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ECOLOGICAL CHARACTERIZATION OF THE FISH COMMUNITIES WITHIN LOWER DANUBE RIVER

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Abstract
The main goal of the current study is to analyze the fish species of the Lower Danube River course in the context of river engineering projects that have modified the river bed and river shores and added structures which were necessary for flood protection, converting terrain to agriculture and maintaining the navigation lanes. In order to gain knowledge, the fish species were grouped into fish guilds. The Danubian fish are an important food source for the inhabitants of the Lower Danube River and their populations can act as a good indicator for human pressures, for instance for hydromorphological alterations. In the case of the Iron Gates II – Călărași (rkm 853 – 375), Călărași – Isaccea (rkm 375 – 100) and Danube Delta-Black Sea (rkm 100 – 0) sectors, a fair distribution of the rheophil A and rheophil B, eurytopic, stagnophil and anadromous fish guilds can be observed. The anadromous fish guild in not present upstream of the Iron Gates I in the Baziaș –Iron Gates I river sector (rkm 1075–943). The gobies are present in all sampled river sectors, including upstream of the Iron Gates.
The results show no evidence of a shift in the ecological guilds during the intensive monitoring of the Călărași – Isaccea river sector with rheophil B and eurytopic being dominant.
Further research is required in order to update the INCDPM Bucharest database and use the findings to consolidate upcoming policies regarding the implementation of measures meant to improve the conservation state of species and habitats.

Keywords: Fish guilds, Lower Danube, hydromorphological alterations.

1. INTRODUCTION

The Danube River Basin has a total drainage area of 801,463 km^2 and has fish stocks that are important to its inhabitants as food source or for commercialization. In addition to their commercial importance, changes in fish populations are also a potentially good indicator of human pressures, especially hydromorphological alterations (Joint Danube Survey 2: Final Scientific Report, 2008).
The Danube`s floodplains are an important natural source that positively affects the regeneration of the fish fauna during spring floods when the water inundates and creates suitable habitats for fish reproduction, the particularly important spawning and nursery habitats. The distribution of the

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floodplain area is greater on the Romanian side of the river with an estimated total area of 460.000 ha, however, in recent times, the construction of enhancements for agricultural expansion have dramatically reduced the total floodplain area.
In the context of historical use of the Danube River as an important navigation route, Baltălungă and Dumitrescu (2008) highlight this important contribution of the Danube for navigation and thus the European economy which, has led to the regulation of the Sulina branch by the European Danube Commission as early as 1856 and to construction of the Danube - Black Sea channel in 1984 and the Daube-Main-Rhine channel in 1992. Owing to the Belgrade Convention, of which Romania is a contracting party, our country has the obligation to manage and maintain the navigation regime for its Danube River sector.
The importance of fish as a biological resource for human consumption as well as maintaining the ecological equilibrium of the aquatic environment has given rise to the need to research the impact that different hydroworks have on the fish fauna. This fact is supported worldwide by the previous studies that have called attention to the impact of hydropower dams on the fish fauna (Australia - Walker, 1985; Africa - Dowidar, 1988; Europe - 1989; South America - Barthem et al., 1991; North America - Stanford and Nelson, 1994; Penaz et al., 1995; Ruiz, 1998; Worldwide - Henninger et al., 2000; Asia - Yi et al., 2010;). In Romania, authors like Bacalbașa-Dobrovici (1989, 1991, 1999), Ioniță (1997), Ciolac (2004), Oțel (2007) and Molara and Man (2012) have analyzed both the effect of the hydropower dams Iron Gates I and II on fish fauna and the effect of embankments during the communist era with the aim of increasing the total agricultural area.
This study aims to give an ecological characterization of the fish communities from the different Lower Danube river sectors in the context of their hydromorphological alterations. This study takes a step further than reporting only presence/absence data and groups the fish species that exploit a resources in a similar way into fish guilds (i.e functional groups) (Bergers, 1991). Species can be grouped into guilds depending on a variety of different life-history traits. Previous studies have group fish species by their feeding ecology (Bergers, 1991; Allan, 1995; van den Brink et al., 1996; Berrebi dit Thomas et al., 1998), by their flow preferences (Schiemer and Waidbacher, 1992; Schouten and Quak 1994) and by their spawning habitats and behavior (Balon, 1975a, 1975b, 1981; Holcík, 1989; Vriese et al., 1994).

