LIFE4FISH PROJECT: DOWNSTREAM MIGRATING FISH PROTECTION AT HYDROPOWER PLANTS ON THE RIVER MEUSE IN WALLONIA

by

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1 INTRODUCTION

River damming is a key element in navigable rivers equipment. It also creates adequate conditions for hydropower production. However, the construction of dams and weirs leads to river fragmentation, which can affect the natural flow dynamics in certain segments of the river and has a severe impact on river ecology with potentially detrimental effects on fish populations [Vörösmarty et al., 2010 ; Liermann et al., 2012]. In particular, such structures hinder fish migration to and from spawning grounds and subsequently threaten the aquatic biodiversity. First science-based efforts to facilitate upstream migration of fish through or around hydraulic structures were noted in the beginning of the 20th century [Katopodis and Williams, 2012], while downstream passage was considered more recently. However, fish passage efficiency for both upstream and downstream migration is still not enough [Ovidio et al., 2017 & 2021] and additional actions are required.

In this context, the EU funded Life4Fish project (www.life4fish.be) aims at restoring downstream connectivity at six hydropower plants (HPP) along 83 km of the Meuse River in Wallonia by testing and implementing passage solutions for European eels (Anguilla anguilla) and Atlantic salmon smolts (Salmo salar), while minimizing renewable energy production loss.

The project is carried out by an interdisciplinary and intersectoral team gathering people from research and industry, with biology or engineering background, and extends over 5 years (Figure 1). It started with an initial field survey aiming at characterising the initial situation (reference situation) in terms of fish passage at the HPPs but also fish presence and health status in the Meuse River and its main tributaries. Indeed, HPPs may not only have a direct impact in terms of mortalities, injury and migration delay but also an indirect one in terms of physiological or immune changes that can compromise Atlantic salmon smolts and European adult's eel ability to escape successfully to the ocean [Ben Ammar et al., 2020-2021]. Therefore, it is important to assess the health status to estimate the efficiency of turbines and passage solutions on fish ability to migrate.

Then, varied solutions to improve downstream passage have been developed and designed at two pilot sites. These solutions include temporary shut off of the HPP coupled to a migration prediction model, implementation of a safe downstream passage route (through mobile dam flap gate or a dedicated passage) possibly coupled to a repulsive barrier, and implementation of eco-sustainable turbines. The solutions have been implemented for testing at the 2 pilot sites and a second field survey has been conducted to assess their efficiency for both eels and smolts migration. Then, the most effective solutions have been implemented for each of the 6 HPPs along 83 km of the Meuse River. The efficiency of the global solution will be assessed on next year by a third field survey.

In this paper, we present the varied solutions that have been tested to improve downstream passage in the framework of the project.

