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INNOVATIVE BY-PASS SOLUTION FOR IRON GATES I TO RECONNECT THE HISTORICAL MIGRATION ROUTES OF WILD ANADROMOUS STURGEON SPECIES, IN ORDER TO IMPROVE THEIR CONSERVATION STATUS

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Abstract

The anadromous sturgeon species in the lower Danube are currently critically endangered and based on the studies of the INCDPM expert team and the 2022 report of IUCN-SSG (Sturgeon Specialist Group) it appears that the future prospects of these populations are unfavourable. This situation occurs mainly as a result of anthropogenic impacts, especially due to intensive fishing, poaching and hydrotechnical constructions (e.g.: dams, immersed obstacles such as the bottom sill on Bala Branch). The dams interrupted the historical spawning migration routes of these species and the bottom sill can interrupt them in the future. In this context, INCDPM has elaborated an innovative by pass solution for the Iron Gates I, based on the longterm monitoring of ultrasonically tagged sturgeons from the Black Sea to the Iron Gates. This article presents the methodology developed by INCDPM in order to ensure the implementation of the innovative by-pass solution with minimal risk of unseccesful restoration of the historical migration routes. The study aims to present the specific migration conditions and the actual routes, which have been determined by over a decade of in-situ monitoring of ultrasonically tagged specimens. Additionally, simulations of upstream migration will be conducted and GIS maps will be developed to present historical migratory routes, with consideration given to hydrodynamic conditions and climate change scenarios.

Keywords*: Sturgeon species; Historical migration; Innovative by-pass solution: Anthropogenic Impact; Ichthyofauna monitoring; Hydromorphodynamic monitoring*

Introduction

Study area

The history of the Iron Gates Hydropower and Navigation System hydroelectric power stations complex, a joint undertake of the Romanian and Yugoslavian (now Serbian) governments, began in 1964 with the construction of the Iron Gates I dam that was commissioned in 1972. In 1984, the Iron Gates II dam became operational (Fig. 1).

It was one of Europe's largest projects at the time and remains the most significant and largest hydroelectric initiative in the region. Through its functions, which include the production of electricity, the provision of water to irrigation systems, the improvement of

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navigation conditions and, consequently, the expansion of the capacity to import and export goods, it has been a significant adjuvant in water flow management actions [1-3].

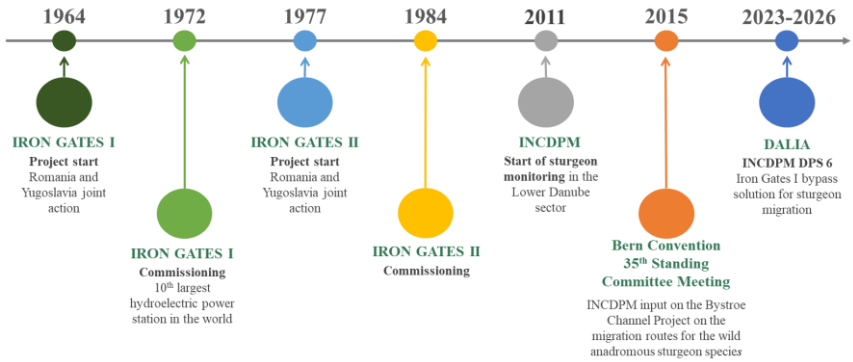

Fig. 1. The history of the Iron Gates in relation with actions taken to improve wild sturgeons' conservation status.

Comprehensive studies on the potential impact of these works on natural habitats and specific biodiversity were not considered, resulting in a gradual ecological transformation of the area and the disruption of the historical migration routes for wild anadromous sturgeon species (Fig. 2). In this context, INCDPM implements DPS6 that tackles the issue of Sturgeon migration by-pass Iron Gates I and II within DALIA (Danube Region Water Lighthouse Action), funded through Horizon Europe, that represents the EU's key funding programme for research and innovation, for the EU 'Restore our Ocean, seas and waters by 2030' Mission [4, 5].

