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Opportunities for collaboration between infrastructure agencies and conservation groups: Road-stream crossings in Oklahoma

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ABSTRACT

Rivers and streams worldwide are highly fragmented by dams and road crossings, and there is a pressing need to retrofit the most problematic structures to ensure aquatic organism passage. At the same time, a majority of the transportation infrastructure within developed nations is beyond its projected lifespan and significant investments will be needed to ensure that this transportation infrastructure remains safe and functional. Historically, these two problems have been addressed separately. Here, we use a rapid survey methodology to identify road-stream crossings that are likely high-priority projects for both conservation and infrastructure agencies. We conducted a field assessment of more than 700 road-stream crossings across Oklahoma to determine if they blocked fish movements and to determine their physical condition. We then developed an index of ecological impact, and an index of infrastructure condition, based on physical variables measured at each crossing. This survey revealed a subset of crossings that are both fragmenting the river network and in poor physical condition. These crossings are high-priority locations where culvert replacement may have both high ecosystem benefit and would eliminate a piece of transportation infrastructure with a high risk of failure. We discuss opportunities for cost-sharing between conservation and transportation agencies.

1. Introduction

Habitat fragmentation and loss threaten freshwater biodiversity and ecosystem health worldwide (Nilsson et al., 2005; Dudgeon et al., 2006; Perkin et al., 2015a). In the coterminous United States, 85% of large rivers are fragmented by dams and road culverts that block fish movements (Perkin and Gido, 2011). Although this is a problem throughout the world, the Great Plains region of the United States is a region of particular high concern (Gido et al., 2010). Over 19,000 dams and hundreds of thousands of road-stream crossings have been built since the 1930s, resulting in habitat loss, degraded water quality, and a loss of aquatic biodiversity (Costigan and Daniels, 2012).

Within the Great Plains, stream fragmentation and hydrological alterations have led to a dramatic decline of native fish diversity (Perkin et al., 2015a). Many native fishes are pelagic spawners, a reproductive guild that requires long stretches of free-flowing river to successfully reproduce because their semi-buoyant eggs must remain suspended in the water column during development (Perkin and Gido, 2012). As a result, pelagic spawning fish are commonly missing from short river fragments upstream of barriers (Perkin et al., 2015a). Improvements to longitudinal river connectivity by retrofitting road culverts to restore fish passage are likely to improve the abundance and distribution of pelagic spawning fishes and help preserve fish biodiversity in the Great Plains (Perkin and Gido, 2012; Perkin et al., 2015a, 2015b).

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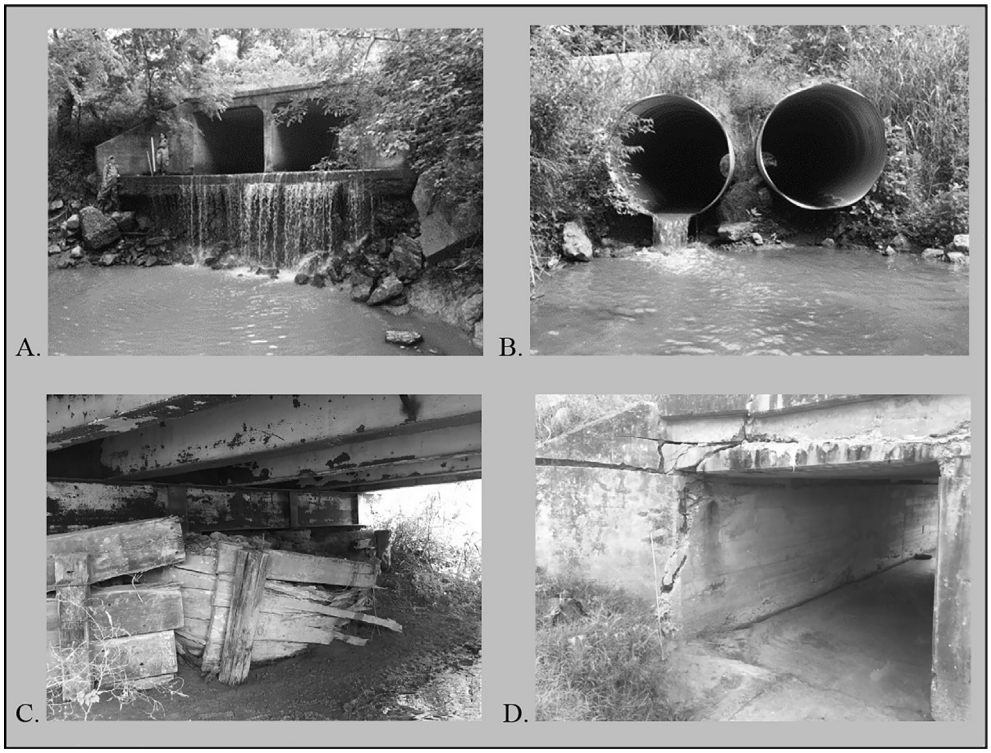

