique and fastest-growing delta in Southeast Europe, is a pivot

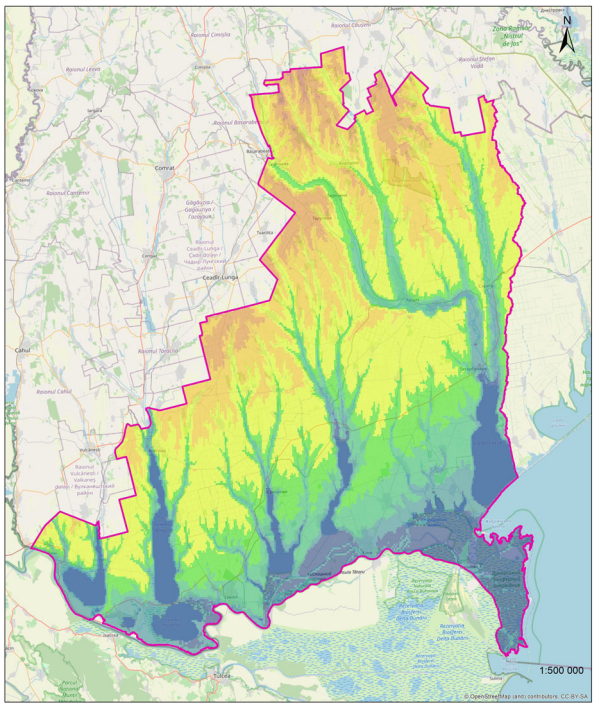

Figure 1. The study area.

of the region. Together with the adjacent small river basins, they have formed a valuable natural community with different landscape types that contribute to the development of rich biodiversity. However, the delta and its adjacent areas have also suffered from considerable man-made transformation. Vast coastal areas were embanked and converted into agricultural lands. Small rivers were transformed into a set of reservoirs, ponds and canals. Canals and hydrotechnical facilities were intensively built, focusing on transporting the Danube water to various parts of the region. Most of these activities had a negative impact on the integrity of natural communities and led to a decrease in regional species abundance.

Vertebrate taxa such as fish, reptiles, amphibians, birds, and mammals (except for Chiroptera) were chosen as biodiversity indicators. Compared with other taxa, they are more often on top of the ecological pyramid and are sensitive to the slightest changes in ecosystems. Their status makes it easier to judge the environmental processes in the natural region, and the concentration of their species abundance can diagnose the degree of importance or transformation of various spatial areas.

The assessment of selective zoological diversity is based on the results of regional fieldwork carried out during 1970-2022.

A grading scale for species abundance within each taxon was developed to assess diversity. First, each type of taxon was associated with its own habitat. Then, using QGIS methods, a regular grid was made for the region, consisting of 200 hexagons, each with an area of about 5 thousand hectares. According to the ratio of habitats in one or another hexagonal polygon, a quantitative assessment of the species abundance for a particular taxon in the polygon was made. Given the significant differences in species abundance among birds, reptiles, amphibians, fish and mammals, ranked scores were determined for each taxon to standardise and align the obtained data. For this purpose, the share of species abundance in a given hexagon was correlated with the total species abundance of a given taxon in the region. Based on the scores in each taxon, a table of the integral zoological value of the species abundance in each polygon was formed. Therefore, the data from zoological studies were correlated with the obtained regular grid. For the integral assessment, the method of heat maps was also used in accordance with the scores within the hexagon, which, on the one side, gives a smoother picture, and on another side, reliably identifies the most critical parts of the region.

The analysis of the region transformation used the open data on land use classification posted by the European Space Agency "ESA WorldCover" [15]. According to this classification, the following types of land surface with different land use are distinguished in the Danube region: 1) tree vegetation; 2) shrub vegetation; 3) herbaceous vegetation; 4) agricultural land; 5) buildings; 6) areas without vegetation or with sparse vegetation; 7) reservoirs with a permanent presence of water; 8) wetlands and reservoirs overgrown with vegetation. We also classified types 4 and 5 as significantly transformed and the remaining ones as natural and semi-natural.

Spatial analysis was conducted using the QGIS software.