2. MATERIALS AND METHODS

On the Lower Danube River, the teams of experts from INCDPM Bucharest have undertaken several monitoring campaigns of the Danubian fish fauna (INCDPM, 2011-2018; 2009-2019; Core Program, 2014-2015; 2015-2017) using either scientific electrofishing (SR EN 14011/2003) to monitor the fish species that occur near the shoreline or by use of filtering tools (trammel and gill nets) to capture the pelagic fish from the middle of the channel or at bigger depths.
Taking into account that, over the years, the Lower Danube has suffered a series of river morphological modifications as a result of the implementation of hydroworks for energy production, redistribution of the river discharge, embankments to enlarge the agricultural terrains or river regulation to maintain and/or improve the navigation corridors, the analysis of the fish fauna was done by dividing the Romanian Danube sector into five sections (Figure 2):

- section 1 – rkm 1075 – rkm 943 (Baziaș – Iron Gates I);
- section 2 – rkm 943 – rkm 853 (Iron Gates I – Iron Gates II);
- section 3 – rkm 853 – rkm 375 (Iron Gates II – Călărași);

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- section 4 – rkm 375 – rkm 100 (Călărași – Isaccea);
- section 5 – rkm 100 – rkm 0 (Isaccea – Danube Delta, Black Sea).

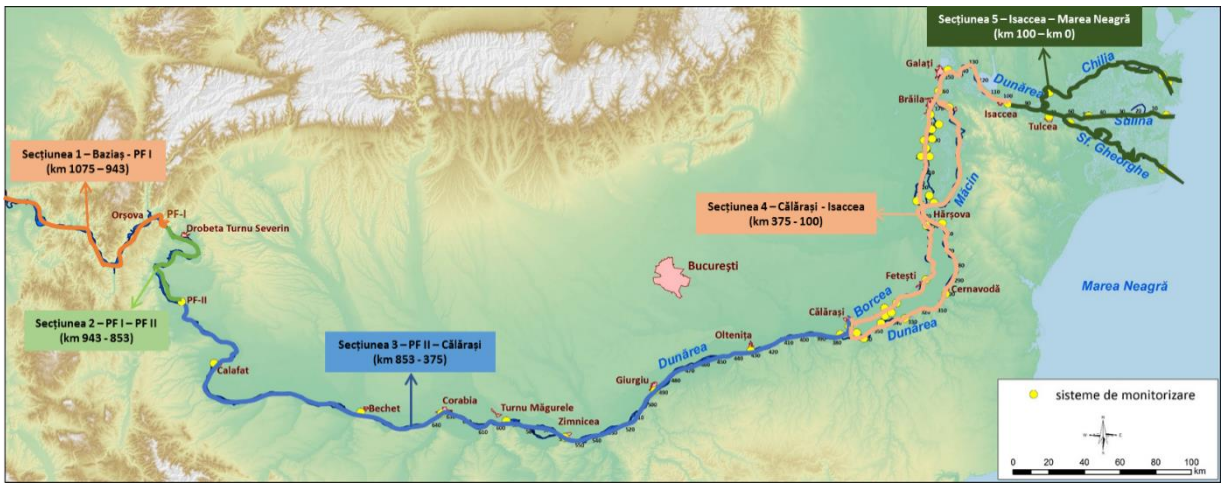

Figure 1. Maps showing the five different river sectors

In addition to this river sectors, a study area that was intensely monitored, for the quantification of the effect of the newly built bottom sill, is the Caleia branch. In addition to drift netting, scientific electrofishing for the identification of fish species present in the Caleia branch (Figure 2) was done using two methods:

- bank electrofishing and capturing the fish using a spoon-net;
- electrified benthic frame trawl.

Using these two methods and analyzing their subsequent catches highlighted some advantages and disadvantages that are summarized in Table 1.

