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Reducing current and future risks: Using climate change scenarios to test an agricultural conservation framework

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ABSTRACT

Evaluating the potential effects of changes in climate on conservation practices can help inform strategies to protect freshwater biodiversity that are robust, even as conditions change. Here we apply a climate change "test" to a framework for estimating the amount of agricultural conservation practices needed to achieve desired fish conservation outcomes for four watersheds in the Saginaw Bay region of Michigan, USA. We developed three climate scenarios from global climate model outputs (high emissions scenario, "2080s" timeframe) to provide insight on potential impacts of a climate driver that represents a key uncertainty for this management system, the amount and timing of spring and summer precipitation. These scenarios were used as inputs to agricultural watershed models, which produced water quality outputs that we compared to thresholds in fish biodiversity metrics at the subwatershed scale. Our results suggest that impacts of climate change on evaporation rates and other aspects of hydrology will shift the relative importance of key stressors for fish (i.e., sediment loadings vs. nutrient concentrations) across these different watersheds, highlighting the need to design resilient implementation plans and policies. Overall, we found that changes in climate are likely to increase the need for agricultural conservation practices, but that increasing the implementation rate above current levels will likely remain a good investment under current and future climate conditions.

Introduction

Achieving water quality and stream health standards in agricultural landscapes remains a persistent challenge, despite substantial research and investment in agricultural conservation practices (Sowa et al., 2016; Tomer et al., 2014). In watersheds across the US Great Lakes region, a variety of stakeholders are developing and testing innovative solutions to increase the effectiveness of conservation investments, including new or improved practices, multi-scale targeting, and new financial mechanisms (e.g., Bosch et al., 2013; Douglas-Mankin et al., 2013; Kalcic et al., 2015a, 2015b; Legge et al., 2013; Tomer et al., 2013). While these innovations represent important advances, there is increasing evidence that the performance of many agricultural conservation practices can be influenced by climatic factors (Delgado et al., 2013, Garbrecht et al., 2014; Hatfield et al., 2013). As a result, it is quite likely that current site- and regional-scale solutions for addressing agricultural nonpoint source pollution will need to be updated over time to account for the effects of climate change. We suggest that framing the risks that changes in climate drivers pose to these innovative solutions is an essential component of crafting approaches that will help us achieve and sustain desired conservation outcomes.

The Nature Conservancy (TNC) and many partners are working to achieve strategic agricultural conservation across the Saginaw Bay basin in Michigan, USA, a body of work described in Fales et al. (2016). These collaborative efforts focus on developing and testing different methods to more effectively and efficiently implement conservation practices, including establishment of outcome-based performance goals, targeting practices, reducing administrative burdens, and tracking and assessment of progress. Much of this work was made possible by analyses and models described in Sowa et al. (2016), which established spatially-explicit relations between conservation practices, water quality, and fish community health in four watersheds. Here we use a series of models, such as the Soil and Water Assessment Tool (SWAT; Arnold et al., 1998, 2012), and statistical analyses to develop dose-response relationships between the percent of agricultural land that is managed by a suite of conservation practices (the "dose") that is intended to address water quality variables limiting the fish

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community, which, results in improved fish health (the "response"; Sowa et al., 2016). These relationships can be used to ask "how much conservation is enough" to achieve fish community health goals for specific watersheds or subbasins, which can inform the establishment of short and long-term implementation goals (Fales et al., 2016).

There is broad agreement in the conservation community that conservation approaches such as the ones described in Fales et al. (2016) will be more successful if practitioners implement an adaptive management approach (The Conservation Measures Partnership, 2013) that enhances learning from the management experience. While adaptive management can help practitioners update approaches as climate change occurs, the magnitude of potential climate risks and time required to modify established management systems and policies require a need to anticipate, rather than just react to, ongoing changes (Bierbaum et al., 2013). Building on previous climate change vulnerability and adaptation frameworks (e.g., Cross et al., 2012; Glick et al., 2011; Stein et al., 2014) and assessments (e.g., Bierbaum et al., 2013; Pacifici et al., 2015; McDowell et al., 2016), we anticipated that directly exploring potential impacts of climate change on climate-sensitive elements of conservation strategies would be the most effective way to appreciate climatic risks to conservation outcomes. Further, we suggest that the process of assessing the "vulnerability" of a conservation approach can help us identify components or tools that imply the false assumption that the climate drivers of the systems will remain "stationary" (i.e., will vary within the same distribution over time; Milly et al., 2008), potentially contributing to inappropriate conservation decisions.

