Journal of Great Lakes Research 40 (2014) 574–577

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Commentary

Research to help Lake Erie: Proceedings of the "Phosphorus along the Land–River–Lake Continuum" research planning and coordination workshop

Laura T. Johnson*, David B. Baker, Remegio B. Confesor Jr., Kenneth A. Krieger, R. Peter Richards

National Center for Water Quality Research, Heidelberg University, 310 East Market Street, Tiffin, OH 44883, USA

ARTICLE INFO

Available online 15 August 2014

Keywords:
Lake Erie
Phosphorus
Nonpoint source pollution
Runoff
Eutrophication
Agriculture

Research on re-eutrophication of Lake Erie

Lake Erie has entered a new era of cultural eutrophication following a period of partial recovery in the mid-1990s from past nutrient enrichment. The decline in eutrophication from ~1970 to 1990 and the increase from ~1995 to the present are well documented via phytoplankton biomass (Kane et al., 2014-in this issue), *Microcystis* biovolume (Bridgeman et al., 2013), satellite imagery (Stumpf et al., 2012), and central basin hypoxia (Scavia et al., 2014). Coinciding with these changes in eutrophication, dissolved reactive phosphorus (DRP; i.e., soluble reactive phosphorus or SRP) loads and flow-weighted mean concentrations in the primarily agricultural Lake Erie tributaries, namely the Maumee and Sandusky rivers, decreased from 1975 to 1995 and have been increasing since 1995 (Joosse and Baker, 2011; Baker et al.,2014-in this issue). Similar decreases occurred in an urban tributary, the Cuyahoga River, from 1982 to 1990, yet DRP has remained consistently low since that time (Baker et al., 2014-in this issue). Recent models developed for the western basin of Lake Erie have indicated that spring loading (March–June) from the Maumee River has the largest influence on HAB intensity and area (Stumpf et al., 2012). In order to encourage improvement in Lake Erie health, multiple target P loads have been proposed. The Ohio Phosphorus Task Force II final report recommends a ~40% reduction in annual total P (TP) loads as well as spring TP and DRP loads from the Maumee River and other western basin tributaries, in order to significantly reduce HABs in the Western Basin (http://www.epa.ohio.gov/dsw/lakeerie/index.aspx.). In order to reduce central basin hypoxia to an area of 2000 km^2 lasting no more than 10 days per year, Scavia et al. (2014) recommend a 46% reduction in TP loads and a 78% reduction in DRP loads to the western and central basins of Lake Erie. Thus, the big question is how to best reach these targets and/or are there other factors to address to help improve Lake Erie.

Because of the resurgence in Lake Erie HABs and hypoxia, research on P has been stimulated. The series of ten papers in this issue reflect some of the coordinated research efforts to link phosphorus dynamics from watersheds, through rivers, and into the lake (Pennuto et al., 2014-in this issue). It is clear from these papers that more research is warranted. As a follow-up to those activities, a workshop supported through the Great Lakes Protection Fund was held to help coordinate research along the watershed-to-lake continuum and to identify potential research gaps. The primary goal of the "Phosphorus along the Land–River–Lake Continuum" workshop was to discuss major research questions along the continuum from land to river to lake and to thus facilitate research collaboration throughout the watershed. Prior to the workshop, a research survey was sent to 127 researchers and returned by 54. The survey asked two broad questions — (1) what research are you currently conducting, and (2) what are the most important research questions regarding P dynamics in the Lake Erie watershed (electronic supplementary material (ESM) Table S1). By combining the survey results with the workshop discussions, we were able to identify current research needs and gaps in our understanding of P in the Lake Erie watershed. The workshop brought together a diverse group of researchers (ESM Tables S2 and S3) to help meet these goals. The outcomes of the discussions are summarized below and detailed in ESM Table S4.

Research needs

Lake

The impetus for this workshop and the primary reason for developing target P loads is the ongoing eutrophication in Lake Erie. In part, the consensus was that P is the root cause of both HABs and hypoxia, so the problem has been identified. Further research serves to help understand details of the dynamics of blooms and hypoxia, which could shape management recommendations, but the main management need is a reduction in P entering the lake. Other research topics that could have the largest influence on the understanding of eutrophication in Lake Erie include: (1) quantification of internal P loading from lake

* Corresponding author. Tel.: +1 419 448 2056.
E-mail address: ljohnso1@heidelberg.edu (L.T. Johnson).

http://dx.doi.org/10.1016/j.jglr.2014.07.001

sediments and its interaction with dreissenid mussels, (2) the effect of timing and seasonality of external loading, (3) the effect of nitrogen on bloom formation especially in determining the prevalence of toxic vs non-toxic strains of cyanobacteria, (4) the role of winter ice cover and diatom blooms, and (5) the impact of the microbial food web on enhancing bloom formation or toxicity. A final topic addressed was the development of P targets for the lake. A current need is to better understand if one P target will achieve all goals for the lake, or if instead by reaching a low P target there may be unintended consequences (e.g., reduced fisheries production). More pressing, however, is to develop strategies to detect when a target is reached in the face of climate change and inherent variability in weather. Because the lake seems to respond to variations in annual and seasonal P loading, improved understanding of those linkages can lend more certainty to the development and refinement of target loads.

