Cooperative Science and Monitoring Initiative: Lake Erie 2014

Assessment of Nutrient/Eutrophication Dynamics in Western Lake Erie

Executive Summary

August 2016

lakeerie.ohio.gov/GLRI/CSMI.aspx

Questions

In recent years, nutrient loading to the western basin of Lake Erie has been recognized as a pivotal component in the re-occurrence of harmful and nuisance algal blooms (HABs) throughout the lake and hypoxia in the Central Basin. Through a combination of in situ experiments, laboratory studies, and modeling, our project sought to improve the current understanding of the roles of external and internal nutrient loading, especially as influenced by weather forcing events. A useful framework is to consider the research aimed at answering the following questions:

1. What is the contribution of lake sediments to phosphorus (P) loading relative to tributary loads in western Lake Erie?

2. If recommended reductions in tributary P loading are achieved, will legacy P in lake sediments cause a significant delay in achieving reduced harmful algal blooms?

3. How may future climate change scenarios affect tributary and lake sediment phosphorus loads?

4. How might decreasing external P loading from various sources be expected to affect algal blooms in the western basin?

Participants

The following group of researchers was assembled to provide expertise in lake sediment sampling and experimentation, watershed monitoring and modeling, and lake ecosystem simulation modeling. Administrative guidance and organizational support were provided by the Ohio Lake Erie Commission (OLEC).

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Rem Confesor (NCWQR*)
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Jeff Reutter (Ohio Sea Grant)
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Several other investigators, post-docs, graduate students, undergraduates and staff technicians participated.

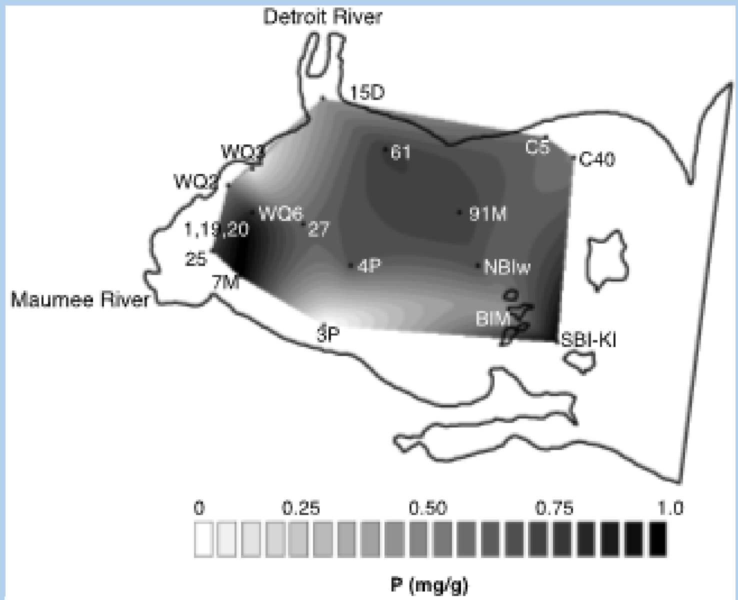


Figure 1: Sample sites in western Lake Erie

Answers

1. What is the contribution of lake sediments to phosphorus (P) loading relative to tributary loads in western Lake Erie?

Answering this question required updated measurements of phosphorus release per unit area per time (P flux) at a variety of locations and sediment types in western Lake Erie (Figure 1). Since P flux measurements may depend on the method used, several different methods were employed including SCUBA diver-placed bottom chambers, sediment core incubations, and P-electrode profiles. All of the methods yielded comparable measurements, which were in agreement with P flux values used in models. Details are available in a recently published scientific paper:

Matisoff G., Steely, R., Kaltenberg, E., Seo, J. Hummel, S., Gibbons, K. Bridgeman, T.B., Seo, Y., Behbahani, M., James, W., Doan, P. Dittrich, M., Evans, M., Chaffin, J., 2016. **Internal Loading of Phosphorus in Western Lake Erie**. Journal of Great Lakes Research. In press, available online, doi:10.1016/j.jglr.2016.04.004.

