APPLICATION OF IBER HYDRAULIC SIMULATION MODEL FOR ASSESSING PHYSICAL HABITAT SUITABILITY (WUA) FOR FISH

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Iber is a two-dimensional numerical model for simulating unsteady flows and environmental processes in river hydraulics. A new module on physical habitat suitability has been incorporated to the Iber model. This study shows the application of the new module to a river reach, which allows satisfactorily characterizing and evaluating in an effective way, the spatial distribution and quality of physical habitat availability, as well as the WUA.

1 INTRODUCTION

The characterization and quantification of Weighted Usable Area (WUA) for fish based on numerical models of hydraulic simulation designed ad hoc, has been widely used in the environmental management of rivers. The calculation of WUA is based on the availability of suitability curves for the target species, as well as the use of hydraulic simulation models (preferably two-dimensional models), capable of incorporating both hydraulic and hydrobiological variables at the same model.

Iber is a numerical simulation model of turbulent free surface unsteady flow, as well as environmental processes in river hydraulics [1]. This model allows to obtain values of hydraulic variables (depths, water velocities, etc.) and hydrobiological variables (temperature, salinity, dissolved oxygen, etc.) for different scenarios.

The objective of this study is to show an application of a new module of Iber, called physical habitat suitability (PHS), which allows incorporating preference curves of any aquatic species and stage of development for the calculation of the spatial and temporal distribution of the corresponding WUA.

2 METHODS

2.1 The Iber simulation model

The numerical model for hydraulic simulation Iber solves the equations of shallow water in two dimensions, or two-dimensional Saint Venant equations, on a mesh of finite volumes, which can be irregular and unstructured, formed by triangles, quadrilaterals or combinations of both. For its resolution Iber uses the method of finite volumes with the Roe scheme [2] (Figure 1).

The former version of Iber consisted of four main computational models: a hydrodynamic module, a turbulence module, a sediment transport model and a water quality module. Based on the substantial improvement of a two-dimensional model with respect to a one-dimensional model, and taking advantage of the powerful calculation engine of iber, a new module on physical habitat suitability (PHS-Iber) has been created. This new module contains a data base of different suitability curves, and allows obtaining the maps of habitat suitability as well as WUA from the hydrodynamic variables (particularly depth and water velocity). WUA can be defined as the stream wetted surface area weighted by its suitability for use by an aquatic organism (target species), and it has been traditionally computed by multiplying area by habitat suitablity index of the different variables (usually velocity, depth, and substrate or cover), and normalized to square units per 1000 linear units [3].

$$\frac{\partial h}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = 0$$

$$\frac{\partial q_x}{\partial t} + \frac{\partial}{\partial x}\left(\frac{q_x^2}{h} + g\frac{h^2}{2}\right) + \frac{\partial}{\partial y}\left(\frac{q_x q_y}{h}\right) = -gh\frac{\partial z_b}{\partial x} - \frac{\tau_{b,x}}{\rho} - \frac{\partial}{\partial x}\left(h\,\overline{u_x' u_x'}\right) - \frac{\partial}{\partial y}\left(h\,\overline{u_x' u_y'}\right)$$

$$\frac{\partial q_y}{\partial t} + \frac{\partial}{\partial x}\left(\frac{q_x q_y}{h}\right) + \frac{\partial}{\partial y}\left(\frac{q_y^2}{h} + g\frac{h^2}{2}\right) = -gh\frac{\partial z_b}{\partial y} - \frac{\tau_{b,y}}{\rho} - \frac{\partial}{\partial x}\left(h\,\overline{u_x' u_y'}\right) - \frac{\partial}{\partial y}\left(h\,\overline{u_y' u_y'}\right)$$

Figure 1. Method of finite volumes with Roe scheme used in the computational process of the Iber model.

2.2 Study case: the Eume river

The selected study area was a reach 3km long of the Eume river located in the region of Galicia, northeastern Spain (Figure 2). The river reach is characterized by a high slope in the initial part of the reach (up to 5% average, with pools and rapids) and a moderate slope (up to 2%) in the final part.

