Using river restoration operations to test predictive ecohydraulic models: fish and invertebrate communities of the Rhône river

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USING RIVER RESTORATION OPERATIONS TO TEST PREDICTIVE ECOHYDRAULIC MODELS: FISH AND INVERTEBRATE COMMUNITIES OF THE RHÔNE RIVER.

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Despite strong investments dedicated to river physical restoration, it is still difficult to assess the ecological effects of restoration operations. This is largely due to the difficulty of organizing long-term scientific surveys that anticipate operations and allow comparisons of their effects over multiple years in multiple sites. It is even more difficult to assess how ecohydraulic models can predict actual biological responses to stream restoration. As other large rivers in Europe, the Rhône River has been regulated for navigation, irrigation and hydroelectricity since the 19th century. A restoration program of the river started officially in 1998. It has involved minimum flow increases in bypassed main channels, the modifications of the connections of several dozens floodplain channels with the main river and the dredging of their sediments. So far, four bypassed main-channel sections and 26 floodplain channels have been restored. We used the Rhône restoration project as a template for testing the predictive power of several ecohydraulic models. In particular, we developed models to predict how fish and macroinvertebrate communities should respond to the physical restoration of the river. Some of these were based on hydraulic microhabitat models, that predicted how observed microhabitat preference of fish and invertebrate taxa should result in community changes after restoration. Other models were based on observed correlations between community structure and the degree of connectivity of floodplain channels with the main river. Several years after restoration, important community changes were observed in the restored sites and partly matched model predictions. Most reliable predictions corresponded to situations with strong physical contrasts (e.g. minimum discharge rate multiplied by 10, or reconnection between the floodplain and the main channel). Observations also revealed complex population dynamics and the development of invasive taxa that were not predicted by the models. Such results show the potential of ecohydraulic models for guiding management plans and contribute to quantify their uncertainty.

1 INTRODUCTION

Despite important investments dedicated to the physical restoration of rivers, assessing the ecological effects of such operations remains challenging. This is largely due to the difficulty of organizing long-term scientific surveys that anticipate restoration operations and allow comparisons of their effects over multiple years and multiple sites. It is even more difficult to assess how ecohydraulic models can predict biological responses to river restoration. The need to monitor community responses over the whole lateral dimension of the floodplain (i.e. from the main river channel to isolated cut-off channels) represents a further challenge.

As other large rivers in Europe, the Rhône River has been regulated for navigation, irrigation and hydroelectricity since the 19th century. A restoration programme of the river started in 1998 and involved i) the increase of minimum flow in bypassed sections, ii) the modifications of the connections of dozens of floodplain cut-off channels with the main river and iii) the dredging of their sediments. So far (i.e. in 2011), four bypassed sections and 26 floodplain cut-off channels were restored.

2 METHODS

We used the Rhône restoration project as a template for testing the predictive power of models relating species to those environmental conditions that are modified by restoration operations.

In the main river channel (bypassed sections), predictions were based upon hydraulic microhabitat models that predicted how observed microhabitat preference of fish and macroinvertebrate taxa could result in community changes after restoration (Lamouroux *et al.* [1], Mérigoux *et al.* [2]).

In the floodplain cut-off channels, models were based upon observed correlations between macroinvertebrate community structure and diversity and the connectivity of floodplain channels with the main river. An index based upon environmental variables known to be representative of the lateral connectivity was used as surrogate for the level of lateral connectivity of each floodplain site (Paillex *et al.* [3]).

The data considered here were collected on several sampling dates before and after restoration in four sectors of the French Rhône (Chautagne, Belley, Brégnier-Cordon, Pierre-Bénite) between 1995 and 2010. Pierre-Bénite (Figure 1) was subject to an initial program that started in 1995, while restoration started in 1998 for the three remaining sectors.

