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

Michigan Sea Grant Archives

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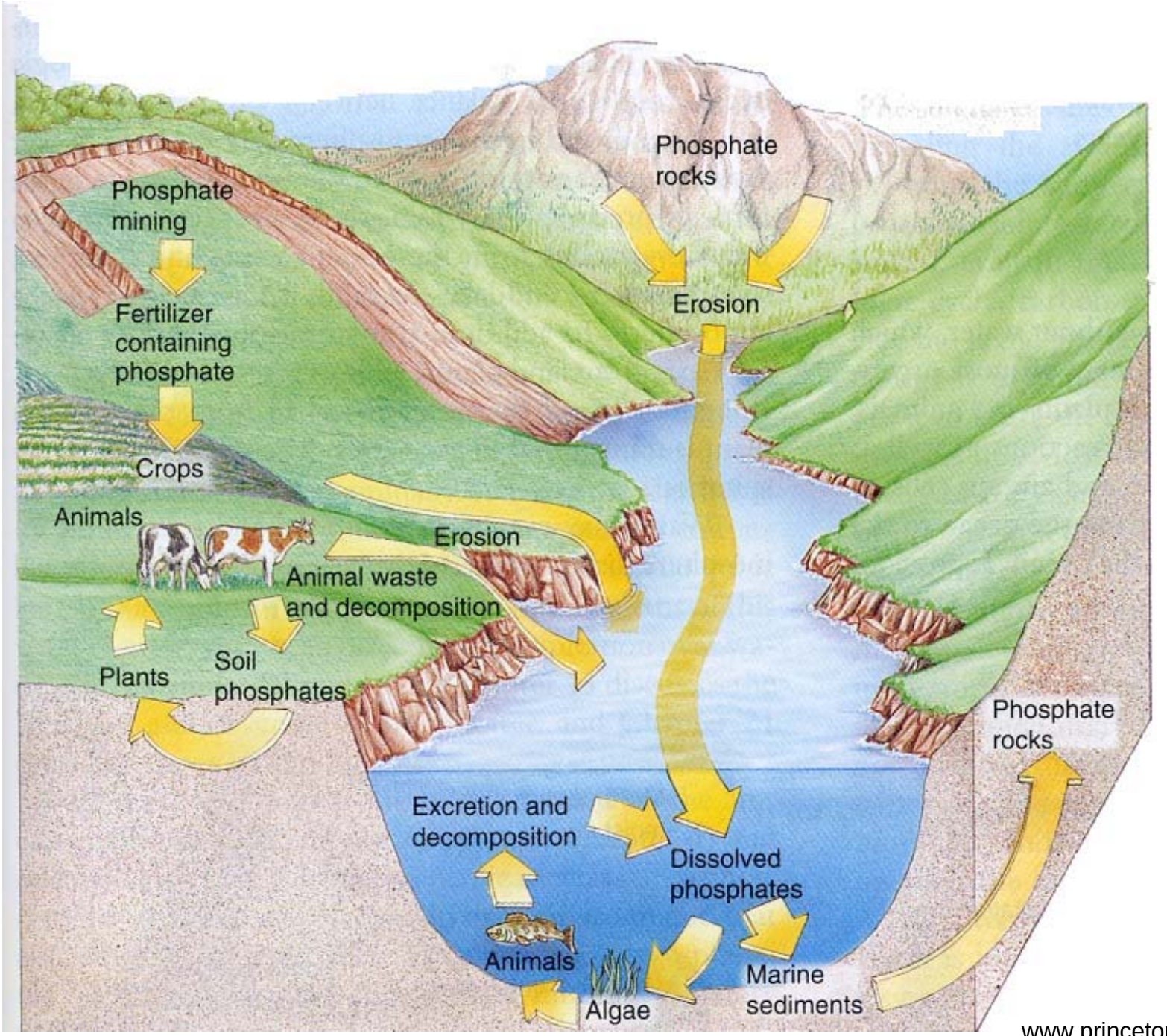
EPA Saginaw Bay AOC website

