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Past and present of fish passes. Short literature review within the Romanian context

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Abstract: Implementing the Water Framework and the Habitats Directives, Romania is increasing its efforts to make rivers again available for fish migration. This paper is analysing literature on fish passage available in Romanian language, addressing also the international scientific background. The surveyed titles cover various subjects, like the legal frame, fish ecology, transversal barriers, fish pass design, monitoring, and environmental flow.

Keywords: fish, dam, fish pass, longitudinal continuity.

1. INTRODUCTION

Romanian legislation has undergone various stages, most recently adapting the national legislation to the European directives. Like any transition, this too was marked by contradictory provisions, lack of methodological norms, many delays, lack of information on the public side coupled with a lack of transparency on the part of the authorities. Several barriers on the rivers and inefficient fish passes in the Romanian landscape triggered this short review.

2. METHODS

For this study, older and up to date literature has been consulted. Previous studies and field trips during monitoring activities have broadened the perspective on this subject.

3. RESULTS

3.1 Legal Frame

European and national legislative provisions are utterly complex, so this section will not refer to the legislation itself, but only to the literature that addresses this issue and has strict relevance for this country.

The legal framework for the measures aiming to achieve longitudinal continuity is summarized in [1] during the public participation process for the basin management plans, while the legal framework for the construction of small hydropower plants is illustrated in [2], but making only general remarks on solutions for environmental protection.

A particularly useful report on the analysis of small hydropower specific legislation was developed in [3], in this report detailing not only legal, but also environmental consequences of the overall situation on the environment. Numerous opportunities to improve legislation have been identified, the organization being already involved in official negotiations for legislative improvement with the competent authorities. In January 2014 a protocol was signed between this NGO and the Ministry of Environment, which adopted some measures that could stop the adverse effects on rivers in protected areas until the implementation of a coherent legal framework in this area, taking into account environmental requirements and riparian ecosystems, ensuring the achievement of the environmental objectives set during the implementation of the Water Framework Directive and Habitats and Birds Directives. Implementation of common guidelines in the European space entails channelling the efforts in a definite direction. Thus, over 25 specialists have contributed to compiling a very useful guide for managing environmental impacts resulting from economic activities [4]. Along with a coherent analysis of Water Framework Directive requirements, examples of good practice mitigation measures are provided, together with an assessment of the resulting effects. Inclusively the conditions are detailed, under which river continuity can be ensured for upstream as well as for downstream migration.

The International Commission for the Protection of the Danube River was involved in the implementation of European directives, forming a manual of best practices in sustainable waterway transport [5], identifying the relevant legislation, presenting a model of an integrated planning process and finding relevant examples in this matter.

A short but conclusive identification of legislation and policies that contribute and those that prevent the restoration of natural conditions in aquatic ecosystems was undertaken in the RESTORE project [6], which emphasizes the importance of collaboration between different institutions and public involvement

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in the decision process because most projects are covered by several pieces of legislation, which sometimes serve different purposes. The lack of implementation of European and national legislation is identified as the most important barrier to restore rivers, especially on a local level, where the restoration itself is needed.

An analysis of the current status of surface waters is done in [7], also identifying options for sustainable management

3.2. Biology and migration

On the territory of today's Romania, the documented research on fish starts with Marsigli's observations, which arrived around 1690 to Ada-Kaleh, leaving in the *Danubius pannonicus-mysicus* of 1726 valuable information on the fish fauna of those places, including five species of sturgeon. A special contribution in research and knowledge of aquatic ecosystems brought Grigore Antipa, also known as the founder of the Romanian hydrobiology and ichthyology school. Leading the fisheries authority, his efforts concentrated on establishing a modern and sustainable fishing industry. His work and research shows a deep understanding of the dependence of the individual fish on the river ecosystem, including flood plains, but also on natural phenomena, which are often perceived as disasters. In its work, Antipa addresses the longitudinal continuity of the river by revealing the migrations of the sturgeons from the Black Sea to the Danube , but also deals with the phenomenon of lateral connectivity of river with its floodplain, proposing a system of submerged dikes, in order to efficiently exploit the ecosystem services of the floodplains. The industrial revolution and the changes due to this cultural and social upheaval have made the ideas of Antipa to be abandoned, a final "non-submersible levee" system was adopted, so that the fishery became an almost negligible branch in the country's economy. The biology research work of Gigore Antipa was carried on by many biologists, but "Romania's Fauna" written by Bănărescu in is still the reference work in Romania. It is desirable that the current process of designation and monitoring of protected natural areas and the implementation of European directives will encourage scientific research, allowing updating of the information left by all these valuable scholars.

