Science of the Total Environment 560–561 (2016) 266–273

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Coupling systematic planning and expert judgement enhances the efficiency of river restoration

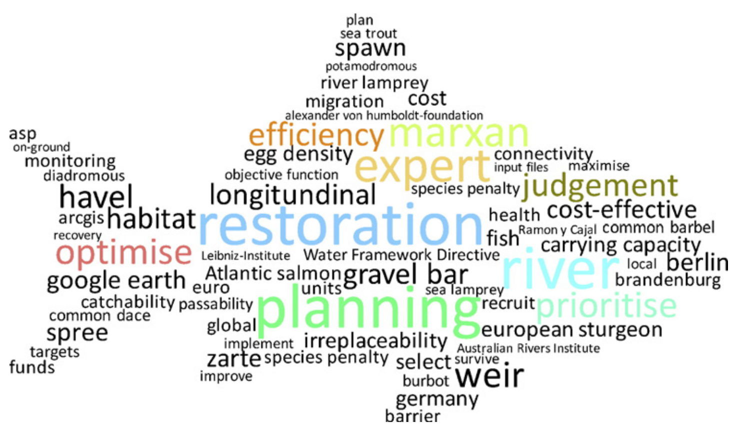
Simone D. Langhans [a,*], Jörn Gessner [a,b], Virgilio Hermoso [c], Christian Wolter [a]

[a] Leibniz-Institute of Freshwater Ecology and Inland Fisheries IGB, Müggelseedamm 310, 12587 Berlin, Germany
[b] Society to Save the Sturgeon, Rostock, Germany
[c] Centre Tecnològic Forestal de Catalunya, Ctra. Sant Llorenç de Morunys km 2, Solsona, Lleida, Spain

HIGHLIGHTS

- River restoration planned systematically often overlooks real-world constraints.
- Coupling systematic planning with expert judgement improves on-the-ground application.
- We test this targeting fish spawning habitat restoration along a large river system.
- Experts identify the extent and location of potential gravel bars and restoration cost.
- Marxan prioritises a cost-effective set of sites that reaches fish population targets.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 16 February 2016
Received in revised form 28 March 2016
Accepted 30 March 2016
Available online 19 April 2016

Editor: D. Barcelo

Keywords:
Cost-efficiency
Ecological status
Marxan
River restoration planning
Spawning habitat
Water Framework Directive

ABSTRACT

Ineffectiveness of current river restoration practices hinders the achievement of ecological quality targets set by country-specific regulations. Recent advances in river restoration help planning efforts more systematically to reach ecological targets at the least costs. However, such approaches are often desktop-based and overlook real-world constraints. We argue that combining two techniques commonly used in the conservation arena - expert judgement and systematic planning – will deliver cost-effective restoration plans with a high potential for implementation. We tested this idea targeting the restoration of spawning habitat, i.e. gravel bars, for 11 rheophilic fish species along a river system in Germany (Havel-Spree rivers). With a group of local fish experts, we identified the location and extent of potential gravel bars along the rivers and necessary improvements to migration barriers to ensure fish passage. Restoration cost of each gravel bar included the cost of the action itself plus a fraction of the cost necessary to ensure longitudinal connectivity by upgrading or building fish passages located downstream. We set restoration targets according to the EU Water Framework Directive, i.e. relative abundance of 11 fish species in the reference community and optimised a restoration plan by prioritising a subset of restoration sites from the full set of identified sites, using the conservation planning software Marxan. Out of the 66 potential gravel bars, 36 sites which were mainly located in the downstream section of the system were selected, reflecting their cost-effectiveness given that fewer barriers needed intervention. Due to the limited overall number of sites that experts identified as being suitable for restoring spawning habitat, reaching abundance-targets was challenged. We

* Corresponding author at: Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany.
E-mail addresses: langhans@igb-berlin.de (S.D. Langhans), sturgeon@igb-berlin.de (J. Gessner), virgilio.hermoso@gmail.com (V. Hermoso), wolter@igb-berlin.de (C. Wolter).

http://dx.doi.org/10.1016/j.scitotenv.2016.03.232

conclude that coupling systematic river restoration planning with expert judgement produces optimised restoration plans that account for on-the-ground implementation constraints. If applied, this approach has a high potential to enhance overall efficiency of future restoration efforts.

1. Introduction

River restoration has become a global priority (Bates et al., 2008) because of both poor conservation status of freshwater biodiversity and increasing pressure on freshwater resources, up to a point that current degradation compromises future human use (Vörösmarty et al., 2010). However, despite the increasing efforts and funds devoted towards the recovery of rivers (Verdonschot and Nijboer, 2002; Bernhardt et al., 2005), the success rate of restorations is far from being substantial (Roni et al., 2008). Planning restoration efforts in a more systematic way (Hermoso et al., 2012) may help improving their effectiveness, meeting management targets set by international conventions and directives. The European Union's Water Framework Directive (WFD; 2000/60/EC of 23 October 2000), for instance, obliges all Member States to reach a good ecological status or potential of their surface waterbodies by 2027. Although substantial improvements have been made over the past decades, current management plans report that 56% of European rivers currently fail to achieve the required good status (Lyche Solheim et al., 2012) with numbers being even worse for Germany (89.7%; Balzer et al., 2015). This tremendous mismatch asks for a more efficient strategy in planning restoration activities.

