Detroit River Phosphorus Loads to Lake Erie

Authors

Donald Scavia, School for Environment and Sustainability, University of Michigan, scavia@umich.edu
Colleen M. Long, Water Center, University of Michigan
Lynn Vaccaro, Water Center, University of Michigan

Background

Among the Great Lakes, Lake Erie is the warmest, shallowest, and most productive, contributing to its sensitivity to phosphorus loading. In the 1960s and 1970s, increasing phosphorus inputs led to severe algal blooms in the lake's western basin and periods of low oxygen (hypoxia) in the bottom waters of its central basin. Phosphorus abatement programs, initiated as part of the 1972 Great Lakes Water Quality Agreement (GLWQA), prompted wastewater treatment facilities to add secondary treatment, phosphorus was removed from most soaps and detergents, and soil conservation programs were enhanced. These changes reduced the amount of phosphorus released into the lake and led to clear improvements in water quality and fisheries. However, in the mid-1990s, water quality degraded as western-basin harmful algal blooms and central-basin hypoxia returned with conditions similar to the 1960s and 1970s, impacting fishing, swimming, tourism, and drinking water systems. Results from monitoring programs, lake models, and experimental studies showed that the increasing spring load of dissolved reactive phosphorus from the Maumee River watershed was the primary driver of the western basin algal blooms, and that the annual load of total phosphorus (TP) to the western and central basins was the primary driver of hypoxia.

In 2012, the United States and Canada signed a revised GLWQA that required new Lake Erie phosphorus loading targets and associated action plans. In response to this commitment, they adopted a target to reduce the annual load to the western and central basin by 40%. The Detroit River is a major contribution to that load.

The Detroit River - The Detroit River provides approximately 80% of the flow that enters Lake Erie. Nutrient concentrations in the Detroit River are relatively low compared to the Maumee River, the other primary source of phosphorus, but discharge is much greater. As such, it delivers a large annual TP load that contributes significantly to central-basin algae production and sedimentation and, ultimately, to hypoxia extent. But because phosphorus concentrations are low, the flow tends to dilute nutrients in the western basin, and as a result it is not a significant driver of the western-basin algal blooms, which are driven primarily by the Maumee River's spring load. The mixing zone between the Detroit River and western basin water is visible in satellite images where algae and sediment concentrations closer to the mouth of the Detroit River are lower (Figure 1), and the water tends to move quickly into the central basin.

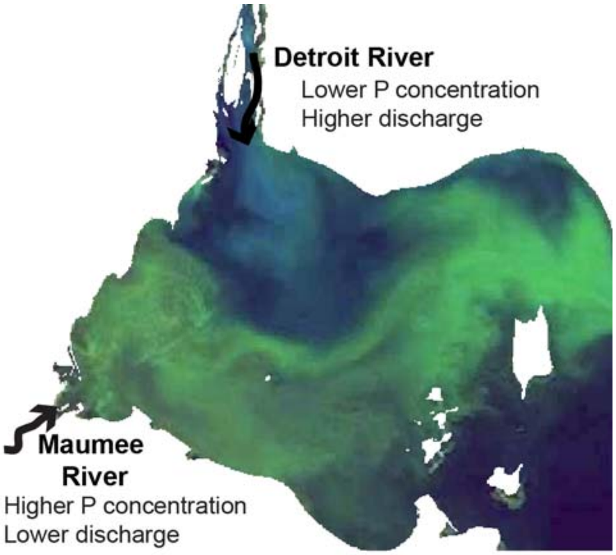

Figure 1. Image of the Western Lake Erie Basin in September 2015. The algal bloom originating from the mouth of the Maumee River is diluted and pushed away by the high volume of water with low phosphorus concentration entering from the Detroit River.

