Phosphorus sources and impacts on water quality in Saginaw Bay

Juli Dyble
NOAA, Great Lakes Environmental Research Lab
Outline

- Sources of P to Saginaw Bay
- Impacts of P on Saginaw Bay
- Projects underway to address P issues
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Contaminants in Saginaw Bay

- **Sources of contaminants**
  - Industrial and municipal discharges
  - Combined sewer overflows
  - Failing septic systems
  - Urban and agricultural nonpoint source runoff
  - Atmospheric deposition
  - Contaminated sediments
  - Old waste disposal sites

- **AOC (US EPA Area of Concern):**
  - 35 km of Saginaw R.
  - All of Saginaw Bay (out to L. Huron)
Saginaw Bay watershed

- Michigan’s largest
  - 8,709 square miles
  - All or part of 22 counties
  - Drains 15% of Michigan’s total land area

- Largest contiguous freshwater coastal wetland system in US
Nutrient inputs to Saginaw Bay

- Drainage basin is 7 times larger than surface area of bay
- Over ½ land use is agricultural
- Urban centers in watershed: Flint, Saginaw, Bay City, Midland
- Saginaw River is dominant tributary
  - ~70% total tributary input
  - ~80% total basin drainage
Saginaw Bay watershed

AuGres/Rifle
KawKawlin/Pine
Pigeon/Wiscoggin
Saginaw

Subbasins

Tom Croley, NOAA-GLERL
Legislation to control nutrient input to Saginaw Bay

- 1972 and 1978: Great Lakes Water Quality Agreements
  - Limit P content in laundry detergents
  - P removal (chemical precipitation) implemented at sewage treatment plants discharging to Great Lakes

- 1987: Great Lakes Water Quality Agreement Supplement
  - 440 metric tons P/yr load to Saginaw Bay
  - 15 µg/L total P concentration in Saginaw Bay
Total Phosphorus

Source: Environment Canada & U.S. EPA - GLNPO

From Breddin, SOLEC, 2002 on State of Lake Huron
Nutrient loading from point sources

- Wastewater treatment facilities
- Combined sewer overflows (CSOs)
  Sanitary sewer overflows (SSOs)
- Industrial discharge
CSO and SSO TP Loads in the Saginaw Bay Watershed (2000-2004)
TP Point Sources in the Saginaw River Watershed (2004-2006)

Kilometers

Carlo DeMarchi, NOAA-GLERL
TP Point Sources in the Saginaw River Watershed (2004-2006)

Met. Ton. P/Year

- 0.01 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.50
- 2.50 - 5.00
- 5.00 - 10.00
- 10.00 - 25.00
- >25

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Nutrient loading from non-point sources

- Manure
- Fertilizer
- Soil erosion
- Urban runoff
- Septic tanks
- Laundry and dishwashing detergents (up to 50% total P input)
- Atmospheric deposition
- Release from sediments (internal loading)

Tom Croley, NOAA-GLERL
% total cropland receiving fertilizer

Data from US EPA Great Lakes National Program Office
# CSO and WWTP Fraction of Saginaw River TP Annual Load

<table>
<thead>
<tr>
<th>Year</th>
<th>CSO/SSO Est. (Met. Ton)</th>
<th>WWTP Effluent (Met. Ton)</th>
<th>Total P Load MDEQ (Met. Ton)</th>
<th>CSO’s Fraction of Load (%)</th>
<th>WWTP Fraction of Load (%)</th>
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</thead>
<tbody>
<tr>
<td>2000</td>
<td>1.78</td>
<td>--</td>
<td>--</td>
<td>0.50</td>
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<tr>
<td>2001</td>
<td>2.43</td>
<td>--</td>
<td>642</td>
<td>0.38</td>
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<tr>
<td>2002</td>
<td>3.02</td>
<td>--</td>
<td>513</td>
<td>0.59</td>
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<tr>
<td>2003</td>
<td>0.59</td>
<td>--</td>
<td>345</td>
<td>0.17</td>
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<tr>
<td>2004</td>
<td>2.98</td>
<td>116</td>
<td>724</td>
<td>0.40</td>
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<tr>
<td>2005</td>
<td>--</td>
<td>110</td>
<td>288</td>
<td>--</td>
<td>38.2</td>
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<td>2006</td>
<td>--</td>
<td>128</td>
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</tbody>
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Modeling nutrient loading in Saginaw Bay watershed (DLBRM)

- Watershed subdivided into 4 basins
- Each basin is divided into a grid of square pixels (1 km x 1 km)
- Water and pollutants move horizontally between neighboring pixels according to difference in elevation
  - hydrology (surface water, ground water, snowpack)
  - soil erosion
  - manure and fertilizer application
  - monthly nutrient surveys (N, P)
Annual total P load to Saginaw Bay
(Saginaw River watershed only)

Model 1
Model 2
Model 3
MDEQ
Discharge

GLWQA Saginaw Bay phosphorus target load
Total P load related to discharge

* At Essexville

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Discharge

- Varies by season (related to amount and timing of precipitation)
  - Daily discharge:
    - 0.6 billion gallons/day in fall
    - 7.4 billion gallons/day in spring
  - ~80% total basin drainage through Saginaw River
## Saginaw Bay TP Annual Load (2004-06), projected