3. Results

Based on the developed method, we have received maps of species abundance for some taxonomic groups in the Danube region (figures 2-5). Colour gradation shows the score range of species diversity: dark green (1), light green (2-3), yellow (4-5), orange (6-8) and bright red (9-10 points).

There are some peculiarities in the distribution of fish species abundance in the region (figure 2). Thus, the Danube floodplain houses the highest species diversity. In most drainage basins, the fish species composition is extremely poor. Small rivers are drying up, but the embanked areas still preserve some species abundance in their middle reaches. Only in the Kohylnyk and Sarata rivers (the easternmost ones in the figure), the water content of which is

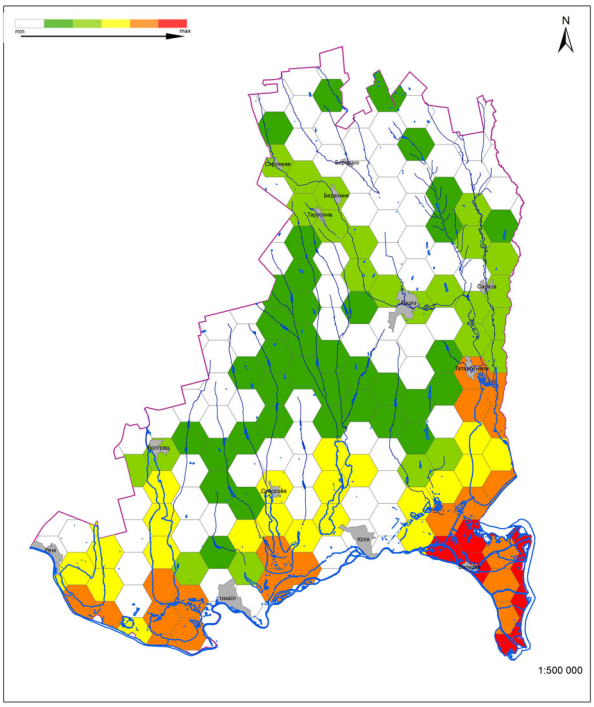

Figure 2. Abundance of fish species.

higher, relatively low species diversity persists throughout the entire length of their channels (the Kohylnyk River) almost to the regional borders.

The highest diversity index of reptiles and amphibians is recorded in the Danube floodplain (figure 3) as all the amphibian species typical for the region are available there, along with water reptiles (the European pond turtle *Emysor bicularis* Linnaeus, 1758, dice snake *Natrix tessellata* Laurenti, 1768, grass snake *Natrix natrix* Linnaeus, 1758). Suitable habitats for reptiles and amphibians are located not only along the slope landscapes of small rivers but also along numerous forest belts in agricultural lands that ensure a much wider distribution of the optimal species composition of reptiles compared with fish in the middle reaches of small steppe rivers.

Birds form the basis of the species richness of vertebrates in the region (figure 4). The avian diversity is represented by more than 320 species. A deeper colour of the Danube floodplain indicates the predominance of waterbirds, although their distribution is limited along small rivers. The species composition of this taxonomic group is very dynamic and depends on the landscape diversity and seasonality. Birds, due to their plasticity and mobility affected by external factors can quickly disperse within the Danube region of Ukraine and outside its boundaries.

The areas of high mammal biodiversity (figure 5) are concentrated in latitudinal zones along the Danube floodplain and in the north of the region. This diversity is most affected by the heterogeneity of landscapes and habitats. Thus, the northern part of the Danube region is located on the elevation, streaked with channels of small rivers, gullies and ravines, with vast Tarutinska Steppe and forest tracts. This determines the high species diversity of mammals, mainly rodents (Rodentia). The landscapes of the Danube floodplain are highly mosaic, with large areas of riverine forests, meadow ecosystems and floodplain lakes that ensures a high species abundance of all orders of mammals typical for the region. Moreover, the inaccessibility of the territory together with the border control and environmental regimes, contribute to the