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

Nutrients

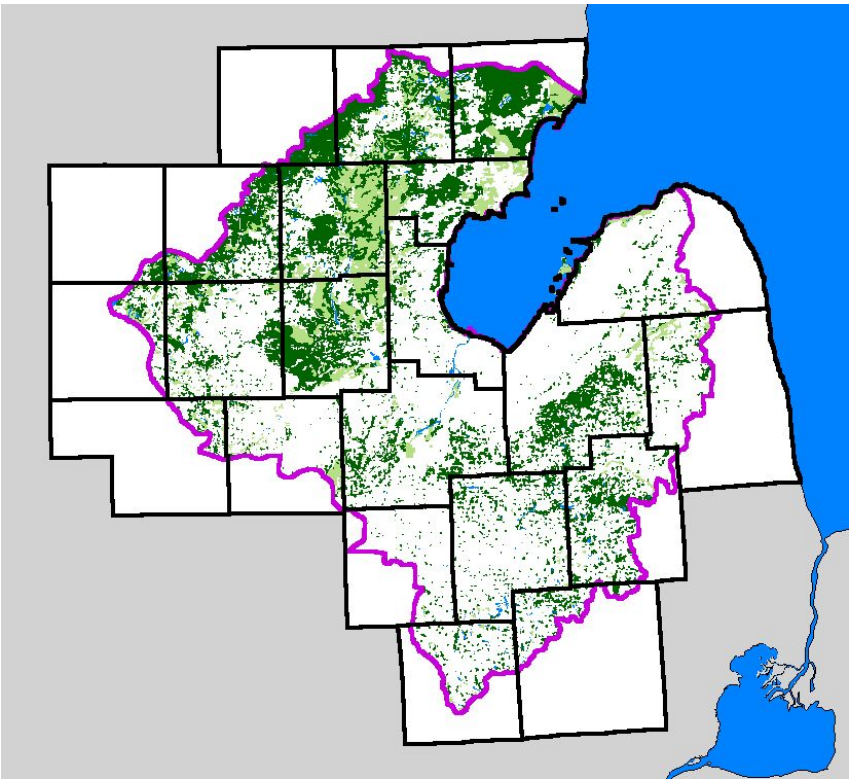
- AOC (US EPA Area of Concern):
  - 35 km of Saginaw R.
  - All of Saginaw Bay (out to L. Huron)



www.princeton.edu

Saginaw Bay watershed

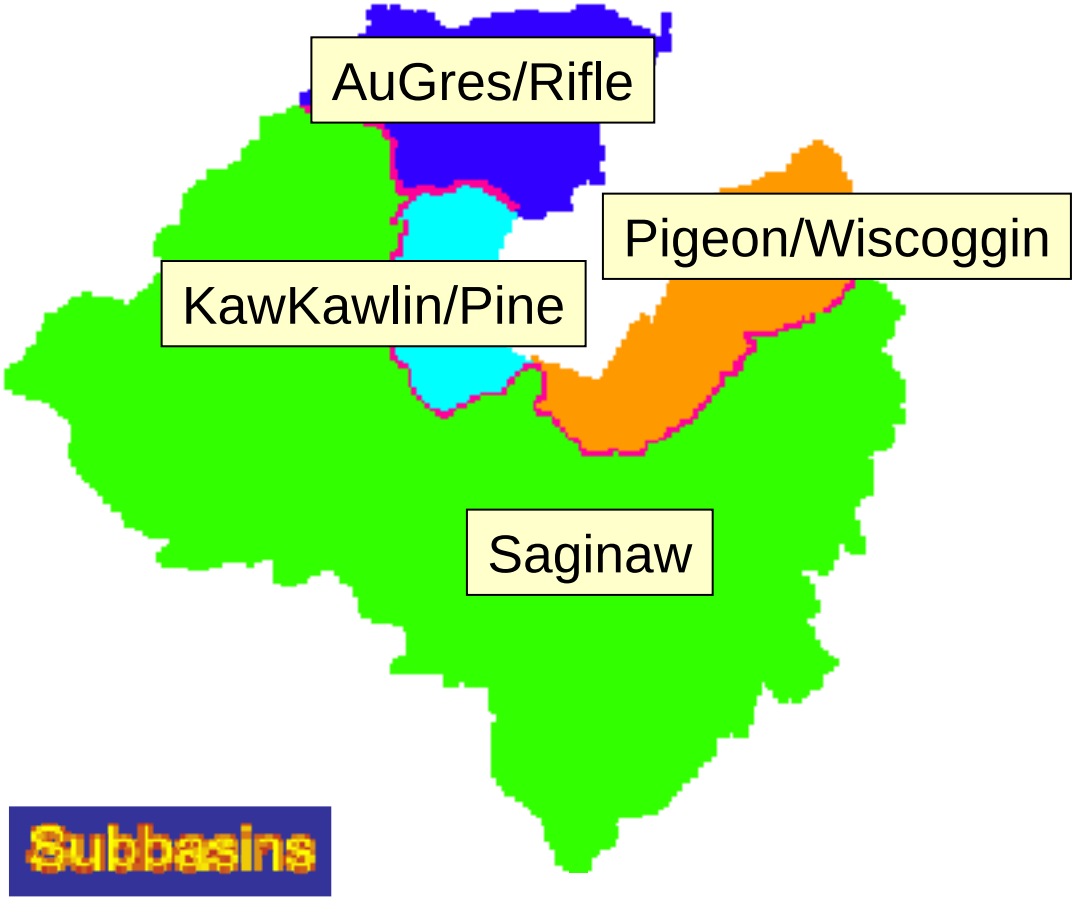
- Michigan's largest
  - 8,709 square miles
  - All or part of 22 counties
  - Drains 15% of Michigan's total land area
- Largest contiguous freshwater coastal wetland system in US

