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Using models of farmer behavior to inform eutrophication policy in the Great Lakes

Robyn S. Wilson [a,*], Derek A. Schlea [b], Chelsie M.W. Boles [b], Todd M. Redder [b]

[a] 210Kottman Hall, 2021 Coffey Road, The Ohio State University, Columbus, OH 43210, USA
[b] LimnoTech, 501 Avis Drive, Ann Arbor, MI 48108, USA

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ABSTRACT

To address the management of eutrophication in aquatic systems, the behavioral mechanisms that drive change at the individual level must be considered when designing policy interventions. This analysis identifies the beliefs that are critical to behavioral change, and explores the likelihood that farmers will adopt two management practices believed to be critical to reducing nutrient loading to recommended levels in Lake Erie. We find that there is potential for farmers to adopt key infield practices needed to reduce nutrient inputs. And further, that increased adoption of such practices is possible by increasing the perceived efficacy of the majority of farmers who are motivated to take action. Integrating these findings with physical models of nutrient movement indicates that adoption of these practices in combination with edge of field practices can attain phosphorus reduction targets for the lake. Future research should focus on measuring the effectiveness of education and outreach programs aimed at engaging farmers and promoting adoption of recommended practices. Such programs may only be effective if they are successfully building farmer confidence in their ability to implement the practices (i.e., perceived self efficacy) and increasing farmer's belief in the effectiveness of the practices at reducing nutrient loss and improving local water quality (i.e., perceived response efficacy).

1. Introduction

Eutrophication of aquatic systems is a significant challenge across the globe (Brooks et al., 2016; Johnk et al., 2008; Brookes and Carey, 2011). From Lake Erie to the Gulf of Mexico to the Baltic Sea, aquatic systems, and the people who rely on them, have suffered from excessive nutrient loading. Nutrient loading in marine systems is caused primarily by nitrogen, and leads to hypoxia. Eutrophication in freshwater systems is caused primarily by phosphorus, and leads to harmful algal blooms that restrict recreational opportunities, change the taste and odor of local water supplies, and pose a public health threat through an increase in toxic microcystin (Bejankiwar et al., 2013).

Managing eutrophication will require significant changes in farmer behavior as eutrophication is often driven by non-point source pollution from agricultural lands (i.e., phosphorus and nitrogen from fertilizer applications). Key to addressing this challenge is knowing 1) what behaviors or management practices need to change, 2) the probability of those changes occurring in response to different policy interventions, and 3) the impact of such changes on the downstream ecological system. This requires an integrated modeling approach that collectively addresses potential changes in farmer behavior and resulting changes in nutrient inputs into tributaries and the lakes as a result of changing land management decisions.

Recent studies in the Great Lakes have provided insight into the practices that need to be implemented to help meet the 40% reduction targets set for lakes like Lake Erie, and thus provide insight into the farmer behaviors that need to change (Keitzer et al., 2016; Natural Resoures Conservation Service, 2016; Scavia et al., 2017). However, these studies have not addressed the likelihood that a sufficient number of farmers will change their behavior to achieve the desired levels of implementation suggested by these watershed and lake ecosystem models. There are many factors that can affect a farmer's decision to adopt recommended management practices. Generally speaking, behavioral theories that aim to explain why one might change their behavior in response to a potential threat suggest that the individual must first perceive a threat (i.e., high perceived risk or personal concern), and that they

* Corresponding author.
E-mail address: Wilson.1376@osu.edu (R.S. Wilson).

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must then believe there are effective actions available to reduce the risk (i.e., high perceived efficacy) (Floyd et al., 2000; Armitage and Conner, 2001). Prior evidence from the western Lake Erie basin suggests that farmers are highly motivated to reduce nutrient loss on their farm (Wilson et al., 2014; Prokup et al., 2017). This motivation stems from concern about a variety of perceived threats or problems, including the impact of nutrient loss on water quality, as well as the economic costs of nutrient loss to the farm and concern about future regulation (Prokup et al., 2017). According to behavioral theories, these concerned and motivated farmers must then evaluate the suite of actions available to them, in order to identify what practices they can successfully implement on their farm to reduce nutrient loss. Prior evidence from western Lake Erie also suggests that farmers' perception of their ability to successfully implement recommended practices (i.e., perceived self efficacy or confidence), and their perception of how successful each practice will be at mitigating the risks (i.e., perceived response efficacy or perceived effectiveness of the behavior), is highly variable and particularly low for those who have not yet adopted the recommended practices (Prokup et al., 2017; Zhang et al., 2016; Burnett et al. 2018).

These prior findings suggest that farmers do not lack the motivation to act, rather they lack the appropriate levels of perceived efficacy to take action. Specifically, they may lack the confidence in their ability to use recommended practices on their farm (i.e., self efficacy), and/or the ability of such practices to effectively solve the identified problem (i.e., response efficacy). We might expect that only farmers with high levels of perceived efficacy are using the recommended practices. According to previous research (see Markowitz, 2013 for a review), these individuals are likely those with positive past experience with the practice, who have the resources to innovate (i.e., more education, older, a tolerance for risk), who are not limited by external factors (i.e., low farm income), and who likely have higher levels of specific knowledge about the recommended behavior.