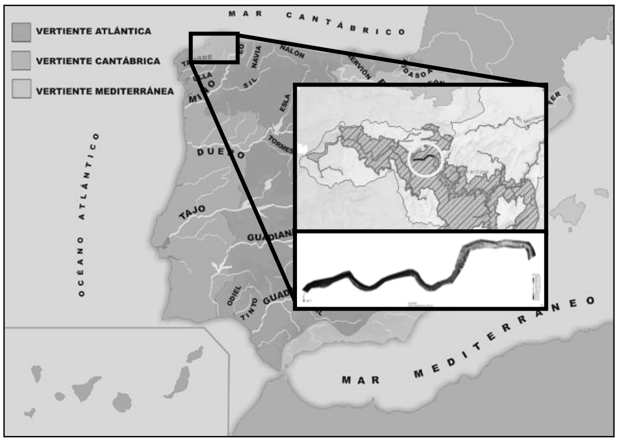

Figure 2. Location of the study area.

The numerical model is characterized by having more than 72 thousand elements that allow to properly describe the river bed topography using the DEM.

The range of water flows used for the calculation in the different scenarios went from 0.149 m^3/s (minimum flow at the Hydrological Plan of the watershed) and 11.350 m^3/s (average flow).

The PHS-Iber module has been applied to evaluate the availability of physical habitat for fry, juvenile, and adult brawn trout (*Salmo trutta*) as a function of depth and water velocity using the suitability curves shown in Figure 3[4].

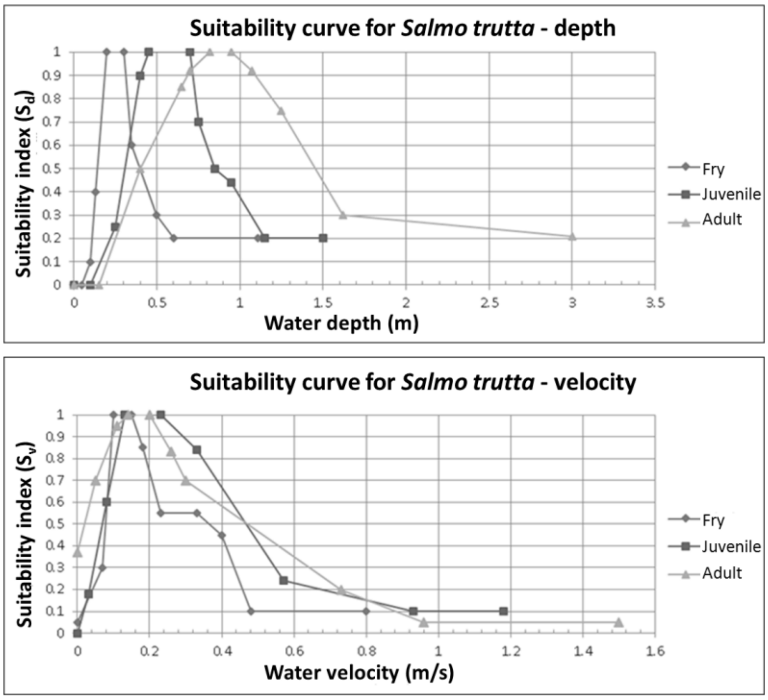

Figure 3. Suitability curves for *Salmo trutta* used in the study case.

3 RESULTS

The application of the PHS-Iber module to the study area, including the calculation of suitability index for depth (S_d) and water velocity (S_v), as well as the overall Habitat Suitability Index (HSI) (computed as HIS = S_d x S_v), provided a relationship between WUA and discharge flow for the different life stages of brown trout (Figure 4).

