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USING A TWO DIMENSIONAL APPROACH TO EVALUATE CHANNEL REHABILITATION IN A MEDITERRANEAN STREAM (SOUTHERN PORTUGAL)

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ABSTRACT

Concern about ecological, social and economic losses caused by stream degradation has recently stimulated major conservation and managements efforts worldwide. In Mediterranean rivers, the problem is exacerbated by the higher demand for freshwater. A rehabilitation program was undertaken in a Mediterranean river segment affected by intensive agriculture, unstable banks and degradation of the riparian gallery. Moreover, it will be further impacted by a water supply dam, which is presently under construction. To assess potential habitat enhancement for the different life stages of two critically endangered cyprinid species – the Iberian nase *Iberochondrostoma almacai* and the Iberian chub *Squalius aradensis* – five different restoration scenarios were considered, simulated and compared with the unmodified segment (control), in terms of Weighted Usable Area (WUA), by means of a two dimensional hydraulic model, the River2D. Results showed that habitat improvement was best achieved for both species life-stages, when considering the introduction of islands in the middle of the channel (mean % increase of WUA: nase, 37.7%; chub, 39.6%). The introduction of lateral bays was found to be beneficial for nase (mean % increase of WUA *c*. 2.7%) but not for chub where a decrease in the mean amount of area suitable for habitat, *c*. 3.6%, was noted. The other restoration scenarios, particularly the meandering of the river channel with a submerged weir or with islands in the middle of the channel, revealed a considerable decrease in the WUA for all species life-stages, especially for nase. The results of this study could be useful elsewhere, particularly in other Mediterranean-type rivers where fish species conservation and management are a priority.

Key words: rehabilitation, Mediterranean stream, River2D, nase, chub, WUA

1. INTRODUCTION

River restoration tests the possibility of recreating complex ecosystems, based on simpler and degraded streams, which is a great ecological challenge (Woolsey et al., 2007). Restoration projects have become a powerful tool in river conservation (Smith et al., 2002; Lacey and Millar, 2004; Wheaton et al., 2004; Woolsey et al., 2007). These projects aimed to restore the ecological conditions of natural rivers, create upstream and downstream fish passes, implement instream flows, improve longitudinal and lateral connectivity, and protect habitat and ecosystem (Katopodis, 2006; Brunke et al., 2001). Introducing habitat structures in the stream may restore an impacted river, allowing fish to meet their biological requirements.

The amount of fish habitat that these structures provide can be assessed with computer modelling (Lacey and Millar, 2004; Pasternack et al., 2004). More effective fish habitat structures can be built by improving the tools used to assess habitat availability (Smith et al., 2002). Hydrodynamic models evaluate the influence of flow and morphology changes on biological diversity (Ghanem et al., 1996).

Two-dimensional models have recently been used to assess river habitat conditions since they accurately represent complex mosaics of depth and velocity distributions (Crowder and Diplas, 2000). They can predict habitat changes resulting from flow alterations and channel morphology (Lacey e Millar, 2004) and are, therefore, useful for river restoration projects (Ghanem et al., 1996; Crowder and Diplas, 2000; Waddle et al., 1996; Leclerc et al., 1995).

The goal of this study is to evaluate potential habitat improvement within a river segment of a Mediterranean-type river, the Odelouca River (SW Portugal), by simulating the establishment of five distinct stream habitat enhancement options, in a two-dimensional hydraulic model, the River2D (Steffler, 2000). This model is a depth-averaged 2D hydrodynamic and fish habitat model designed for use in natural streams. This model can accurately represent the usually complex flow of natural rivers. In every hydrodynamic solution, it shows the local velocity and depth along the stream. By combining this information with habitat suitability curves (HSC) developed for target species, the Iberian nase *Iberochondrostoma almacai* and Iberian chub *Squalius aradensis*, two critically endangered cyprinid species, the weighted usable area is computed. Restoration scenarios to be simulated include river meandering along with introduction of submerged weirs or small islands, placement of islands in the river channel and introduction of lateral bays and deflectors. Therefore, quantifying species habitat enhancement under different morphological scenarios is extremely important for an adequate strategy of species conservation and management and can have a wider application in other Mediterranean rivers.