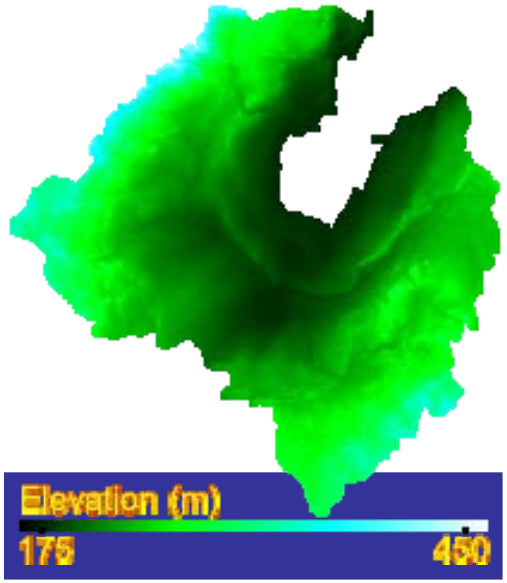


Nutrient inputs to Saginaw Bay

- 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





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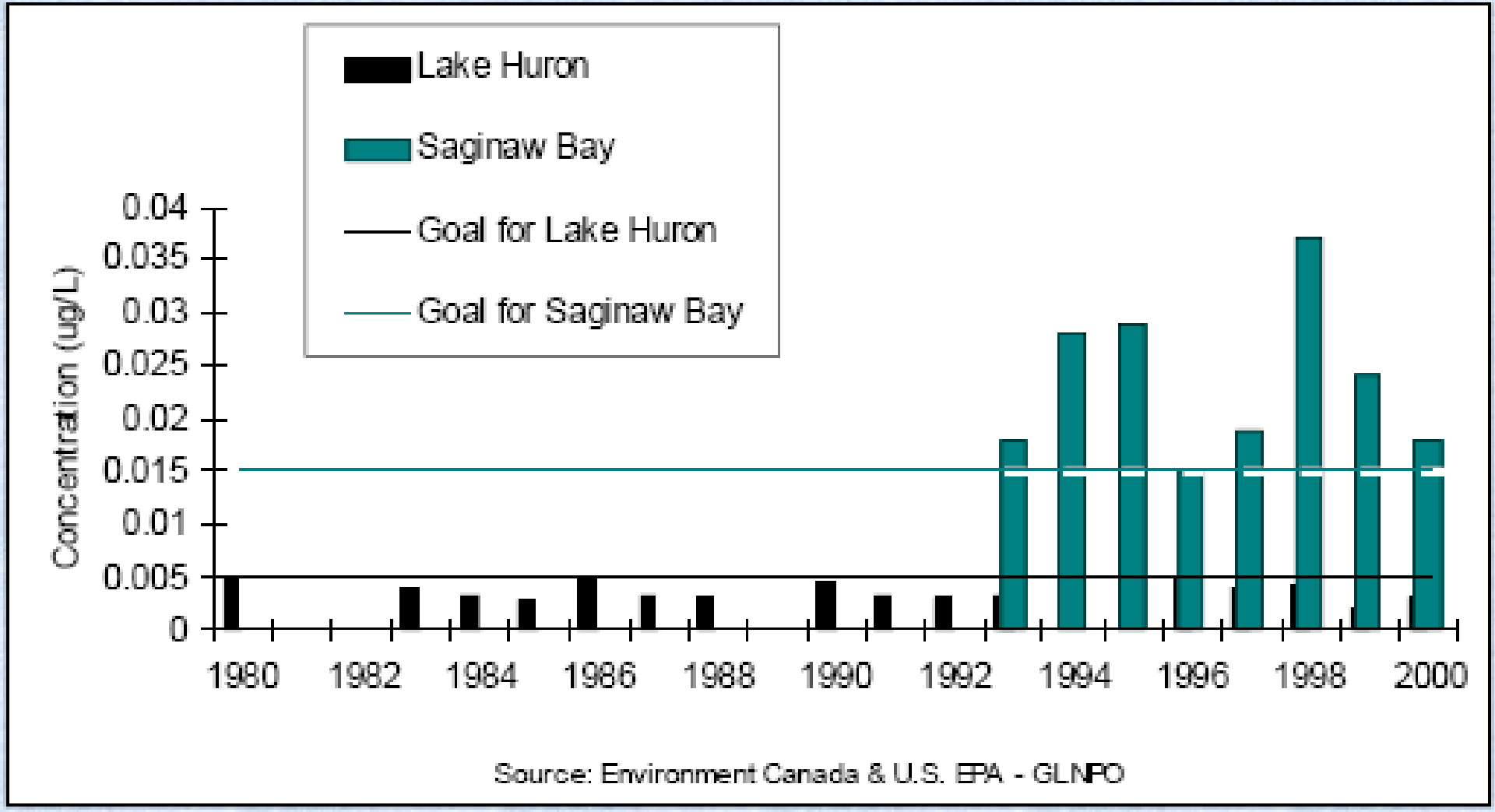
Legislation to control nutrient input to Saginaw Bay