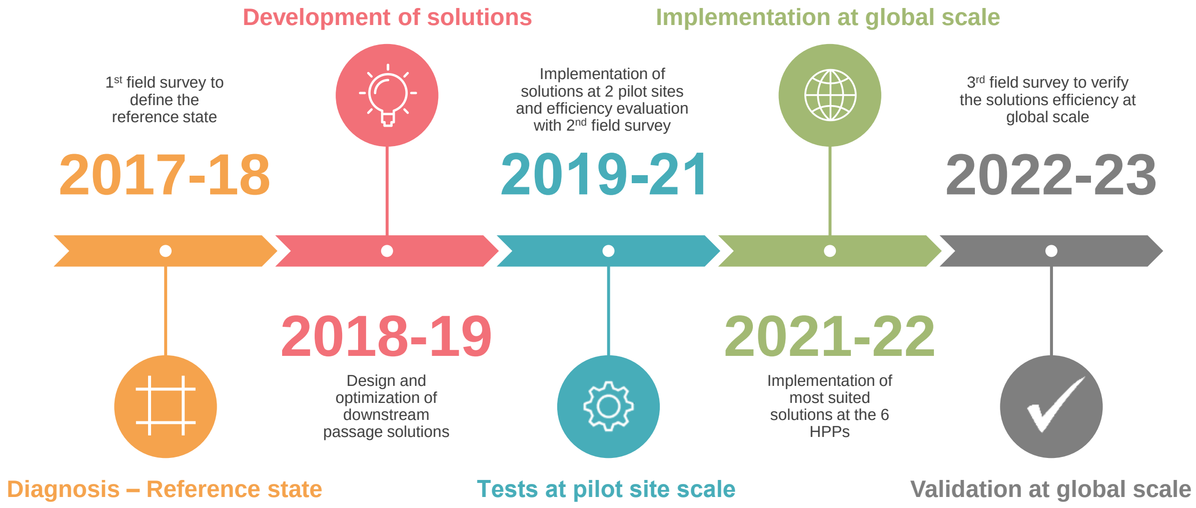

Figure 1: Timeline of the Life4Fish project

2 MIGRATION PREDICTION MODEL

If fish migration can be predicted timely and accurately, decisive mitigation measures such as HPP temporary shutdown and sluice gate opening can be implemented with high efficiency and with a limited impact on energy production.

Logistical models for salmon smolts and eels migration prediction have been developed in the framework of the Life4Fish project [Teichert et al., 2020a-b-c]. They are based on hydrological data such as river discharge, water temperature and photoperiod. The model for eels predicts the migration peaks during a fixed period (September to February). The model for salmon smolts provides a phenological indicator such as onset, end and duration of migration with high accuracy (Figure 2).

3 DOWNSTREAM PASSAGE ROUTE AND REPULSIVE BARRIERS

To prevent fish passage through the turbines during downstream migration, it is mandatory to offer an alternative safe route. Such a route can be created either using existing elements, for instance flap gates at mobile dams, or by creating a dedicated structure. Location of the fish passage is extremely important since fish will have to find it prior to going through the turbines, which means that the passage must be located on the path followed by the fish when they swim to the turbines. Also, the passage has to be attractive, i.e. has to induce flow conditions prone to encourage migrating fish to swim through it.

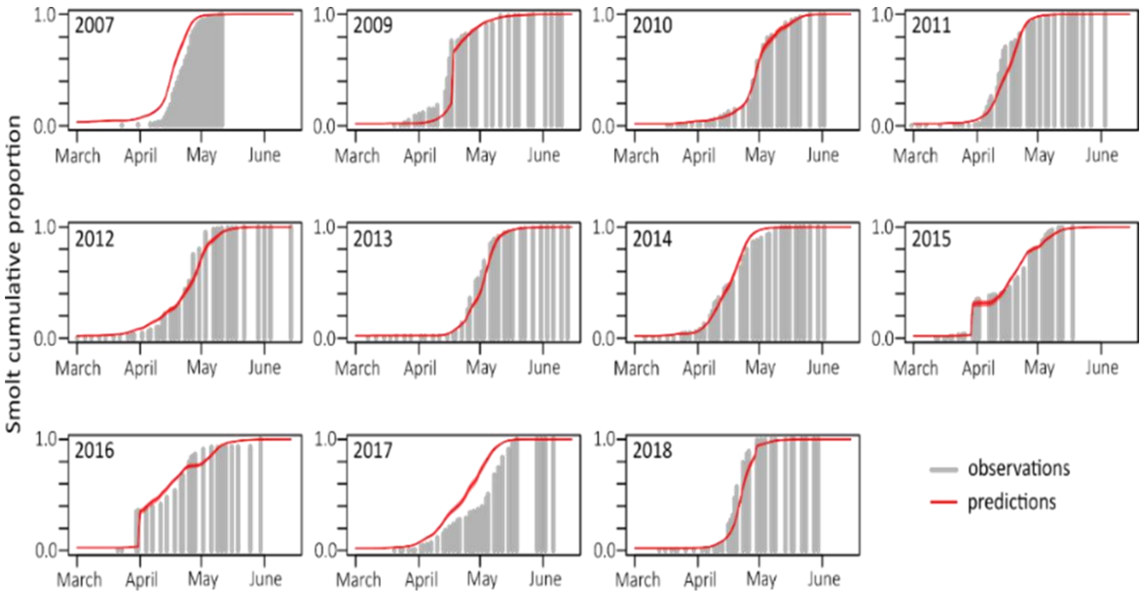

Figure 2: Example of logistical model results for salmon smolt migration on the Ourthe River [Teichert et al., 2020a]