2. MATERIAL AND METHODS

This study was conducted in the Odelouca river, the largest tributary (total length = 92 km) of the Arade basin (987 km^2). It is a medium-sized Mediterranean-type river located in the Algarve region of southwest Portugal. Geology includes schistose rocks in the upper parts, with alluvial deposits in the lower river reaches. The climate is typical Mediterranean, with more than 80% of the rainfall occurring from October to March and with virtually no flow from July to September.

A 250 m length study reach which best represented the river segment was selected in the lower part of the main river course, 4 km downstream from a partially constructed water-supply dam, which is scheduled to begin operating by 2010. Catchment area at the study site is 466 km^2 with a mean annual flow of 4.05 m^3/s. In this reach, the cross section range from 7 to 30 m wide, with a 0.0035 m/m slope.

The river bed topographic was surveyed with a combined association of a total station with a Global Position System, GPS. Overall, 4 129 spots were surveyed. Collected information included the X and Y coordinates, bed elevation and substrate composition according to a modified Wentworth scale (Bovee, 1986) [(1) organic cover; (2) silt (1-2 mm); (3) sand (2-5 mm); (4) gravel (5-25 mm); (5) pebble (25-50 mm); (6) cobble (50-150 mm); (7) boulder (>150 mm) and (8) bedrock]. To calibrate the model, a series of points were located along Y cross-sections where significant alterations in depth, water velocity, substrate composition and slope were noted. Depths were measured with a graduated stick. Water velocities were measured with a water flow probe (model FP101, Global Water Instrumentation, USA) at 60% of the distance from the surface to the riverbed (Bovee and Milhous, 1978). The bed roughness was registered from observations of bed material and bedform size to establish the effective roughness height.

Habitat suitability curves (HSC) had been previously developed for depth, water velocity and substrate according to the procedure outlined in Bovee (1986). The target species considered were the Iberian nase *Iberochondrostoma almacai* and Iberian chub *Squalius aradensis*, two critically endangered cyprinid species. HSC were determined for two size-classes 5-7, > 7 cm for nase and 4-6, > 6 cm for chub, roughly corresponding to life stages of juveniles and adults, respectively – in two periods – spring/summer and autumn/winter. Sampling was performed by means of electrofishing with low voltage to reduce the effect of positive galvanotaxis. A detailed description of the sampling procedure is given in Santos et al. (in press).

The amount of Weighted Usable Area (WUA = quantity of area suitable for habitat) was then computed to evaluate the performance of five potential habitat enhancement measures, relatively to the stream reach under unmodified conditions: (i) meandering of the river channel with submerged weirs (Fig. 1); (ii) meandering of the river channel with two islands in the mid-section of the channel (Fig. 2); (iii) introduction of three islands in the mid-section of the channel (Fig. 3); (iv) introduction of two lateral bays on opposite banks (Fig. 4); and (v) introduction of four alternate triangular deflectors (Fig. 5). These scenarios were designed with a CAD and GIS program and then exported to the River2D model. The WUA was calculated as the product of depth, velocity and substrate suitability indexes. The values of discharge used for the simulations varied between 0.1 and 8.0 m^3/s, which represent the range of the ecological flow regime to be released by the dam.

In order to quantify and compare the habitat improvement, considering the ecological flows to be released by the dam, the WUA was calculated for each month, as well as the increase and decrease of such habitat availability. The HSC Spring-Summer was used for discharges between October to March, and the HSC Autumn-Winter was used for discharges between April-September.

3. RESULTS AND DISCUSSION

The results for depth and for each habitat enhancement measures are display in Fig. 1, Fig. 2, Fig. 3, Fig. 4 and Fig. 5.