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<tbody>
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<td>Saginaw</td>
<td>16,680</td>
<td>71.6</td>
<td>119</td>
<td>85.6</td>
<td>716</td>
<td>374</td>
<td>788</td>
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<tr>
<td>AuGres/Rifle</td>
<td>2,777</td>
<td>11.9</td>
<td>4.2</td>
<td>3.0</td>
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<td>62</td>
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<tr>
<td>KawKawlin/Pine</td>
<td>1,409</td>
<td>6.0</td>
<td>5.8</td>
<td>4.0</td>
<td>61</td>
<td>31</td>
<td>67</td>
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<tr>
<td>Pigeon/Wiscoggin</td>
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<td>10.5</td>
<td>10.3</td>
<td>7.4</td>
<td>104</td>
<td>55</td>
<td>115</td>
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<tr>
<td>Total</td>
<td>23,291</td>
<td>139</td>
<td>999</td>
<td>521</td>
<td>1099</td>
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</tbody>
</table>

* Average projected values

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What does impacted water quality look like for Saginaw Bay?
Microcystis blooms
**Microcystis in the Great Lakes**

- Colonial harmful algal bloom species (HAB)
- Forms blooms and scums
  - Taste/odor issues
  - Loss of recreational and fishing value to affected waters
  - Hypoxia/anoxia, may lead to mortality in benthic invertebrate community and fish kills
Microcystin

● Hepatotoxin

● Health effects
  ◆ Animal mortality: livestock, wildlife, birds, pets
  ◆ Human illness:
    ● Gastrointestinal, dermatitis (short term exposure)
    ● Liver damage (chronic exposure)

● WHO recommended exposure limits
  ◆ 20 μg/L – recreational exposure
  ◆ 1 μg/L – drinking water

● Some evidence of bioaccumulation in fish, mussels and zooplankton
Cladophora
Limits of *Cladophora* distribution

- **Horizontal**
  - Substrate limited
- **Vertical**
  - Light limited
- **P** stimulates growth
- **Growth** begins at 40°F, dies off at 75°F

Scott Higgins, University of Waterloo
In situ Phosphorus Additions
No P Added

P Added

1 week later

Scott Higgins, University of Waterloo
GREAT LAKES
MOST UNWANTED
AQUATIC INVASIVE SPECIES

ZEBRA MUSSEL
*Dreissena polymorpha*

Description: The zebra mussel is a small barnacle-like mussel, about the size of a fingernail. Its D-shaped shell has alternating dark- and light-colored stripes. Zebra mussels form clusters that attach to hard surfaces.

Distinguishing Features: year. They also multiply rapidly and consume...
Mussels promote benthic algal growth

- Improves water clarity for increased light penetration
- Provide hard substrate for attachment
- Localized nutrient excretion
  - remineralization of N, P
  - more rapid nutrient cycling

Filtration to remove phytoplankton and particulates from water column
Stressors on Saginaw Bay water quality

Land use
- Nutrient loading
- Sedimentation

Climate change
- Water temperature
- Precipitation
- Lower lake levels
- Storms: mixing, resuspension

Invasive species
- Dreissenids
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5 year, $3.76 million grant
NOAA Center for Sponsored Coastal Ocean Research

NOAA Great Lakes Environmental Research Laboratories
Michigan State University
University of Michigan
University of Akron
Limno-Tech, Inc.
Western Michigan University
Michigan Department of Natural Resources
Michigan Department of Environmental Quality
Coupled bio-physical 3D models

Empirically based (Bayesian) Simple statistical (e.g. regression) Artificial Neural network

Ecosystem Stressors
- Land & Resource use
- Climate Change
- Invasive Species

Ecosystem Models
- Ecosystem Characterization
  - Watershed model
  - Hydrodynamic model
  - Biophysical data and processes

Ecosystem endpoints
- Fish community dynamics
- Water quality & Human health

Socio-economic integration to guide management
- Economic models
- Public preference
- Workshops

Recommendations for ecosystem characterization
- Experimental
- Monitoring
- Synthesis
Goals of Multiple Stressors project

- Determine impact of interacting stressors on Saginaw Bay
- Involve managers in identifying management priorities
- Predict effectiveness of management strategies on water quality (and fish production)
Sampling

- Measuring nutrient inputs through watershed
- Regular sampling of water quality
  - **Physical**
    - Temperature
    - pH
    - Dissolved oxygen
  - **Chemical**
    - Nutrients (TN, NO$_3$, NH$_4$, TP, SRP, DOC)
  - **Biological**
    - Chlorophyll a (size-fractioned)
    - Phytoplankton composition (pigments for major groups)
    - Benthic algal biomass
    - Dreissenids (abundance, physiological health)
    - Zooplankton (abundance, composition, egg ratios)
    - Fish (abundance, composition, etc.)
Sampling sites

10 inner bay
3 outer bay
Summary

- Multiple P inputs to Saginaw Bay from point and nonpoint sources
- Excess P has significant impacts on water quality in Saginaw Bay
- There are not easy solutions, but work in progress that hopefully will provide some guidance
Thank you!