In the framework of the Life4Fish project, downstream passage solutions identification, design and optimisation has been done by means of experimental and numerical models considering fish location data from field survey and hydraulic data from numerical modeling (Figure 3). Fish presence density maps gained from onsite survey showed where fish were searching for a passage to continue their way downstream when they were blocked upstream of the powerplant. This is a key information to locate properly a fish passage. Hydraulic numerical modeling of the area upstream of the powerplant provided detailed flow conditions. These are key data to understand why fish were concentrated at some places and to pre-design a passage structure able to influence flow conditions where fish were located. Then, the pre-designed fish passage has been implemented on a physical scale model and tested for varied flow conditions considering the river and powerplant operating configurations in order to assess its efficiency in creating attraction current and to optimise its design. Finally, the passage solution has been implemented on site. In addition to fish passage implementation, repulsive barriers (electrical or bubble curtain) have been installed to assess their efficiency in guiding fish to the passage and in preventing them to swim through the turbines.

Depending on the sites configuration, it has been found that suited passage for salmon smolts can be provided by using a flap gate at the mobile or required building of a peculiar structure.

This analysis has been complemented with specific experimental tests in a laboratory flume considering real salmon smolts in order to analyze the influence of some fish passage parameters (trash rack geometry and location) on the fish behavior [Erpicum et al., 2022].

New in situ survey with eels and salmon smolts proved the effectiveness of the implemented solutions to improve fish passage at both pilot sites.

