Do current deflectors actually improve habitat in channel-like natural streams? A two-dimensional approach

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ABSTRACT: In the south of Spain there are rivers with brown trout (*Salmo trutta* L.) populations. In the upper reach of one of these streams, river Castril, we have assessed the effectiveness of the introduction of current deflectors in the riverbed, under different instream flow conditions. By means of the Instream Flow Incremental Methodology (IFIM) and with a two-dimensional approach, we have measured the potential value of stream habitat for brown trout requirements by Weighted Useful Area (WUA). This habitat evaluation was carried out under unmodified conditions and also supposing a series of alternate deflectors in the riverbed. By comparing habitat evaluations in both cases, we have been able to assess deflectors effectiveness as a restoration measure. No habitat improvement was attained with deflectors' introduction. For discharges bigger than 4 m^3/s habitat is similar in both scenarios. At lower flows, every development stage suffers a habitat reduction, which is stronger for juveniles. Under a natural flow regime there is a decrease in the mean annual habitat, ranging from 3.62% (adults) to 6.31% (eggs). Therefore, these type of habitat improvement measure is not recommended in these natural streams.

1 INTRODUCTION

Southern rivers of Spain maintain brown trout populations, isolated since the end of the last glaciation (García-Marín et al. 1999, Machordom et al. 2000, Suárez et al. 2001). They are very close to the southern limit of the species natural distribution, in northern Africa. In these rivers, fish habitat is often quite degraded by human activities. The effectiveness of a particular habitat restoration measure has been investigated in order to know if it is useful to implement it.

There are several types of structures used to improve fish habitat in rivers: current deflectors, low dams, boulders, half-logs, bank overhangs and others described in the literature (García de Jalón 1995). Current deflectors are frequently used structures for habitat restoration. They work changing the stream direction with the aim to protect the river margins, to dig pools, to concentrate water in summer or to create rapids (González del Tánago & García de Jalón 2001). Wesche (1985) gives technical details for their construction. Usually, a series of alternate current deflectors is placed. Each one produces an accumulation of materials downstream and changes flow direction, eroding the opposite river bank. Usually, deflectors are triangular and have their longest side strongly fastened in the river border. According to White & Brynildson (1967), they must not exceed more than 25 cm the summer water level in a year with normal rains.

Before carrying out any physical habitat improvement, managers should take into acount natural recovery processes (Cairns et al. 1977, Gore 1985, Reice et al. 1990) and the biogenic capacity of the reach, in order to act with nature (Heede & Rinne 1990).

The aim of this paper is to answer, by means of two-dimensional habitat simulation, the question raised in the title: if we place a series of instream deflectors in a channel-like but natural stream, do we actually enhance the available habitat for fish?

2 STUDY SITE

The chosen place to develop this study is the uppermost reach of river Castril, in the southeast of Iberian Peninsula (latitude: 37º52'N), province of Granada. This stream belongs to the river Guadalquivir watershed which discharges in the Atlantic Ocean. The studied reach, where brown trout inhabits, rises in the south slope of the Sierra de Segura mountains, which are composed principally of limestone, and flows southward. This basic stream is mainly fed by groundwater acuifers, so it does not have summer droughts, in spite of being located in a dry Mediterranean region.

Brown trout is the only species present in the upper Castril. This population is known to be native and non-introgressed (Martínez-Portela et al., unpubl.). The extremely low genetic variability among Castril trouts reveals its long time isolation since the last glacial retreat.

Principal land uses are cattle raising, mainly sheeps, and the cultivation of some species of trees, like poplars, almond trees and walnut trees. Not far downstream from the studied site, there is a small dam which diverts an important part of the discharge to a small hydroelectric power station.

3 METHODS

In this paper, habitat changes are assessed by means of the Instream Flow Incremental Methodology (IFIM), developed by the US Fish and Wildlife Service and amply described by Bovee et al. (1982, 1995, 1998). IFIM is based on habitat characterization with the aim of see, considering fish requirements, how useful habitat changes depending on the stream flow variations.

We have employed the software River2D (Steffler 2000) developed at the University of Alberta, in Canada. We have chosen a two-dimensional approach, because these models are useful in studies where it is important the detailed local distribution of depths and velocities (Steffler et al. 2000). Two-dimensional approaches have been used before in stream habitat studies, (Crowder & Diplas 2000, Crowder & Diplas 2002, Ghanem et al. 1996). Vehanen et al. (2003) assessed the effectiveness of habitat enhancement measures for grayling in a channelled river, consisting in the location of small islands, reefs and cobble-boulder structures. Leclerc et al. (1995) studied the habitat of juvenile Atlantic salmon after a water diversion was planned.

River2D simulates hydraulic conditions (depth, water velocity and direction, water surface elevation, etc.) in the studied reach. It also allows to estimate the potential value of stream habitat for the requirements of different species and development stages by Weighted Useful Area (WUA).

