Integrated methodology for assessing the effects of geomorphological river restoration on fish habitat and riparian vegetation

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ABSTRACT

Changes in fluvial geomorphology may have serious impacts, causing losses in the dynamics and naturalness of their forms. In many cases these changes go from a natural meandering river, with balanced erosion and sedimentation processes, to a channelized narrow channel with rigid and stable margins, with dynamics restricted to only vertical dimension, with a consequent alteration of the river bed. On the other hand, these changes affect the naturalness of the banks, limiting the development of riparian vegetation and reducing the cross connectivity of the riparian corridor.

Common channelizations and disconnections of meanders increase the channel slope, and therefore water velocity, resulting in processes of bed degradation and regressive erosion, effect increased as a result of the narrowing of the channel and the concentration of flows. This process of incision may turn the floodplain to be "hung", being completely disconnected from the water table, with important consequences for vegetation.

The Arga river has been channelized and rectified, as it passes along the meander RamalHondo and Soto Gil (Funes, Navarra). Geomorphical restoration through remeandering is to be projected. This paper analyses the effects of these designs on fish habitat and riparian vegetation. Two very contrasting restoration scenarios, in terms of geomorphology, have been established to assess the effects of these changes have on the habitat of one of the major fish species in the area (*Luciobabus graellsii*) and on the riparian vegetation. To accomplish this goal, we run 2D hydraulic simulations (Infoworks RS), evaluating hydraulic and habitat conditions using digital elevation models from LIDAR flight and bathymetric data. The results obtained helped to evaluate the effects of past geomorphologic alterations on habitat. They also allowed to evaluate the effects of contrasting scenarios on fish and vegetation habitat.

1-. INTRODUCTION

The geomorphological processes are the key for the appropriate functioning of rivers as ecosystems. The geomorphological deterioration of European rivers is increasing progressively, as more direct actions on channels and floodplains related to urbanization, agriculture or industrial processes are carried out every time; these actions are especially aggressive against geomorphological processes and river morphologies. (Ollero, 2008)

This invasion of the floodplain by uses other than those strictly related to the floodplain has generated an increment of the vulnerability to flooding, what has generated channelized narrow channels with rigid and stable margins and disconnections of their natural meanders. As an important consequence, habitat loss has been observed and documented, what has generated a new movement towards the recovery of the natural structure and processes of these ecosystems.

In this paper an example of a high geomorphological alterated reach has been selected: the river Arga between the towns of Peralta and Funes, in Navarra region (Spain), where works against flooding damages started in year 1966, and whose consequences can be seen in the present and thought to keep incrementing in time. As main consequences of these processes, changes in fish habitat conditions (depth, velocity) and vegetation characteristics (vertical connection with water table) have been observed.

According to this, the objectives of this research was:

-Analyze the responses of fish and vegetation communities to different alternatives of geomorphological restoration.

2-. METHODOLOGY

Area of study

River Arga, is one of the main tributaries of the Ebro River, in NE of Spain. It is a left bank tributary of the Ebro river, and its basin extends from “el Collado de Urquiaga” to the river Ebro in Milagro. It has a surface of 2689.2 km2, and a length of 145 km.

The river reach selected for this research is situated between the villages of Peralta and Funes, in Navarra Region (Spain), where the river was channelized and completely disconnected from the meanders “Ramalhondo and Soto Gil”.

The total study area presents a surface of 108 ha, of which 13 ha belong to the channelized river and 95 ha to the disconnected meander. The channelized part has a length of 1,2 km.