Wetland

One of the main points regarding wetlands brought up throughout the workshop was why wetland research was receiving so little attention. In part this could be a result of few wetland scientists present at the workshop, but wetlands also appear to be overlooked in most discussions on Lake Erie. Most likely, wetlands are overlooked because they have been extensively lost through conversion to cropland and diking along the coast (Herdendorf, 1992). Thus, the potential reduction of P loading to the lake via wetland retention is assumed to be low because of the small amount of wetland coverage in the basin. Wetlands may have a great potential for nutrient retention and transformation, though they have been studied more as processors of N than of P. Consequently, a major research need is a better understanding of P uptake capacity and saturation of wetlands and subsequent changes with biota, residence time, seasonality, and climate change. Given the loss of wetlands in the watershed, there is a large need for research on the effectiveness of wetland restoration and construction, as well as on the value of wetlands to various aspects of society. There appears to be a wealth of publications on some of these topics; thus a meta-analysis or review of existing research as it could be applied to Lake Erie is warranted.

River

The river, defined here as any lotic ecosystem, serves in part as the intermediary between the land and the lake. Water quality patterns in the river reflect inputs from the land, yet also dictate what is delivered to the lake. For this workshop, discussion centered on the river independent of these other ecosystems, and considered the river ecosystem as more than simply a conduit from land to lake. One obvious research question that follows is what effect riverine processing has on nutrients, particularly during high-flow conditions, when the model of a river as a pipe may be appropriate. Other needed research includes quantifying the different sources of nutrients (point vs. non-point, agriculture vs. urban), understanding the effect of nutrients on stream ecosystem function and health, and the potential for stream nutrient retention. Similar to wetlands, many streams and rivers are disconnected from their floodplains and have diminished riparian zones; thus there is a need to better understand the role of these areas in nutrient retention. Finally, as climate change predictions project more intense storms and prolonged drought for this region, it will be important to quantify the impact of climate change on flow and ecosystem functions of rivers.

Land

Most of the questions regarding P dynamics in the Lake Erie watershed were generated from the need to understand the influence of agricultural land use practices on P runoff. From an abundance of detailed questions, some general themes emerged. First, there appears to be a need to better understand and assess the risk of P runoff that incorporates (1) dissolved P as well as total P, (2) management practices (including BMPs), (3) stratification of P on the soil surface, and (4) the interaction between hydrology and fertilizer application methods. Similarly, there needs to be a rating scheme for BMPs specific to dissolved P runoff that incorporates the ease or likelihood of adoption, such as a flowchart for what BMPs would be most effective at reducing dissolved P runoff under given soil types, management plans, and proximity to a water source. Another theme that emerged was a need for more information regarding how to target areas of the watershed for BMP adoption and a better understanding of whether dissolved P runoff is a widespread issue from many farms or an acute problem from a few farms. Also, a major concern is how to increase BMP implementation when much of the agricultural land is rented.

More specific research needs identified include (1) understanding the interactions of P with other soil nutrients (macro and micro) and organic matter, (2) documentation of past land use changes to help understand the long term patterns in riverine dissolved P loading, and (3) quantification of tile drain and macropore P losses. Finally, some questions were raised regarding the current ways of assessing the need for fertilizer application. Are the recommended rates correct? Are there other soil tests that may better estimate plant available P? Is there a feasible compromise between having P available for crops in the soil and low P runoff? Overall, the entire Lake Erie community may need to manage expectations as the reduction in P runoff is such a low proportion of applied P; there are some questions as to whether target loads set in the lake can actually be met.

Across the continuum

Although most research easily fits within habitats (lake, wetland, river, land), some research inherently spans the continuum. These needs include gaps in our environmental framework such as a better understanding of how P interacts with other nutrients from land to lake. In addition, we need to better understand and define legacy P inputs along the continuum and compare with the analogous principle of internal P loads in aquatic ecosystems. For instance, what time frame defines a source of legacy P? Although legacy P is more difficult to manage, many BMPs are developed to control and trap P runoff, in addition to the BMPs aimed to prevent P runoff. Yet, legacy P or internal P loading from aquatic systems may make reductions needed in field runoff to reach target P loads more difficult to attain. Understanding legacy P or internal P within the lake will be essential to gaging a timeframe for recovery.

Although representation of agricultural socioeconomists was low at the workshop, a better understanding and communication of socioeconomics was a major factor identified as a research need. Researchers in the watershed need to understand how to achieve effective implementation of BMPs for DRP runoff, that is, how to convince a majority of growers in the region to adopt BMPs. Furthermore, there is an economic need to determine the losses associated with eutrophication in Lake Erie balanced with the cost of adopting different BMPs. It was further acknowledged that scientists tend to give mixed messages regarding suggestions to the farming community, so a question raised was "how much do we need to know to make clear and forceful suggestions?" Though this question was specifically raised regarding dynamics in the lake related to action on the land, this is a valid question regarding the adoption of BMPs. One aspect that became clear was that researchers along the continuum, particularly those modeling the land or the lake, need to have better communication and access to growers to fully understand the common practices as well as the logistics of farming when it comes to recommending adoptable BMPs.

The use of models to link from land to watershed to lake is a powerful technique to address questions along the continuum. We identified a number of gaps in these models that require empirical measurements