Table 1. Advantages and disadvantages of the two scientific fishing methods used by INCDPM Bucharest in the monitoring campaigns

Bank electrofishing		Electrified benthic frame trawl	
Advantages	Disadvantages	Advantages	Disadvantages
1) High efficiency in catching pelagic fish species; 2) Wide utilization on a wide range of river orders (e.g. streams, rivers); 3) Efficient utilization from the boat or by wading	1) Reduced efficiency in catching benthic species; 2) Reduced efficiency in waters with depths over three meter.	1) High efficiency in catching benthic species; 2) Ability to capture a high number of individuals due to the netting.	1) Reduced efficiency in catching pelagic fish species; 2) High risk of entanglement and equipment loss; 3) Usable only from the boat and on higher order rivers.

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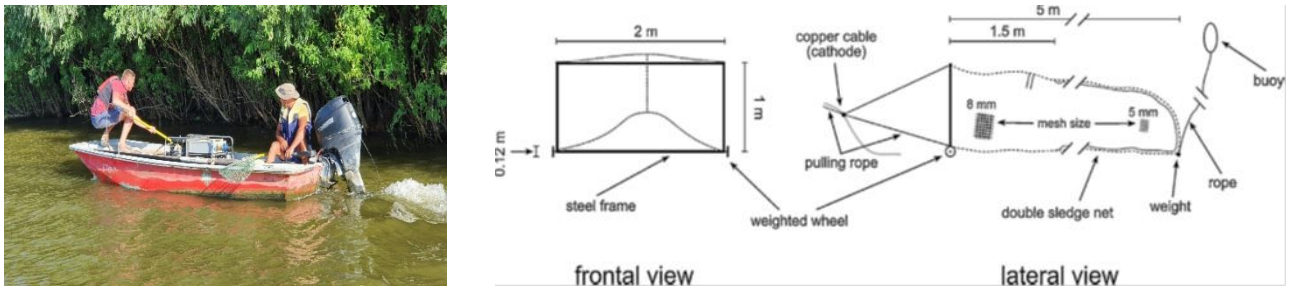

Figure 2. Fishing techniques used by the ICPDR. Left: bank electrofishing. Right: electrified benthic frame trawl Source: ICPDR (2013)

The classification of the fish species into fish guilds was done takin into account their ecological preferences regarding water velocity and thus riverine habitats but also their reproductive behavior. The same classification was used during JDS2 and JDS3 (Joint Danube Survey 2: Final Scientific Report, 2008; Joint Danube Survey 3: Final Scientific Report). The following characterization is used in this study:

- Rheophil A = All freshwater stages of life history are confined to the main river (e.g *Romanogobio vladykovi* and *Gymnocephalus schraetser*);
- Rheophil B = some stages of life history are confined to well-connected backwaters or tributaries (e.g *Blicca bjoerkna* and *Sander lucioperca*)
- Rithral = some stages of life history require cold and oxygen rich headwaters (e.g *Lota lota*, Cobitis spp.);
- Eurytopic = all stages of life history can occur in both lotic and lentic waters (habitat generalists);
- Stagnophil = all stages of life history are confined to lotic waters with macrophites (e.g *Rhodeus amarus* and *Lepomis gibbosus*);
- Anadromous = adults migrate upriver to spawn (e.g. *Huso huso, Acipenser stellatus*, Alosa spp.);
- Gobies = inhabit rivers, lakes and coastal areas in crevices of rocky substrate (e.g. *Neogobius fluviatilis* and *Neogobius kessleri*).

Ecological indicators such as relative abundance were calculated using the following formula:

$$A = \frac{n_i}{N} * 100$$, where:

A = relative abundance;
n_i = number of individuals from a certain species belonging to the total sample size;
N = number of the total individuals from all the samples.

All data processing and graphs were made using Microsoft Excel 2013.

3. RESULTS AND DISCUSSIONS

This river classification has been made in order to highlight the ichthyofauna composition present in the five sections that display different ecological characteristics as a consequence of river regulation.

According to the results from figure 3, when the analysis is made using the presence data, a characterization could not be made for the Iron Gates 1-II river sector do to an incomplete dataset. From the literature, only information regarding the cyprinid character of the waters was found, with

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species from the Ciprinidae family being dominant. These fish species are: *Alburnus alburnus*, *Abramis brama* and C*arassius gibelio*. Moreover, as a consequence of the transformation of area between the Iron Gates I and II into a novel lotic ecosystem, we may conclude that, at this study area, the fish species present are stagnophil rheophil-stagnophil species that are typical for such an environment.