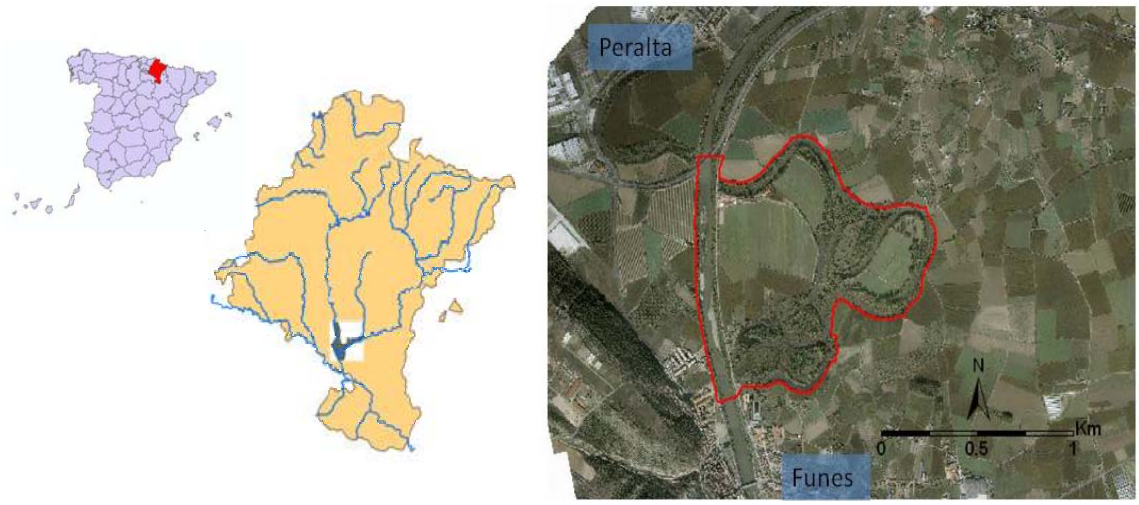

Figure 1-. Meanders of Ramalhondo and Soto Gil (River Arga): location in Navarre province (Spain)

Restoration image and design of alternatives

For the design of the restoration image, we analyzed pressures and impacts on the fluvial reach and we compared the actual situation with the reference conditions for this reach (meandering river). The main feature of the restoration image was to reconnect the old meanders to the main channel, with the following aims: a) restoration of fluvial geomorphologic dynamics b) increase river space controlling river bed degradation processes c) promoting native fish species and d) reduce the impact of floods on Funes town.

Two alternatives where designed corresponding with two very contrasting restoration scenarios, in terms of geomorphology. The first alternative consisted of reconnecting old meanders during annual maximum floods (discontinuous connection for flows higher than 407 m^3/s). The second alternative aimed at reconnecting old meanders almost continuously, for average flows (40 m^3/s)

2D Hydraulic simulation and fish habitat evaluation

A Digital Elevation Model of the area of study was built integrating LiDAR data for the floodplains and bathymetric profiles for the wet channel (Source: TRACASA, 2009). The digital elevation model was modified in ArcGIS to fulfil the requirements of each designed alternative, allowing a certain degree of connection between the channel and the old meanders.

For the hydraulic simulation it was used the Infoworks RS software. It is a model that simulates water depth, level and speed in two dimensions (x, y) for each pixel of a given terrain under certain flow conditions (input hydrograph, output level, roughness). Infoworks RS works iteratively solving the equations of continuity averaging the speed of flow in the water column above each terrain pixel (2D model)

For the evaluation of fish habitat we followed the GIS-integrated methodology proposed by Marchamalo et al. (2007), based on the evaluation of the Weighted usable area (WUA) for different stages (adults, juveniles, fry and spawning) of the most representative fish species in the area, the Ebro barbel (*Luciobabus graellsii*) using preference curves elaborated for Spain by ECOHIDRAULICA (2010)

The studied reach is mainly a gravel bed river for substrate suitability. Once evaluated the suitability (0-1) for depth (Sd), velocity (Sv) and substrate (Ss) conditions for each fish stage and simulated flow, it was calculated the Composite Suitability Index (CSI) for each wetted pixel as the geometric mean of the three indicators:

$$CSI = \sqrt[3]{Sd \bullet Sv \bullet Ss}$$

Finally, the Weighted Usable Area (WUA) (Bovee, 1982) for each brown trout stage under different flow conditions was calculated as an aggregate of the product of the Composite Suitability Index (CSI, range 0-1) evaluated at every pixel and the area of the pixel.

