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Analysis of hydrological conditions for the comfortable life of fish populations in the Uzh River of Zakarpattia Oblast

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SUMMARY

This article provides an example of utilizing a hydrological model developed in the HEC-RAS software package to study the normal hydrological conditions for riverine organisms. It should be noted that due to accelerated water runoff in the Uzh River, new habitats with favorable conditions for various fish species are being created in its floodplain area. However, upon examining the entire Uzh River, it becomes evident that the accelerated water flow leads to a reduction in spawning habitats for these fish species, mainly because these areas are located in the river's mountainous regions. Consequently, if the rate of water runoff does not decrease in the coming years, the populations of fish species listed in the Red Book of Ukraine may be at risk of extinction. This issue is relevant not only for the Uzh River but also for most rivers in the Transcarpathian region.



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Introduction

Creating models for determining normal hydrological conditions for the activity and distribution of ichthyofauna is a relevant part of hydrological and sectoral research. Climate change and the irrational use of natural resources are provoking the reduction or even extinction of fish populations, thereby diminishing the gene pool of river ichthyofauna. Modeling and predicting zones of uncomfortable conditions for the life of these organisms allow us to better understand the risks and prevent negative processes. Thanks to this, a strategy can be developed to improve the living environment of ichthyofauna, which will have both an economic and ecological effect. In this article, we provide an example of forecasting zones with normal conditions for the life and distribution of fish, using data from hydrological posts of the Uzh River within the city of Uzhgorod, as well as the methodology for presenting such a system as a web resource.

Method and results

In the study by Andrew Schied titled 'Habitat mapping with HEC-RAS,' methods for researching fish habitats using HEC-RAS software are analyzed. The article by Papadaki C., Bellos V., Stoumboudi M., Kopsiaftis G., & Dimitriou E. titled 'Evaluation of streamflow habitat relationships using habitat suitability curves and HEC-RAS' describes the methodology for researching fish distribution. The aforementioned works help to form a comprehensive view on the possibilities of modeling fish distribution zones and to conduct their analysis.

The aim of this paper is to create maps that reflect ecologically favorable conditions for the activity of ichthyofauna, as well as to investigate changes in these conditions. The project can forecast risks that have negative consequences for fish populations. The system is designed to assist managers and researchers in implementing effective measures to improve conditions for the normal habitation of fish.

In this study, we will analyze the hydrological conditions for the comfortable habitation and distribution of fish of a specific species, as indicated in Table 1.

Table 1 Hydrological conditions for the life of selected populations (Red Book of Ukraine, 1994)

№	Population name	Velocity	Depth (m)	Water temperature
1	The European barbel (Latin: <i>Barbus barbus</i>) is a fish from the carp family, which is listed in the IUCN Red List, the European Red List, and the Red Book of Ukraine. Age – 3 years.	High	to 1,2	15 °C.
2	The Common Nase (<i>Chondrostoma nasus</i>) is a freshwater fish from the carp family that is listed in the Red Book of Ukraine. It can grow up to 40 cm in length and weigh up to 1.6 kg. The lifespan is up to 10 years.	High	2-3	10 — 12°C
3	The Common Minnow (often referred to simply as "minnow") is a fish from the carp family. Its body length typically ranges from 10 to 12 cm, rarely exceeding 17 cm, and it can weigh up to 60 grams.	Average	to 0.5	10 — 12°C


To start work, create a new project in the HEC-RAS software package, set the unit of measurement and coordinate system. Add a digital elevation model (DEM) in RAS-Mapper under Terrains using



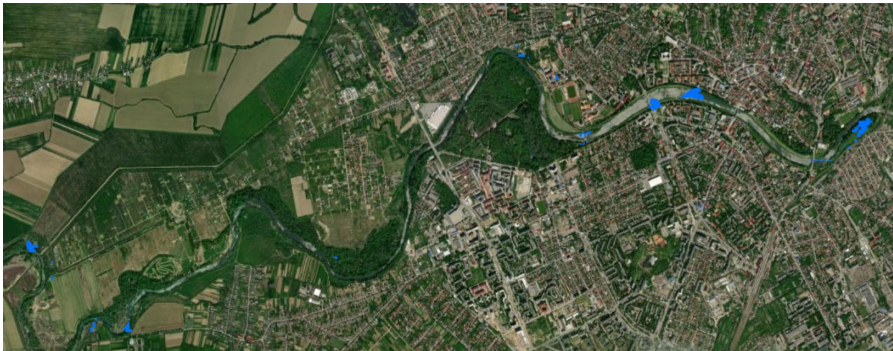
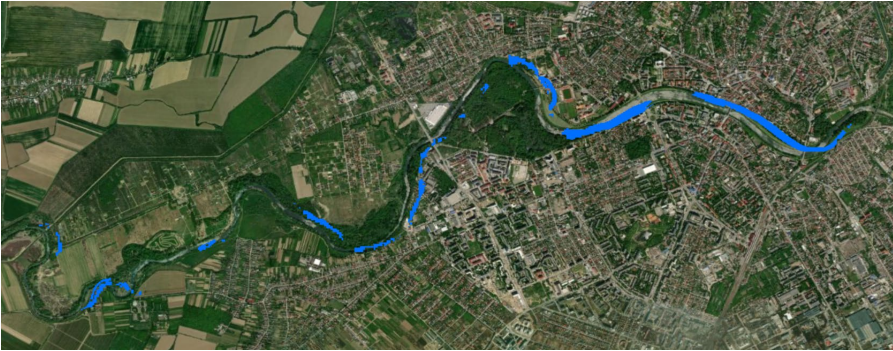
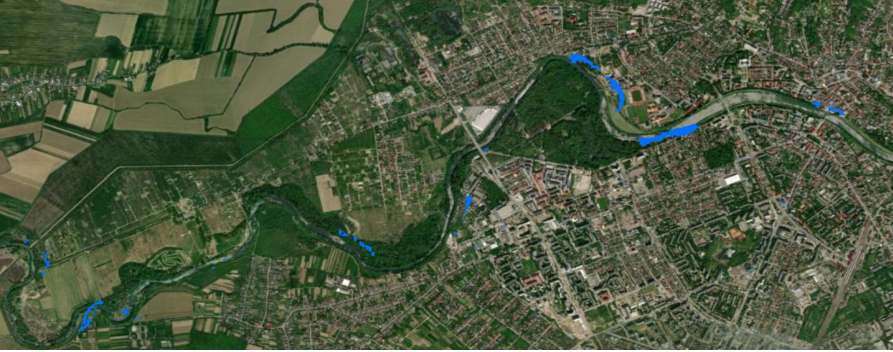