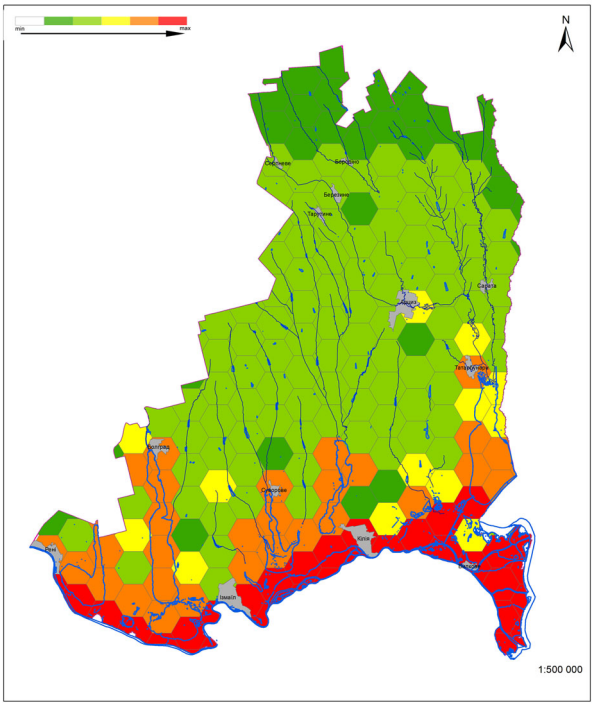

Figure 3. Abundance of herpeto- and batrachofauna species.

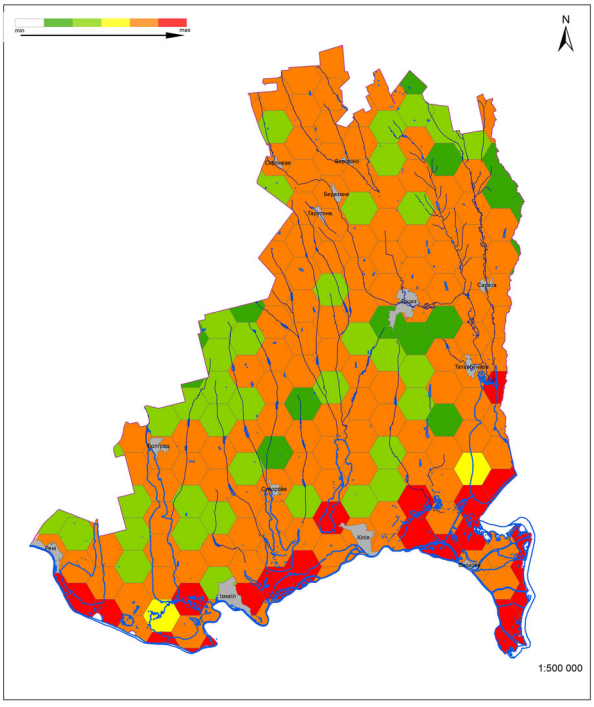

Figure 4. Abundance of avifauna species.

conservation of biodiversity.

An integrated assessment of the whole zoological diversity (figure 6) quite fully illustrates the cohesion of this natural region, the absence of any hiatuses and clear latitudinal demarcation

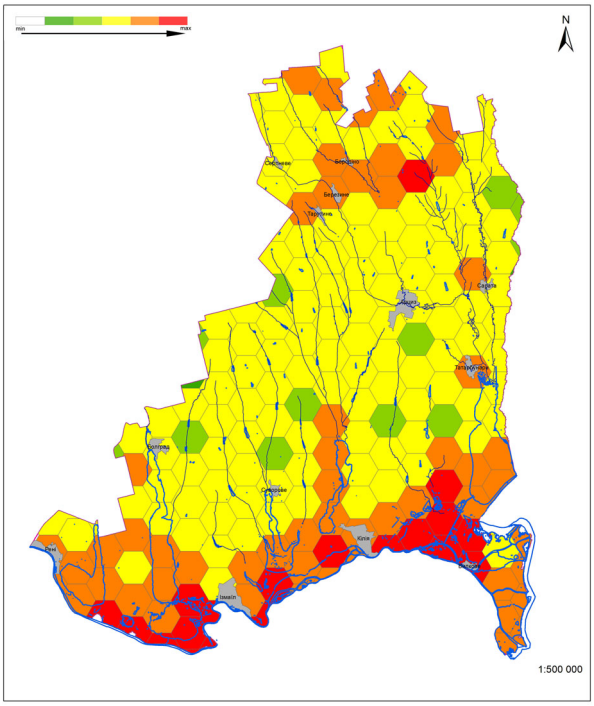

Figure 5. Abundance of mammal species.