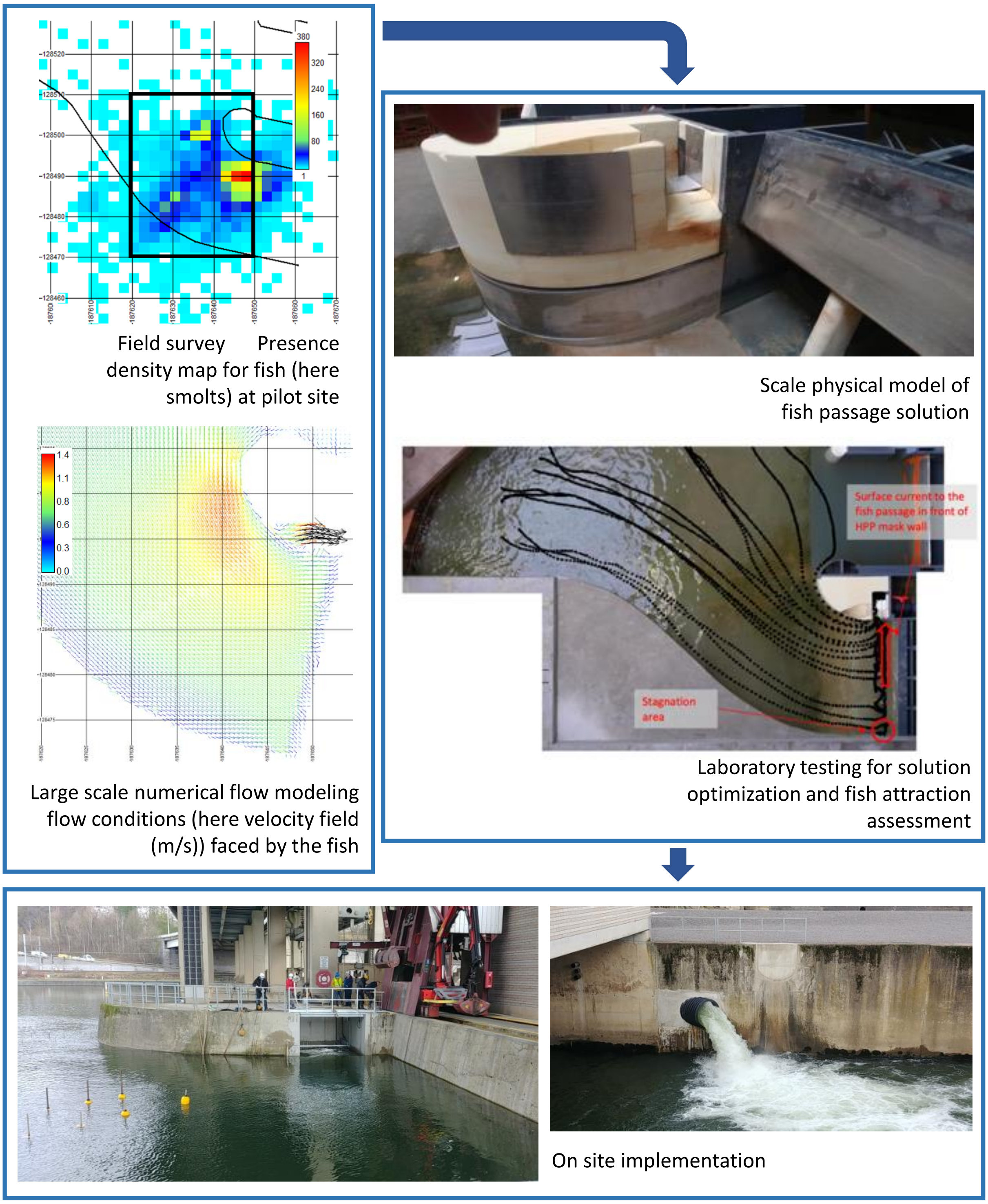

Figure 3: Procedure for downstream passage design by means of field survey, and experimental and numerical hydraulic modeling

For eels, a repulsive barrier working with low voltage electrical field has been deployed across the HPP forebay to virtually close the entrance of the power station. For river flow conditions where the HPP subtracts more than 50 % of the river discharge, the barrier reduced by 52 % the entrainment rate of eels towards the turbine and favored an escapement through the mobile dam. For higher hydrological conditions, most of the eels already migrated through the mobile dam, with less need of guidance away from the turbines.

For salmon smolts, the operation of the new downstream passage enabled to safely transfer 55 % of the fish, while the observed attractiveness of the inlet was 68 %. The operation of this fish passage improved by a factor more than 3 the escapement rate of smolts on the pilot site. With 100 % survival rate and based on physiological and immune parameters measured, the passage through the bypass seems to not impact health status and vulnerability of salmon smolts. An electrical barrier installed in order to guide smolts to the entrance of the fish bypass was not effective, since apparent too high voltage associated with too high water velocities induced electrical narcosis and favored the passage of smolts through turbines. The in-situ tests showed thus that careful tuning of electrical barrier characteristics is extremely important to avoid counterproductive effect on fish movements. In addition, bubbles barrier implementation was seen to be difficult and its satisfactory operation challenging.

The 50 cm or 90 cm opening of the dam flap gate close to the HPP intake also succeeded to safely transfer 49 % to 65 % of the smolts. At another site, a 90 cm opening of the dam flap gate on the opposite bank of the HPP intake only attracted 41 % of the smolts. Also, if a flap gate of the mobile dam can be used as downstream passage, this eases the management of floating debris that is challenging with dedicated fish passage structure. Depending on the dam configuration, this may also be a cheaper solution than building a new dedicated structure, even if flow rate and then energy production lost are generally more important when using a flap gate.

4 ECO-SUSTAINABLE TURBINES

The turbines of Monsin HPP were more than 70 years old and required a full refurbishment. Even if the retrofit of the turbines was not part of the Life4Fish project funding, such an operation may represent a huge opportunity to improve HPP impact on fish passage. Indeed, recent developments in turbine design proved to be effective in decreasing drastically the impact on fish swimming through the machine.

However, due the high level of complexity of hydraulic turbine design, it is difficult to obtain contractually a commitment from the manufacturer regarding fish impact. Consequently, it has been decided to set up a specific protocol summarising all known technologies related to the design of turbines with proven very low impact on fish passage, i.e. eco-sustainable turbines. As a result, a dedicated list of specifications has been produced with key relevant criteria enabling to select the best turbine features and best supplier. These specifications concern the rotating speed, the numbers of blades, the width of the blades, the minimum gap between all moving and rotating parts (2 mm is required).

