Ecological consequences of the construction of the Iron Gates and Gabčíkovo dams and prospects for mitigating the effects on migratory fish species

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The largest hydropower plants constructed on the Danube River

Starting from the Black Sea and upstream along the Danube River, the first dam and barrier for anadromous fish species on their spawning migration from the Black Sea and the Danube Delta is the Iron Gate II hydroelectric power plant (HPP) that was completed in 1984 at river km 863. The second obstacle is Iron Gate I at river km 943 that started operating in 1970, and the third is the Gabčíkovo HPP on river km 1816, completed and put into operation in 1992 *(fig. 1)*.

The Iron Gates are the largest hydropower dam and reservoir system along the Danube River, and are jointly operated by Romania and Serbia. The Gabčíkovo HPP is the second largest dam on the Danube and is operated by Slovakia. There are no fish passes on any of these dams and reopening of Iron Gates I and II could unlock an additional 900 km for the migration of anadromous fish species, with suitable wintering, spawning, nursery and feeding habitats. Similarly, reopening of the Gabčíkovo HPP could enable migratory fish to reach Vienna upstream.

The impact of damming on migratory fish species

In the past, beluga sturgeons *(Huso huso)* migrated in the Danube River up to Bratislava in Slovakia (river km 1,860–1,870), with a few records in the Austrian and even German (Bavarian) stretch of the Danube River up to Straubing, river km 2,320 (Reinartz 2002). Russian sturgeons *(Acipenser gueldenstaedtii)* regularly reached Bratislava but rarely travelled as far as Vienna and Regensburg, while stellate sturgeon *(Acipenser stellatus)* rarely came upstream to Komárno and Bratislava (Reinartz 2002).

Anadromous migration represents a life history characteristic that increases the sensitivity of fish species to human-induced mortality. Overfishing of sturgeon due to their valued caviar was one of the main reasons for their decline. Records of a decreasing trend in sturgeon catches in the 16th century were noted in Hungary, with constant subsequent overfishing that caused large migratory sturgeons

Figure 1: *The Iron Gate dams I and II and the Gabčíkovo dam (map: ICPDR)*

Figure 2: a) Pontic shad, Alosa immaculata, caught in the Danube River downstream of Iron Gate II near Prahovo (Višnjič-Jeftić 2012) b) Azov shad – Alosa tanaica, caught upstream of Iron Gate II (Mihajlovac Bay) in May 2016 (Photo credits: Katarina Tošić)

to become an occasional catch in the Hungarian section of the Danube in the 19th century (Guti 2006). Habitat changes in the second half of the 19th century further negatively impacted sturgeon migration along the Danube, while construction of the Iron Gates restricted migration to the Middle Danube.

Only two catches of beluga sturgeon (in 1972 at river km 1613 at Ercsi, and in 1987 at river km 1531 at Paks) have been reported in Hungary since the onset of the Iron Gates' operation (Guti 2006). The construction of Iron Gates I and II prevented the migration of anadromous fish species (sturgeons, shads) to the Middle Danube. According to the FIThydro project (Fish Friendly Innovative Technologies for Hydropower – https://www.fithydro.eu), sturgeon is classified in the group of 18 fish species of "highest sensitivity" (species under very high risk during hydropower operation) among 148 native European fish and lamprey species. This negative impact of Iron Gates I and II was evident on sturgeon as fish passes were not constructed, and as compensation for blocking fish migration, a sturgeon hatchery was built in the locality of Mala Vrbica (Serbia), 16 km downstream of Iron Gate I dam, but it is not in function anymore.