Here we evaluate how several exploratory climate change scenarios influence the relationships between conservation practices, water quality and fish community health established in Sowa et al. (2016). The objectives of our project were to assess if 1) under these climate change scenarios, the amount of conservation practices needed to achieve fish community health would change and 2) the underlying framework of this approach (e.g., models and conservation practices used) was likely to be sensitive to changes in climate drivers. Collectively addressing these objectives provides insight into how we might need to modify the scientific framework of Sowa et al. (2016) and the conservation strategies that build upon it (Fales et al., 2016) to be better prepared to meet conservation goals as climate conditions change.

Methods

Study area

As described in detail in Sowa et al. (2016), we evaluated variations in modeled conservation outcomes as a function of changes in conservation investments within four watersheds of the Saginaw Bay drainage to Lake Huron (eastern Michigan, USA; Fig. 1). Agriculture is a dominant land use across the Saginaw Bay region, but there is substantial heterogeneity in its intensity (Fig. 1). The four focal watersheds represent a gradient, ranging from 8% agricultural land use in the Rifle River watershed, to 41–42% percent in the Cass and Shiawassee, respectively, and 68% in the Pigeon-Pinnebog. While impacts on water quality are detectable in each watershed, especially those with more land in agriculture, all continue to provide important habitats for aquatic biodiversity, and all have been identified as high priority watersheds for conservation (TNC, 2001).

Projected climate change impacts

Within the Great Lakes region, we expect to see continued increases in temperature, leading to multiple impacts due to increases in the length of the growing season, evapotranspiration rates, stream temperatures, and drought risk (Mishra et al., 2010; Pryor et al., 2013, 2014). While there is strong agreement across Global Circulation Model

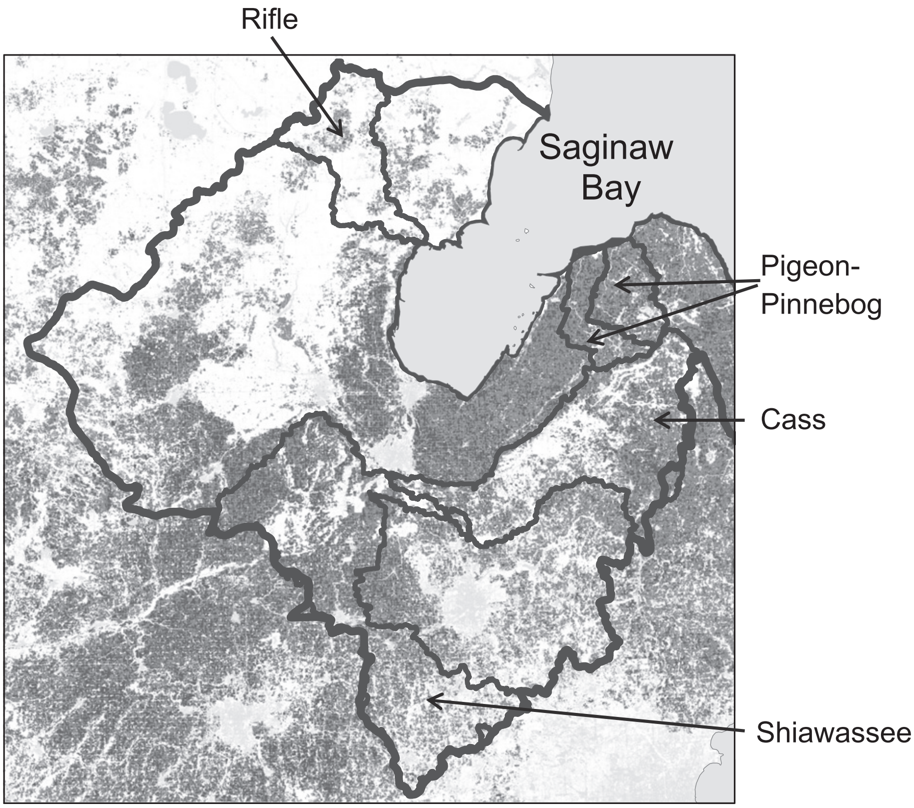

Fig. 1. Map showing the Saginaw Bay basin (Michigan, USA) outline, and indicating locations of the four focal watersheds (Rifle, Shiawassee, Cass, and Pigeon-Pinnebog) where conservation and climate scenarios were evaluated. Dark gray shading indicates landcover that is dominated by agriculture, while light gray indicates urban areas, and white represents natural land cover.