To carry out the simulation it is necessary to input the riverbed topography, which was acquired using an Electronic Total Station PENTAX PCS-315 and an appropriate prism. The kind of substrate in every point was also noted down. Instream flow magnitude was gauged as a boundary condition, using a metric tape, a graduated stick (to measure depth) and an Electromagnetic Flow Meter VALEPORT 801 (for water velocity).

To estimate WUA, River2D also need to know the preferences of depth, current velocity and substrate of all the development stages of the target fish. In this study, we considered the following brown trout life stages: adult, juvenile, fry and eggs. We have employed the preference curves done by Heggenes (1990) after some modifications, as shown in Figures 1-3.

WUA is the surface (m^2) that can be potentially used, with a maximum preference, by the considered species or development stage. The study of WUA allows us to know how a species can use the river habitat depending on the stream characteristics and flow variations.

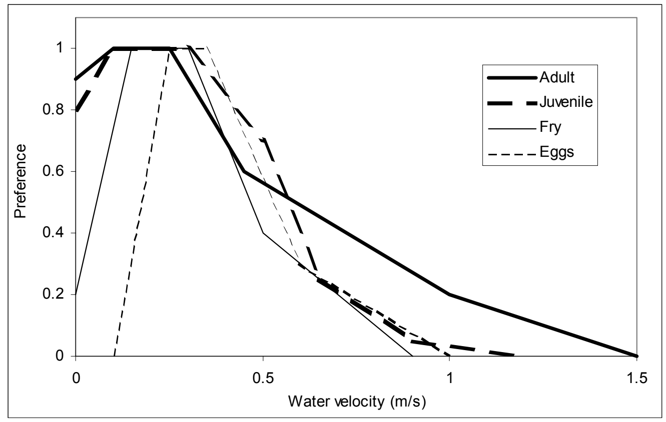

Figure 1. Water velocity suitability for brown trout.

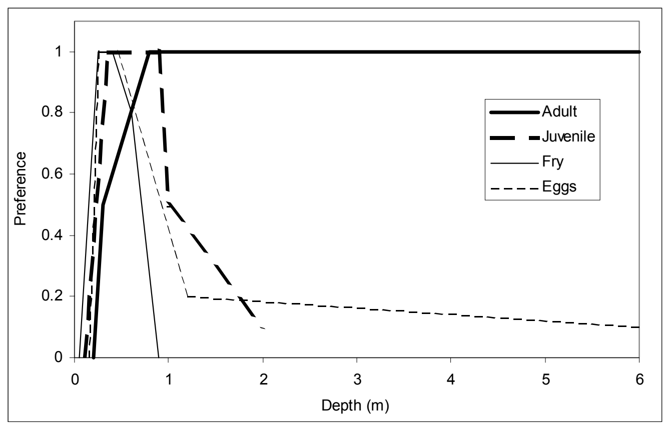

Figure 2. Depth suitability for brown trout.

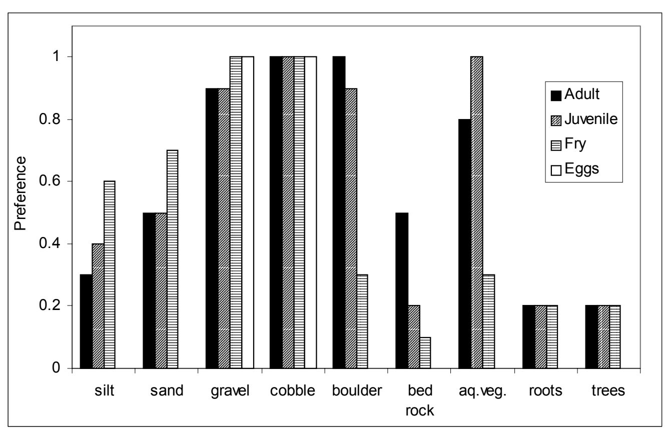

Figure 3. Substrate suitability for brown trout.

Firstly, habitat evaluation was carried out for the stream reach under unmodified conditions, for its use as control. Next, we supposed the introduction in the riverbed of two alternate triangular deflectors and we made the simulation again, to see how the stream habitat changes. By comparing recorded WUAs in the control conditions with those obtained under this technique, we have been able to assess deflectors effectiveness as a restoration measure.

With the aim of evaluate quantitatively the habitat change, we calculated one habitat value (which we will call "frequency weighted habitat"), by adding all the WUAs weighed by the frequency of their corresponding discharges. This way, the most frequent flows will have more influence in the final result. This frequency weighted habitat signifies the real habitat improvement under natural flow regime.

