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LABORATORY STUDY OF THE EFFICIENCY FOR NATIVE IBERIAN FISH SPECIES OF A VERTICAL SLOT FISHWAY

BY FELIPE MORCILLO AND MIRIAM CASTILLO

IAHR Institute Member, the Hydraulics Laboratory of the Centre for Hydrographical Studies (CEDEX), Spain has in recent years examined fish passage behaviour in a specific vertical slot fishway. The hydraulics of this type of fishway, and its impact on the behaviour of four native Iberian fish species has been studied in order to evaluate the efficiency and thus improve the application of

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The Hydraulics Laboratory of the Centre for Hydrographical Studies (CEDEX) has examined in recent years the fish passage behaviour of a specific vertical slot fishway built in the laboratory. The project has been commissioned by the General Directorate for Water, of the Ministry of Agriculture, Food and Environment, Government of Spain, and it has been entrusted to CEDEX. The Department of Zoology and Physical Anthropology of the University Complutense of Madrid, the Civil Engineering School of A Coruña University and the Department of Forestry Engineering at the Politechnic University of Madrid have also been involved.

River connectivity and fish fauna biodiversity conservation are one of the main challenges of the EU Water Framework Directive. Freshwater ecosystems have been altered, chiefly during the last 100 years, as a consequence of the impact of hydraulic infrastructures such as dams and weirs. These works can pose a barrier to fish breeding and no-breeding movements. The most common mitigating measure is the construction of fishways. However, their design and assessment needs a detailed knowledge of the fishway hydrodynamics, as well as the fish swimming ability.

Methodologies applied

The hydraulics of this type of fishway design, together with the swimming abilitiy and the behaviour of four native species, has been studied in order to provide suitable design criteria. The species considered comprise the salmonid brown trout *(Salmo trutta)*, the cyprinids Iberian nase *(Pseudochondrostoma polylepis)*, the common barbel *(Luciobarbus bocagei)*, and Mediterranean barbel *(Luciobarbus guiraonis)*. Cyprinidae is the most important family of fish in the Iberian Peninsula because of its abundance, distribution, richness and biodiversity. Most of the studies about this subject which have been carried out have considered only and exclusively hydraulic criteria; in cases where the biology of fish have been considered, only the salmonid family has been the target species. However, fishways designed for salmonids are not necessarily as effective for cyprinids.

An aligned vertical slot fishway has been built in the Hydraulic Laboratory. Fish ascending in two flow conditions (100 l/s and 250 l/s, respectively), during 24 hours, have been monitored using an RFD system. Experiments were carried out in the breeding season for each species. Underwater cameras have been used to observe how the fish pass through the slot. Images captured by overhead cameras have been processed with a new technique based on an artificial neural network and computer vision techniques developed by the Civil Engineering School of A Coruña University. This technique allows knowledge of the complete fish trajectory and variables such as swimming velocities, accelerations or times of ascent for the different individuals.

Another approximation to the swimming ability is the fatigue status, characterized through physiological parameters in blood and muscle samples. The parameter levels of individuals that completed the ascent have been compared to parameter levels of individuals brought to maximum fatigue, and of individuals at rest.

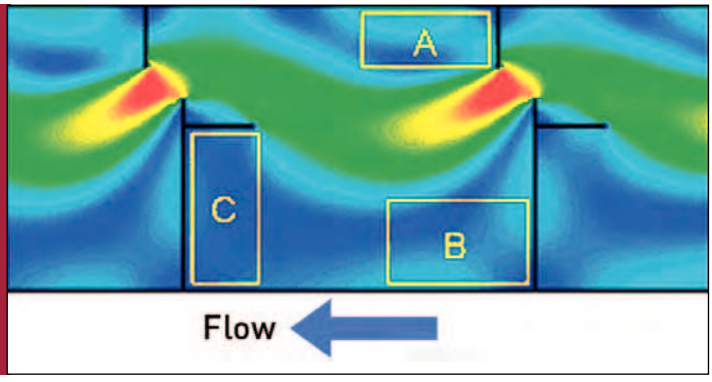

Diagram of slot configuration of the fishway built in the CEDEX Hydraulics Laboratory

Iberian nase individuals ascending the vertical slot fishway built in the CEDEX Laboratory

Results obtained

The results obtained until now have been published in two technical papers and they have been used to calibrate and improve a computer software designed by the Civil Engineering School of A Coruña University. This software has been created for the analysis and design of vertical slot fishways according to the requirements of the target species.