The watershed that feeds the Detroit River covers 19,000 km^2 between lakes Huron and Erie, with a large urban area in Michigan and extensive agriculture in Ontario (Figure 2). The Detroit River thus carries water and nutrients not only from its own direct watershed, but also from the Lake St. Clair and St. Clair River watersheds and Lake Huron. It is difficult to monitor what the Detroit River delivers to Lake Erie because the river is large and not well mixed, requiring extensive sampling across the river and over time. In addition, Lake Erie seiches occasionally cause flows to back up into the river, confounding estimates of river discharge.

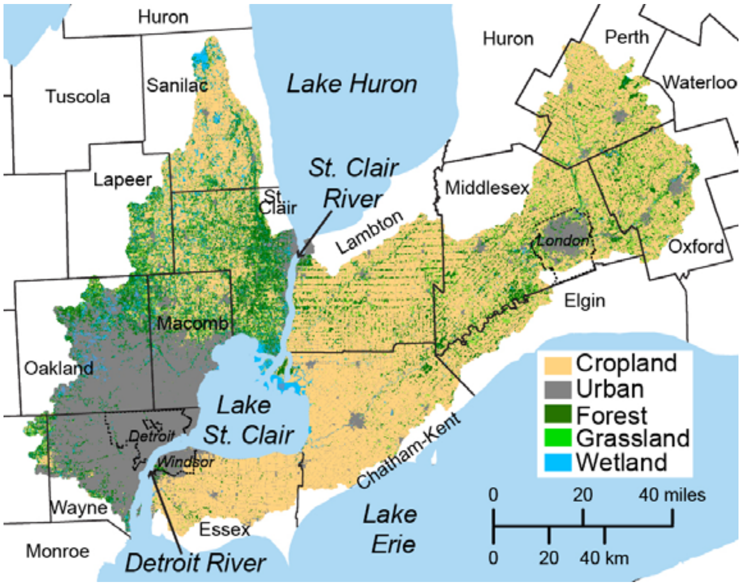

Figure 2. Land use (USDA-NASS, 2015; AAFC, 2015) in the St. Clair-Detroit river system watershed, all of which feeds the Detroit River.

***The role of Lake St. Clair on Detroit River loads* -** To understand relative contributions of different subwatersheds and sources of phosphorus to the Detroit River's load to Lake Erie, it is necessary to consider the effect of Lake St. Clair on processing water and nutrients. On average between 2001 and 2015, Lake St. Clair retained 20% of its TP inputs annually (Scavia et al., 2019a), *albeit* with substantial inter-annual variability (Figure 3). Phosphorus sources upstream of Lake St. Clair thus contribute less to Lake Erie than they deliver to the St. Clair River or Lake St. Clair.

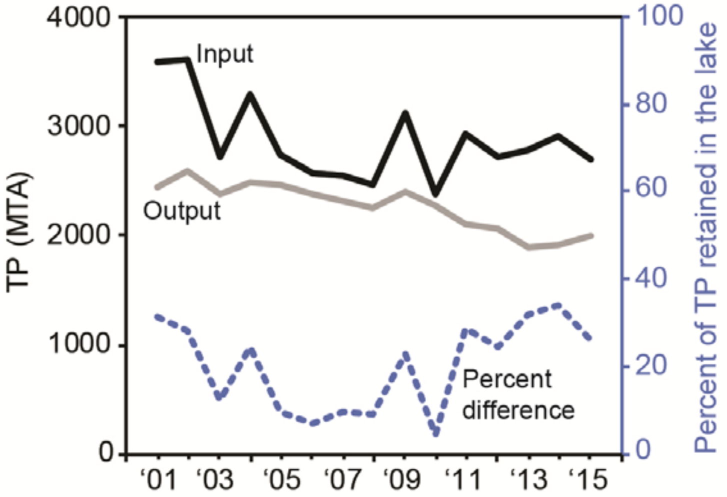

Figure 3. Input (solid black line), output (solid gray line), and percent of annual TP input that is retained in (dashed blue; right y-axis) Lake St. Clair.