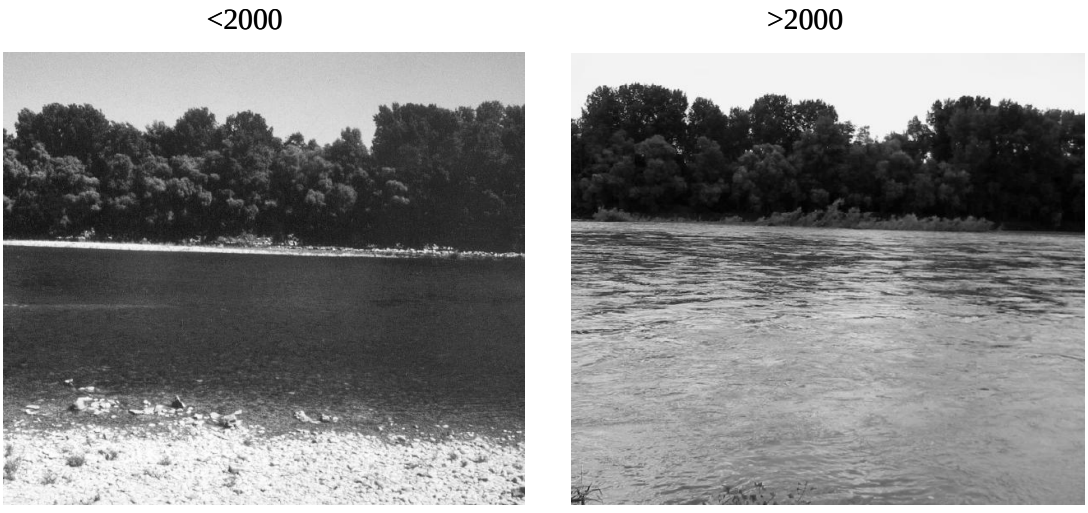

Figure 1. A reach of the main channel of the Rhône river at minimum flow (at Pierre-Bénite), before and after flow restoration.

3 RESULTS AND CONCLUSION

In the bypassed river sections where minimum flow was increased five to ten-fold, important changes in community composition were observed (e.g. the proportion of fish individuals belonging to species preferring fast-flowing and deep microhabitats increased between two- and three-fold). The hydraulic habitat models partly predicted these changes, which were observed in several reaches and involved several species. In contrast, in bypassed reaches for which flow was less modified, community changes were unrelated to model predictions. Results also revealed complex population dynamics and the establishment of alien taxa that were not considered in the models.

In the restored floodplain cut-off channels, the modification of the lateral connectivity induced predictable changes in the taxonomic richness and composition of macroinvertebrates. Taxa such as lotic Ephemeroptera, Plecoptera and Trichoptera increased noticeably in the reconnected channels. Richness of alien taxa reached a maximum in channels with a high lateral connectivity and was enhanced by restoration operations, but never represented more than 4% of the entire community. At the scale of the entire floodplain, the diversity of restoration measures led to a post-restoration increase in the taxonomic diversity of macroinvertebrate assemblages in the cut-off channels.

Several years after restoration, important community changes were observed in the restored sites and partly matched model predictions. Most reliable predictions corresponded to situations with strong physical contrasts (e.g. minimum discharge rate multiplied by 10, or reconnection between the floodplain and the main channel). Observations also revealed complex population dynamics and the development of invasive taxa that were not predicted by the models. Such results show the potential of ecohydraulic models for guiding management plans and contribute to quantify their uncertainty.

REFERENCES

[1] Lamouroux N., Olivier J.M., Capra H., Zylberblat M., Chandesris A. and Roger P., "Fish community changes after minimum flow increase: testing quantitative predictions in the Rhône River at Pierre-Bénite, France", *Freshwater Biology*, Vol. 51 (2006), pp. 1730-1743.

[2] Mérigoux S., Lamouroux N., Olivier J.M. and Dolédec S., "Invertebrate hydraulic preferences and predicted impacts of changes in discharge in a large river", *Freshwater Biology*, Vol. 54 (2009), pp. 1343-1356.

[3] Paillex A., Dolédec S, Castella E. and Mérigoux S. "Large river floodplain restoration: predicting species richness and trait responses to the restoration of hydrological connectivity", *Journal of Applied Ecology*, Vol. 46 (2009), pp. 250-258.

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