the "Create a New RAS Terrain" tool, where you choose the appropriate raster. Additionally, you can add land features by first creating a copy of the raster "Clone Terrain (Virtual)", then "Add New Modification Layer," and choose from the dropdown list as needed. This stage requires accurate and relevant data. Using Geometries in RAS-Mapper, add new geometry data with "Add New Geometry." Using the Rivers layer, define the river, and with Bank Lines, outline the riverbanks. Add the river basin with 2D Flow Areas; after Perimeters, start depicting this area; in the editor, you can change Computation Points. Also add Boundary Condition Lines at the basin boundaries. Add engineering structures (bridges, dams, etc.) using Geometric Data. Use the SA/2D Connection tool to display the approximate location of the bridge. After that, in the SA/2D Connection editor, in Structure Type, indicate "Bridge (Internal to 2D Flow Area)." Define data about the roadway (Deck/Roadway), supports (Pier), and shore supports (Sloping Abutment). This stage requires design data of engineering structures. Enter the ManningsN and Percent Impervious coefficients. In Map Layers in RAS-Mapper, create a new layer "Land Cover Layer" in "Create a New RAS Layer," in Import Extents specify "Entire Input File(s)," then add the shapefile with layers and identifiers according to the selected ID Standards. According to this standard, in the properties of the layer "Edit Land Cover Data Table," enter the ManningsN and Percent Impervious values. Analyze the water level data.

In the Edit menu of the program, select Unsteady Flow Data. Proceed to Select Location and then select Boundary Condition Type, add data with Add SA/2D Flow Area . For the upper boundary of the basin, set the Flow Hydrograph, where we specify the volume of water and slope at that point; for the lower boundary, set Normal Depth, and determine the Friction Slope (the rate at which energy is lost along the river). Using the Run menu of the program, we analyze Unsteady Flow Analysis, where we specify the time over which the analysis will be conducted and receive the result (Merwade, 2012).The study is based on depth and speed, identifying favorable hydrological conditions for fish. The modeling area is the Uzh River within the city of Uzhgorod. The data for hydrological modeling are the indicators of average monthly runoff for 2015 and 2022, which are 93.9 and 140.3 m3/s, respectively. We will use the ArcGis software as well as the Spatial Analyst (Model Builder) module for geospatial analysis.For the study, from the base hydrological model, we will take data for the habitat of organisms, specifically the depth and flow speed, especially for Common Barbel (around 5 years old), for comfortable living a depth of up to 1.2 meters is necessary as well as a high flow speed. After running the modeling process, we obtained the results which are presented in Table 2.

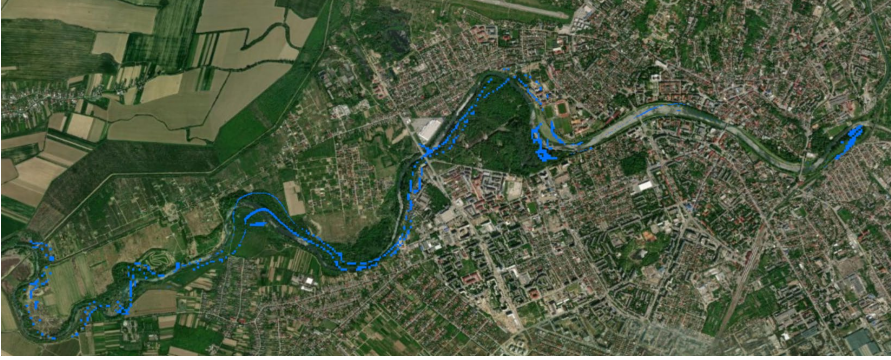
Table 2 Research Results

Population name	Year	Range of favorable conditions
European barbel	2022	



Population name	Year	Range of favorable conditions
European barbel	2015	
The Common Nase	2022	
The Common Nase	2015	
The Common Minnow	2022	



Population name	Year	Range of favorable conditions
The Common Minnow	2015	

Conclusions

This article provides an example of utilizing a hydrological model developed in the HEC-RAS software package to study the normal hydrological conditions for riverine organisms. It should be noted that due to accelerated water runoff in the Uzh River, new habitats with favorable conditions for various fish species are being created in its floodplain area. However, upon examining the entire Uzh River, it becomes evident that the accelerated water flow leads to a reduction in spawning habitats for these fish species, mainly because these areas are located in the river's mountainous regions. Consequently, if the rate of water runoff does not decrease in the coming years, the populations of fish species listed in the Red Book of Ukraine may be at risk of extinction. This issue is relevant not only for the Uzh River but also for most rivers in the Transcarpathian region.

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