Herein we assess the probability of farmers in the western Lake Erie basin adopting two in-field practices that have been identified as important to reducing nutrient inputs into the lake (Scavia et al., 2017). Specifically, we identify what factors influence the likelihood of adopting these two practices (focusing on concern and perceived efficacy), and the degree to which phosphorus loading would decrease given increased levels of adoption in response to these factors. We pose the following overarching research questions: What is the likelihood that farmers in the western Lake Erie basin will adopt cover crops and subsurface application of fertilizer? What set of beliefs are most likely to influence the likelihood of adoption? And to what extent would changing these beliefs actually increase adoption and reduce nutrient loading to recommended levels? Our results provide insight into the likely impact of targeted outreach and education on phosphorus loading in the downstream system by examining the extent to which changing critical beliefs may increase adoption of recommended practices and improve water quality.

2. Materials and methods

2.1. Study context

The location of this study was the western Lake Erie Basin (WLEB) watersheds (see Fig. 1). This includes a total of 10 HUC-8 watershed boundaries spanning much of northwestern Ohio and extending into southern Michigan and eastern Indiana. Lake Erie is the most biologically and economically productive of the Great Lakes; however, this productivity is increasingly threatened by Harmful Algal Blooms (HABs) (Ohio Lake Erie Phosphorus Task Force, 2013). While phosphorus can enter the lake through a variety of sources and take multiple forms, the primary source is dissolved reactive or soluble phosphorus from non-point sources entering the lake through the Maumee River (Ohio Lake Erie Phosphorus Task Force, 2013). In the western basin, nonpoint sources from the agroecosystem are estimated to contribute over 80% of the annual total phosphorus load driving harmful algal blooms (Ohio Lake Erie Phosphorus Task Force, 2013).

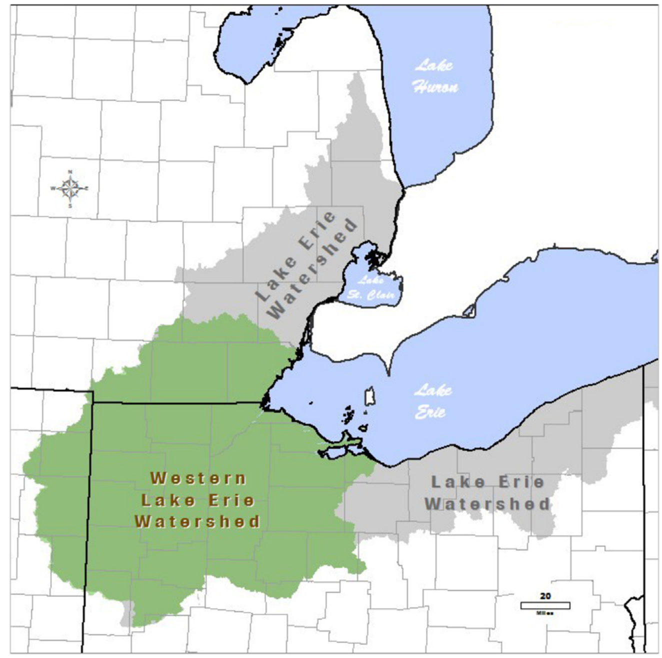

Fig. 1. Map of the study area in green (Source: The Fertilizer Institute at 4rcertified.org).

In many ways, the current issues with HABs in Lake Erie are a climate adaptation problem, or a function of current agricultural management practices not being sufficient given changes in the physical climate system (Bosch et al., 2014; Michalak, 2013). Current nutrient application and retention practices may need to improve or increase given the increased frequency of spring storm events, and warmer lake temperatures in the summer (Ohio Lake Erie Phosphorus Task Force, 2013). The Great Lakes Water Quality Agreement (GLWQA) Nutrients Annex Subcommittee recommends a 40% phosphorus load reduction in the Maumee river (from 2008 values) to reduce the frequency and severity of HABs (Annex 4 Objectives and Targets Task Team, 2015). Furthermore, recent physical models of the watershed indicate that such a reduction is possible with the increased adoption of particular practices across the watershed (e.g., in-field practices like cover crops and subsurface placement, as well as edge-of-field practices like filter strips) (Scavia et al., 2017). In our analysis, we were particularly interested in examining likely farmer adoption of cover crops and subsurface placement. In contrast to filter strips, it is possible that cover crops and subsurface placement provide enough on-farm benefits to justify their adoption without targeted financial investments from the government or other entities to off-set short-term costs. In other words, there is the potential to motivate a voluntary change in behavior by relying solely on cognitive tools or interventions for practices that do not negatively impact farm yields and revenue.

2.2. Survey methods

We conducted a representative mail survey of farm households