Fig. 1. Examples of high-priority road culverts from the freshwater conservation (A, B) and road network infrastructure (C, D) perspectives. The road culverts in (A) and (B) likely have substantial negative impacts on freshwater ecosystems because their vertical outlet drops are impassable to aquatic organisms; culvert (B) also likely represents a velocity barrier at high flows. The road culverts in (C) and (D) are likely high priorities for replacement by infrastructure agencies because they exhibit structural deficiencies including major cracking of the concrete culvert walls and substructures.

There is growing support for restoring ecosystem connectivity by removing dams and upgrading road crossings throughout the Great Plains. Although any barrier removal project will improve longitudinal connectivity of river systems to some extent, the most dramatic connectivity gains can be achieved only by systematic spatial prioritization of barrier removal projects (Perkin et al., 2015a; Fullerton et al., 2010; Januchowski-Hartley et al., 2013). Traditionally, barrier removal projects were selected based on opportunism and local priorities (Magilligan et al., 2016), and this piecemeal approach to barrier removal has often resulted in sub-optimal improvement in habitat connectivity. Increasingly, barrier removal projects are selected by considering both the local benefits of the project and the spatial context of that barrier in the river network (O'Hanley and Tomberlin, 2005; Fitzpatrick and Neeson, 2018). For example, coordinating barrier removals across a large region has been proven to be nine times more efficient (in terms of habitat reconnected per dollar spent) than local-scale planning at reconnecting fish to suitable spawning habitat (Neeson et al., 2015).

While road culverts often block fish movements, this transportation infrastructure is primarily managed by a collection of municipal, county and state transportation agencies whose primary objective is to maintain a safe and functional road network given limited budgetary resources. In the Great Plains, the vast majority of road-stream crossings are past their projected lifespan, and large investments are needed to keep this transportation infrastructure functional and safe (ASCE, 2013). For example, a significant fraction of bridges and road culverts in the United States are estimated to be structurally deficient (Alkhrdaji et al., 1999; ASCE, 2013).

Typically, these two problems of fragmentation and infrastructure condition have been addressed separately: conservation practitioners have prioritized particular road crossing projects to maximize benefits for stream ecosystems, while transportation agencies have prioritized other projects to maintain roadway infrastructure (Fig. 1). Though these two types of organizations have traditionally operated independently, we hypothesize that there may be opportunities to identify road crossing projects that would provide benefits to both river ecosystems and transportation networks. By identifying locations that are in need of repair with respect to both of these dimensions, conservation practitioners and infrastructure agencies could potentially share project costs and restore more sites than might be possible if they had been operating independently.

Here, we combine a large-scale field survey of road culverts with a spatial prioritization analysis to identify road stream crossings that are both fragmenting river networks and in poor condition as transportation infrastructure in Oklahoma. First, we assessed the physical attributes and spatial context of more than 700 road culverts across Oklahoma, and then identified a subset of road crossings that would provide high ecosystem benefit if removed. Second, we identified a different subset of road crossings that are in poor condition as transportation infrastructure; if these road culverts were replaced, it would provide a large increase in the condition and