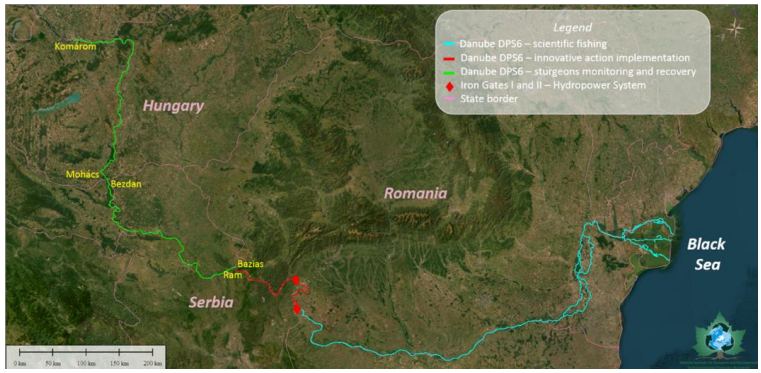

Fig. 2. Scientific fishing and monitoring area in the Lower Danube; the location of the innovative by-pass solution implementation and the area needed for ultrasonic tagged sturgeons monitoring, in order to prove the efficiency of the solution

The status of wild anadromous sturgeon species in the Lower Danube

INCDPM Bucharest has over a decade of experience in monitoring the wild sturgeon's population in the Lower Danube with over 740 tagged sturgeon specimens between 2011-2024. Within the years of studying their populations effectives and behavior, it was concluded that 2 species are already extinct: *Acipenser sturio* and *Acipenser nudiventris*. The worst impact is attributed to illegal fishing activities, 80% of the ultrasonic-tagged sturgeon specimens being lost due to poaching [6-9].

IUCN SSG (Sturgeon Specialist Group) report highlights the continuing decline of this taxonomic group on a global level. The three species of anadromous sturgeon species still extant in the Lower Danube (*Acipenser stellatus* - the stellate sturgeon, *Huso huso* - the beluga

sturgeon and *Acipenser gueldenstaedtii* - the russian sturgeon) are maintain their previous classification, as Critically Endangered, with a consistent population decline trend [10].

Another significant factor that affects their historical behaviour was the disruption of migration routes due to hydrotechnical projects, such as the installation of bottom sills on Bala Branch and the operation of hydropower stations like Iron Gates [11-14].

As this severe decline could only result in the extinction of these species, from 2006 onwards, Romania has enabled a series of measures to ensure the sustainability of sturgeon populations by implementing the Prohibition Law (Fig. 3).

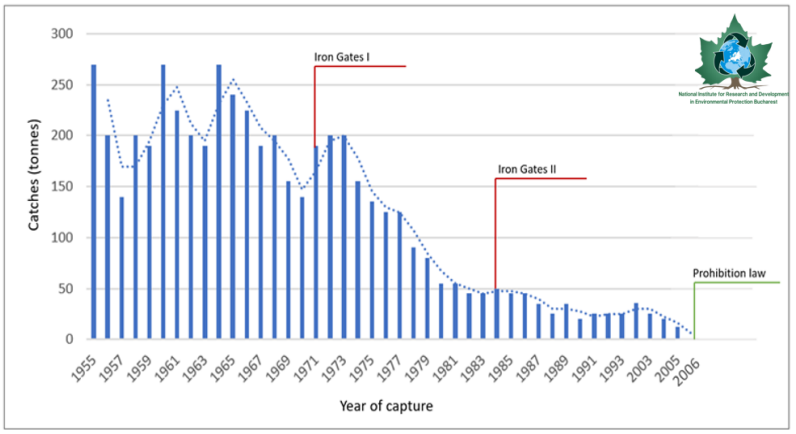

Fig. 3. Severe decline in commercial catches of sturgeon species (combined) between 1955 and 2005

The authors have previously analyzed the status of sturgeon populations in the Lower Danube based on IUCN Red List of Threatened Species data by employing realistic scenarios. In four years, the stellate sturgeon (*A. stellatus*) population has decreased by 72.5%, the beluga sturgeon (H. *huso*) population has decreased by 60% and the russian sturgeon (*A. gueldenstaedtii*) population has decreased by 99%. Figure 4 depicts the normal distribution of values for the population size of each species over various time intervals, including the entirety of the catch, tagging and release interval covered by INCDPM field activities.

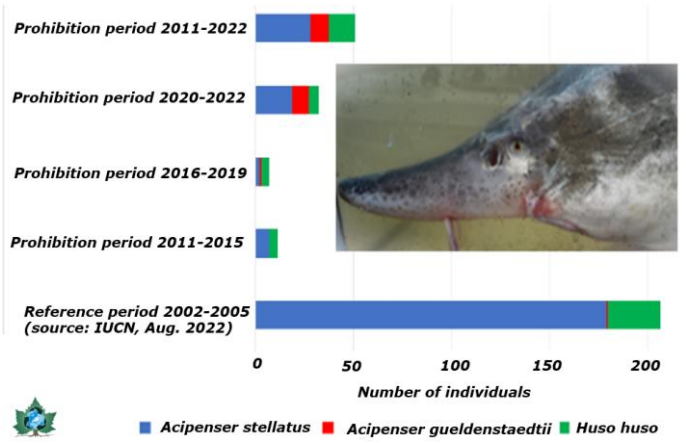

Fig. 4. The Evolution of sturgeon population size under the impact of poaching, compared to the reference period