3-. RESULTS AND DISCUSSION

Figure 2 shows the results of the hydraulic simulations under the two alternatives and three design flows (5.5 m^3/s, 40 m^3/s and 407 m^3/s). Displayed images present the stabilized water depth for each alternative and simulated flow. It can be noted that full connection is attained for alternative 1 with a shallow water table at 407 m^3/s whereas this connection is effective an alternative 2 for flows higher than 40 m^3/s.

Figure 3 presents the evaluation of available habitat for the Ebro barbel (*Luciobabus graellsii*) under different hydraulic conditions. Alternative 2 provides more effective habitat for the target species than alternative 1.

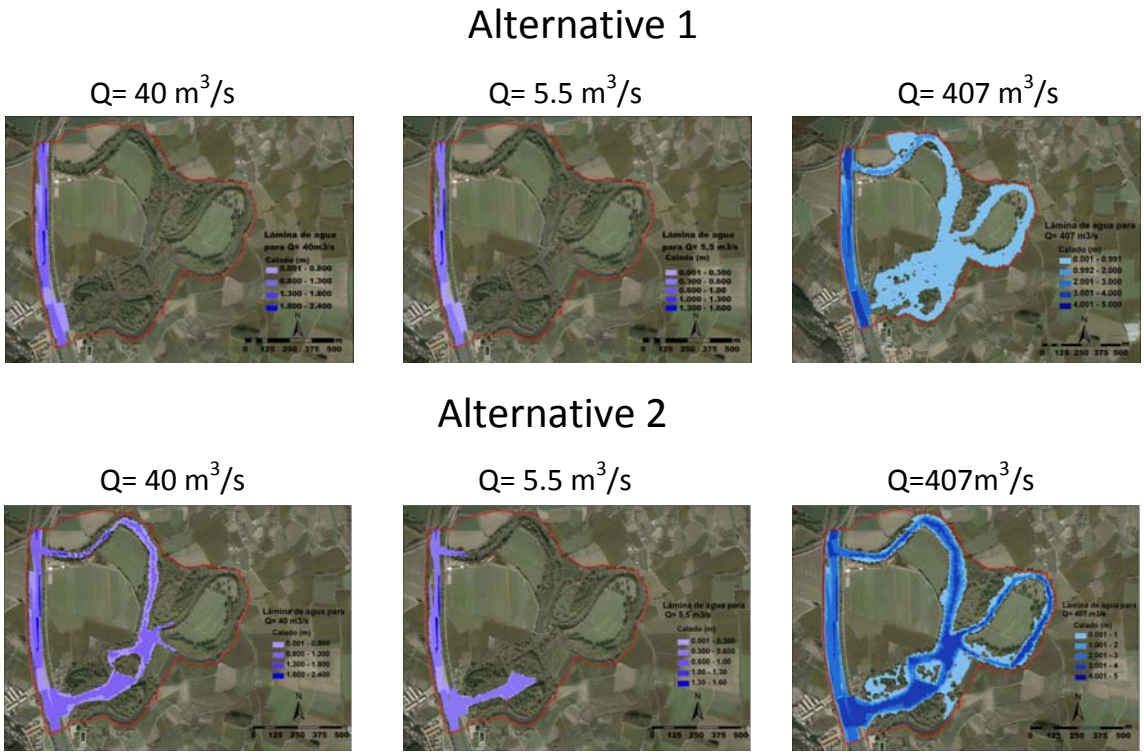

Figure 2-. Depth of water after hydraulic simulation in two different restoration alternatives for the meanders of Ramalhondo and Soto Gil (River Arga)

