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Editorial

The news from Saginaw Bay: Where the mussels are strong, the walleye are good-looking, and all the phosphorus is above average

> "I was born in Saginaw Michigan. I grew up in a house on Saginaw Bay. My dad was a poor, hard-working Saginaw fisherman. Too many times he came home with too little pay."

Saginaw Bay has experienced some ups and downs since "Saginaw Michigan" was a hit song for Lefty Frizzell in 1964. By the 1960s the cumulative impact of years of anthropogenic stressors had taken its toll on the fishery and the ecosystem supporting it. The Bay was suffering from numerous water quality impairments including eutrophication, nuisance beach deposits (aka "muck"), and taste and odor problems at the drinking water intakes. A growing recognition of the loss of Saginaw Bay's ecosystem services, as they have since come to be called, helped catalyze a series of mitigation actions. In 1972 the US Congress passed the Clean Water Act which established defined water quality goals and began the process of regulating point and non-point discharges. The 1978 Great Lakes Water Quality Agreement set target total phosphorus loads for the Great Lakes, including a 440 MT/year target specific to Saginaw Bay, and a goal that the Bay should attain a mesotrophic state. Modeling efforts to support these developments established a template for subsequent efforts under the Clean Water Act, and the target loads became the prototype for what we now call TMDLs (Total Maximum Daily Loads). Initial assessments in the 1980s documented improvements in eutrophication-related water quality symptoms (Bierman et al., 1984); but then, attention was diverted to issues associated with toxic contaminants and nutrient monitoring lapsed.

The 1987 Great Lakes Water Quality Agreement Amendments affirmed the ongoing problems in Saginaw Bay, designating the Bay as one the of 43 Areas of Concern (AOC) due to impairment of the following beneficial uses:

- Restrictions on fish and wildlife consumption
- Eutrophication or undesirable algae
- Tainting of fish and wildlife flavor
- Restrictions on drinking water consumption, or taste and odor
- Degradation of fish and wildlife populations
- Beach closings
- Degradation of esthetics
- Bird or animal deformities or reproduction problems
- Degradation of benthos
- Degradation of phytoplankton and zooplankton populations
- Restriction on dredging activities
- Loss of fish and wildlife habitat.

Since 1988, seven Remedial Action Plans (RAPs) have been developed for the Saginaw River/Bay AOC with each listing activities to address the sources contributing to these beneficial use impairments (BUIs) and the progress that has been made to restore the AOC. Two of the 12 BUIs were removed in 2008, including the fish and wildlife tainting, and drinking water taste and odor impairments.

In 1991 zebra mussels invaded Saginaw Bay. Their discovery catalyzed a multi-year study by the National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory (NOAA GLERL) that was summarized and featured in the *Journal of Great Lakes Research* (Nalepa and Fahnenstiel, 1995) reviewing the effects of the mussels as of that time.

In 2007 the NOAA Center for Sponsored Coastal Ocean Research (CSCOR) awarded a grant to NOAA GLERL and a team of partners to study the ongoing effects of multiple stressors on the Saginaw Bay ecosystem. This supplemental issue of the *Journal of Great Lakes Research* provides an updated picture on the state of the Bay at a time when the ratification of the 2012 updated Great Lakes Water Quality Agreement provides a new catalyst for action, and continued funding under the Great Lakes Restoration Initiative offers hope that actions pursuant to the new Agreement can be accomplished. Additionally, we invited several other researchers to submit papers on their Saginaw Bay-related studies to provide information on topics that were not included in the CSCOR project.