Returning to the theme of sturgeons, research was continued by scientists like Nicolae Bacalbaşa-Dobrovici and Holcik, but took a special scale in the Danube Delta National Research Institute, whose experts have addressed the complex issues about biology, ecology, fishery, conservation, restocking management, genetics or migration. All these efforts have led to a better understanding of the ecological requirements of different sturgeon species, now scientific elements beginning to emerge upon which effective measures can be built for the management of sturgeon populations and for sustainable fisheries.

As one can expect, the international scientific literature is very rich in publications about the biology and the migration of the aquatic fauna. Actually, the reference works on fish passes address the subject of the ecological requirements of fish, which is the basis for a scientific approach in achieving longitudinal river continuity and in deciding on fish pass type, dimensions or location.

3.3. Transversal barriers on water courses

Regarding the impact of small hydropower plants on aquatic ecosystems, states that "even under very restrictive environmental protection, sustainable and peaceful coexistence is possible for small hydropower plants with the environment" and "for the small hydropower plants it is much easier to meet environment protection requirements than for large hydropower plants". If the latter statement could theoretically be argued in a logical way, case studies like demonstrate that in the field, in Romania "very restrictive environmental protection" is a pure theory, unfortunately not related to the reality.

The lack of implementation of mitigation measures and the lack of any environmental flow downstream of the abstraction sites, amplified by the large number of MHC required to match an efficient hydroelectric power plant, gives rise to the question whether altering numerous mountain rivers is indeed compatible with sustainable development. The poor efficiency of small hydropower plants becomes evident when taking into account that the revenue received by the investor is represented mainly by subsidies in form of "green certificates". Moreover, shows that transversal structures in the rivers and low flows associated with the small hydropower sector are among the most important threats to fishery yield and biodiversity.

All over the world, the effect of barriers on aquatic fauna has been studied extensively, since it was almost instantly noticed by the inhabitants of the river in form of fishery collapse and subsequently livelihood loss. The effects of dams on fish production are discussed in detail in, which examines various methods of removing negative impact. Noting that both literature and water managers highlight the impact, especially of large dams, shows that small obstacles in the way of migration have the same effect as large obstacles. Anyway, the principles for improving negative effects are the same, only the solutions will differ only to fit the constructive parameters of the transversal structures.

With regard to the Danube, found a significant effect on fish populations due to the longitudinal continuity interruption at the Gabcikovo dam, proposing some general solutions. The construction of the Iron Gates I and II dams brought about the same effects. Also, current navigation improvement projects are monitored by specialists in this field from all over Europe. For example the International Association for Danube Research - IAD prepared a note, stating its concern about the building of the bottom sill on the Bala arm of the Lower Danube, arguing its position by the findings of the team from BOKU Vienna, which demonstrate the incompatibility of the proposed structure with sturgeon migration.

An interesting approach, that could be useful in Romania, is presented in, which proposes a simple method for prioritizing the sections for longitudinal continuity restoration at dams, using information about the presence of fish, barrier type, river course length made available, distance from the river or stream mouth etc. Case studies from Romania show that no prioritizations were made for the measures seeking to restore longitudinal continuity, but also that there is no inventory of the barriers on the rivers or that access of the public to such a list is not desired.

Cada G. F. describes different protection measures at abstraction sites, but identifies only scarce data to assess the effectiveness of these measures, a few years later describing a theoretical method of evaluating the effects of turbine passage on fish populations.

In a broad PhD thesis, addresses the effects of hydropower plants on 15 families of fish, for two years assessing thoroughly the survival rate for every fish family, studying causes of death, internal or external wounds, presenting computational models of survival in different turbines and making observations on the various mitigation methods. The studied trash rack width being 90 mm, the drop 4.55 m and the turbines of vertical Kaplan type with a flow of 120 m^3/s, the results can be extrapolated to large Romanian rivers. The mortality ranged between 11 and 46%, the values varying for different families of fish, only catfish (*Siluridae*) making an exception with 6%.

Studying eel survival after passage through turbines, found a survival rate of 26% for individuals who came in contact with the 20 mm spaced trash rack and eventually with the turbines, although the recorded water velocity at the rack was relatively small measuring 0.5 - 1.2 m/s, the rack being inclined at 63.4 degrees. It should be noted here that these fish are excellent swimmers, covering large distances during their migration, and have an extraordinary ability to slip through tight spaces. Surprisingly, 40% of individuals survived being placed behind the rack, so they passed only through the turbines. A few years later addresses the same site, proposes and applies solutions by tilting the trash rack at 35 degrees, operating various modifications to ensure downstream passage, so that mortality decreased to below 10%. It is obvious that classic 20 mm spaced racks have to be replaced with new facilities, but an alternative downstream migration pathway must be provided. The concept of downstream migration survival rate is present in the US, the rate being fixed in the regulatory acts. Electric power companies are making serious efforts in this direction, allowing even for substantial changes in the structure of the dams and in the operation modi. Even if this subject is a taboo in Romania, in the US the survival rate to be ensured reaches 95% for the dam passage, respectively 93% for the passage of both impoundment and dam. In time, Romanian authorities and water resource managers will have to take measures to ensure downstream fish migration.