lines from the stripes of hexagons with low species abundance, including the transition from the Danube floodplain to the small steppe basins. This is especially pronounced when species diversity within the ecological framework is reflected using GIS grids. However, some biodiversity loss is recorded in the interfluvial areas and the middle reaches of the rivers flowing into Lake Katlabuh and Stensivsko-Zhebrianski Plavni.

4. Discussion

Geospatial assessment of the ichthyofauna species diversity (figure 2) clearly shows the consequences of water flow regulation in small rivers, or more precisely in their intermediate reservoirs of the Danube lakes and, consequently, almost complete isolation of them from the Danube floodplain, especially during floods. It has caused a rapid depletion of the ichthyofauna in the lakes and rivers, formerly used for upstream migration by spawning shoals of semi-anadromous fish species. More than half a century of isolation led to a decrease in the previous abundance of fish species. The current negative situation can only be solved if the water exchange between the basins of small rivers and the Danube floodplain is restored. It will improve the water content of small rivers and progressively restore their slopes and the underground springs blocked by layers of landslide soils.

The concentration of a high diversity of amphibians, reptiles and mammals in the Danube floodplain (figures 3, 5) indicates the need to restore the channels and slope sections of small rivers. Acting as ecological corridors, they will promote the unimpeded dispersal of species in the meridional and latitudinal directions. Otherwise, it is impossible to maintain the population homeostasis of representatives of the batracho-, herpeto- and mammal fauna, predominantly rare and vulnerable species.

Birds, as the most mobile zoological component of biodiversity, easily colonise well-preserved discrete natural areas along the floodplains and slopes of small rivers (table 1), thus determining the “elongation” of integral grids of optimal and high species diversity along the channel sections