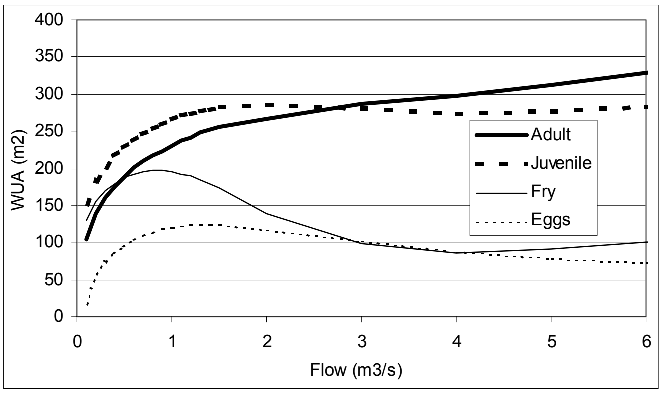

Figure 4. Relationship between Weighted Useful Area (WUA) and flow under natural conditions.

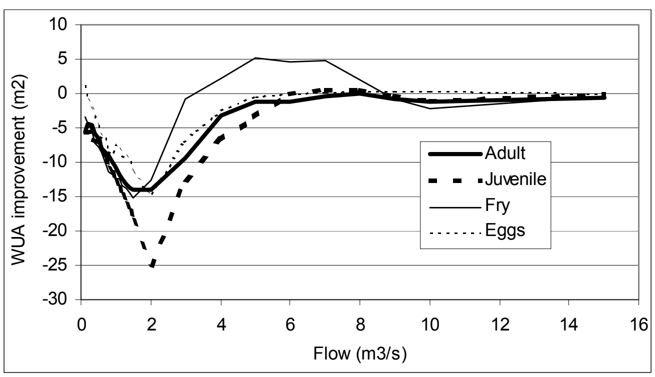

Figure 5. Habitat with deflectors minus natural habitat, related to instream flow magnitude.

4 RESULTS

Under natural conditions hydraulic simulation shows that WUA increases with discharge up to a maximum. For bigger flows habitat can either decrease or fluctuate in a narrow range of values (Fig. 4). Adult habitat is the exception because no relative maximum was attained by its curve. Probably, adult maximum habitat would be reached with discharges bigger than 15 m^3/s (highest simulated flow).

After the introduction in the riverbed of a series of two alternate deflectors, hydraulic simulation gave us a similar pattern of habitat-discharge curves, but with differences in WUA values. As shown in Figure 5, Fry is the only life stage which experience a slight habitat enhancement within the range 3-9 m^3/s. At 2 m^3/s all the development stages suffer an important reduction, which is stronger for juveniles. For bigger flows habitat remains similar to the natural one.

We obtained a reduction in frequency weighted habitat for every life stage. The younger the development stage, the stronger the habitat loss is, as follows: adults 3.62%, juveniles 4.25%, fry 4.67% and eggs 6.31 %.

5 DISCUSSION

A detailed local distribution of depths and water velocities is needed in order to attain sufficient accuracy to compare habitat availability after implanting this habitat improvement measure. This detailed distribution can be reached by a two-dimensional hydraulic simulation (Steffler et al. 2000). Ghanem et al. (1996) compared results obtained from both (1-D and 2-D) methods, and the two-dimensional approach was significantly better than 1-D. In a similar way, in this study a better description of flow complexity is expected to be obtained by applying the two-dimensional hydraulic model.

Results obtained in the present work show that no habitat enhancement is attained by the introduction of current deflectors in the riverbed of this particular reach. In fact, habitat losses have been obtained as results of this measure. Probably, so little stream habitat is gained that the structures themselves occupy a bigger area than the potential habitat area attained with their location.

Huusko & Yrjänä (1997) showed, by means of habitat simulation, that instream enhancement structures actually improve habitat availability in a channelized river. Thus, the study reach, which is straight and quite uniform, was expected to be susceptible of giving a good response when placing such structures in it. For this reason, our results suggest that such habitat improvement techniques could only be recommended for very homogeneous habitat scarce channels, instead of using them in a natural reach like the studied site at river Castril.

Often, physical habitat improvement measures are undertaken without a previous diagnosis of the problem, which leads to a failure in the final objective, the enhancement of the fish community. These actions are best carried out through a planned project, with multiple objectives (Gardiner 1991) and directed by multi-disciplinary teams using a bioengineering assessment (Orsborn & Anderson 1986). Firstly, an evaluation of fish populations and their habitat should be done, in order to realize which are the habitat problems and population bottle-necks. After this stage, we can consider the possibility of carrying out any habitat improvement measure, but before its implementation it is advisable to use habitat simulation as a tool for quantifying the final result. Finally, if some habitat improvement structure is placed, it will be essential to monitor its effectiveness and maintenance. Reeves et al. (1991) have suggested that the monitoring program must focus both on quantitative evaluation of habitat change and on fish population changes.

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