In the course of this work we amassed a lot of data, both old and new. Some of the information generated by these data has already been reported in various journal articles, a summary report was released as a NOAA technical document (NOAA, 2013), and some analyses are still underway, to be reported in future papers. Like any large, interesting research project we encountered a few surprises along the way. Surveys at established dreissenid sampling sites revealed that mussel densities were down from the 1990s and are now predominantly quagga rather than zebra mussels (>75%). Our *a priori* assumption was that beach muck, composed of decaying *Cladophora*, along the Saginaw Bay shoreline had diminished following phosphorus abatement actions and was a resurgent problem associated with dreissenid mussel establishment, as has been reported in other Great Lakes areas (Higgins et al., 2008). However, a review of a Park Ranger log book entries from the Bay City Recreation Area revealed that muck was a regular problem throughout that interim period with entries such as:

> June 18, 1978 — Considerable time was spent removing muck from the swimming area. Our muck problem is very bad again this year.

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June 10, 1979 — Our muck problem is very severe at the present time. The muck is about a foot deep and extends along the entire beach and approximately 25 ft from the shoreline out into the Bay.
June 20, 1982 — The prevailing NW winds have piled up the muck on our beach to the extent that our bombardier tractor can't push it.
Aug 5, 1984 — Muck on the beach is very thick.
May 31, 1987 — A lot of people are coming out to the beach in spite of the fact that lower lake levels have resulted in an increase in the amount of muck along our shore line.
Jul 10, 1988 — Hot dry weather brought people to the beach to cool off, in spite of the muck that is starting to stink with the high temperatures.
May 21, 1989 — We have a very low water level in the Bay and a very big concentration of muck.

Additionally, we discovered that although there was a lot of *Cladophora* in the Bay, and sometimes it constituted a significant proportion of the muck, there were numerous constituents, including other benthic filamentous algae and macrophytes, reflecting the diverse benthic community of the Bay (Francouer et al., 2014–this issue). Though the presence of macrophytes may complicate efforts to control beach fouling, phosphorus limitation was common among the benthic filamentous algae (Peters Winslow et al., 2014–in this issue), suggesting that these muck sources may be curtailed with further phosphorus reductions. We also note that, while beach muck is regarded by the public as a nuisance, Verhougstraete and Rose (2014–in this issue) found that it harbors microorganisms of concern from a public health perspective.

We also report in this special issue that phosphorus inputs to the Bay remain high (Stow et al., 2014–in this issue). Although phosphorus concentrations in some areas show declines, the 440 MT/year phosphorus target has not been met, and He et al. (2014–in this issue) indicate that most of this phosphorus is of non-point origin. Phosphorus inputs from the smaller tributaries are sparsely monitored; Voss et al. (2014–in this issue) suggest that low oxygen conditions in the Kawkawlin River may promote periodic phosphorus mobilization. Additionally, wave-induced resuspension events offer the potential for phosphorus reintroduction to the water column, particularly during the fall (Hawley et al. 2014–in this issue).

While additional phosphorus reductions may help reduce continuing eutrophication symptoms, Yu-Chun et al. (2014–in this issue) caution that achieving the 1978 target load could compromise the current productivity of the Saginaw Bay fishery. High primary productivity and warm waters currently make the inner Bay excellent nursery habitat for larval fishes, contributing to successful walleye and whitefish recruitment (Sesterhenn et al., 2014–in this issue; Pothoven et al., 2014–in this issue-a). However low yellow perch overwinter mortality is relatively high (Pothoven et al., 2014–in this issue-b), a possible consequence of food-web dynamics that are in transition as the influence of a suite of introduced species plays out over time (Roswell et al., 2014–in this issue; Staton et al. 2014–in this issue).

Invasive species have significantly changed the food web; selective consumption by invasive mussels has altered the phytoplankton community (Tang et al., 2014–in this issue), and predation by the invasive cladoceran *Bythotrephes* is high during the summer (Pothoven and Hook, 2014–in this issue). Microzooplankton continues to comprise an important food-web link with predation on and by cyanobacteria and quagga mussels, respectively (Lavrentyev et al., 2014–in this issue). In addition to affecting the Bay directly, Mifsud (2014–in this issue) reports that the invasive Phragmites has strongly influenced the distribution of herpetofauna in fringing coastal wetland habitats. Cooper et al. (2014–in this issue) also describe coastal wetland community changes, albeit as a function of water levels that have been unusually low since the late 90s. Generally, from the papers in this issue, we find that Saginaw Bay is a system in transition. Although the Bay still experiences eutrophication symptoms and invasive species complicate future planning, documentation of the presence of Hexagenia (Siersma et al., in this issue), a key indicator of benthic habitat quality, offers evidence that restoration efforts are paying off. Selzer et al. (in this issue) present their perspectives on the progress reported to date, and outline priorities for the future.