3.4 Fish pass design

Various publications appeared in Romania, addressing the subject of fish passages. Having an instructive character, these works explain the principles for the choice of fish pass location and outline the operation of various types of passages. But in the last 25 years, a significant experience and many innovations have been accumulated in this area. Another paper about globally and locally used measures for fish migration was published by the National Institute of Hydrology and Water Management and contains brief references to the types of passages used in the world and in our country, trying to assess the current situation in Romania. However, proposing solutions to restore continuity, the author exposes in other works an opinion, unfortunately so often shared in Romania: “the design of technical solutions proposed ... requires neither technical knowledge nor outstanding engineering skills, making them feasible from this point of view". The same opinion is repeated in. The rife failures bear witness to the complexity of fish pass design, special knowledge on the biology and ethology fish being needed, as well as on river hydrology and on hydrotechnical engineering.

Different publications make proposals of measures to ensure the longitudinal continuity, e.g. of Barca river, Iad River or Crişul Repede River, but these either do not offer concrete solutions or do not indicate a scientific reasoning for proposed measures.

Fish passage monitoring has not been addressed explicitly in Romania, however is referring to the "functionality" of existing passes. But in the absence of scientific monitoring studies, it can be assumed that the passages were classified as "functional" only based on structural integrity and an existent water flow, considers, in turn, that the existing passages are useless, while the case study shows the lack of functionality of all six fish passes in the Sebes River basin.

A brief overview of the evolution of different models and fish passages history was presented by as introduction to a fish pass guide, together with a list of relevant literature of the past 100 years.

Citing a comparison made by Redeker and Neumayer, reveals that, although there is a great abundance of information, the international standards overlap in most directions, be it about location, entrance or dimension of fish passes. Differences are present in form of different maximum speeds in the migration corridor, but only because of the focus on different target species.

Different publications approach the numerical modeling of fish passes, especially after the fascinating IT sector development. In Oberle P should be noted, presenting both theoretical foundations and different meshing methods and validating the results on a prototype. Algorithms for optimizing a vertical slot passage are presented by modeling different configurations to achieve the desired results, showing thus the advantages of numerical modeling: saving

time and material resources.

The biggest fish passage in Europe today lies on the Elbe River in Geesthacht, which was initially designed and optimized using a 2D model, then a 3D model, a process described by, in which the centre of gravity was on adaptation to local conditions, especially to varying downstream levels, because of the tidal influence.

But numerical modeling is not required only to optimize fish passages, it is absolutely necessary in case of large hydro technical structures or in the case of relatively uncertain results. Thus conducts a very complex study on the Danube between Calarasi and Braila, of direct relevance to our country, where the navigation companies desire a deflection of the gross flow of the Bala arm into the Old Danube. Following the introduction of various data in this analysis and after the validation of the results, a 3D model of the entire system was obtained, with an estimation of water levels, flows, velocities etc. for different configurations of the bottom sill. The results were contradictory with those expected by designers, but will enable a decision process based on solid data.

Surely large fish passes built in the USA and the USSR were evaluated by means of physical scale models, but probably due to their age, those studies are not in electronic databases. Theoretical and practical aspects of vertical slot passages resulted from numerous scale studies conducted by Rajaratnam in, which reveals through a systematic approach the influence of different pass sizes and configurations on the flow in the passage and offers ideal measures to achieve a continuous sinuous and less turbulent flow. Various studies can be mentioned here, for example carried out in, each contributing to the development of today`s passages.

As shown, numerical models were performed for the Geesthacht fish pass and configurations have been changed, more than 50 variants being tested, but the results were translated into a 1:13 scale model on which only relatively minor optimization changes were operated. Anyway, the research team went further, making tests with live animals, ensuring that the final confirmation of the passage and monitoring system will be accepted by the fish. But as the scale model is not suitable for such experiments, the critical sections of the future fish pass were reproduced in order to be checked for the "live" efficiency. As a model or fragment passage may not reproduce all the conditions in the prototype, there is still a need for a careful monitoring during the operation of the fish pass.

