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How is success or failure in river restoration projects evaluated? Feedback from French restoration projects

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ABSTRACT

Since the 1990s, French operational managers and scientists have been involved in the environmental restoration of rivers. The European Water Framework Directive (2000) highlights the need for feedback from restoration projects and for evidence-based evaluation of success. Based on 44 French pilot projects that included such an evaluation, the present study includes: 1) an introduction to restoration projects based on their general characteristics 2) a description of evaluation strategies and authorities in charge of their implementation, and 3) a focus on the evaluation of results and the links between these results and evaluation strategies. The results show that: 1) the quality of an evaluation strategy often remains too poor to understand well the link between a restoration project and ecological changes; 2) in many cases, the conclusions drawn are contradictory, making it difficult to determine the success or failure of a restoration project; and 3) the projects with the poorest evaluation strategies generally have the most positive conclusions about the effects of restoration. Recommendations are that evaluation strategies should be designed early in the project planning process and be based on clearly-defined objectives.

1. Introduction

Impacts of human activities (e.g. damming, gravel extraction, channelization) on physical and ecological processes in rivers have been observed in many countries for many years (Gore, 1985; Gregory, 2006). Repairing environmental degradation has become a priority for western industrialised societies. Legal requirements regarding the environmental quality of waterbodies have been designated by the US Water Act (1972), the Canadian Water Act (1985), and more recently by the EU Water Framework Directive (WFD) (2000). Hence, regional standards have been used to define which quality level is deemed sufficient for waterbodies. River restoration, which aims at meeting these standards, has become one of the major practices in river management (Brierley and Fryirs, 2005; Wohl et al., 2005). In France for instance, 480 actions declared as restorative were carried out between 1985 and 2009, according to a recent online census (Morandi and Piégay, 2011). The implementation of the WFD has caused a large increase in the number (264) of these actions since 2000.

Although restoration projects are now more frequent than before, there is still a lack of evaluation and feedback (Jenkinson et al., 2006; Kondolf and Micheli, 1995; Nakamura et al., 2006). Several surveys of river restoration projects were carried out as part of national and international research programs. Most aimed at sharing experience about restoration and evaluation. Such programs included the National River Restoration Science Synthesis in the USA (Bernhardt et al., 2007), the European Centre for River Restoration (http://www.ecrr.org/) and the Asian River Restoration Network (http://www.a-rr.net/). In France, water management institutions (e.g. the Onema, French National Agency for Water and Aquatic Environments, and water agencies) have developed databases documenting the realisation of actions for river restoration. Still, little attention is given to the strategies and conclusions of restoration evaluation. In the USA, Bernhardt et al. (2007) concluded that only 10% of projects included "before, after & reference" monitoring related to goals or success criteria. In Japan, Nakamura et al. (2006) emphasised that evaluations were rare in the 1990s and had only been implemented in recent projects.

There are two main issues regarding the evaluation of restoration projects. First, evaluation contributes to fundamental scientific knowledge. According to Bradshaw (1996), if restoration is "an acid

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test of our understanding", then the main outcome of restoration projects are the conclusions of its evaluation. This is a critical element if restoration projects are to be considered to be experimental manipulations of a hydrosystem. Second, evaluations provide operational feedback and guidance for future restoration projects and for implementing adaptive management (Downs and Kondolf, 2002). In either case, assessing whether the restoration objectives have been achieved is crucial (England et al., 2008). In particular, restoration success can be evaluated based on the achievement of "good ecological status" or "good ecological potential" as defined by the WFD.

Reviews of existing basic and applied research have characterised and quantified the effects of some specific restoration measures (Kail et al., 2007; Roni et al., 2002). Conceptual frameworks for evaluation have been developed (Kondolf and Micheli, 1995; Palmer et al., 2005; Roni, 2005) and discussions of metrics or indicators are numerous (Friberg et al., 2011; Niemi and McDonald, 2004; Skinner et al., 2008; Woolsey et al., 2007). However, many fundamental questions remain unanswered concerning restoration effects, and the practical implementation of knowledge remains difficult despite the best efforts of practitioners and scientists.