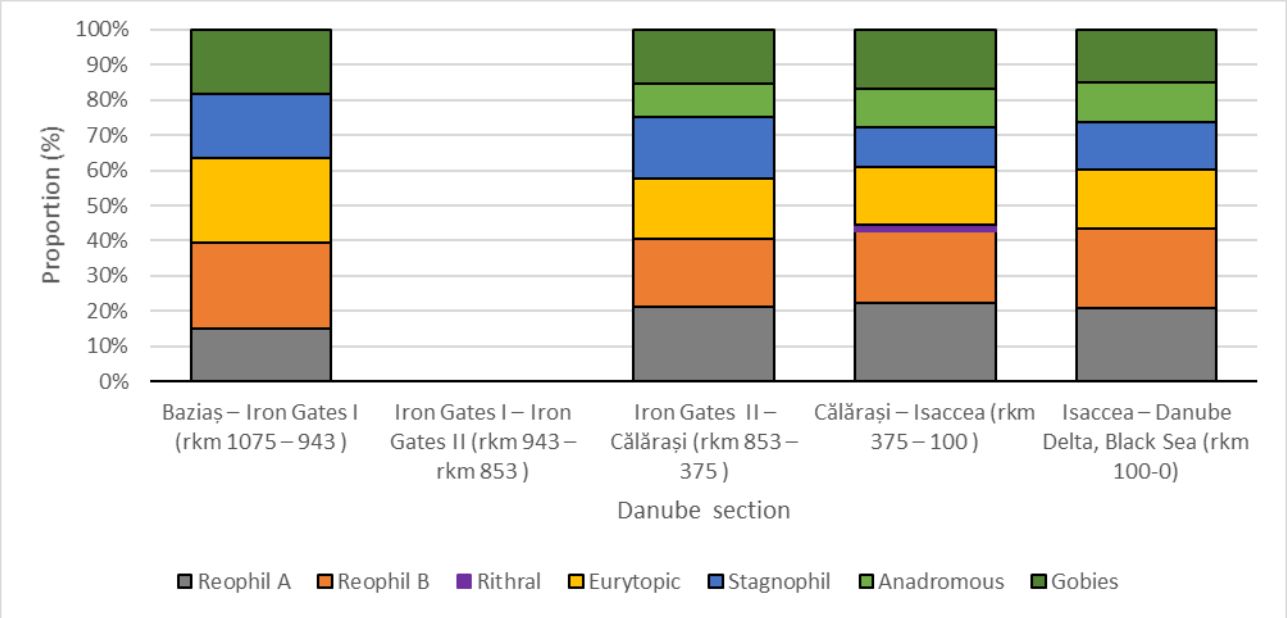

Figure 3. Distribution of the fish species classified by fish guilds on the entire Lower Danube (based on presence data)

The absence of migratory fish species like *Barbus barbus*, *Acipenser ruthenus*, *Alosa immaculata*, *Alosa tanaica*, *Acipenser stellatus*, *Acipenser gueldenstaedtii* and *Huso huso* from the anadromous fish guild may be confirmed. As a consequence of the construction of hydroworks from the Romanian side of the Danube River (mainly the Iron Gates I and II) have limited the access to upstream habitats causing habitat fragmentation, some migratory species are considered to be absent upstream of the damns (Danalache, et al. 2019).

The analysis of figure 3 shows that anadromous fish are missing from the ecological structure of the aquatic ecosystems from Baziaș – Iron Gates I sector (rkm 1075 – 943) and the Iron Gates I and II sector– missing data (rkm 943 – 853). A possible explanation for this might be because the interruption of river connectivity caused by the construction of the hydropower plant at Iron Gates II.

The missing data regarding the fish fauna composition between the Iron Gates I and II made the realization an evaluation of the fish guilds in that sector impossible.

In the case of the Iron Gates II – Călărași (rkm 853 – 375), Călărași – Isaccea (rkm 375 – 100) and Danube Delta-Black Sea (rkm 100 – 0) sectors, a fair distribution of the rheophil A and rheophil B, eurytopic, stagnophil and anadromous fish guilds can be observed. This denotes that no significant modifications to the aquatic ecosystems led to the fish fauna destabilization.