Status and Trends

***Sources of the Detroit River's phosphorus load to Lake Erie* -** Lake Huron's contribution to the Detroit River load is much larger than has been assumed in the past (Burniston et al., 2018, Scavia et al., 2019a) due to the identification of a previously "unmeasured load" that evades monitoring stations at the head of the St. Clair River (Scavia et al., 2019a). The most recent estimates demonstrate that Lake Huron contributes more than half of the Detroit River TP load to Lake Erie, even taking into account retention in Lake St. Clair (Figure 4). After Lake Huron, the largest sources of phosphorus are the Great Lakes Water Authority Water Resource Recovery Facility (GLWA WRRF) in Detroit, followed by the Thames River watershed, unmonitored loads from small drainage basins around Lake St. Clair, and the Sydenham and Clinton river watersheds (Figure 5). The remaining 10% of the system's load comes from unmonitored areas that drain to the Detroit and St. Clair rivers, and the Black, Rouge, Belle, and Pine river watersheds.

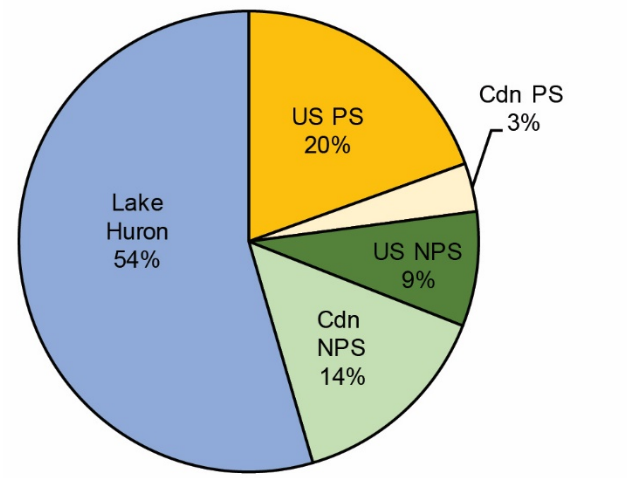

Figure 4. Proportions of the Detroit River's TP load to Lake Erie from Lake Huron and U.S. and Canadian point sources (PS) and nonpoint sources (NPS). This calculation takes into account retention in Lake St. Clair.