Migration of shad (Pontic shad, *Alosa immaculata, fig. 2a;* Azov shad – *Alosa tanaica, fig. 2b)* was also interrupted by the construction of the Iron Gates. In the past, isolated individuals of Pontic shad migrated for spawning into the Danube as far as Budapest (river km 1650, Bănărescu 1964). New data based on eDNA analysis performed within the Joint Danube Survey 4 (JDS4) and MEASURES project (Managing and Restoring Aquatic Ecological Corridors for Migratory Fish Species in the Danube River Basin – http://www.interreg-danube.eu/approved-projects/measures) revealed that Alosa sp. was recorded at 954 river km (Pont et al. 2021), which showed that shad specimens could pass through both Iron Gates via ship locks.

Not only anadromous migratory fish species are affected by the Iron Gates but also semi-anadromous populations of vimba bream *(Vimba vimba),* which migrate upstream from brackish waters into rivers for spawning, as well as potamodromous freshwater populations of vimba bream that exist in the Danube. Other potamodromous migratory fish species, such as sterlet *(Acipenser ruthenus),* sabre carp *(Pelecus cultratus),* common nase *(Chondrostoma nasus),* barbel *(Barbus barbus),* asp *(Leuciscus aspius)* and Danube carp *(Cyprinus carpio),* could also suffer from a lack of access to spawning and nursery habitats due to the loss of connectivity. Telemetry investigation of European catfish *(Silurus glanis)* carried out downstream of Iron Gate II showed that it migrated upstream during the spawning period, and that the dam and ship locks were obstacles for its migration (Lenhardt et al. 2021).

In the case of Gabčíkovo HPP, the true loser was the inland delta of the Danube, the last large wetland of Europe (Balon & Holčik 1999). The Gabčikovo Water Project, which included dam construction and canalizing, destroyed most of the 230 km^2 of wetlands that have become almost permanently separated from the main channel. The Gabčíkovo HPP is a system of three dams, the upper dam (Čunovo) obtains water from the old Danube channel to the derivation canal that is blocked by the lowermost dam (Gabčíkovo). The discharge of the old Danube channel has decreased to one fourth of the average discharge of the former Danube. This has led to a decrease of the water level in the old Danube channel, and a system of dikes was built to maintain the water level in the remaining inland delta side arms system. The inland delta system of side arms was one of the most

important spawning areas for migratory fish species, and it is now connected with the old Danube channel only during high floods. In general, the Gabčíkovo HPP has impacted not only longitudinal but also lateral connectivity. This has led to a decrease in fish abundance by a third (Černý et al. 2003), which continues unabated (Kováč, personal communication).

Possibilities for construction of fishways on HPPs

There have been many attempts to make the Iron Gates passable for migratory fish species. A scoping mission for the preliminary assessment of the feasibility of providing free passage to migratory fish species at Iron Gates I and II was organized in May 2011 by the FAO (Comoglio 2011). It involved different stakeholders, including representatives from the Romanian and Serbian Hydropower Company. Experts that participated in the mission suggested possible solutions for the management of upstream and downstream migrations over and around the dams. Potential solutions for upstream passage included a close-to-nature type of fish pass (bypass channel), a technical fish pass, a fish lift, as well as possible use of a navigation lock for fish passage. Suggestions for downstream passage included surface guide walls in the forebay of the HPPs that would lead fish towards surface bypasses. Following the FAO scoping mission, the project "Fish Migration at the Iron Gates I and II" further developed some of the most promising solutions for fish migration (De Bruijne et al. 2014). The prefeasibility study at the Gabčíkovo dam has also identified the most promising solutions (van de Kamp el al. 2014).