The present contribution provides a review of the evaluation of 44 restoration projects. These projects were documented by interviewing scientists and practitioners. Our objectives are: 1) to describe the general characteristics of restoration projects (observed degradation, objectives set, measures undertaken), 2) to describe evaluation strategies (monitoring framework, metrics and references) and to relate them to the nature of the authorities implementing the project, and 3) to focus on the results of evaluations and relate them to evaluation strategies.

2. Material and methods

2.1. Interviews and study of documentation

An online census by Morandi and Piégay (2011) was used to identify potential interviewees involved in restoration projects. From an initial list of 104 projects with monitoring information, a list of 66 potential interviewees was identified, including researchers (44%), stakeholders (11%), practitioners from local authorities (17%), members of fisheries (11%) and nature protection structures (11%). Of the 66 potential interviewees, 78% agreed to be interviewed. The remaining 22% declined formal interviews but provided documents and some help for identifying relevant projects. Interviews were recorded following confidentiality agreements and interviewee consent, with the exception of one who refused recording. All interviews were semi-structured (Mason, 2004) and began by presenting the objectives of the interview. The interviews were all carried out by phone for more effectiveness (Alexander and Allan, 2007; O'Donnell and Galat, 2008). A bibliographic review was performed to check interview data and to supply more detailed information. A systematic acquisition of documentation related to the restoration projects under consideration was undertaken. The documentation included scientific articles, reports, PhD theses, presentation supports or public documents. Among the 325 documents studied, most were scientific reports (38%) or technical documents (30%).

2.2. Selection process for the analysis of restoration projects

Based on the interviews and documents, we selected 44 restoration projects (Supplemental Table S1) located along 44 different rivers in France. Seven of them involved multiple sites on several reaches (Supplemental Fig. S2), and all projects were implemented between 1996 and 2009 (Supplemental, Fig. S3a). Selection used the following criteria:

1) A restoration project is defined as a homogeneous group of actions aiming to achieve one or several restoration objectives. A project can be implemented at different times or at different sites.
2) Only projects aiming at restoring or improving the ecological status of waterbodies were included. Restoration, rehabilitation or habitat enhancement were not differentiated, and will all be referred to as "restoration" in the article.
3) Only physical restoration measures were analysed. Biological measures (e.g. species reintroduction, treatment of invasive species) were considered only if they had been complementary to physical restoration measures.
4) Only projects with a thorough evaluation strategy were included. Projects were not included in this study when their evaluation processes consisted of a simple visual monitoring or basic electric fishing census.
5) Data regarding yearly monitoring frameworks and metrics used had to be both available and detailed for each restoration project.
6) Restoration had to have occurred before 2011. Ongoing evaluations were considered only if they had started in 2011 and if the forthcoming evaluation stages were already financially guaranteed.

2.3. Description of restoration projects and evaluation strategies

The restoration projects were analysed through a conceptual framework with a particular emphasis on evaluation (Fig. 1). This conceptual framework led us to build a database organising the information collected from interviews and documents. Damage, restoration measures, and authorities in charge of the project were identified. Projects were dated and geographically situated.

Concerning the evaluation, the following four actions were taken: 1) Six biophysical groups were defined, that is, hydromorphology, physico-chemistry, vegetation (including aquatic and riparian vegetation), fish, invertebrates, and other biological groups (e.g. amphibians, mammals, birds). 2) The metrics used for each biophysical group were identified. 3) The monitoring frameworks based on different possible combinations of the Before-After-Control-Impact (BACI) framework were analysed. 4) The ecological state of reference was defined as the state used (i.e. the degraded pre-restoration state or a general notion of good ecological status) to evaluate the observed post-restoration state. Specifically, references used for evaluation were classified into two classes:

i) Relative references. These are "before restoration references" and "control references", and are based on a specific project site at a particular time. They are closely linked with monitoring frameworks.
ii) Absolute references. These are similar to restoration references as defined by previous authors (Clewell and Aronson, 2007; Palmer et al., 2005; Rey Benayas et al., 2009). They are generally proposed either *a priori* by practitioners and scientists in charge of restoration, or as the result of an external and independent process conducted at a regional or national scale. The first kind of reference are spatial references. Spatial references refer to non-degraded rivers close to a restored river with the same biophysical characteristics as the restored river. The second kind of reference, the expert reference, is based on evaluators' expertise. An expert reference may not always be scientific or evidence-based. It might, for instance, take into account services and benefits provided