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How much conservation is enough? Defining implementation goals for healthy fish communities in agricultural rivers

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ABSTRACT

“How much conservation is enough?” is one of the most important and difficult questions to answer. In this work, we demonstrate an approach to specifically answer this question for conservation strategies designed to address nonpoint source pollution in agriculturally-dominated watersheds. We developed empirical models relating conservation investments and actions to measures of stream water quality and fish community health. Our results are consistent with other studies that demonstrate a need for extensive implementation of conservation practices in agricultural landscapes to see measurable improvements in ecological conditions. Our results also demonstrate the influence spatial grain can have on answering “how much conservation is enough?” Our coarse-grained analyses suggest that water quality in at the outlets of four watersheds could be improved to the point that water quality was no longer limiting the fish community with only about 18% of the agricultural lands treated with conservation practices and incentive payments totaling $7.7M. Yet, finer-grained subbasin analyses predict fish communities would still be limited in many tributaries of these watersheds even with ~50% of lands treated and incentive payments totaling ~$44M. Consequently, coarsegrained analyses could significantly underestimate scope of the solution needed to address these impacts to stream ecosystems. Finding balanced solutions to address agricultural nonpoint source pollution throughout the Great Lakes will require unprecedented collaboration from local to regional scales. Herein, we provide examples of how this work is supporting collaborative efforts to establish realistic ecological goals and associated performance measures and strategic implementation of practices throughout the Saginaw Bay drainage.

Introduction

The question of “How much conservation is enough?” is one of the most important questions to answer for biodiversity conservation efforts (Kautz et al., 2006; Wilhere, 2008). It involves estimating costs and benefits of different management scenarios against desired ecological and socioeconomic outcomes (Tear et al., 2005). This information can then be used by stakeholders, with often competing interests, to assess tradeoffs and find balanced solutions among these interest groups. Ultimately, answering this question is critical to setting ecologically-grounded and socioeconomically realistic conservation action goals and related program performance measures that provide the foundation for all adaptive management strategies (Fig. 1; Tear et al., 2005; Fales et al., 2016).

The question of “how much conservation is enough?” is particularly important to finding balanced solutions for addressing agricultural nonpoint source pollution impacts to water quality and freshwater biodiversity. There are multiple interest groups affected by this issue and significant conservation investments that are made to address it (Mausbach and Dedrick, 2004). As this special issue of JGLR makes clear, agriculture is critical to the quality of life of people within the Great Lakes and throughout the world (Kerr et al., 2016). In 2007, within the US side of the Great Lakes region alone, it was estimated that there were nearly 126,000 farms with total agricultural sales of about $14.5 billion (USDA NRCS, 2007). However, the potential impacts of agriculture on water quality, freshwater biodiversity, and related ecosystem services are well documented generally and specifically within the Great Lakes region (Waters, 1995; Richter et al., 1997; Rankin et al., 1999; Cuffney et al., 2000; FISRWG, 2001; Allan, 2004; Wang et al., 2006, 2007; Weigel and Robertson, 2007; Blann et al., 2009).

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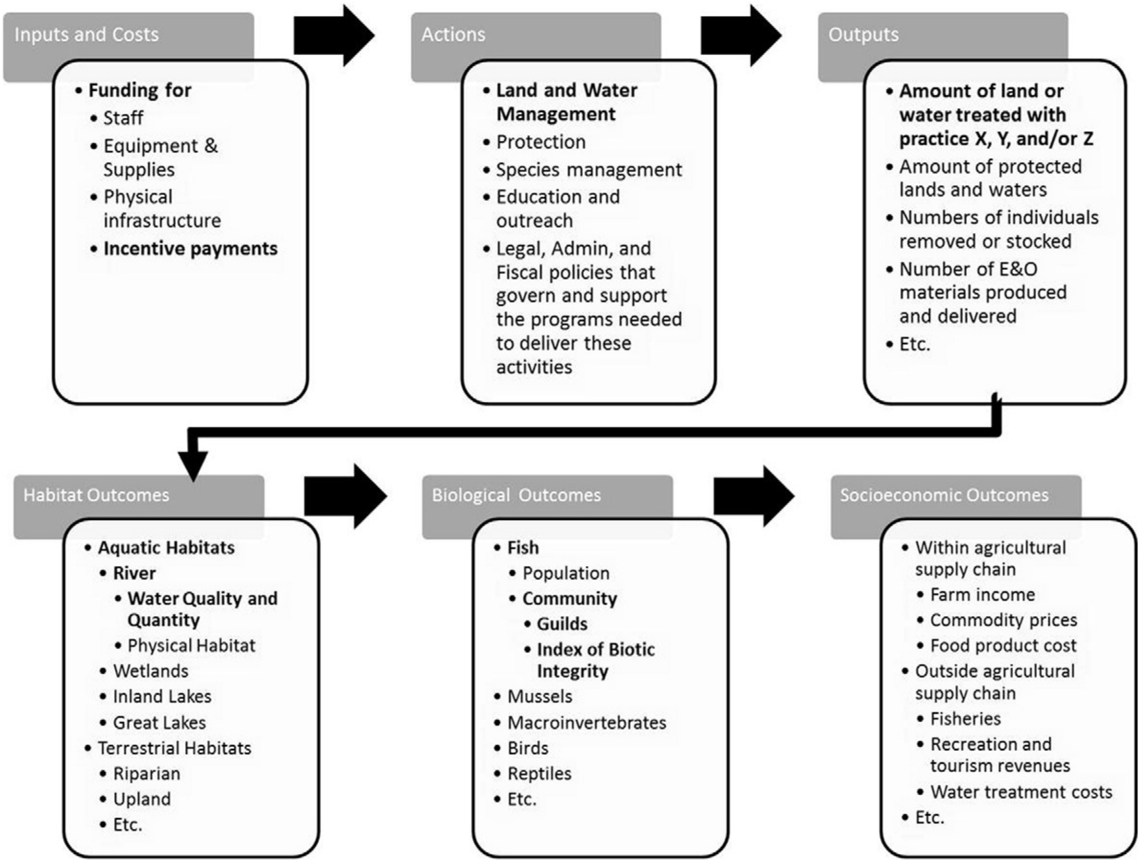