First of all, it has been observed that fish have ascended the vertical slot fishway using the recirculation areas as resting areas, avoiding if possible the main flow. Fish do that even when passing through the slot, and to do so, they have passed through the slot next to the baffle. Most of the barbels and brown trout have passed through nearby or at the bottom. On the other hand, most of the Iberian nase individuals have passed through the slot along the water column.

Besides that, differences in the percentage of ascents have been found among the target species, even between species of the same family of ciprinids. Common barbel is more successful than Iberian nase. The individuals' origin, fish farm or nature, must be avoided in order to control the influence of this parameter. For example, Iberian nase individuals originated from a fish farm whilst the common barbel came from the Cofio river.

Related to the slight velocity variations along the water depth in the slot according to the flow, a larger number of fish has ascended in the 100 l/s flow experiments than in the 250 l/s flow experiments. The more turbulence related to high flows, the smaller number of successful ascents registered, independently of the species.

Regarding to physiological and fatigue status, differences have been found among plasma glucose and lactate levels of the different experimental groups aforementioned. However the objective way to know which fishway design is the most efficient. The required input data are: total height of the obstacle where the fishway is placed, the target species and their size and the fishway type (to choose among different vertical slot fishway typologies). These input data must be completed together with the flow due to its influence on the efficiency as previously mentioned.

The computer software uses water velocity and depth restrictions to compute the design pool dimensions necessary to ensure the ascent of the fish. Focusing on water velocity restrictions, maximum flow velocities attained in the slot are compared with the fish burst speed, and the velocity field in the pools is compared to the fatigue curves of species. The fatigue curves indicate the maximum swimming distance of a fish related to a particular water velocity. The results of the experiments agree with the first restriction but not with the second one.

Differences were noticed between the theoretical computer software results and the observation in the experiments which could be explained because the fatigue curves used by researchers were for species other than the target ones in this study. Furthermore, the fatigue curves were obtained in open channels, respirometers or swimming chambers, and the fish behaviour in these devices where the fish is constrained could differ from the fish behaviour in a fishway.

A corrector coefficient has been obtained for each species and flow in order to calibrate the computer software with the experiment results until more realistic fatigue curves are available for each of the target species.

Finally, it is necessary to compare the results obtained in experiments in the laboratory with those obtained with a similar type built in a river in order to reach a better knowledge of this interesting subject.

Felipe Morcillo **has been involved in technical and scientific projects for IGME (Spanish Geologic and Mining Institute) related to environmental impact assessment for seven years. He has worked in the efficiency of mitigation measures of energy infrastructure projects and in the application of conservation and biodiversity policies from the European Union (Birds and Habitats Directives). In addition, he has considerable experience of working on several aspects of aquatic organisms and ecosystems, in particular those dealing with freshwater fish. After finishing his PhD in Biology, he started working at CEDEX in 2007. During this time he has been working on projects aiming to advance the understanding of behaviour and adaptability of native fish in vertical slot fishways, and to better understand the migrating path of fish and swimming costs.**

Miriam Castillo **started working in the Hydraulics Laboratory of the Centre for Hydrographical Studies (CEDEX) after finishing her Biology degree in the University Complutense of Madrid. She has completed a Masters in Hydrology and is currently working on a PhD in Biology related to Iberian native fish fauna in a vertical slot fishway, focusing in fish movements and physiologial studies.**

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