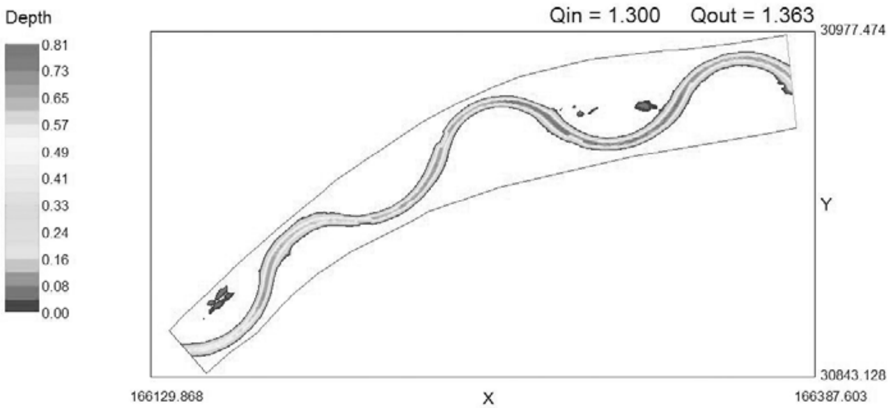

Figure 1 – Meandering of the river channel with submerged weirs. Flow depth for a discharge of 1.3 m^3/s.

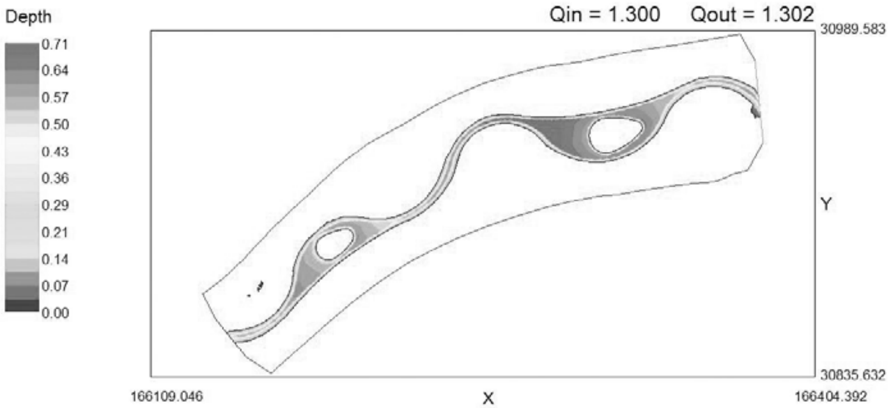

Figure 2 – Meandering of the river channel with islands in the centre of the channel. Flow depth for a discharge of 1.3 m^3/s.

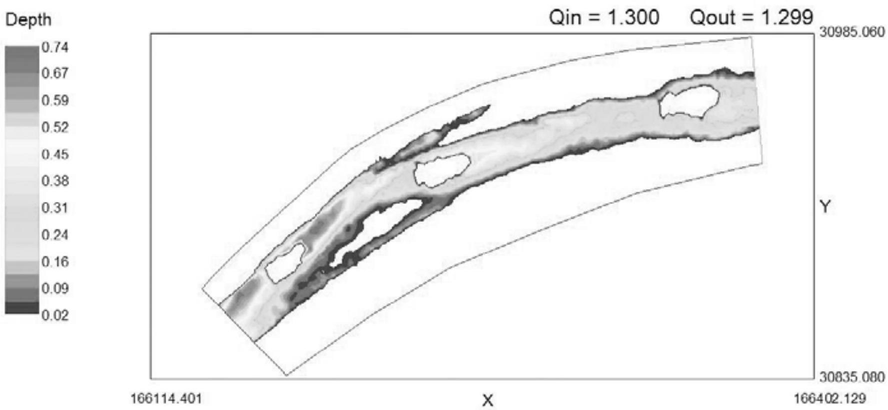

Figure 3 – Islands in the middle of the channel. Flow depth for a discharge of 1.3 m^3/s.