While there are hopeful signs, the mistake that was made in the 1980s when progress was noted should not be repeated. At that time, there was a general notion that lakes were either broken or fixed, and fixing a broken lake was fairly straightforward: remove the main stressors and recovery was inevitable. When improvements were documented around the Great Lakes (DePinto et al., 1986), the job was considered finished, monitoring diminished and consequently, there is a gap in our understanding of how recovery proceeded; and why it has been uneven. Since that time, our appreciation of ecosystem behavior has evolved and we now recognize that responses to stressors may be non-linear and difficult to predict. We also must acknowledge that management is an enduring process; the broken vs. fixed view is inadequate. The concept of Adaptive Management was new in the 1980s and not widely appreciated, but it is now encoded in Article 2 and Annex 10 of the 2012 Great Lakes Water Quality Agreement as "a framework for organizing science to provide and monitor the effect of science-based management options". Implicit in this language is the notion that Adaptive Management is an active process, with an imperative for monitoring, learning, and refining management actions based on improved understanding of system behavior and detecting changes that occur. Embracing this concept will be key to achieving the objectives of the 2012 Agreement, and a resilient ecosystem (Walker and Salt, 2006) that delivers a rich suite of valued services.

References

Bierman, V.J., Dolan, D.M., Kasprzyk, R., Clark, J.L., 1984. Retrospective analysis of the response of Saginaw Bay, Lake Huron, to reductions in phosphorus loadings. Environ. Sci. Technol. 18, 23–31.

Cooper, M.J., Lamberti, G.A., Uzarski, D.G., 2014. Spatial and temporal trends in invertebrate communities of Great Lakes coastal wetlands, with emphasis on Saginaw Bay of Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 168–182 (in this issue).

Depinto, J.V., Young, T.C., Mcilroy, L.M., 1986. Great Lakes water quality improvement — the strategy of phosphorus discharge control is evaluated. Environ. Sci. Technol. 20, 752–759.

Francoeur, S.N., Peters Winslow, K.A., Miller, D., Stow, C.A., Cha, Y., Peacor, S.D., 2014. Spatial and temporal patterns of macroscopic benthic primary producers in Saginaw Bay, Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 53–63 (in this issue).

Hawley, N., Redder, T., Beletsky, R., Verhamme, E., Beletscky, D., DePinto, J.V., 2014. Sediment resuspension in Saginaw Bay. J. Great Lakes Res. 40 (Supplement 1), 18–27 (in this issue).

He, C., Zhang, L., DeMarchi, C., Croley II, T.E., 2014. Estimating point and non-point source nutrient loads in the Saginaw Bay watersheds. J. Great Lakes Res. 40 (Supplement 1), 11–17 (in this issue).

Higgins, S.N., Malkin, S.Y., Howell, E.T., Guildford, S.J., Campbell, L., Hiriart-Baer, V., et al., 2008. An ecological review of *Cladophora glomerata* (Chlorophyta) in the Laurentian Great Lakes. J. Phycol. 44, 839–854.

Lavrentyev, P.J., Vanderploeg, H.A., Franzé, G., Chacin, D.H., Liebig, J.R., Johengen, T.H., 2014. Microzooplankton distribution, dynamics, and trophic interactions relative to phytoplankton and quagga mussels in Saginaw Bay, Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 95–105 (in this issue).

Mifsud, D.A., 2014. A status assessment and review of the herptofauna within the Saginaw Bay of Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 183–191 (in this issue).