In the previous mentioned river sectors, a balanced distribution between rheophil B, eurytopic and stagnophil species can be observed. The high diversity in the river sectors Iron Gates II – Călărași

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(rkm 853 – 375), Călărași – Isaceea (rkm 375 – 100) and Danube Delta – Black Sea (rkm 100 – 0) may be due to the co-occurrence of rheophilic and eurytopic forms (Schiemer, et al. 2003).
Rheophilic B species (e.g. *Abramis ballerus, Aspius aspius, Leuciscus idus*) require that the river and the floodplains are connected so that the species have access to additional habitat for feeding and as a wintering. These species are excellent indicators of lateral connectivity between lotic and lentic conditions (Schiemer, et al. 2003). Therefore we may conclude that in the river sectors downstream of the Iron Gates II, there is still connectivity between the two ecosystem types.
The gobies fish guild is present in all the river sectors, including upstream of the Iron Gates I.
Figure 4 bellow shows the results of the intense monitoring on the Călărași – Isaceea river sector including the Caleia branch. In general, there is no evidence of a shift in the ecological guilds, with rheophil B and eurytopic being dominant. The changes in the anadromous group may be caused by the temporal variability of their migration or site-specific environmental factors that affected the sampling effort and catch success of the different surveys. The data from 2013 has a much higher sample size because it coincided with JDS 3 and the novel use of the electrified benthic frame trawl by the specialist teams, however the proportion of the relative abundance is similar to the other fishing campaigns.

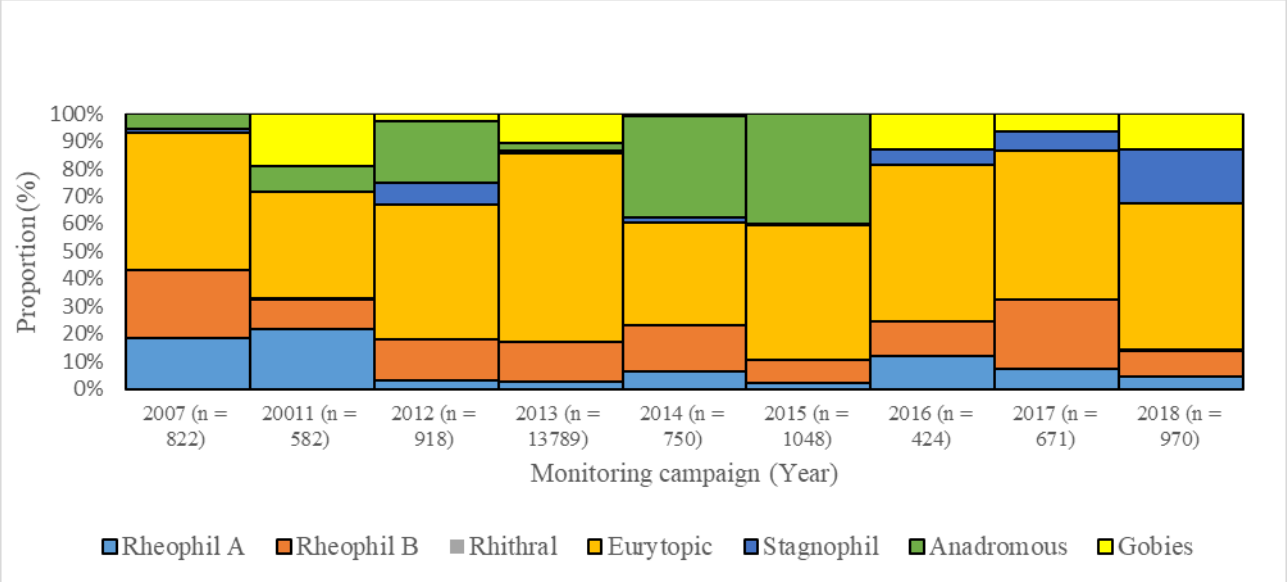

Figure 4. Relative abundance of the fish species occurring in the Călărași – Isaceea (rkm 375 – 100) river sector grouped by fish guilds (based on calculated abundance)

