Evaluating immediate and long-term effects of river restoration projects in the Polish Carpathians

Évaluation des effets immédiats et à long terme des projets de restauration des rivières dans les Carpates polonaises

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RÉSUMÉ

La rareté des projets de restauration suivis fait que les preuves scientifiques des changements survenus dans les rivières restaurées sont maigres, notamment en ce qui concerne les techniques de restauration innovantes et les effets à long terme des activités de restauration. Les projets de restauration réalisés au cours de la première moitié des années 2010 dans trois cours d'eau polonais des Carpates ont permis d'établir un corridor érodable dans les tronçons des rivières Biała et Raba et d'installer des rampes de blocage dans le ruisseau Krzczonówka, profondément encaissé, en aval d'un barrage de retenue abaissé. Un suivi environnemental a été effectué dans les phases initiale et finale des projets de restauration et doit être répété 5 ans après leur achèvement. Cette étude (i) informe sur les objectifs et la mise en œuvre des projets de restauration, (ii) décrit la méthodologie de la surveillance environnementale et de l'analyse de l'efficacité immédiate et à long terme des projets dans l'amélioration de l'état écologique des cours d'eau et la réduction des risques d'inondation, et (iii) donne un aperçu des résultats de la phase initiale de la surveillance.

ABSTRACT

A scarcity of monitored restoration projects causes that scientific evidence of changes in restored rivers is meagre, particularly with respect to innovative restoration techniques and long-term effects of restoration activities. Restoration projects realized in the first half of the 2010s in three Polish Carpathian watercourses resulted in establishing of an erodible corridor in reaches of the Biała and the Raba rivers and installation of block ramps in the deeply incised Krzczonówka Stream downstream of a lowered check dam. Environmental monitoring was conducted in the initial and final phases of the restoration projects and is to be repeated 5 years after their completion. This study (i) informs on the objectives and implementation of the restoration projects, (ii) outlines the methodology of the environmental monitoring and of the analysis of immediate and long-term effectiveness of the projects in improving the ecological state of the watercourses and reducing flood hazard, and (iii) overviews outcomes from the initial phase of the monitoring.

KEYWORDS

Ecological river state, flood hazard, hydromorphological quality, mountain river, river restoration

1   INTRODUCTION

Significant degradation of ecological state of rivers and increased flood hazard in their valleys resulting from human impacts on river systems have induced attempts to restore rivers in many countries. The need to improve the ecological state of rivers and to reduce flood hazard necessitates recognition of cost-effective river restoration measures to achieve both these goals. To date, only a small proportion of restoration projects worldwide have been accompanied by programmes aimed at monitoring their effects, especially after project completion. Also, many of the monitored projects showed limited effects in terms of achievement of the expected goals. In the early 2010s restoration projects were implemented in three Polish Carpathian watercourses with the use of innovative methods: erodible river corridors were created in the Biała and the Raba, and block ramps were constructed in the deeply incised channel of Krzczonówka Stream to capture bed material released from a lowered check dam upstream. Although the implementation of these restoration projects was accompanied by environmental monitoring, there was no framework allowing for systematic analysis of collected data and continuation of the monitoring after completion of the projects. Recently, our team has started a scientific project *'Immediate and long-term effects of river restoration projects in the Polish Carpathians'* that aims to evaluate effects of the above mentioned restoration projects on flood hazard and the ecological state of the rivers.

2   PROJECT OUTLINE

In the Biała, an erodible corridor was delimited in two river reaches: in the mountain river course on the length of 14.5 km and in its foothill course on the length of 5.9 km. An erodible corridor in the upper course of the Raba was established in a 2.3-km-long reach where roads and settlements are located close to valley slopes, leaving a few hundred metres wide undeveloped corridor for the river. In Krzczonówka Stream, a 3.7-m-high check dam was lowered to make it passable for fish and fourteen block ramps were installed in the deeply incised downstream reach to facilitate entrapment of the sediments released from the reservoir of the lowered check dam.

Analysis of data collected at the beginning and end of the river restoration projects implemented in three Polish Carpathian watercourses as well as data collected 5 years after their completion will allow for the assessment of immediate (during the restoration project) and longer-term efficiency of the restoration measures in improving the ecological state of the rivers and reducing flood hazard (Fig. 1). We aim to verify hypotheses that the realization of the restoration projects significantly improved the following characteristics of the rivers: (i) hydromorphological river quality; (ii) physical habitat parameters; (iii) taxonomic richness of benthic macroinvertebrates and benthic invertebrate-based index of ecological river state; (iv) species richness and abundance of fish and fish-based index of ecological river state; (v) species richness, abundance and diversity of ground beetle community in the riparian area; (vi) flow velocity, unit stream power and bed shear stress, i.e. the hydraulic parameters of flood flows responsible for erosional damage during floods; and (vii) retention potential of flood flows in floodplain areas. The monitoring will thus focus on the river attributes allowing us to evaluate changes in the above indicated river characteristics (Fig. 1).