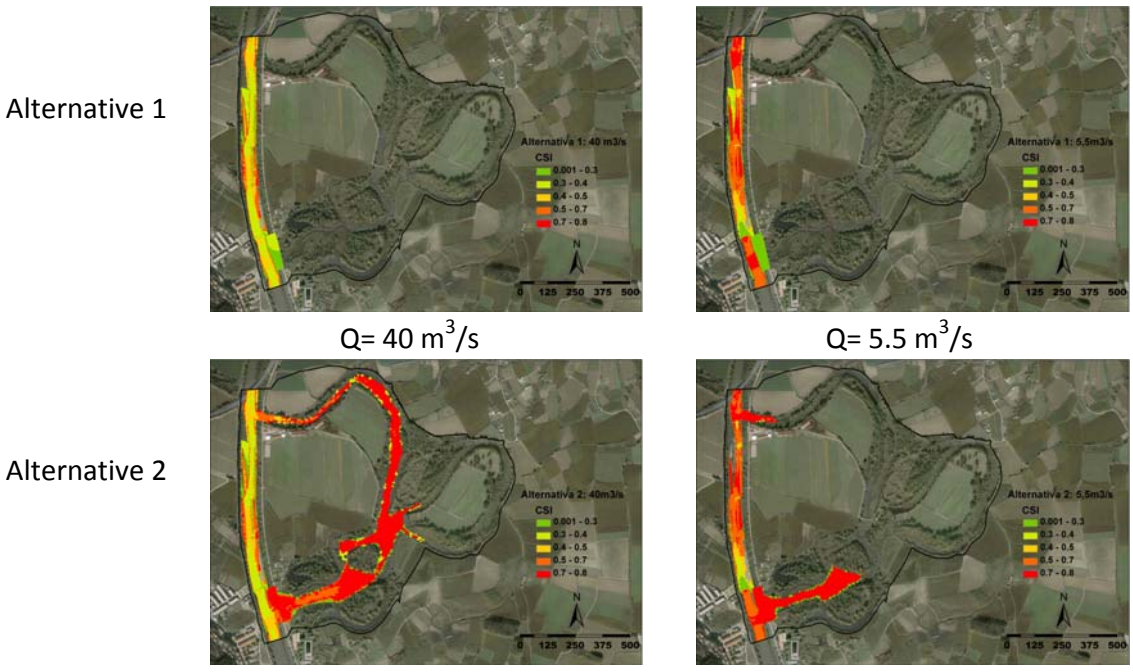

Figure 4-. Combined suitability index for the Ebro barbel (*Luciobabus graellsii*) in **two different restoration alternatives for the meanders of Ramalhondo and Soto Gil (River Arga)**

As it can be seen in Table 1, total weighted usable area is almost tripe in Alternative 2 for average flow than in alternative 1

Table 1-. Evaluation of total wet surface and weighted usable area (WUA) for different simulated flow and alternatives

	Alternative 1		**Alternative 2**	
	Q= 5.5 m^3/s	Q= 40 m^3/s	Q= 5.5 m^3/s	Q= 40 m^3/s
Total surface (m^2)	64,288	75,844	99,382	189,388
WUA (m^2)	35,113	32,985	63,356	112,631
% (WUA/Total)	54.6	43.4	63.7	59.4

In table 2 it has been summarized the degree of accomplishment of the objectives previously established with the reconnection of the old meanders. As it can be seen, under alternative 2 the objective of fish habitat enhancement is achieved, because it increments the weighted usable area (WUA) in comparison with the present situation (see table 1). Also under this alternative a lower impact of floods on Funes town has been observed due to the amount of water accumulated in the reconnected old meanders. However, for the rest of objectives, no significant differences have been detected. In both alternatives the geomorphologic dynamics, riparian characteristics and riparian habitat would be enhanced in comparison with the actual situation but with no significant differences under the two studied alternatives.

Table 2-. Evaluation of the alternatives in terms of different objective meetings ("+++"objective completely accomplished; "+" objective barely accomplished; "¿+"objective accomplish in a unknown degree; "0" not accomplished objective)

Objective	Geomorphologic dynamics	Riparian enhancement	Riparian habitat enhancement	Fish habitat enhancement	Flood protection
Alternative 1	¿+	++	++	0	++
Alternative2	¿+	++	++	+++	+++

4-. CONCLUSIONS

The geomorphologic restoration of rivers, in this case the reconnection of the river with their old meanders can help to recover the dynamics and natural structure of the ecosystem. However, it must be studied the effect of these actions on the different components of the fluvial ecosystem.

In this example positive responses of fish habitat to geomorphological restoration have been showed, but for further conclusion in terms of vegetation habitat, the simulation in the long term with the sediment component integrated could help to estimate better how it will respond to these actions.

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