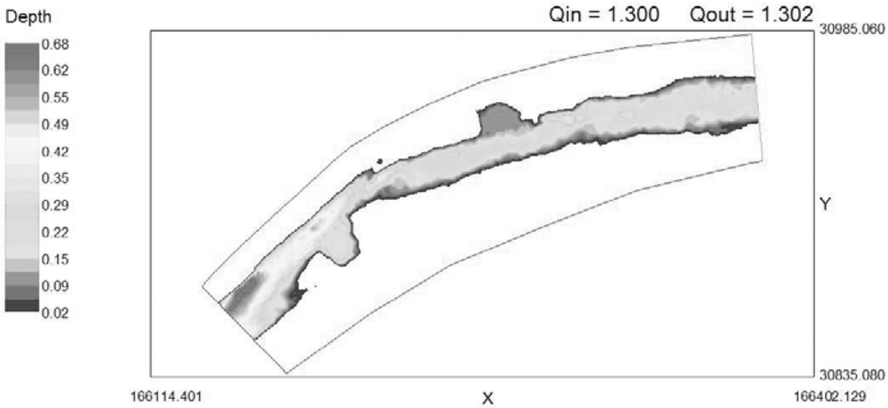

Figure 4 – Lateral bays. Flow depth for a discharge of 1.3 m3/s.

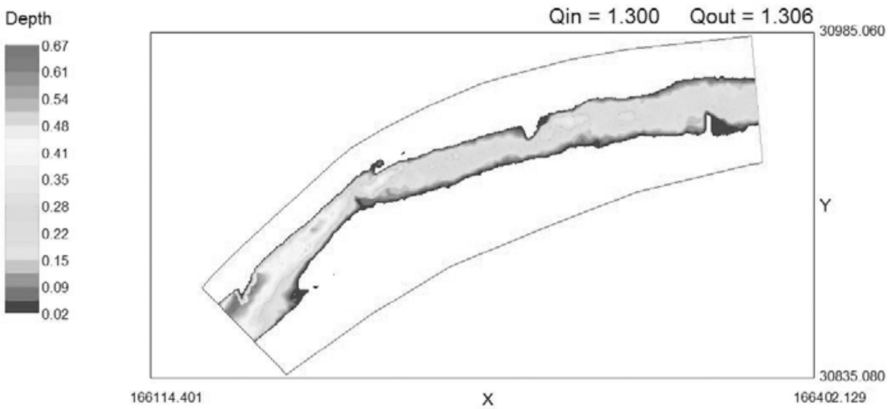

Figure 5 – Lateral deflectors. Flow depth for a discharge of 1.3 m^3/s.

Habitat simulations carried out on the five improvement measures under the ecological flow regime, produced distinct results relatively to the control conditions (Tab. 1). The introduction of three islands in the middle of the channel and of the two lateral bays were the only restoration scenarios that represented an effective habitat gain, particularly the former, with a mean monthly increase of WUA for both life stages of the target species. Although both adult and juvenile nase habitat experienced an improvement *c*. 2-3%, when introducing lateral bays, a concurrent decrease of WUA was found for chub (1.2% for adults and 6.1% for juveniles).

Table 1 – Mean monthly increase and decrease of WUA for target fish species (%).

Restoration scenarios	Nase		Chub	
	Adults	Juveniles	Adults	Juveniles
Meandering of the river channel with submerged weirs	-94.6	-90.8	-43.5	-77.4
Meandering of the river channel with islands in the centre of the channel	-85.3	-69.7	-10.0	-60.2
Islands in the middle of the channel	28.9	46.5	46.5	32.7
Lateral bays	2.4	2.9	-1.2	-6.1
Lateral deflectors	-24.8	-28.2	-5.7	-12.6

Both channel meandering scenarios represented the worst restoration technique, since a considerable decrease in the amount of WUA was found. This is due to the fact that the decrease of the cross section for low flows implies the decrease of wet surface area. For these two meandering scenarios, a smaller decrease on the mean monthly WUA was computed in the case of the two islands in the middle of the channel relatively to the submerged weir scenario. For the nase, the mean monthly WUA decrease is 92.7% considering the submerged weirs and 77.5% for the islands in the middle of the channel; for the chub these reductions are 60.4% and 35.1%, respectively.