The main objective of the project "Fish Behaviour Preparatory Study at Iron Gate Hydropower Dams and Reservoirs" (DDNI 2015) was to restore fish migration on the Danube River by focusing on the main migration barrier (the Iron Gate hydropower dams between Romania and Serbia) as part of the legal requirements under the Water Framework Directive. Specific objectives were as follows: (1) to test and adapt different telemetry techniques (radio and acoustic) on sturgeons in order to identify the resolution required to precisely determine the preferred location of the fish pass entrances at the Iron Gate hydropower and navigation system, and (2) to prepare and train sturgeon tagging and tracking teams from Bulgaria and Serbia by a Romanian team in order to become partners in the forthcoming larger telemetry study *(fig. 3).*

The project MEASURES was initiated in 2018 and will be completed in 2021. The main aim of the project is to improve the conservation measures of endangered migratory fish species at the Danube basin by identifying and fostering the connectivity of habitats, and by promoting the establishment of ecological corridors. A map of migratory fish habitats has been prepared within the framework of this project. It shows that with a reopening of the Iron Gates there will be suitable wintering, spawning, nursery and feeding habitats upstream, meaning sturgeons and other migratory species would be provided with adequate conditions for reproduction and juvenile growth upstream of the dams (http://www.interreg-danube.eu/approved-projects/measures).

The project "Facilitating Fish Migration and Conservation at the Iron Gates" (WE PASS) started in 2018 with the main goal of preserving and reestablishing the migration route of endangered fish species in the Danube, specifically at the Iron Gates. Monitoring of fish behavior at Iron Gates I and II by acoustic telemetry is one of the aims of this

Figure 3: *Hands-on training of teams from Bulgaria and Serbia by the Romanian team on handling and surgical implanting of acoustic transmitters in the body cavity of sub-adult beluga sturgeon (total length 165 cm) using the electro-narcosis tube, Lake Sărulești (March 11, 2015)*

project. The other task relates to the building of models of the Iron Gate dams using hydrological and technical data (https://www.we-pass.org/).

In the area of the Gabčíkovo HPP, several LIFE projects that are currently running are focused on the interconnection of the inland delta or some side arms with the main Danube or old Danube channels. The LIFE + project "Restoration and Management of Danube Floodplain Habitats" aims to provide greater lateral connectivity. A newly submitted LIFE integrated project, "Implementation of the River Basin Management Plan in Selected River Sub-basins in Slovakia", will deal with complex and long-term proposals for restoration actions, particularly for the Danube River section in Slovakia, including fish migration and how to overcome barriers of the Gabčíkovo HPP.

Conclusion

The absence of fishways on the largest dams on the Danube River (Iron Gates and Gabčíkovo) make them mostly impassable for migratory fish species apart from the random passage of some fish via navigation locks. The negative impact on populations of migratory fish species is evident, especially on sturgeons. First steps in solving this problem were initiated in 2011. Since then, several projects have been completed and some are still ongoing, indicating a positive development in making the Iron Gates and Gabčíkovo dams traversable for fish. The construction of fishways would enable sturgeon to reach the majority of their historical spawning habitats.

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Mitigating ecological impacts of hydropower

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Introduction

Impacts on riverine ecosystems as a consequence of using rivers for hydropower (HP) production can be mitigated in various ways, whereby possibilities for gaining ecological benefits depend on many factors such as type and dimension of HP plant, river type of concern and other existing stressors. In principal, mitigating negative impacts is important throughout the entire HP planning as well as during pre- and post-implementation processes.

Mitigating impacts by strategic planning of HP

Mitigation starts at the planning stage, where dam siting decides in which way and to what extent catchments may become affected by HP use. Considering e.g. major fish migration routes, sensitive habitats and/or sites of high conservation value already during the dam siting safeguards environmentally-friendly implementation of HP. The ICPDR has developed a guidance document employing a number of economic and ecological criteria for classifying river sections from "favorable" to "non favorable" for HP use (ICPDR 2013). Following these guiding principles, new regulations for HP planning have been implemented in Austria at the provincial level and other countries (e.g. Bosnia and Herzegovina).

Mitigating impacts during and after HP implementation

Nowadays, a number of well-tested mitigation measures are available to improve the ecological conditions related to river continuity, sediment transport, hydrology, river morphology and water quality. Guidelines or guiding documents have been developed and are subsequently updated at national, European or international level supporting the planning and implementation of effective mitigation measures *(tab. 1).*