Figure 4: New eco-sustainable turbine at Monsin HPP

After the new turbines (Figure 4) commissioning, dedicated validation tests have been done. The results overpassed expectations since the impact of the new turbines on the two reference species has been drastically reduced compared to the one of classical Kaplan turbines. Indeed, direct impact on smolts has been found to be below 2 % impact and for eels below 7 %. Considering these very encouraging results, it is foreseen to follow the same process for refurbishment of turbines at other HPPs. Several health parameters were also studied, including mid-term mortality, stress and immune biomarkers. They will allow to evaluate the short- and medium-term impact of the turbine on the survival, the physiological and health status of both species and assess whether the ability of fish to escape successfully to the ocean is compromised or not.

5 DISCUSSION AND CONCLUSION

The design and implementation of effective fish passage solutions at dams and hydropower plants is a complex problem that requires an interdisciplinary approach, with inputs from biology and hydraulic experts [Williams et al., 2012 ; Sylva et al., 2018 ; Renardy et al., 2021]. Varied solutions may be proposed but no one is perfect nor implementable at every location. However, when the problem is considered holistically, it is usually possible to set up efficient solutions that remain also effective regarding green energy production.

The Life4Fish project is a successful example of such a global multidisciplinary approach. The experience gained by the project partners is now available and can be deployed to any hydraulic site featuring limited fish passage capacities.

6 ACKNOWLEDGMENTS

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SUMMARY

The EU funded Life4Fish project aims at restoring downstream connectivity at six hydropower plants along the Meuse River in Wallonia by testing and implementing passage solutions for European eels and Atlantic salmon smolts, while minimising renewable energy production loss. The project is carried out by an interdisciplinary and intersectoral team gathering people from research and industry, with biology or engineering background, and extends over five years. This paper presents the varied solutions that have been tested to improve downstream passage in the framework of the project.

RESUME

Le projet Life4Fish, financé par l'UE, vise à restaurer la connectivité en dévalaison de six centrales hydroélectriques le long de la Meuse, en Wallonie, en testant et en mettant en œuvre des solutions de passage pour les anguilles européennes et les smolts de saumon de l'Atlantique, tout en minimisant les pertes de production d'énergie renouvelable. Le projet est mené par une équipe interdisciplinaire et intersectorielle réunissant des personnes issues de la recherche et de l'industrie, ayant une formation en biologie ou en ingénierie, et s'étend sur cinq ans. Cet article présente les diverses solutions qui ont été testées pour améliorer le passagevers l’ aval dans le cadre du projet.

ZUSAMMENFASSUNG

Das von der EU geförderte Projekt Life4Fish zielt darauf ab, die stromabwärts gerichteten Verbindungen an sechs Wasserkraftwerken entlang der Maas in Wallonien wiederherzustellen, indem Lösungen für die Durchgängigkeit für europäische Aale und atlantische Lachssmolts getestet und umgesetzt werden. Das Projekt wird von einem interdisziplinären und sektorübergreifenden Team aus Forschern und Industrie mit biologischem oder technischem Hintergrund durchgeführt und erstreckt sich über fünf Jahre. In diesem Beitrag werden die verschiedenen Lösungen vorgestellt, die im Rahmen des Projekts zur Verbesserung der Durchgängigkeit flussabwärts getestet wurden.

RESUMEN

El proyecto Life4Fish, financiado por la UE, tiene como objetivo restablecer la conectividad aguas abajo en seis centrales hidroeléctricas del río Mosa, en Valonia, probando y aplicando soluciones de paso para las anguilas europeas y los esguines de salmón atlántico, al tiempo que se minimiza la pérdida de producción de energía renovable. El proyecto lo lleva a cabo un equipo interdisciplinar e intersectorial que reúne a personas de la investigación y la industria, con formación en biología o ingeniería, y se extiende durante cinco años. Este documento presenta las diversas soluciones que se han probado para mejorar el paso aguas abajo en el marco del proyecto.