The Bottom Line

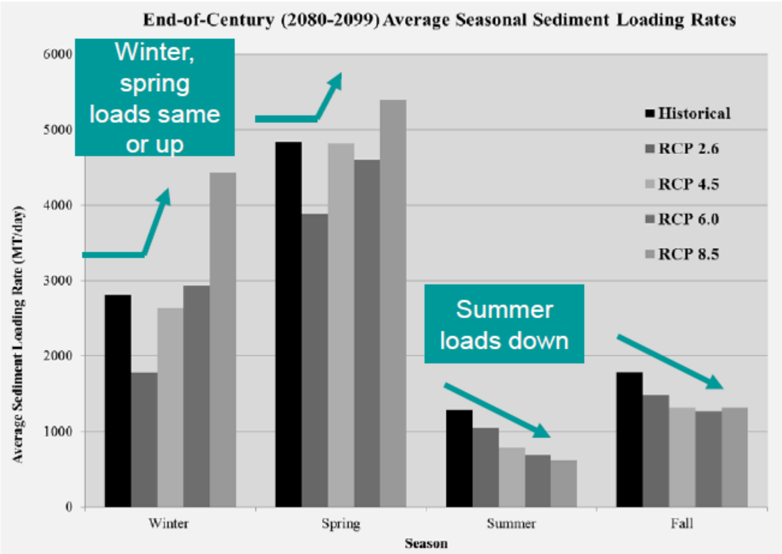
Under normal summer conditions, western Lake Erie sediments contribute on average 1.4 mg P/m^2/day. The P flux rate calculated in this study translates to a mean annual loading that is only 3 - 7% of target (40% reduction) tributary load.

2. If recommended reductions in tributary P loading are achieved, will legacy P in lake sediments cause a significant delay in achieving reduced harmful algal blooms?

The relatively small calculated contribution of sediments to P loading is in agreement with HAB observations. The spring tributary loading and 2011 HAB were the largest to date. However when tributary loads decreased dramatically in 2012 due to a spring drought, the resulting 2012 HAB was small. This 'natural experiment' suggests very little carryover effect from sediments from one year to the next.

The Bottom Line

Lake sediments are normally not a large factor in P loading or the resulting harmful algal blooms. Therefore the impact of external P load reductions will not be substantially delayed by internal loading (recycling) of phosphorus.



3. How may future climate change scenarios affect tributary and lake sediment phosphorus loads? (Part 1)

This question was addressed in two parts. In the first part, we used SWAT models for the Maumee watershed, coupled with several future climate change scenarios. Because P loading is highly correlated with discharge from the Maumee River, the SWAT model loading outcomes were largely influenced by seasonal and overall changes in precipitation and evapotranspiration that caused changes in river discharge.

In all climate change scenarios, summers were drier and therefore summer P loads decreased (Figure 2). Under mild to moderate climate change scenarios (RCP 2.6-6.0), winter and spring river discharge (and P loads) decreased. However, in the severe warming scenario (RCP 8.5), spring and winter discharge increased dramatically. For more details, see the recent scientific publication:

Cousino, L.K., Becker, R.H., and Zmijewski, K.A. 2015. **Modeling the effects of climate change on water, sediment, and nutrient yields from the Maumee River watershed.** Journal of Hydrology: Regional Studies pp 762–775.

The Bottom Line

It depends. Mild to moderate climate change will not increase phosphorus loading from the Maumee River watershed. Severe climate change, however, will increase river discharge and P loads during the late winter and spring - the critical loading period for the development of summer HABs.

Figure 2 (left): Seasonal loading changes under four climate change scenarios ranging from mild to severe, compared to recent historical loads.

3. How may future climate change scenarios affect tributary and lake sediment phosphorus loads? (Part 2)

In part 2, we incubated sediments under in-lake climate change scenarios (warmer water and less oxygen near the bottom). In these experiments, sediments without oxygen (anoxic) released more dissolved reactive phosphorus (DRP) than sediments with oxygen, and warmer anoxic sediments released much more DRP than cooler anoxic sediments.

