



Aligning dam removals and road culvert upgrades boosts conservation return-on-investment



Kimberly B. Fitzpatrick*, Thomas M. Neeson

Department of Geography and Environmental Sustainability, University of Oklahoma, Norman, OK 73071, USA

ARTICLE INFO

Article history:

Received 30 June 2017

Received in revised form 30 October 2017

Accepted 17 November 2017

Available online 12 December 2017

Keywords:

Stream-resident fish
Anadromous fish
Fragmentation
River restoration
Freshwater
Conservation planning

ABSTRACT

Dams and road culverts fragment river ecosystems worldwide by restricting the movement of aquatic species. In many watersheds, a diverse set of actors coordinates the removal of these barriers. Non-governmental organizations often focus on small dams and road culverts, while large dam removal projects are coordinated by federal agencies or coalitions of partners. Here we evaluate the return-on-investment of these strategies by exploring a continuum of methods for selecting barrier removal projects, ranging from a focus on many small barrier removal projects to a few large ones. We used estimated removal costs of more than 100,000 barriers in the North American Great Lakes to construct economically realistic barrier removal scenarios. We then simulated the movement of stream-resident and anadromous fishes through model river networks with a few large dam removals, many road culvert retrofits, or a mix of both. We found that the strategy of removing both dams and road culverts had the greatest potential to benefit both stream-resident and anadromous fishes, but only when projects were aligned longitudinally within the river network. Our results demonstrate the importance of allocating conservation resources to both small and large restoration projects, and highlight a need for increased coordination and communication among the many different organizations investing in barrier removals. Our findings complement optimization approaches to prioritizing barrier removals by providing general guidelines for practitioners to follow when project selection must depart from a prescribed portfolio of projects.

© 2017 Published by Elsevier B.V.

1. Introduction

Habitat fragmentation is a leading cause of global biodiversity decline (Fischer and Lindenmayer, 2007; Perkin et al., 2015). The impacts of fragmentation are particularly devastating for many freshwater fishes (Kanehl et al., 1997; Warren and Pardew, 1998; Catalano et al., 2007) because they are restricted to river networks (Fagan, 2002); consequently, a single barrier in a river network can completely block fish movements. In most fragmented watersheds, barriers include dams and road crossings, both of which can be detrimental to stream fishes (Warren and Pardew, 1998; Nilsson et al., 2005; Bouska and Paukert, 2010; Januchowski-Hartley et al., 2013). To remedy this situation, local and national conservation organizations are increasingly interested in restoring freshwater connectivity by removing dams and retrofitting road culverts (Grossman, 2002; Magilligan et al., 2016). In most cases, completed barrier removal projects have been selected by a process of strategic

opportunism (Magilligan et al., 2016) which includes both strategic planning and the identification of unexpected opportunities to remove particular barriers at low economic or sociopolitical cost.

In many watersheds, investments in restoring ecosystem connectivity are coordinated by a diverse group of governmental natural resource management agencies and non-governmental conservation organizations with varying budgets, focal geographies, and species priorities (Neeson et al., 2015). Due to diverse institutional constraints, different organizations often prefer to focus on different classes of barrier removal projects. In general, barrier removal strategies exist along a continuum, ranging from efforts to remove a small number of large dams, to a preference for many small dam and road culvert projects. Large dam removals are often complex, costly, highly politicized, and can take years of effort by conservation and government organizations to be implemented (Grossman, 2002; Wildman, 2013). Notable examples include the recently removed Elwha Dam in Washington (Service, 2011) and the ongoing deliberation concerning the Rodman Dam in Florida (Grossman, 2002). Though challenging to carry out, large dam removals can be particularly beneficial for anadromous fishes, providing a dramatic increase in access to the river network and upstream spawning habitat. At the opposite end of

* Corresponding author at: 111 Fernow Hall, Cornell University, Ithaca, NY 14853.
E-mail addresses: kimberly@ou.edu (K.B. Fitzpatrick), neeson@ou.edu (T.M. Neeson).

the spectrum, local watershed-level organizations tend to focus on small dam removals and road culvert upgrades. Although removing these structures can still be contentious depending on ownership and location (Grossman, 2002; Fox et al., 2016), they are typically much cheaper to execute and less controversial. Barrier removals in small headwater streams will not aid anadromous species if the mouth of the tributary remains blocked, but can still benefit stream-resident species by reconnecting previously isolated sub-populations and increasing accessible habitat (Bednarek, 2001; Catalano et al., 2007).

Given the growing interest in restoring ecosystem connectivity and a general lack of available funds for meeting conservation needs (McCarthy et al., 2012), it is critical to identify strategies that enable a diverse set of natural resource managers to collectively maximize return-on-investment (ROI; Murdoch et al., 2007) from barrier removal projects. In a conservation context, ROI is the amount of conservation benefit that could be achieved for a given budget (Murdoch et al., 2007). For barrier removals, the benefit is typically measured as the increase in accessible habitat across the river network (i.e., connectivity; Kemp and O'Hanley, 2010). Although any barrier removal will improve connectivity, benefits may vary dramatically among projects depending on available habitat for beneficiary species, spatial context of the barrier within the river network, and the set of other barrier removal projects completed or planned within the watershed. Inefficiencies can arise from lack of communication between agencies focused on different species or project classes (O'Hanley et al., 2013), or from piecemeal planning of projects leading to missed opportunities for aligning barrier removals (Neeson et al., 2015). Furthermore, if species dispersal patterns, life history strategies, and habitats are not considered while planning a barrier removal, the benefits can be limited to only a few species.

