Lake Erie Background from a Nutrient Perspective
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The physical characteristics of Lake Erie have a direct bearing on how the lake ecosystem reacts to various stressors. As the shallowest of the Great Lakes, it warms quickly in the spring and summer, and cools rapidly in the fall. During cold winters a large percentage is covered by ice, but in warmer years there may be no ice at all. The shallowness of the basin and the warmer temperatures make it the most biologically productive of the Great Lakes. It is also readily influenced by climate/meteorological conditions. Overall current and wave patterns in Lake Erie are complex, highly changeable and often related to wind direction.

Lake Erie is naturally divided into three basins. The western basin averages 24 ft. deep with a maximum depth of 62 ft., and lies west of a line from Cedar Point to Point Pelee, ON. Stratification is rare and brief, but can cause hypoxia/anoxia rapidly. The central basin is quite uniform in depth averaging 61 ft. deep with a maximum depth of 84 ft. It lies from the western basin line east to a sand and gravel bar between Erie, PA and the base of Long Point, ON. The eastern basin averages 80 ft deep with a maximum depth of 210 ft. The central and eastern basins thermally stratify every year, with the shallow hypolimnion of the central basin often going anoxic. Stratification impacts the internal dynamics of the lake, physically, biologically and chemically. These physical characteristics cause the lake to function as virtually three separate lakes.

Approximately 80% of the lake's total inflow comes through the Detroit River, 11% from precipitation, and 9% from the other tributaries. However, most of the nutrient and sediment loading comes from the tributaries, particularly the Maumee River. Of all the Great Lakes, Erie is exposed to the greatest stress from urbanization, industrialization and agriculture, and also receives the largest sediment load. As use of the lake and surrounding lands changed over the years, so too did the issues of concern in the lake. Interestingly, many of the issues recur, albeit for different reasons. One of these issues is phosphorus.

Accelerated euthrophication spanned the 1950s to 1970s with much of the central basin hypolimnion becoming anoxic by late summer. Algal blooms became rampant, thick Cladophora lined rocky shorelines, and dead fish were a common sight. Anoxia in the western basin wiped out the mayfly population in 1953. Phosphorus was deemed to be the main culprit.

The Great Lakes Water Quality Agreement set limits for phosphorus loadings and outlined the measures needed to attain them. Binational phosphorus reduction strategies were implemented including: reducing phosphorus discharge from wastewater treatment plants; limiting the use of phosphorus containing detergents; and adopting BMPs to reduce phosphorus runoff from agricultural operations. By the late 1980s, phosphorus levels prescribed in the GLWQA were being attained most years.

Then, things changed again:

- Zebra mussels introduced in the late 1980s triggered a tremendous ecological change in the lake. Additional exotics, such as quagga mussels, gobies and several large zooplankton species, further complicated the system. All of these species contributed to changing habitat characteristics; altering the food web dynamic and energy transfer pathways; and modifying how nutrients and contaminants were cycled within the lake ecosystem.
- Total phosphorus and soluble reactive phosphorus concentrations in the open lake remain comparatively low; however, concentrations in nearshore areas and bays are rising, even though TP tributary loads are not increasing.
- Cyanobacteria blooms returned unexpectedly in 1995, although this time the dominant species was the non-nitrogen-fixing *Microcystis aeruginosa*. Past cyanobacteria blooms were dominated by nitrogen-fixing *Anabaena* and

Aphanizomenon. It is suspected that the blooms are associated with dreissenids and a changing P/N ratio in the lake.

- *Cladophora* was back, coating shorelines and piling up on beaches.
- Central basin anoxia was occurring earlier and covering a larger area.
- Size structure and composition of the phytoplankton community have changed.
- Phosphorus may no longer be the limiting nutrient. Nitrogen and carbon may be playing a more important role.
- Benthic production has become more important in the food web dynamic. The formerly pelagic-based system of sunlight → phytoplankton → zooplankton → fish now includes a partitioning of the food energy derived from zooplankton to dreissenids, thus sunlight → phytoplankton → dreissenids → fish.
- Chlorophyll *a* concentrations may no longer be an accurate measure of primary productivity.
- While the western basin mayfly populations have rebounded, recruitment fluctuates dramatically from year to year.

Lake Erie is in a state of transition. New models are needed to incorporate these changes. Always a dynamic and difficult to monitor area, the nearshore (river/lake interface) continues to be an area to where additional research and monitoring are needed. Changing land use practices, the effectiveness of landscape-based BMPs and point source controls on phosphorus loading, and changes in the nearshore aquatic community structure must all be assessed in respect to ecological requirements for the maintenance or recovery of healthy aquatic communities. Nitrogen and carbon must be included in impact assessments.

The Lake Erie Trophic Status Collaborative Study supported the collection of data during 2002 and 2003 and produced 24 papers that clarified some of the current dynamics in the lake, but also raised additional questions. USEPA and Environment Canada conduct annual monitoring at set stations in the open lake. A collaborative monitoring program between the US and Canada supports more intensive data collection on Lake Erie every 5 years. The next cycle is scheduled for 2009. The 2009 effort will include a more extensive collection of data on tributary loading for nutrients, hopefully including SRP in tributaries where it has not been monitored before, and a focus on the nearshore. Over the next five years a linked set of models will be developed to forecast changes in nutrient loads to the lake, the impact of these changes on central basin hypoxia, and the potential ecological response. The Lake Erie Lakewide Management Plan (LaMP) is currently developing ecological objectives, targets and indicators related to nutrients.

The level of change in the Lake Erie ecosystem has been extensive, and in many cases, irreversible. We cannot return to pre-settlement conditions, but we can work toward achieving a healthier, more diverse and less contaminated ecosystem. Changes in land use that represent a return towards more natural landforms, or that mitigate the impact of urban, industrial and agricultural land use, are the most significant actions that can be taken to restore the Lake Erie Ecosystem.