- 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

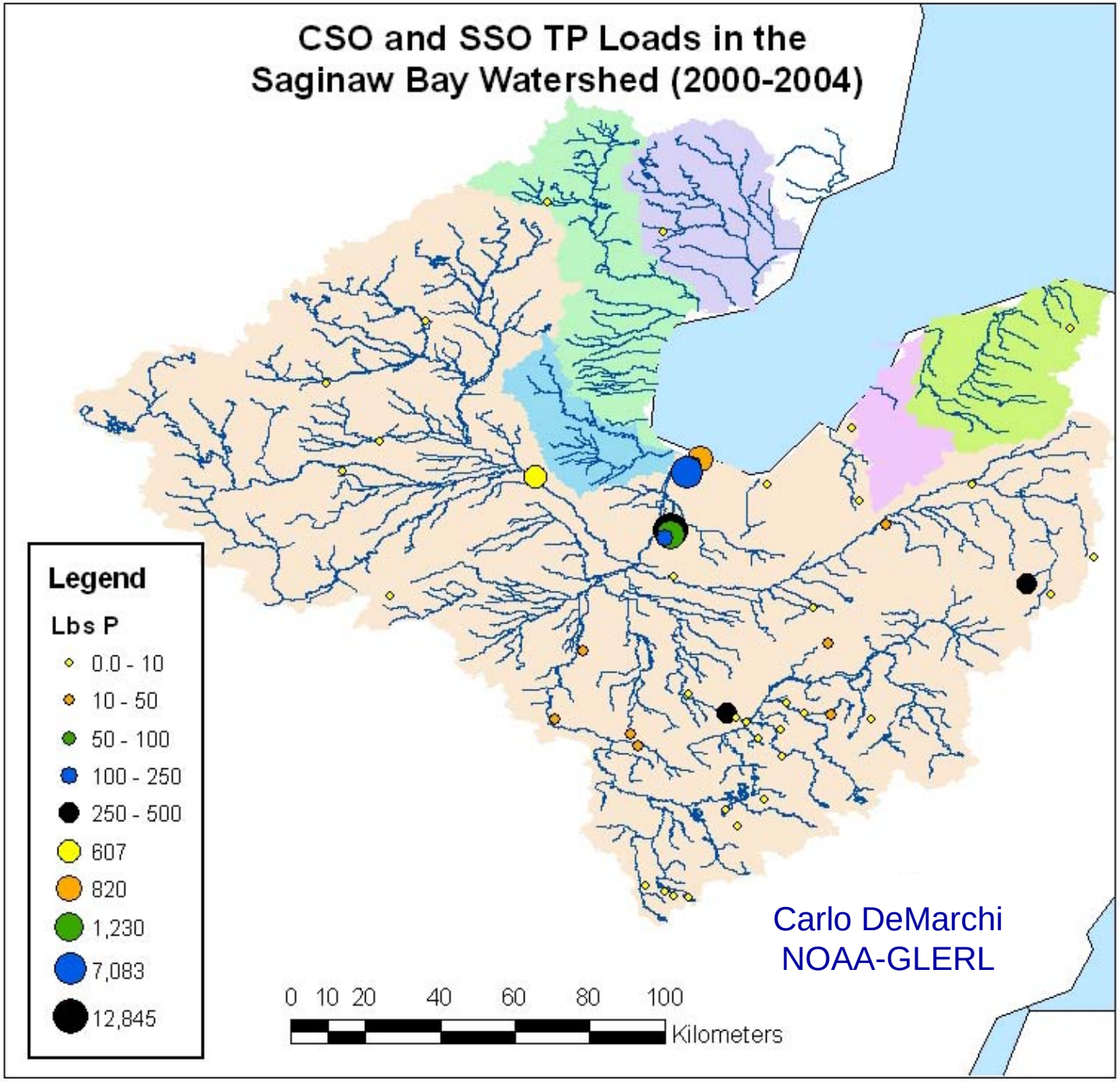
Total Phosphorus



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)
Legend
Lbs P