In the Biała and the Raba rivers with established erodible corridors, effects of the implementation of this restoration measure will be determined by comparing the indicated river characteristics between two sets of closely located, freely developing and channelized cross-sections. The proximity of the surveyed cross-sections of both types causes that they represent similar hydrological conditions, but differ in hydromorphological conditions. Observations on the effects of functioning of the two rivers in the erodible corridors follow a *BACI* experimental design for studies of the effects of environmental changes: *Before/After* the change versus *Control* (i.e. channelized)/*Impacted* (i.e. restored) river cross-sections (Fig. 1). Such a study design allows for distinguishing between changes resulting from river dynamics within the erodible river corridor and those induced by temporal variability in climatic and hydrological conditions during the study period. Addition of the observations performed 5 years after the end of the restoration projects will replace the classical before/after comparison with the comparison of changes recorded at the time span of the restoration projects and in the longer term (Fig. 1). In Krzczonówka Stream, where block ramps were constructed in the incised channel downstream from a lowered check dam, temporal changes in the modified stream reach will be analysed at 10 stream cross-sections delimited at progressively larger distances from the lowered check dam (Fig. 1).

Timing and components monitored
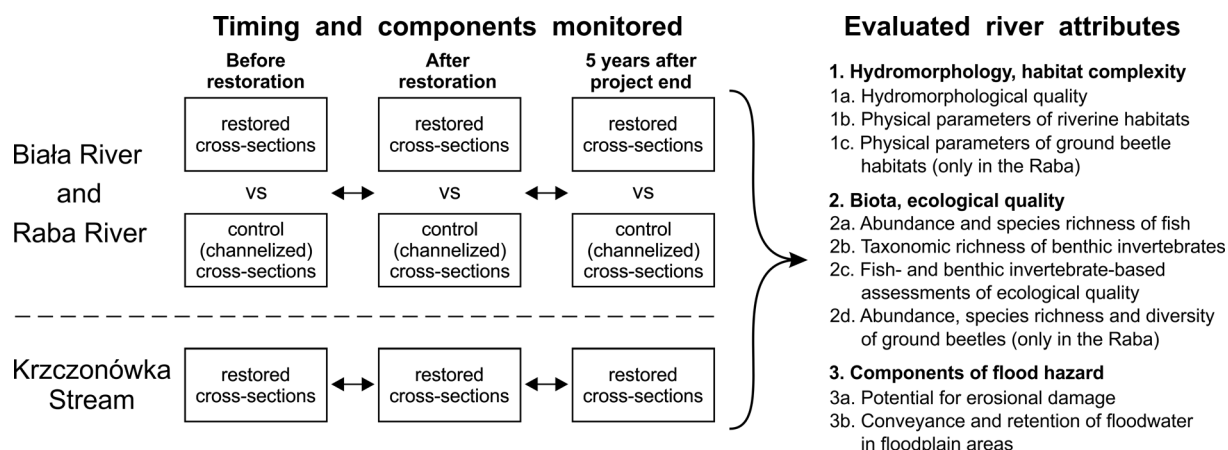
Evaluated river attributes

Figure 1. Workflow of the evaluation of restoration projects realized in three Polish Carpathian watercourses. In the Biała and the Raba rivers, temporal changes in the surveyed cross-sections from restored river reaches are compared with temporal changes in the cross-sections from channelized (control) reaches, whereas in Krzczonówka Stream the monitoring comprises only the cross-sections from the restored reach.

3   PREVIOUS WORK AND PUBLICATIONS

Prior to the beginning of the current project, studies were published that compare various attributes of the Biała and the Raba rivers between their freely developing and channelized cross-sections. Testing the relations between taxa richness of benthic invertebrates in 20 cross-sections of the Biała on one hand and water quality characteristics and physical habitat parameters on the other hand indicated physical habitat degradation as a reason for the observed variation in the taxa richness of the invertebrate community (Wyżga et al., 2013). Assessment of hydromorphological quality of the Biała River in unmanaged and channelized cross-sections, performed at the beginning of the restoration project, indicated river hydromorphological features that were severely modified in the channelized reaches and which are likely to improve the most with free channel development in the erodible corridor (Hajdukiewicz et al., 2017). Bednarska et al. (2018) compared ground beetle assemblages collected in unmanaged and channelized cross-sections of the Raba River and found that considerably larger river width in the unmanaged cross-sections is reflected in significantly greater abundance and species richness of the biota than in the neighbouring channelized cross-section.

4   CONCLUSIONS

The presented monitoring programme will allow for the assessment of effects of the implemented restoration measures on ecological river state and elements of flood hazard. In particular, it will show if restoration of degraded mountain rivers through allowing free formation of river channel within the delimited corridor or by construction of block ramps in excessively deep channel can simultaneously improve the ecological state of rivers and decrease flood hazard. Importantly, the results should help bridge the gap in the knowledge on long-term effects of the applied restoration measures, as monitoring of restored rivers usually ceases with the completion of restoration projects.

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