Nalepa, T.F., Fahnenstiel, G.L., 1995. Preface — *Dreissena palymorpha* in the Saginaw Bay, Lake Huron ecosystem: overview and perspective. J. Great Lakes Res. 21, 411–416.

NOAA, 2013. Saginaw Bay multiple stressors summary report. NOAA Technical Memorandum GLERL-160NOAA, Ann Arbor, MI.

Peters Winslow, K.A., Francoeur, S.N., Peacor, S.D., 2014. The influence of light and nutrients on benthic filamentous algal growth: a case study of Saginaw Bay, Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 64–74 (in this issue).

Pothoven, S.A., Höök, T.O., 2014. Predatory demands of *Bythotrephes* and *Leptodora* in Saginaw Bay, Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 106–112 (in this issue).

Pothoven, S.A., Höök, T.O., Roswell, C.R., 2014. Energy content of young yellow perch and walleye in Saginaw Bay. J. Great Lakes Res. 40 (Supplement 1), 133–138 (in this issue).

Pothoven, S.A., Höök, T.O., Roswell, C.R., 2014. Feeding ecology of age-0 lake whitefish in Saginaw Bay, Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 148–155 (in this issue).

Roswell, C.R., Pothoven, S.A., Höök, T.O., 2014. Patterns of age-0 yellow perch growth, diets, and mortality in Saginaw Bay, Lake Huron. J. Great Lakes Res. 40 (Supplement 1), 123–132 (in this issue).

Sesterhenn, T.M., Roswell, C.R., Stein, S.R., Klaver, P., Verhamme, E., Pothoven, S.A., Höök, T.O., 2014. Modeling the implications of multiple hatching sites for larval dynamics in the resurgent Saginaw Bay walleye population. J. Great Lakes Res. 40 (Supplement 1), 113–122 (in this issue).

Staton, J.M., Roswell, C.R., Fielder, D.G., Thomas, M.V., Pothoven, S.A., Höök, T.O., 2014. Condition and diet of yellow perch in Saginaw Bay, Lake Huron (1970–2011). J. Great Lakes Res. 40 (Supplement 1), 139–147 (in this issue).

Stow, C.A., Dyble, J., Kashian, D.R., Johengen, T.H., Winslow, K.P., Peacor, S.D., Francoeur, S. N., Burtner, A.M., Palladino, D., Morehead, N., Gossiaux, D., Cha, Y., Qian, S.S., Miller, D., 2014. Phosphorus targets and eutrophication objectives in Saginaw Bay: a 35 year assessment. J. Great Lakes Res. 40 (Supplement 1), 4–10 (in this issue).

Tang, H., Vanderploeg, H.A., Johengen, T.H., Liebig, J.R., 2014. Quagga mussel (*Dreissena rostriformis bugensis*) selective feeding of phytoplankton in Saginaw Bay. J. Great Lakes Res. 40 (Supplement 1), 83–94 (in this issue).

Verhougstraete, M.P., Rose, J.B., 2014. Microbial investigations of water, sediment, and algal mats in the mixed use watershed of Saginaw Bay, Michigan. J. Great Lakes Res. 40 (Supplement 1), 75–82 (in this issue).

Voss, H.M., VanWert, M.E., Polega, J.R., VanHouten, J.W., Martin, A.L., Karpovich, D.S., 2014. Implications of hypoxia on the North Branch of the Kawkawlin River. J. Great Lakes Res. 40 (Supplement 1), 28–34 (in this issue).

Walker, B., Salt, D., 2006. Resilience Thinking. Island Press, Washington.

Yu-Chun, K., Adlerstein, S., Rutherford, E., 2014. The relative impacts of nutrient loads and invasive species on a Great Lakes food web: an Ecopath with Ecosim analysis. J. Great Lakes Res. 40 (Supplement 1), 35–52 (in this issue).

Craig A. Stow
NOAA Great Lakes Environmental Research Laboratory, Ann Arbor, MI 48108, USA
E-mail address: craig.stow@noaa.gov.