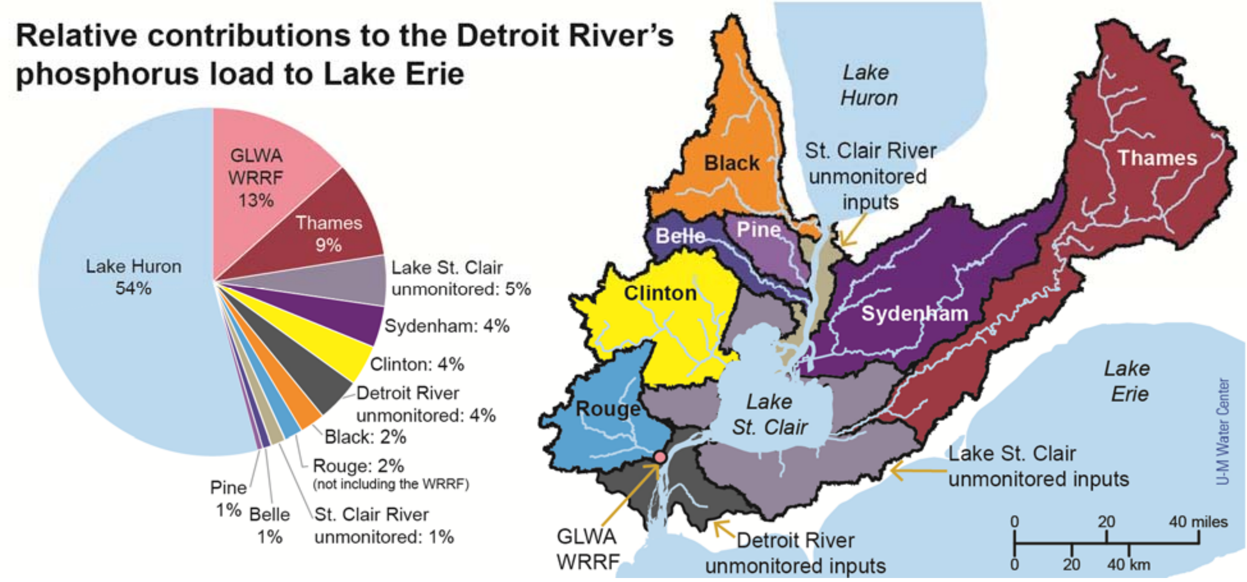

Figure 5. Proportions of the Detroit River's TP load to Lake Erie from all of the system's sources. Colors in the pie chart correspond to the map at right. Note that the GLWA WRRF is in the Rouge watershed, but it shown separately in the pie chart. These estimates do account for retention in Lake St. Clair.

Nonpoint sources provide 57% of the watershed TP load (i.e., the load not including the Lake Huron contribution), with 44% from agricultural nonpoint sources, reflecting both the intensity and extent agriculture in this watershed. The watershed contains some of Canada's most productive farmland, including extensive row crops in the lower parts of the watershed and livestock operations in the upper part. Urban and suburban nonpoint sources (e.g., roadway runoff and runoff from other impervious surfaces, animal waste, turf fertilizer, leaf litter) account for 7% of the watershed TP load.

Point sources make up about 43% of the watershed TP load (502 MTA from the U.S. and 100 MTA from Canada). Wastewater treatment facilities are the largest point source, with industrial facilities such as food processing and metal finishing plants contributing smaller amounts. The GLWA WRRF is one of the largest wastewater treatment facilities in the world, treating sewage from 3 million residents across 77 communities. It also handles stormwater because much of the region has a combined sewer system. It contributes 23% of the watershed TP load, or 326 MTA, which is more than all other point sources combined, and more than any individual tributary.

Detroit River phosphorus loads have declined over the past 18 years - The Detroit River TP load declined from 3,956 MTA in 1998 to 2,502 MTA in 2016, a 37% decline over 18 years (Figure 6)(Scavia et al., 2019b). There are two primary reasons for the declines since 1998 (Scavia et al., 2019a): (1) The concentration of phosphorus in Lake Huron water declined after the 2000-2005 invasion of zebra and quagga mussels, which are voracious filter feeders that concentrate nutrients in their bodies and along the lake bottom; and (2) The Detroit Water and Sewerage Department made significant improvements to operations at its wastewater treatment facility (now called the GLWA WRRF) around 2010. Nonpoint source loads are influenced by precipitation patterns, land management, and land use, and they did not show a statistically significant trend over this time period.

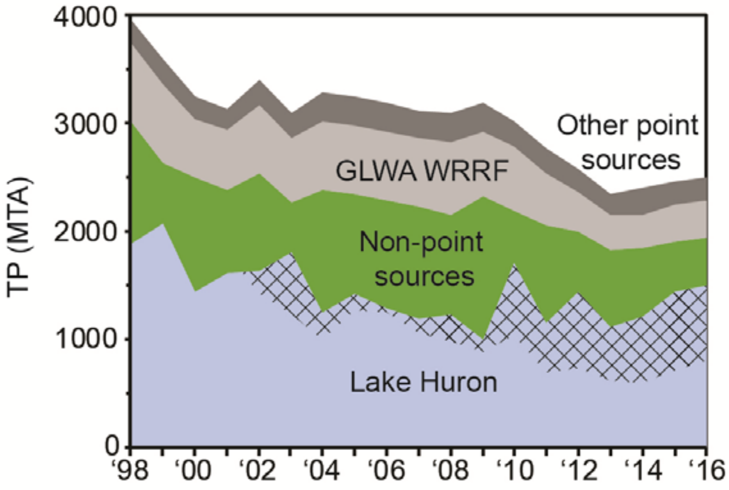

Figure 6. Time series of the total TP load to Lake Erie (which accounts for retention in Lake St. Clair). Hatches lines represent the unmeasured load from Lake Huron. Available data limited the estimate for the unmeasured load to 2001-2015; here, the value for 2016 is assumed to be the same as 2015.