Figure 6 and Figure 7 illustrate the monthly WUA obtained for the control conditions and for the five restoration scenarios, when considering the ecological flow regime. It confirmed that the best restoration scenario for this stream is the construction of three longitudinal islands in the centre of the channel. These physical structures increase the amount of habitat shelters downstream the islands and the reproductive habitats for the target species.

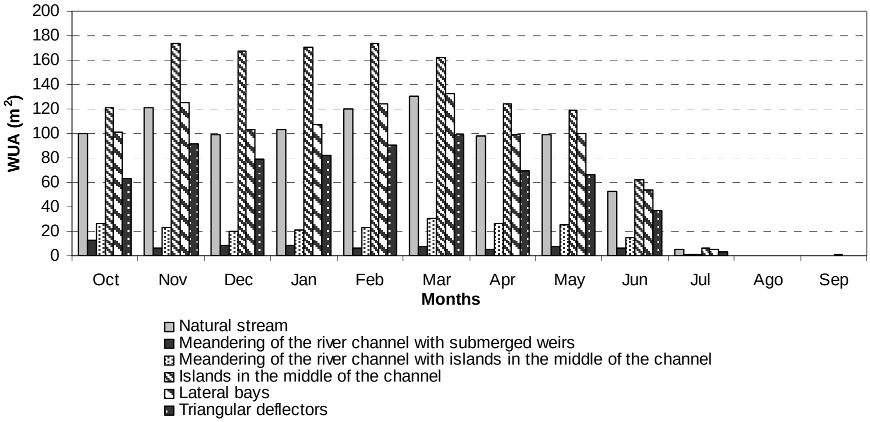

Figure 6 – Weighted usable area (WUA) for Nase and ecological flow regime

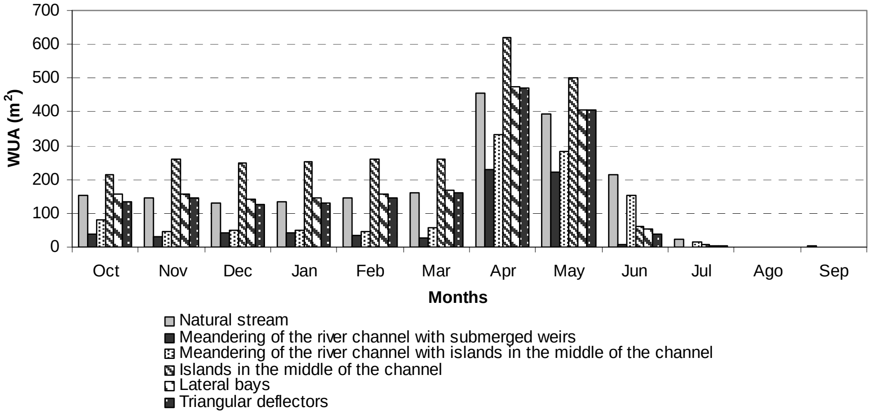

Figure 7 – Weighted usable area (WUA) for Chub and ecological flow regime.

5. CONCLUSIONS

This study highlights the importance of the habitat simulations in analysing the performance of different restoration scenarios, prior to their construction. By applying the habitat modelling to a specific river segment, it is possible to assess if a given set of concrete scenarios will significantly improve fish habitat, quantify their improvement and choose among the best ones, the one that potentially will be worth to be executed. The River2D model provides a useful tool to simulate and compare alternative restoration scenarios for improving fish habitat in a Mediterranean stream.

The methods outlined in this study for a river segment presenting low habitat heterogeneity could also prove extremely useful elsewhere, namely in other Mediterranean-type rivers, where fish species conservation and management are a priority.

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