Fig. 1. Example of performance metrics that can used be used to establish related sets of short and long-term goals and track progress under an adaptive management approach. Variables in bold denote those addressed in this project.

Nutrient pollution and sedimentation, in particular, are consistently considered two of the primary stressors responsible for stream impairment designations and associated impacts to biological assemblages (Waters, 1995; USEPA, 2000, 2004). Significant public and private investments have been made to implement agricultural conservation practices that reduce these non-point source impacts to surface waters. For example, conservation provisions within the 2008 and 2014 US Farm Bills, which provide cost share dollars to help offset the cost to farmers for implementing conservation practices, averaged approximately $5 billion per year (CRS, 2014). At face value these are substantial investments into on-the-ground conservation actions, but are those investments and actions enough?

Thanks to increasing availability of geospatial data and recent advancements in computer processing and watershed modeling we can more easily and accurately model relations between agricultural conservation practices and ecological endpoints (Borah and Bera, 2003; Gassman et al., 2007). This has led to a growth in studies estimating the potential costs and benefits of agricultural management scenarios (Smith et al., 2009; Giri and Nejadhashemi, 2014; Herman et al., 2015). The resulting information is extremely valuable to planning efforts and answering "how much conservation is enough?" Yet, as the reviews by Borah and Bera (2004) and Gassman et al. (2007) demonstrate virtually all of these studies focus on estimating changes in hydrology and water quality of surface waters, not biological endpoints (however, see Einheuser et al., 2012; Keitzer et al., 2016; and Fore et al., in press). Without explicitly extending these assessments to biological endpoints it becomes much more difficult to interpret the potential benefits of these management scenarios to freshwater biodiversity. This is further supported by other recent reviews that conclude our understanding of the benefits of agricultural conservation practices to aquatic communities is poorly understood and much more research is needed (Comer et al., 2007; Knight and Boyer, 2007). The overall goal of our project was to help address these key knowledge gaps and provide information to help answer the question of "how much conservation is enough?" for addressing agricultural nonpoint source impacts to stream fish communities across agriculturally dominated regions of the Great Lakes. Our primary objective was to assess the costs of agricultural management scenarios against potential benefits to instream water quality and fish communities in four watersheds of the Saginaw Bay drainage.

Consideration of spatial extent and grain are fundamental to all ecological investigations (Wiens, 1989; Levin, 1992; Poff, 1997; Fausch et al., 2002). Each play a role in determining the results of analyses, perceived limiting factors and ecosystem drivers, and answers to applied questions. Of particular interest to our study is how changes in spatial grain (e.g., large watersheds vs. subbasins comprising those watersheds) might affect the answer to "how much conservation is enough?" Most studies have assessed the ability of management scenarios to achieve water quality conditions at relatively coarse spatial grains such as the watersheds of large rivers or receiving waters like the Chesapeake Bay, Gulf of Mexico or Great Lakes (Secchi et al., 2007; Rabotyagov et al., 2010; Shenk and Linker, 2013). For instance, Bosch et al. (2013) estimated sediment and nutrient yield reductions under different management scenarios for the outlets of six major watersheds that drain into Lake Erie. These studies provide estimates of the conservation actions and associated costs needed to meet water quality goals for these receiving waters or at *the outlets* of these large watersheds. However, they do not provide corresponding finer-grained assessments (e.g., subbasins or individual stream reaches) of what those management scenarios would mean for water quality or biological conditions throughout the entire upstream network.

Watershed physiography and stream size both have a profound influence on stream habitat, biological assemblages, and responses to