Our results are in accordance to the literature findings where the guild structure of an aquatic ecosystem is often more stable in time than its species composition because, when the environmental variables change to a certain degree, the species within a guild can replace each other's functional role (Aarts and Nienhuis, 2003).
Because sturgeon species are flagship species of the Danube River and of great concern for conservation purposes, this study pays special attention to their status as anadromous migratory species. At present, INCDPM Bucharest holds a unique database at the national level and worldwide regarding the behavior of sturgeon species during migration as a result of the research started in 2011 which demonstrates that the sturgeon species can successfully swim upstream the

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bottom sills form the Bala and Caleia branches that were built in order to redistribute the river discharge (Danalache et al., 2017). As a consequence of data processing of the results collected in over nine years of research, the INCDPM experts have identified the biggest pressure on the conservation state of the sturgeon species represents poaching. In addition, the findings show that the sturgeons possess impressive abilities to migrate long distances, some sturgeons being recorded at the Iron Gate II area at rkm 848.

Regarding the effect of the Iron Gates I and II on the sturgeon species, Bacalbaşa-Dobrovici (1989, 1991, 1999) correlates the Danube damning with the sturgeon species` decline. However, analyzing the findings of Oțel (2007), the decline in sturgeon captures can be observed since 1940, leading to the conclusion that the two hydropower plants may not be the main cause of the decline. Nevertheless, without the implementation of conservation measures the population of sturgeon species of the Lower Danube will diminish and may go extinct.

In addition to the construction of the two large dams on the Lower Danube, another problem with negative outcomes on the ichthyofauna was the conversion of the floodplains into agricultural terrain during the communist era which led to a systematic reduction in floodplain area. Blidaru (2011) has found that the floodplains represent 19.5% from the entire Danube River basin. Molnar and Man (2012) have made a comparison between the baseline situation of the Lower Danube from 1880 and the situation from 2009 and have found that the floodplains have reduced so much that they hardly can be found.

In time, the conversion of the floodplains to agricultural terrain has negatively affected the populations of fish species of commercial interest. These effects on the fish stocks have been observed in Danube Delta Biosphere Reservation in the research of Oţel (2007).

4. CONCLUSIONS

In the case of the Iron Gates II – Călărași (rkm 853 – 375), Călărași – Isaccea (rkm 375 – 100) and Danube Delta-Black Sea (rkm 100 – 0) sectors, a fair distribution of the rheophil A and rheophil B, eurytopic, stagnophil and anadromous fish guilds can be observed. This denotes that no significant modifications to the aquatic ecosystems led to the fish fauna destabilization. Călărași – Isaceea river sector including the Caleia branch. In general, there is no evidence of a shift in the ecological guilds, with rheophil B and eurytopic being dominant.

The gobies fish guild is present in all the river sectors, including upstream of the Iron Gates I.

A limitation of this study is that there is an acute shortage of data regarding the evaluation of fish fauna from the newly formed lentic ecosystem that arose because of the construction of the Iron Gates I and II. Nevertheless, the ecological classification of the fish species into fish guilds highlights the modifications of the fish fauna composition that may be a consequence of the river regulation projects on the upper sectors of the Danube River. Thus, anadromous migratory species are absent upstream of the Iron Gates II areas.

Regarding the anadromous fish guilds, INCDPM Bucharest holds a unique database, at both the national and international levels, on the migration behavior of sturgeons that were tagged with ultrasonic transmitters. This database shows that sturgeons can swim against the water current and successfully pass over the bottom sill areas from the Bala and Caleia branches, given their actual crest height. Moreover, the findings collected over a time period of nine years of research studies have highlighted the fact that sturgeons have the capacity to migrate upstream and still reach the Iron Gates II area. This is confirmed by the presence of a *Huso huso* individual that was detected by a recording station at that location.

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At the present date, the biggest pressure that negatively affects the conservation state of sturgeon species by limiting their population numbers is the phenomenon of poaching, which according to INCDPM Bucharest`s data, has led to the loss of over 70% of the tagged and monitored specimens. Additional research is needed regarding the updating of the national database and closing knowledge gaps in the evolution of the fish fauna, especially in the area between the Iron Gates I and II. Further research studies might explore the characteristics of the novel ecosystem which has resulted from river damning. Moreover, it is paramount to ensure that the monitoring of sturgeon species continues on the Lower Danube course so that the database is kept up to date. In the future, these findings can be used to consolidate upcoming policies regarding the implementation of measures meant to improve the conservation state of species and habitats.

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