Materials and Methods

Scientific fishing campaigns

The procedure for capturing sturgeon species involves the launching of a gillnet from a boat, which is moved by the current of the water and drifted between 500 and 1,000 meters, depending on the fishing area (Fig. 5). Once the fishing gear has filtered the water for the agreed-upon distance, the fisherman lifts it into the boat to examine the capture. The captured fish are untangled from the net without compromising their integrity [15, 16]. The experts that carry out sturgeon scientific fishing are registered on scientific fishing authorizations issued by the Romanian National Agency of Fisheries and Aquaculture, the Environmental and Forests Ministry after the Romanian Academy and the Romanian National Agency for Protected areas.

Fig. 5. Scientific fishing campaigns

Scientific fishing using the filtration gear method is carried out throughout the year for sturgeon species, with a predominance in peak migration periods (spring and autumn). During the summer period, employing the methodology is recommended especially for the capture of sturgeon juveniles resulting from natural summer spawning.

Individuals captured in the nets are released unharmed, after biometric data is collected and the ultrasonic tag is inserted. The ultrasonic tagging is made in accordance with a protocol developed by INCDPM and approved by the International and National Community of Experts [17, 18].

The monitoring of ultrasonic-tagged sturgeon specimens

Monitoring is carried out using both stationary (DKTB stations) and mobile/floating stations (VR100 attached to the boat/DKMR) that collect data on water temperature (Figs. 6 and 7), the depth of the specimen's location and overall provide information on the migration route spanning 1500 fluvial km, from the Black Sea to Baziaș.

By positioning the monitoring stations patented by the INCDPM team of experts (DKMR) at strategic points and distances to ensure the connectivity of potential migration routes, a better understanding of sturgeon behaviour and the accuracy of collected data are ensured [19, 20].

Fig. 6. DKMR monitoring station

Fig. 7. VR100 equipment for mobile monitoring

Detection gates commissioning

In Spring 2024, INCDPM started conducting in situ measurement campaigns for hydrodynamic and morphological parameters in order to determine the exact location for the detection gates to be commissioned, using Multibeam equipment for high-resolution 3D riverbed bathymetry and ADPC single-beam equipment for 2D riverbed bathymetry, water discharge and water current velocity vectors (Fig. 8).

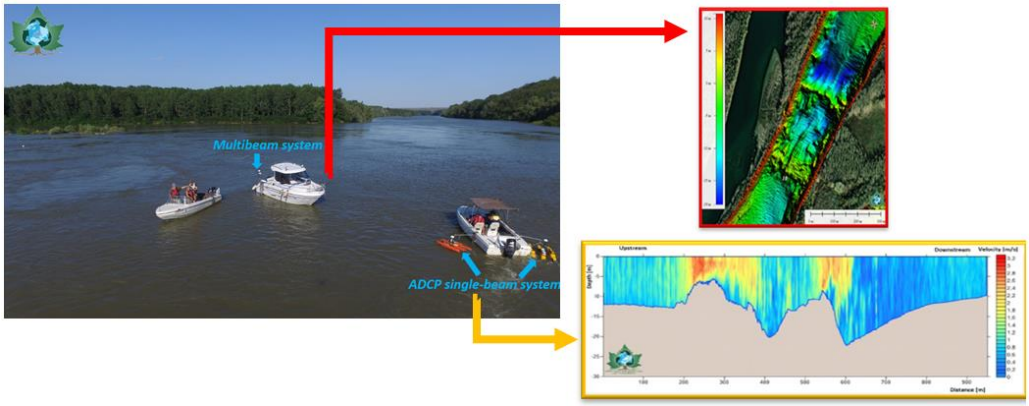

Fig. 8. Multibeam and Singlebeam measurements

The detecting gates will utilize the DKMR type monitoring stations (Fig. 9), this methodology having already been tried and proven in the bottom sills area on Bala Branch.