Management Next Steps

Estimates of tributary loading for 2008 merit special attention because the GLWQA reduction targets use that year as a baseline. Scavia et al., (2019a,c) estimated that the 2008 Detroit River TP load was 3,096 MTA, which is roughly 50% higher than what was used by the U.S. and

Canada when they determined load reduction targets (Maccoux et al., 2016) because that one was based on a considerably lower estimate of the load from Lake Huron.

A 40% load reduction from our 2008 estimate would result in a target load of 1,858 MTA. Because the 2013-2016 average Detroit River loads had already declined to 2,425 MTA, the remaining amount to reduce is 567 MTA (Figure 7). This is equivalent to 23% of the phosphorus load coming from all sources, including Lake Huron. This new understanding of the substantial contribution from Lake Huron is an important consideration for Canada and the U.S. as they refine efforts on the St. Clair-Detroit River System watershed sources. For example, if the U.S. and Canada seek to reduce the remaining 567 MTA from the St. Clair-Detroit River watershed load (i.e., sources not including Lake Huron), they will need to reduce those sources by 51% of the current load (2013-2016 average). Furthermore, because the GLWA WRRF has already reduced its load by over 40% since 2008, further improvements there are not currently part of the reduction strategy outlined in Michigan's action plans. So when removing Lake Huron and the WRRF from consideration, the remaining watershed point and nonpoint sources would need to be reduced by 72% from current levels to reach the target – a daunting challenge. Reducing the Lake Huron and GLWA WRRF loads each by 10-15% leaves 40-50% to be reduced from watershed sources.

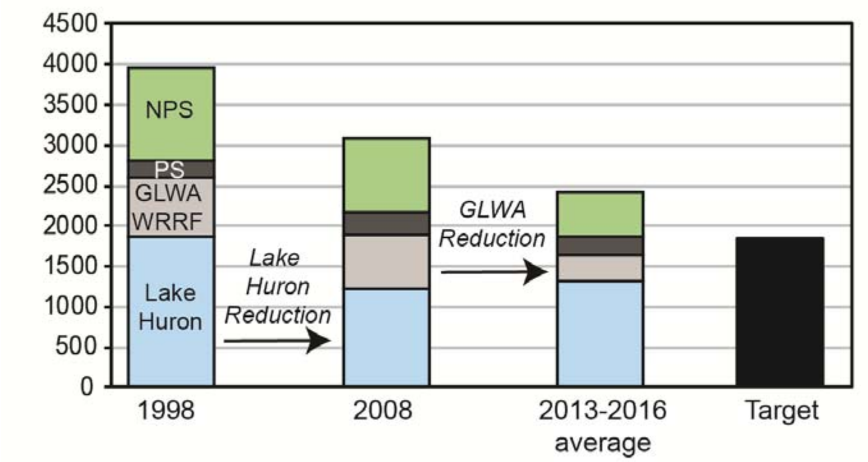

Figure 7. Contributions to the Detroit River TP load to Lake Erie for the water years 1998, 2008, and the 4-year average 2013-2016. The target represents a 40% reduction from the 2008 load as estimated in this report.

When considering sources of TP within the St. Clair and Detroit River System watershed, point and nonpoint sources are approximately equal contributors (Figure 5). While the WRRF in Detroit contributes over half of the point source load, substantial load reductions have already been made from this facility, and the high costs of further technological improvement may therefore be difficult to justify at this time. The other point source loads come from 150 other facilities, and while each is rather minor, accumulated reductions from all of them should help. Substantial reductions would also have to come from the agriculturally-dominated nonpoint sources. Model analyses (e.g., Dagnew et al., 2019) suggest the most effective way to reduce those loads is to apply combinations of practices like cover crops, buffer strips, wetlands, and applying fertilizer low below the soil surface on the lands with the highest phosphorus losses.