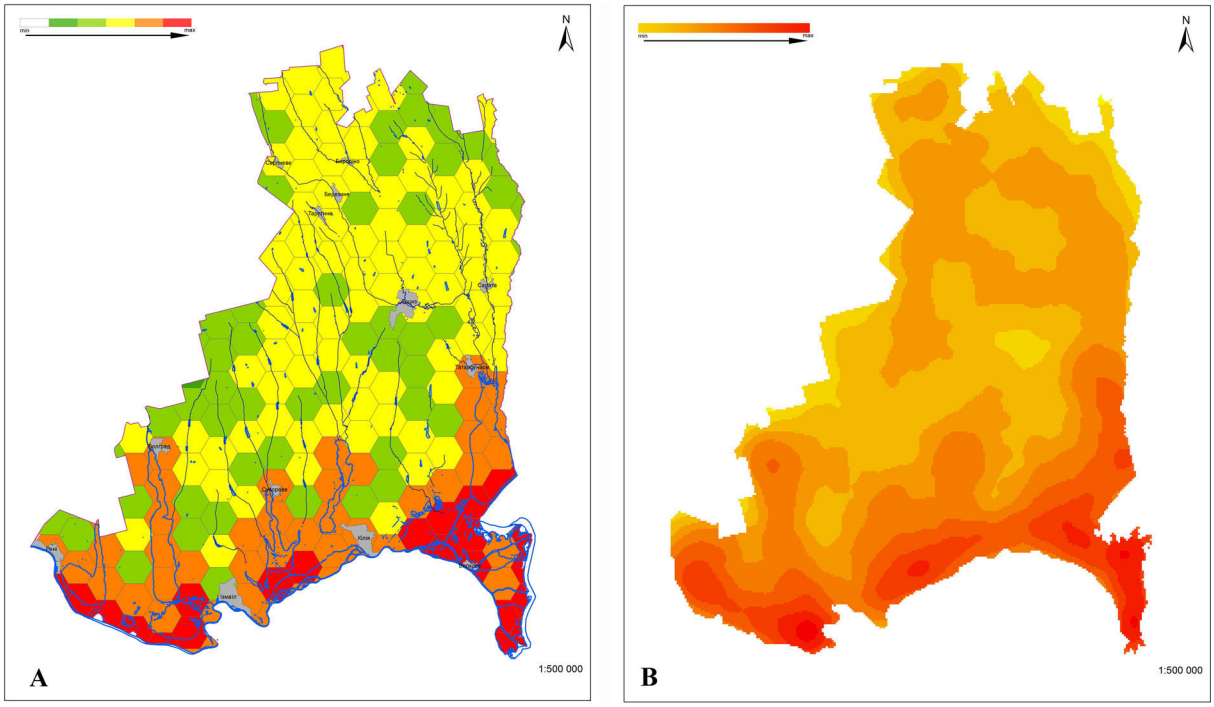

Figure 6. Integral assessment of the abundance of zoological species (A – regular hexagons; B – grids of integral diversity).

of small rivers in figure 6B.

Table 1. The share of natural habitats, in percent of the total area of riverine-floodplain habitats of the main steppe rivers in the Danube region.

Main rivers of the basin	Name of the basin	Percent of natural habitats
Kahul	Lake Kahul	58.5
Velykyi Yalpuh	Lake Yalpuh	82.7
Velykyi Katlabuh	Lake Katlabuh	56.8
Kyrgizh-Kytai	Lake Kytai	60.1
Drakulia	Stensivsko-Zhebrianski Plavni	44.9
Kohylnyk	Sasyk Reservoir	70.6

The preserved natural state of some channels and floodplains of small rivers supports the survival of many animal species, including Ukrainian red-listed ones, thereby enabling the potential expansion of the genetic exchange corridors between fragmented populations and subpopulations of animals (except birds).

However, the critical destruction of steppe and meadow areas, converted to agricultural lands, has led to the loss of many stenobiont animal species. In general, the noticeable predominance of anthropogenically transformed lands and the isolation of individual natural areas hamper the protection of regional species diversity. An essential element of biodiversity conservation in natural communities is the network of protected sites with different statuses. The region encompasses protected areas of national significance, wetlands of international importance and the Emerald network sites. The regional ecological network is also developed, focusing on

integrating valuable areas (cores) into a single system through ecological corridors.

The available data on the biodiversity distribution and existing boundaries of natural conservation areas enable the identification of gaps and the development of a more effective system of protected sites. The data analysis indicates the need to designate three new wildlife reserves and significantly expand the regional ecological network. Total area recommended for the nature conservation areas is 45,934 ha.

This approach will facilitate the complete restoration of the mutual influence between the Lower Danube floodplain and small steppe rivers, expand ecological corridors and biodiversity cores, and contribute to the conservation of fauna populations of this unique natural region.

5. Conclusions

A large-scale geospatial assessment of the Danube region biodiversity has allowed identifying the most valuable areas, naturally located in the Danube Delta and the lower part of the Danube lakes, and the areas with an urgent need of restoration.

A holistic view of the region also showed the role of small steppe rivers in the species exchange and the formation of ecological corridors. The dominance of the Lower Danube floodplain in terms of the animal species abundance may also be associated with the availability of protected areas of different statuses.

Despite the significant transformation of the region (a high percentage of agricultural land use, embankment of the Danube lakes-estuaries, conversion of some sections of small river channels, the Danube region still remains an important area for biodiversity conservation, not only in its key part - the Danube Delta, but also within the boundaries of the adjacent small river basins.

The use of a holistic spatial approach to biodiversity assessment provides wide opportunities for management decision-making, such as identifying potential protected areas, areas for restoration, etc. The data analysis indicates the need to designate three reserves with a total area of 18,178 ha and expand ecological corridors with a total area of 27,756 ha.

Acknowledgments

The authors are grateful to Dr. of Biological Sciences Josef Chernichko for his valuable advice in preparing the manuscript for publication.

The research was carried out within the framework of the European Endangered Landscapes Program and the project “Renewal of wetlands and steppes in the Danube Delta region” (2019-2023), which is being implemented by Rewilding Europe NPO.

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