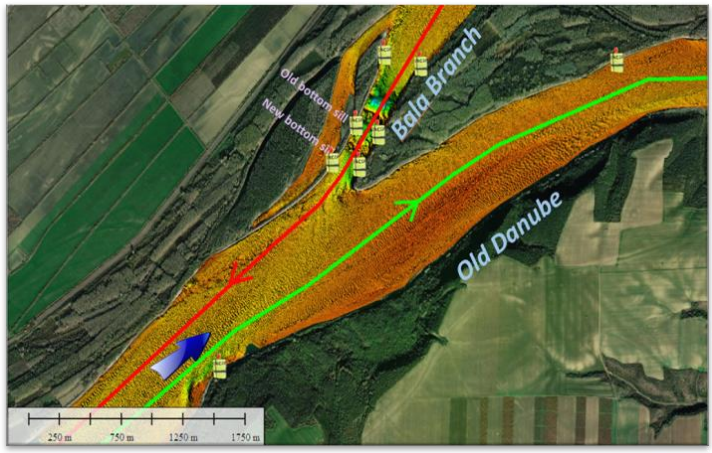

Fig. 9. DKMR monitoring station used as detection gates

Innovative by-pass solution implementation

The innovative by-pass solution to be implemented, tested and validated by the INCDPM team of experts is presently in the theoretical phase and is tailored specifically for the Iron Gates area and is referring to an innovative solution of transporting alive specimens in optimal conditions [21, 22].

The technical scheme and patent application for the installation have already been developed - Autonomous mobile system, monitored by AI, for the transport of wild sturgeons; Patent no.: RO137990 (Fig. 10).

This system will recreate the natural environment of the sturgeons, being filled with Danube water and will be equipped with different sets of sensors in order to mentain optimal parameters both for the water quality and for the species wellbeing, thus differing from other types of water-free systems tested, for example in China [23].

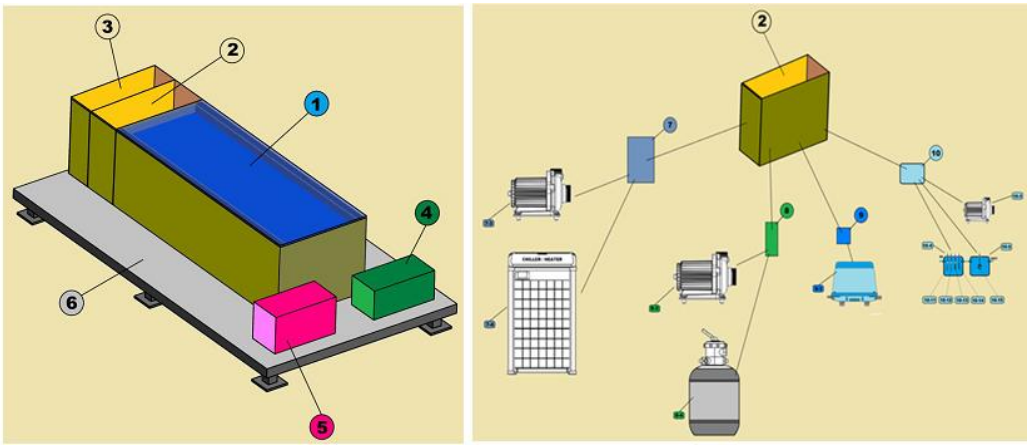

Fig. 10. Autonomous mobile system, monitored by AI, for the transport of wild sturgeons

Once the solution has been implemented and evaluated, its effect on ensuring the continuity of sturgeon migration routes from the lower Danube to the upper river sector can be quantified [24, 25]. In this context, INCDPM Bucharest proposed a Collaboration Protocol with the main stakeholder, Hidroelectrica, concerning the assurance of minimal risk of loss for ultrasonic-tagged sturgeons during their migration from Baziaș downstream back to the Black Sea.

Results and Discussions

Wild anadromous sturgeons' behaviour in the Lower Danube

An important preliminary result was obtained by INCDPM in the Spring 2024 monitoring campaign, which is the basis of the innovative bypass solution promoted by the Institute, representing female vs male behaviour, presented below. It has been proven than multiple males migrate alongside one female, but it is yet to conclude if the migration is initiated by the females or males' specimens (Fig. 11).

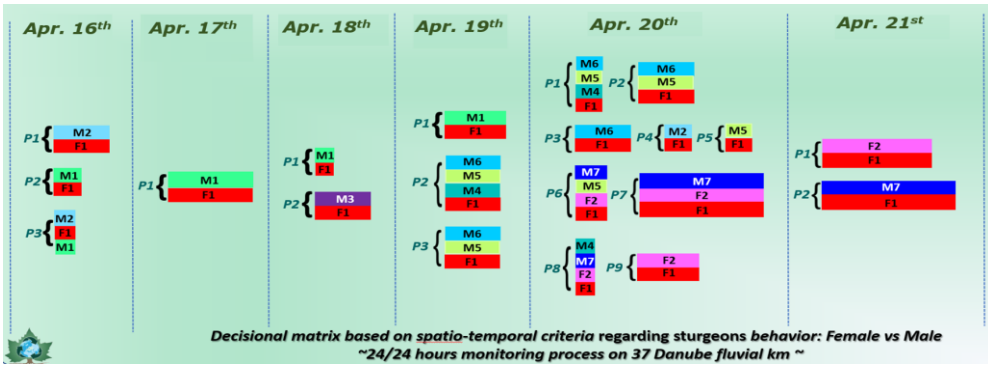

Fig. 11. Male vs female behavior

AI-monitored autonomous mobile system for transporting wild sturgeon

This system was built with the components presented bellow as shown in Figure 12:

Fig. 12. Current status of the AI-monitored autonomous mobile system for transporting wild sturgeon assembly

1. Sturgeon storage basin
2. Compartment systems maintain vital water parameters for stocking sturgeon
3. Monitoring and control compartment for vital water parameters in the sturgeon storage basin, including video monitoring and electricity supply
4. Motor pump for water transport from the Danube
5. Electric current generator
6. Transport platform
7. Cooling and heating system

8. Mechanical filtration system.
9. Aeration System
10. System for measuring the vital physical parameters of the water
11. System for monitoring and managing vital physical parameters of water in the sturgeon storage basin (1)
12. Electric power supply integrator controller.
13. Accumulator.
14. GSM communication mode for (11)
15. GSM communication mode for (16)
16. Underwater video camera.
17. Pool Emptying System (1)

The present invention intends to address an issue in the conservation and monitoring of wild sturgeons and relates to a technical concept for transporting wild sturgeons in a controlled environment to preserve their vital integrity. The technical problem that the invention solves, in comparison to other previous systems, is the possibility of facilitating the transport of wild sturgeons in a controlled environment, which ensures the optimal state of vitality (avoiding injury, decreasing the level of dissolved oxygen and respectively increasing the level of oxidative stress during the transport period), as well as the transmission of data in real-time regarding their health.

Conclusions

Wild anadromous sturgeon species in the Lower Danube are Critically Endangered due to various factors, including intensive fishing, poaching (illegal fishing) and the disruption of the historical migration routes to the Middle and Upper Danube sectors, resulted from hydrotechnical works (bottom sills, dams).For this study, a complex and interdisciplinary methodology was employed in order to obtain important data concerning both the behaviour of sturgeon species and the characteristics of the abiotic environment (river basin).

An important result obtained in spring 2024 is proving the link between female and male sturgeons and how they interact during (spawning) migration. It has been proven than multiple males migrate alongside one female, but it is yet to conclude if the migration is initiated by the females or males' specimens. Furthermore, in more than a decade of ultrasonic-tagged sturgeons monitoring along the Lower Danube, the authors have proven the capacity of these species to overpass submersed obstacles (Bala Branch).

An innovative prototype for transporting wild sturgeons has been patented by the experts in 2023 and for this, a Collaboration Protocol between the National Institute for Research and Development in Environmental Protection Bucharest and Hidroelectica was proposed, in order to ensure minimal loss of sturgeons that passed the Iron Gates and to establish an alternative route that will facilitate the specimens' migration downstream, back to the Black Sea. These steps will ensure all the right premises to develop, implement and validate the innovative by-pass solution proposed by our team of experts.

The process of implementing and validating the innovative by-pass solution is complex, needing several steps dependent on eachother, as it follows:

1st Step –Ultrasonic Tagging of the wild anadromous sturgeon species in the Lower Danube and commissioning the Detection Gates close to the Iron Gates;
2nd Step – Transporting the wild sturgeons upstream of the Iron Gates dams by employing the AI-monitored autonomous mobile system developed;
3rd Step – The acclimatization of the ultrasonic-tagged specimens to the Middle Danube water parameters by holding them within support basins emerged in the river, similar to those used in aquaculture;
4th Step – Blocking the access routes downstream, back to the Iron Gates. This step will be taken simoultaneously with the previous one;
5th Step – Releasing the now acclimatized ultrasonic-tagged specimens;
6th Step – Special upstream monitoring campaigns, from the release point to Vienna, by employing both mobile (VR100) and fixed (DKMR type stations) monitoring systems;

7th Step - Transporting the wild sturgeons downstream of the Iron Gates dams by employing the AI-monitored autonomous mobile system developed, releasing them back in the Lower Danube and monitoring their behviour.

It is crucial to be able to continue the monitoring of the ultrasonic-tagged sturgeons in the Middle and Upper Danube Sectors, for at least 700 fluvial km more. In this regard, the authors are emphasizing on the importance of crossborder collaboration with different R&D organizations from states corresponding to the Danube Basin.

Aknowledgement

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