Research/Monitoring Needs

Lake Huron load - The previously unmeasured contribution to the Detroit River TP load appears to come from sediment resuspended along Lake Huron's southeast region, and any attempts to improve that estimate or to reduce that load will require additional analyses of its sources, phosphorus content, event frequency, and movement toward the outflow to the St. Clair River. It should be possible to enhance monitoring, thereby improving load estimates, by including continuous measurement of phosphorus surrogates, such as turbidity, that can be correlated with phosphorus concentrations (e.g., Robertson et al., 2018).

Watershed dynamics - To focus the most effective land management practices on the most appropriate lands requires a combination of higher resolution observations of properties such as soil P content and more accurate high-resolution models. The models commonly used have been calibrated to the mouths of the major tributaries, but to ensure their fidelity to watershed dynamics at a finer resolution requires nutrient monitoring efforts in the interiors of the sub-watersheds.

Detroit River load - Direct measurement of the Detroit River load is difficult because the river is not well mixed and seiches from Lake Erie complicate discharge estimates. There have been two basic approaches to estimate this load. One is to sum estimates of all of the loads to the Detroit River with (Scavia et al., 2019c) or without (Maccoux et al., 2016) accounting for load retention in Lake St. Clair. This approach avoids the measurement problems at the mouth of the river, but requires extensive monitoring upstream, including the historical difficulties with determining the load from Lake Huron. The second approach is to mount extensive field efforts, sampling frequently and across the profile of the river, sufficiently upstream of the effects of Lake Erie (e.g., Burniston et al., 2018, Totten and Duris, 2019). To ensure temporal and spatial consistency, and to connect load trends to potential actions upstream, both approaches are needed.

References

Agriculture and Agri-Foods Canada (AAFC). 2015. Annual Crop Inventory. Available at: https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9

Burniston, D., A. Dove, S. Backus, and A. Thompson. 2018. Nutrient Concentrations and Loadings in the St. Clair River - Detroit River Great Lakes Interconnecting Channel. J. Great Lakes Res. 44:398-411.

Dagnew, A., D. Scavia, Y-C Wang, R. Muenich, and M. Kalcic. 2019. Modeling phosphorus reduction strategies from the international St. Clair-Detroit River system watershed. J. Great Lakes Res. https://doi.org/10.1016/j.jglr.2019.04.005

Maccoux, M.J., A. Dove, S.M. Backus, and D.M. Dolan. 2016. Total and soluble reactive phosphorus loadings to Lake Erie: A detailed accounting by year, basin, country, and tributary. J. Great Lakes Res. 42: 1151-1165.

Scavia, D., S.A. Bocaniov, A. Dagnew, C. Long, and Y-C Wang. 2019a. St. Clair-Detroit River system: Phosphorus mass balance and implications for Lake Erie load reduction, monitoring, and climate change. J. Great Lakes Res. 45:40-49.

Scavia, D., S. Bocaniov, A. Dagnew, Y. Hu, B. Kerkez, C. Long, R. Muenich, J. Read, L. Vaccaro, and Y. Wang. 2019b. Watershed Assessment of Detroit River Phosphorus Loads to Lake Erie. Final project report produced by the University of Michigan Water Center. Available at myumi.ch/detroit-river.

Scavia, D., S. Bocaniov, A. Dagnew, Y. Hu, B. Kerkez, C. Long, R. Muenich, J. Read, L. Vaccaro, and Y. Wang. 2019c. Detroit River Phosphorus Loads: Anatomy of a Binational Watershed. Journal of Great Lakes Research, *in review.*

Totten, A.R., and Duris, J.W. 2019, Spatial distribution of nutrients, chloride, and suspended sediment concentrations and loads determined by using different sampling methods in a cross section of the Trenton Channel of the Detroit River, Michigan, November 2014–November 2015: U.S. Geological Survey Scientific Investigations Report 2018–5141, 25 p., https://doi.org/10.3133/sir20185141.

U.S. Department of Agriculture- National Agricultural Statistics Survey (USDA-NASS). 2015. CropScape - Cropland Data Layer. Available at https://nassgeodata.gmu.edu/CropScape/