Prioritising sites that together most efficiently reach the defined ecological targets for a large spatial scale, for instance a catchment (Alexander and Allan, 2007), while minimizing the financial input, is a promising approach (Langhans et al., 2014). Although considerable resources are made available for the restoration of river systems, funds are finite and usually not sufficient to address all envisaged measures (Prosser et al., 2001). Hence, it is not only critical to plan restorations in a way that maximises the ecological benefits, but also in a way that makes the most efficient use of the money available. A transparent justification of how restoration funds - a large part of which is usually tax money - are spent can shape people's attitude towards supporting restoration projects. Support from society facilitates the implementation of restoration projects on-the-ground considerably (Buijs, 2009).

Even if the challenges of planning restorations systematically at the appropriate scales (Beechie et al., 2010) and cost-effectiveness are addressed, restorations may still not be successful. This may be the case, if the individual restoration units are not explicitly chosen for implementation, i.e. are too large or randomly assigned (Langhans et al., 2014). Indeed, most on-the-ground restoration efforts are still targeted at individual sites or stream reaches in an ad hoc fashion based on local interests or opportunities (Lake et al., 2007). We argue that, to enhance the value of recommendations that arise from restoration plans, an optimal planning process should be based on a set of only suitable restoration sites. Such suitable sites should be identified by local experts prior to running an optimisation on the spatial configuration of the restoration plan. Local experts may for example include scientists, fishermen, nature specialists or river managers, depending on the restoration goals and therefore the respective expertise needed. Whether or not sites are suitable for restoration is project-specific and depends on their location, characteristics, and feasibility of action implementation among others. An approach that allows prioritising restoration systematically, while at the same time accounting for real-world restoration constraints, has the potential to considerably enhance overall restoration efficiency. This is due to the fact that restoration implementations based on a firm choice of sites are less prone to delays caused by disagreement among stakeholders, such as landowners or other interested groups. Additionally, constraining restoration recommendations to sites, where they are logistically and economically feasible, increases the applicability of restoration plans.

We tested our idea of coupling systematic river restoration planning with expert judgement by establishing a cost-effective restoration plan for fish spawning habitat, i.e. gravel bars, in a river system with supra-regional importance for fish migration in Germany (the Havel-Spree rivers). Ensuring longitudinal connectivity along these rivers, and therewith the possibility for fish to migrate to and from the North Sea, is mandatory and will be enforced until 2027. We targeted to prioritise a minimum set of restoration sites from all suitable areas for restoration previously identified by local fisheries scientist experts, using the conservation planning software Marxan. This minimum set of priority restoration sites should provide sufficient spawning habitat to support the faunal composition of 11 rheophilic gravel spawning fish species native to the studied rivers. We included site-specific costs that consider the restoration of the gravel bar plus a fraction of the costs necessary to ensure longitudinal connectivity: Costs that incur at each weir to upgrade old fish passes or build new ones were spread among the sites that benefit from the measure, i.e. all the sites located upstream of the respective weir.

2. Materials and methods

2.1. Study area

The Havel River and its tributary the Spree are located in the central lowland ecoregion of Germany (Fig. 1). The Havel is a large, slow flowing river dominated by sand and silt bottoms, draining a catchment of 24,297 km^2, which is almost 90% of the area of the State of Brandenburg. Originating in the Mecklenburg lake district north of Berlin, the Havel runs 341 km to meet the Elbe River (Landesumweltamt Brandenburg, 2006). In the middle and lower sections, a series of weirs define the hydrological regime with discharges varying between 3.4 and 290 m^{-3} s^{-1}. These weirs form a number of lakes connected by moderately flowing sections, which are 50 to 80 m wide (Gessner et al.,

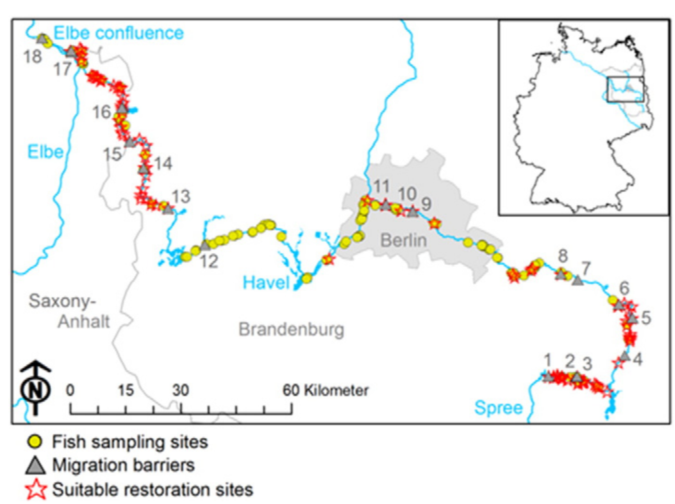


Fig. 1. The Havel-Spree river system. Location of the Havel-Spree river system from the Elbe River to the upstream end of the study area at the weir Alt Schadow (N° 1), flowing through the states of Berlin, Brandenburg, and Saxony-Anhalt in Northeast Germany. The map indicates the potential restoration sites identified by the experts, the fish sampling sites, and the migration barriers (weirs; numbers refer to Table 2).