In a future summer where western Lake Erie approaches 30 °C, a 3-day basin-wide anoxic event could release more DRP from the sediments than the Maumee River contributes during 3 springtime months, on average. A 4-day anoxic event at elevated temperatures could release as much DRP from the sediments as the record-breaking spring Maumee River load of 2011 (Figure 3).

Basin-wide anoxic sediment events have been documented in the past, and under climate-change scenarios, Lake Erie summer water temperatures of 30 °C are possible in the future. Future warmer waters may make temporary anoxic conditions more likely.

The Bottom Line

In certain future climate change scenarios, western Lake Erie sediments could release pulses of DRP that rival the DRP loads of the Maumee River.

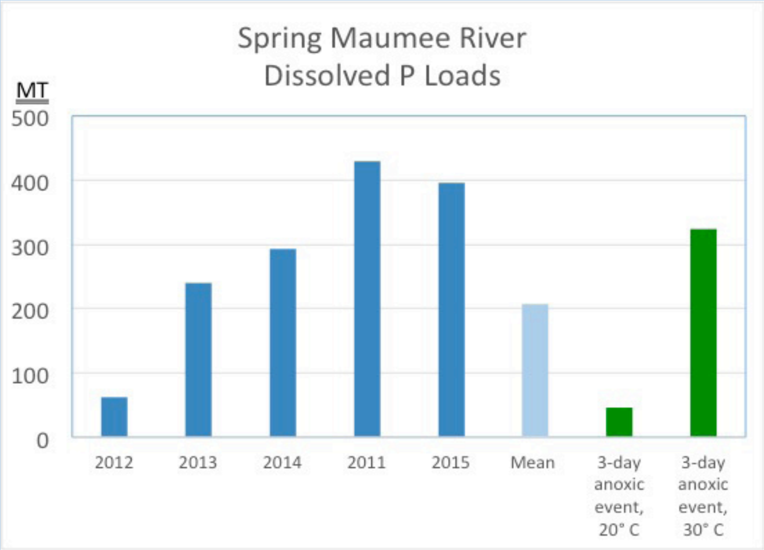


Figure 3: Internal loading of dissolved P from lake sediments (green bars) compared to recent Maumee River DRP loads (blue bars).