Most previous research has focused on the use of optimization models (Kemp and O'Hanley, 2010; McKay et al., 2017) or spatial graph models (McKay et al., 2013; Branco et al., 2014) to identify a set of barrier removal projects that would result in the greatest benefit for stream fishes. These optimal plans often rely on all proposed removals being implemented simultaneously or in the near future (Kemp and O'Hanley, 2010; Neeson et al., 2015), and rarely consider the complex social and political factors that determine the feasibility of a barrier removal project (Grossman, 2002; Fox et al., 2016). In reality, social and political factors often limit conservation practitioners' ability to implement a prescribed portfolio of barrier removal projects (Magilligan et al., 2017). In these cases, conservation organizations would benefit from a general barrier removal strategy that they could follow to maximize ROI in the long term while responding to immediate opportunities to remove particular barriers at low socio-political cost (i.e., a policy of strategic opportunism; Isenberg, 1987).

Here, we aim to develop general guidelines for conservation practitioners to follow when prioritizing barrier removal projects. Specifically, we calculate the ROI for three common strategies for allocating conservation funds for barrier removals: towards the removal of a few large dams, the removal of a larger number of road culverts, or a mixed strategy, consisting of both dam and road culvert removals. Our aim was to draw general conclusions that were not specific to any one river network or a single fish species. Accordingly, we created an individual-based model (IBM) of two fish populations, one of stream-resident fish and the other of anadromous fish, in a generalized representation of a fragmented river network. The IBM approach allows us to examine variability in restoration efficiency resulting from spatial alignment of barrier removals, as well as variability created by stochasticity in the spatial dynamics of the fish populations themselves. Focusing on this combined variability, we investigate the best-case, worst-case, and average outcomes, in terms of population distribution, for stream-

resident and anadromous fishes under these three conservation strategies.

2. Methods

We created an IBM to simulate movement patterns of stream-resident and anadromous fishes through a fragmented river network. The model consists of three components: a river network, a fish population, and a set of barriers that block fish movements. The cost of removing a barrier was based on stream order and derived from a database of more than 100,000 barriers in the North American Great Lakes (Neeson et al., 2015). Thus, our barrier removal scenarios reflect the true range of project choices available to practitioners working in a large freshwater ecosystem. We modeled two general life history strategies of stream fishes (stream-resident and anadromous) to account for the impact of barrier removals on fishes with either type of migratory strategy. We simulated each fish type separately, which enabled us to describe the response of each type of fish to the barrier removal strategies.

2.1. River network submodel

The river network for all model runs is a symmetric dendritic river network with fifteen reaches (Fig. 1A). In defining our river network, we took a patch-based graph approach (Eros et al., 2012) in which each reach within the river network (Fig. 1A) is condensed into a "patch" or "node," and "links" or "edges" represent the possibility for movement between reaches (Fig. 1B). Thus, the river network overall is a graph $G(N, L)$ with nodes N indexed by n and links L indexed by l . We define a reach as the section of river between two confluences, and assume that each reach in the network provides an equivalent amount of fish habitat (Fig. 1B). Each reach is directly connected to a maximum of three other reaches, one downstream and two upstream.

In our model, we assume that a barrier, if present, completely blocks both upstream and downstream movement of fishes between reaches, and that barrier removal restores full movement between reaches (Fig. 1C). Following Perkin et al. (2013), barriers are placed directly between reaches. We refer to each barrier according to the Strahler order of the upstream reach, such that a barrier between a first-order and a second-order reach is a first-order barrier (Fig. 1C).

2.2. Fish submodel

We hypothesized that the way in which individual fish interact with the complex shape of a fragmented river network would play a key role in structuring fish distributions (Neeson et al., 2011, 2012). Accordingly, we chose an IBM approach because it allowed us to capture these individual interactions. We simulated fish populations based on two common life history strategies, stream-resident and anadromous, allowing us to characterize the benefits of barrier removal projects for a diverse community of fishes. Though movement rates vary considerably among species and individuals (McIntyre et al., 2016), our intent was to focus on long-term impacts of barrier removals on equilibrium distributions of stream fishes, which will be insensitive to the speed at which individuals colonize recently-connected habitat. Accordingly, our model uses a weekly time step, which is the finest temporal resolution that captures movement rates of an average migratory fish species (Okland et al., 2001) at the coarse spatial resolution of our modeled river network (Fig. 1). Fast-migrating species (e.g., salmon) would likely reach an equilibrium distribution across the river network more quickly than species with limited movement (e.g., mottled sculpin).

At every time step t , each individual fish must choose whether to move to a directly connected reach j or to stay within its cur-

Download English Version:

<https://daneshyari.com/en/article/8846143>

Download Persian Version:

<https://daneshyari.com/article/8846143>

[Daneshyari.com](https://daneshyari.com)