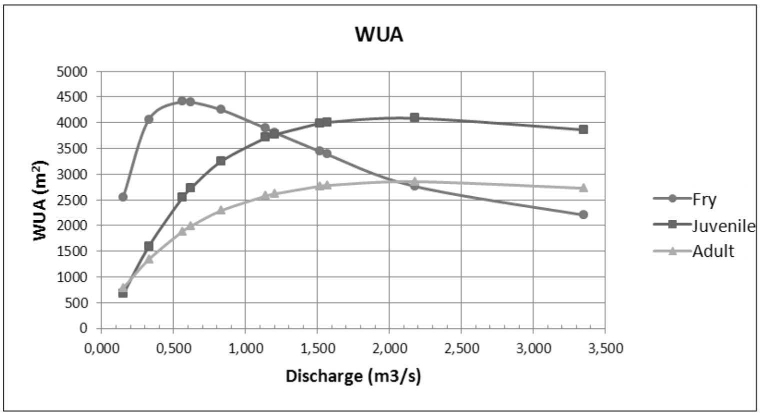

Figure 4. Relationship between WUA and discharge in the study area (river reach) for three different life stages of *Salmo trutta*. Maximum values of WUA were obtained with low discharges (< 2m^3/s).

The spatial distribution of physical habitat availability as a result of the application of the PHS-Iber module is shown in figure 5. Physical habitat quality is based on the categorization of HSI scores from table 1.

Table 1. Categorization of HSI scores used in the determination of the physical habitat availability maps.

S_i Index	Criteria
0.0 – 0.3	Insufficient conditions
0.3 – 0.5	Minimum conditions
0.5 – 0.8	Good conditions
0.8 – 1.0	Excellent conditions

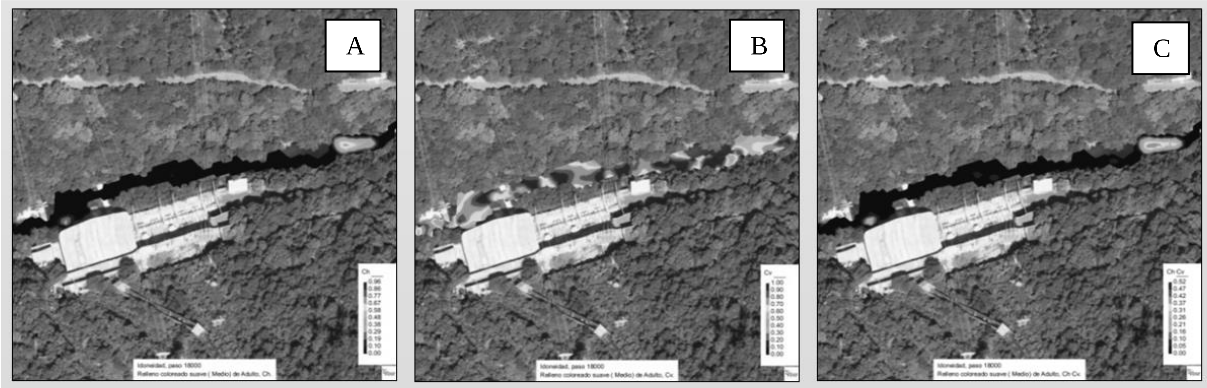

Figure 5. Spatial distribution of habitat suitability for *Salmo trutta* in the study area considering water depth (A), water velocity (B) and both variables (C).

4 CONCLUSIONS

The two-dimensional numerical model Iber allows calculating the hydrodynamics in a more complete way than one-dimensional models. This is of particular relevance in study cases like the Eume river, which shows a high complexity on river sections (presence of riffles, pools, braided channel, etc.) and changes in flow regime (irregular water surface and water velocities distributions).

The new PHS-Iber module, which includes a data base of suitability curves, allows satisfactorily characterizing and evaluating, in an effective way, the spatial distribution and quality of physical habitat availability, as well as the WUA.

The application of the PHS-Iber module to the study area has provided habitat suitability maps for the Eume river and has facilitate the WUA evaluation. The geomorphological characteristics of the studied river reach (very heterogeneous) conditioned the final results:

- The spatial distribution of habitat suitability is concentrated in specific points, and it is highly variable depending on the discharge and the life stages.
- In general, the total WUA for brawn trout does not exceed 15% of the total wetted area in any of the life stages and flows evaluated.

FUNDING
This project was partially funded by Fundación Biodiversidad.

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