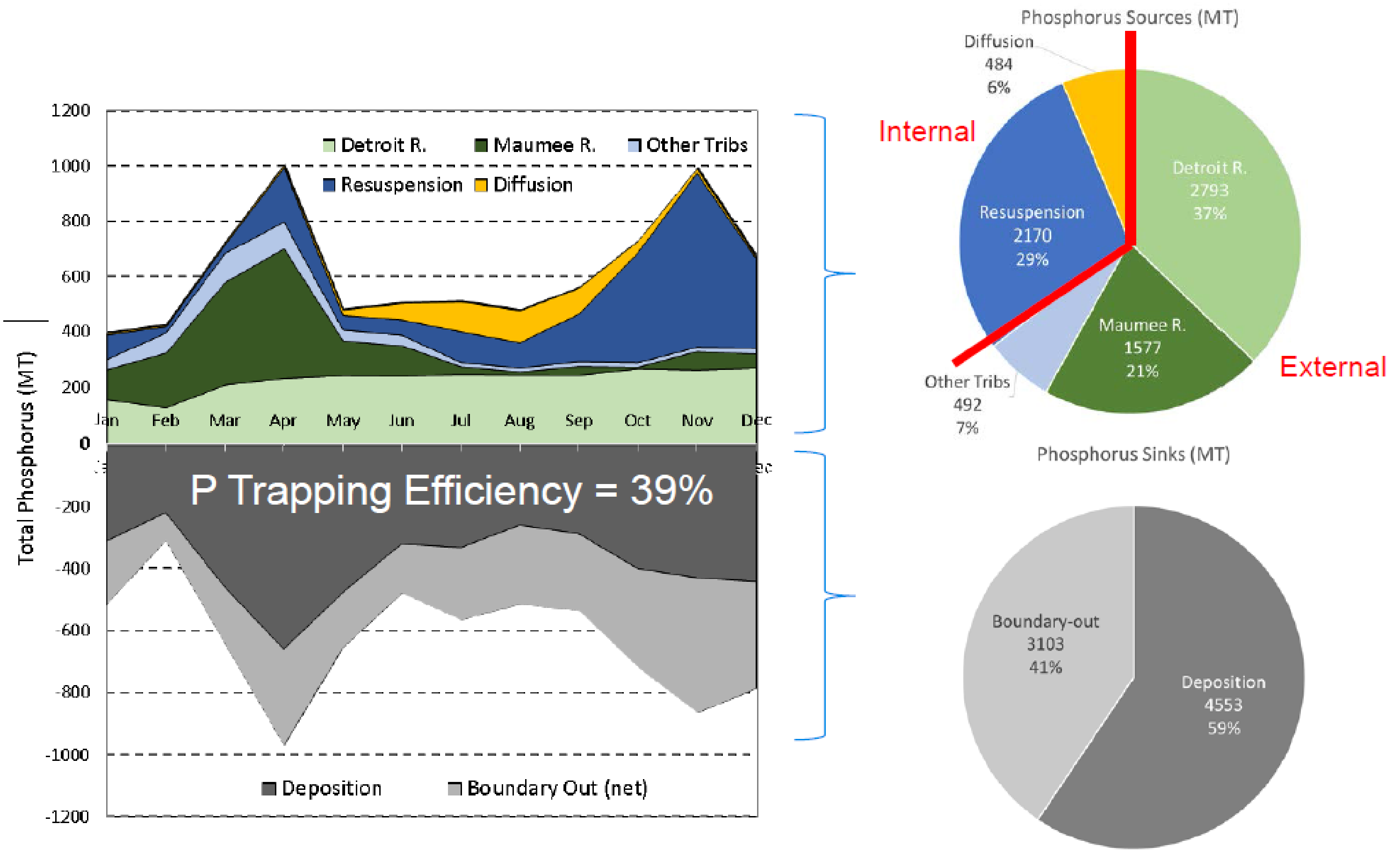


Figure 4: Total phosphorus sources and sinks in western Lake Erie in 2014 modeled by the Western Lake Erie Ecosystem Model. On the left, sources of phosphorus are shown in color above the horizontal axis at 0. Sinks are shown in shades of gray below. Figures to the right indicate total annual loads by source or sink.

4. How might decreasing external P loading from various sources be expected to affect algal blooms in the western basin?

The Western Lake Erie Ecosystem Model (WLEEM) was developed by LimnoTech to simulate the dynamics of the western Lake Erie basin. The model was applied to the year 2014, the first year of our study, and included 12 months of modeled loading.

Measurements and results from this study were incorporated into the WLEEM, along with loading and discharge data from other researchers and agencies, to provide an overall picture of sources and sinks for phosphorus in western Lake Erie.

Sources of phosphorus included the Maumee and Detroit Rivers and other tributaries (Figure 4). Resuspension events –sediment and phosphorus stirred up off the bottom during storm and high-wind events – and dissolved phosphorus diffusion or flux from the lake bottom were also included as sources.

Sinks of phosphorus included burial in the western basin sediments and outflow of water to the central basin of the lake.

Overall, western Lake Erie sediments trapped 39% of the P entering the basin. Diffusion, or P flux from the sediments, accounted for only 6% of P load in 2014, which was consistent with the amount measured in the field experiments.

The Bottom Line

Results of the WLEEM model affirm experimental results and calculations that internal P loading from sediments (bright yellow color in the figure) is a relatively minor contributor to the development of HABs.

The model results reflect the central importance of the Maumee River as a source of phosphorus leading to the development of HABs in western Lake Erie, as indicated by the peak (dark green color in the figure) during the critical spring period.

The WLEEM was also used to model various scenarios (Figure 5).

We explored scenarios that showed the effect of reducing loading from various sources as described in the figure.

We also modeled the effect of the recommended 40% reduction in external P loading on the development of HABs. The resulting HAB blooms are illustrated as biomass in Figure 5.

The Bottom Line

Results of the WLEEM model indicate that if successfully applied to all tributaries, the recommended 40% TP reduction would have had the desired effect of substantially reducing the 2014 HAB.