An example of a study prior to construction works for a fish passage can be that for the fish lift at the Golfech dam on the Garonne River in France, conducted by, describing the scientific rationale and subsequent steps taken over six years. Another, more recent example, can be the study for the Geesthacht fish pass, which describes both relatively advanced methods of monitoring and scientific rationale for the location, dimensioning and configuration of the passage.

A description of the different types of passages, with the principle of operation and guidelines for building passages can be found. It should be noted that these titles were published in a relatively long period in which this field has evolved significantly over the years, so smaller and smaller drops between basins have been adopted along with larger and larger volumes for the pools, resulting in a flow with small turbulence, low velocities and enough space for fish shoal migration.

Numerous passes across the globe are presented in the *From Sea to Source* good practice guide while the meta-analysis comprised by is revealing the benefits of river restauration based on the analysis of 89 scientific studies.

3.5. Fish pass monitoring

So far, no publication could be identified in Romania on monitoring of the longitudinal continuity of rivers or on monitoring and evaluating hydro technical structures to ensure the longitudinal connectivity. Furthermore, no monitoring report can be found for fish passes, although there is a reporting obligation to environmental agencies, at least for protected natural area, including Natura 2000 sites. Moreover, the results of such monitoring should be available for the public, but the authorities are either refusing this or do not obtain these reports, such as described by, stating that the monitoring reports were not delivered, although officially requested.

With the development of technology, different systems to monitor aquatic organisms were adopted. Detailed descriptions can be found in, where applied cutting-edge techniques for acoustic transmitter tagging and placement of automatic receiver stations are described, but also in for applications with underwater cameras based on ultrasound, efficient in water with extremely low visibility or at great depths.

3.6. Environmental flow

A comprehensive study was published by ICAS, the Romanian Institute for Forestry research, taking a closer look at the trout fisheries production. Even if the subject is somewhat complementary to the approach in this paper, the author describes changes in ecosystems lacking natural flow, beginning with low primary productivity, continuing with altered chemistry and oxygen content, with negative impact on groundwater and ending with lower productivity of fisheries of the river. It is also mentioned that a diversion of more than one third of the natural flow of the river entails a deterioration of the river and lowers the quality class. These values are comparable with the results of other authors, results to be presented later in this section.

Compares two methods for calculating the environmental flow for rivers in Romania, finding that the flow Q80% ensures best the environmental needs, taking into account both the depth and speed of the water. The study, however, does not provide data whether a validation of this method in the field was undertaken, since the considered depths were computed for the gauging stations and not in the

critical or pessimal sections of the river.

With reference to the remaining flows in the river bed downstream of reservoirs or water abstractions, presents principles and concepts for the restoration of watercourses and briefly describes measures to concentrate the water flow over only a fraction of the bed width, measures that should be suitable for the restoration of water courses with low flow rates or modified river bed. The concept of "eco hydrograph" is detailed in, analyzing the flow regime of a river before and after being impacted by an impoundment. Noting that the environmental flow calculated using the current method in Romania is actually a survival flow (also called “dilution flow”), concepts are listed that should be considered for a dynamic environmental flow, in order to ensure the requirements of downstream ecosystems. But the solutions are proposed without assessing to which extent those downstream habitats suit the ecological needs of fish, invertebrates or riparian ecosystems.

The results of a particularly comprehensive study is incorporated on 141 pages by , reviewing a number of studies, methods and requirements, making a careful assessment of the effects on sediment, morphology, bank stability, aquatic biotopes, tributaries, flooding processes etc. Different methods and solutions are presented, including triggers for the fish migration. In turn, details the effects of an altered flow regime on ecosystems, includes details about the necessity of flow dynamics, but also about alien species invasion facilitated by altered flow regime.

For conditions in Italy, the guidelines for establishing environmental flows are displayed by, while the concept behind the Austrian guidelines are described in Jäger, P.

4. CONCLUSIONS

Two important conclusions can be drawn after this short analysis of the international and Romanian treatises:

The literature in Romania is deficient and, unfortunately, no guide could be identified in Romanian language, to meet the needs of those involved in fish pass design. The same is true for numerical or physical scale modeling of fish passages. If the lack of scale modeling could find an explanation in the present state of hydro technical laboratories of research institutes in the country, it is obvious that the emergence of a guide for planners is an absolute priority in the field. This guide should address all issues in this area, from location selection to monitoring of the efficiency during operation, all addressed in terms of the latest scientific data.

Compared to this situation, the global literature is relatively rich, consistent, revealing a common understanding and a generally shared direction.

However, the need for extensive research with modern technology is urgent, in order to better understand the behavior of the aquatic fauna and, further, in order to mitigate the effects of the major barriers on the rivers and on the streams.

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