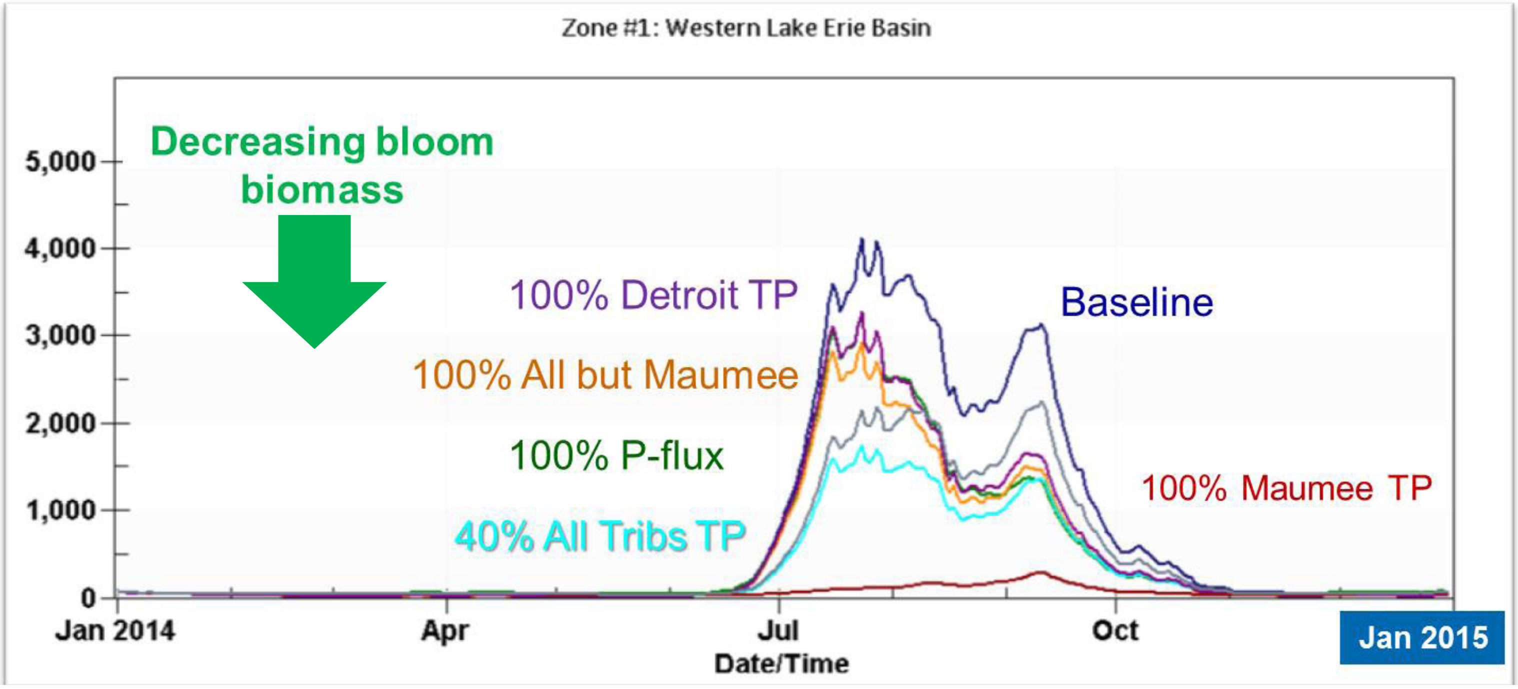


Figure 5: Biomass of western Lake Erie HAB in 2014 (baseline) with modeled effect of reducing P loading from selected sources. "100% Detroit TP" indicates the effect of removing all TP from the Detroit river in 2014. "100% All but Maumee" indicates the bloom reduction effect of removing all TP from all tributaries except for the Maumee River. "100% P-flux" indicates the effect of removing all P diffusive flux from lake sediments. "40% All Tribs TP" indicates the effect of successful implementation of the recommended 40% reduction of loading from all tributaries. "100% Maumee TP" indicates the effect of removing 100% of TP from the Maumee River in 2014.

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