0.0 - 10
10 - 50
50 - 100
100 - 250
250 - 500
607
820
1,230
7,083
12,845
0 10 20 40 60 80 100
Kilometers
Carlo DeMarchi
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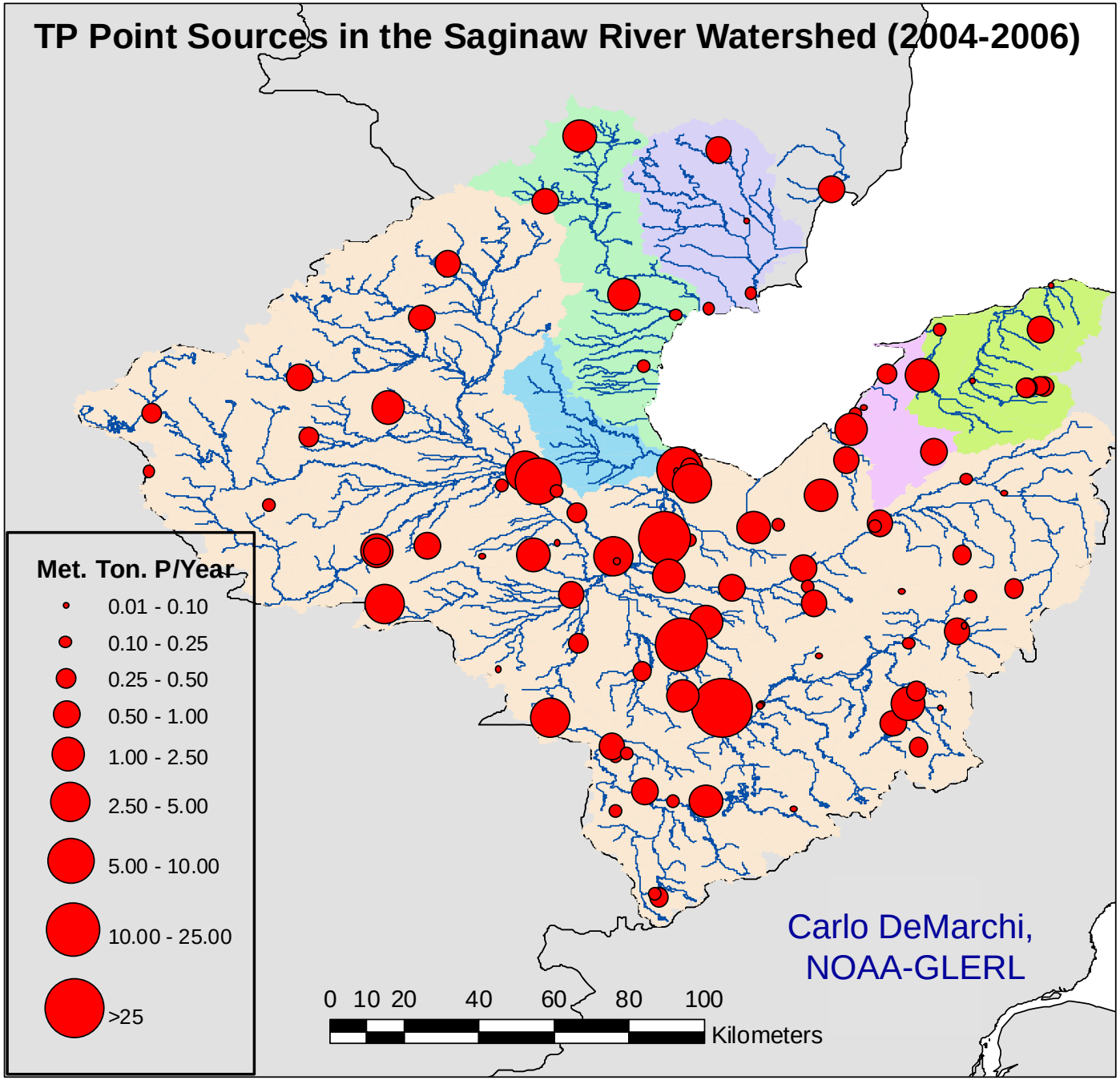
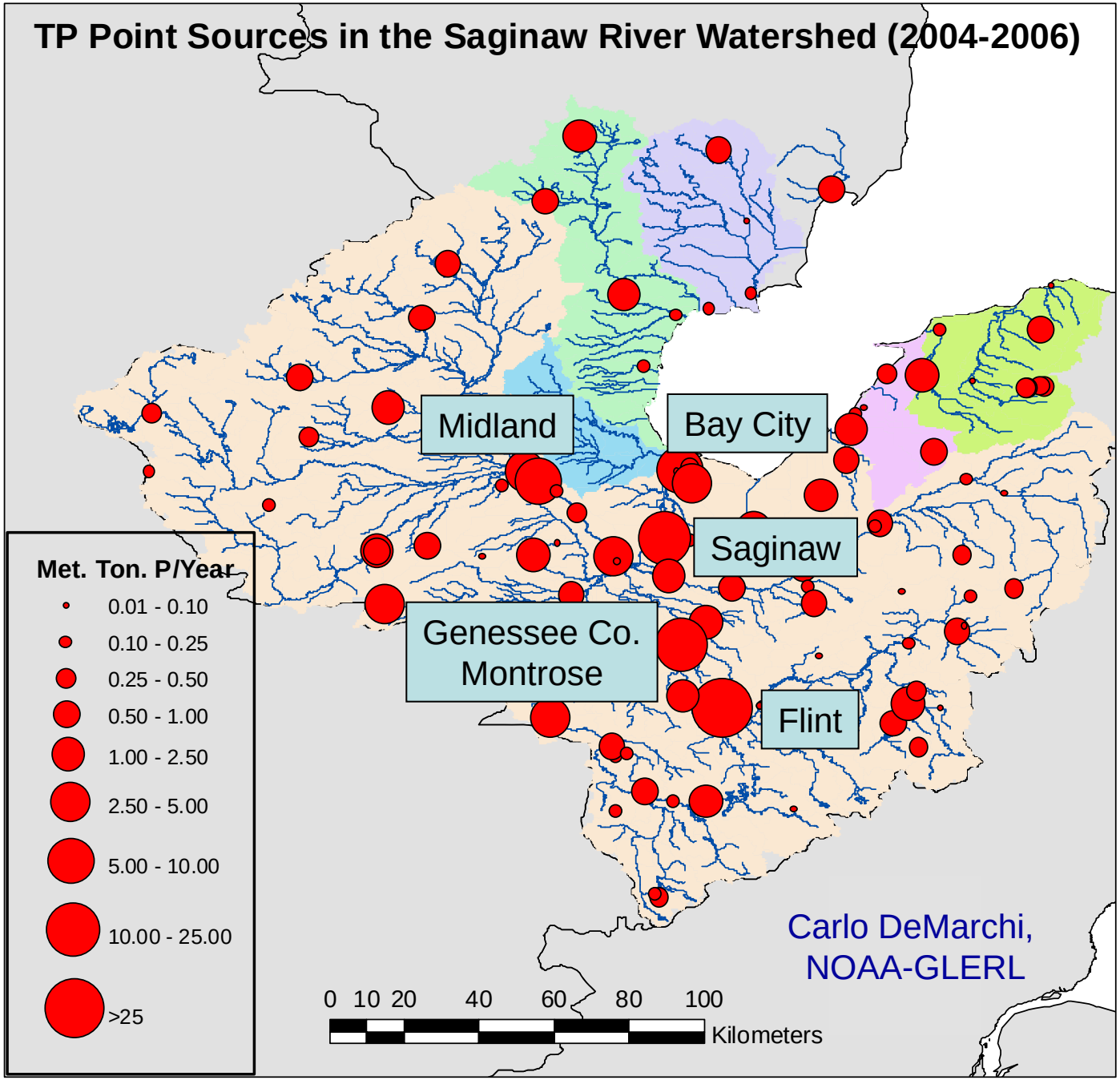
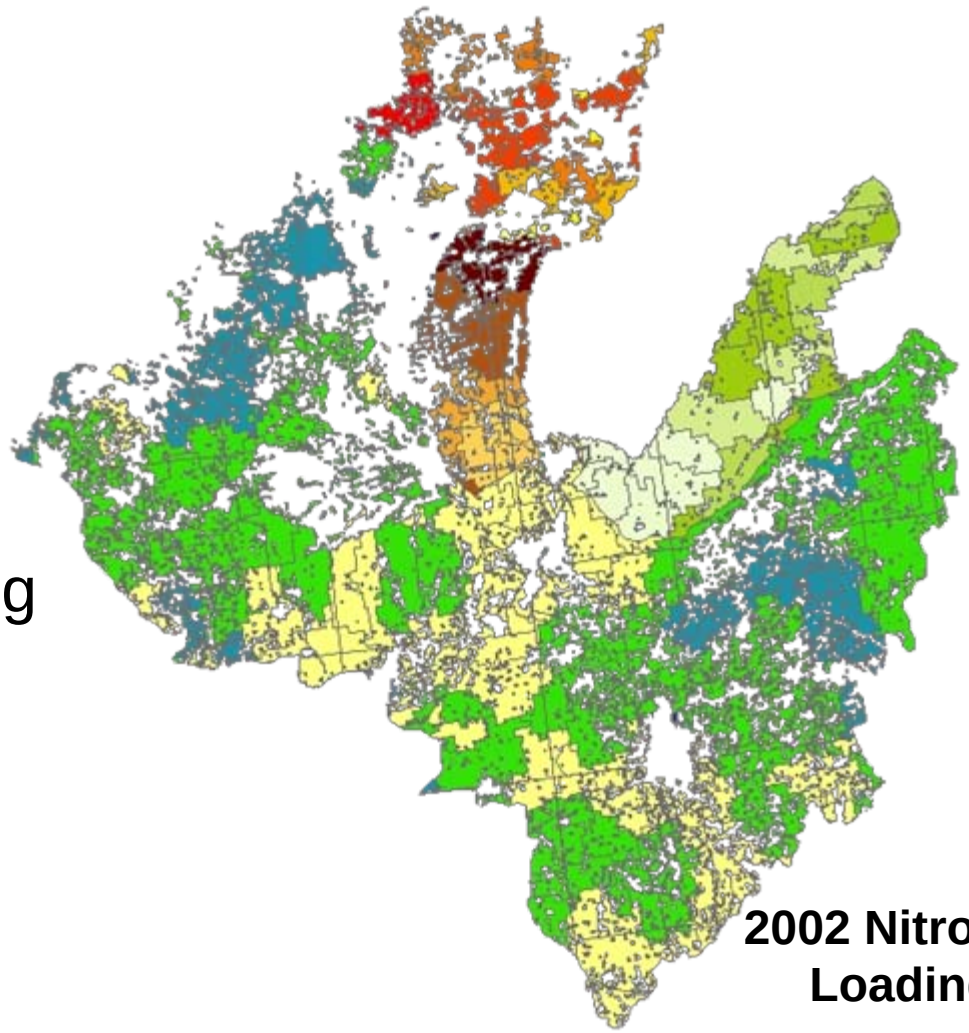

TP Point Sources in the Saginaw River Watershed (2004-2006)
Met. Ton. P/Year
0.01 - 0.10
0.10 - 0.25
0.25 - 0.50
0.50 - 1.00
1.00 - 2.50
2.50 - 5.00
5.00 - 10.00
10.00 - 25.00
>25
0 10 20 40 60 80 100
Kilometers
Carlo DeMarchi,
NOAA-GLERL


TP Point Sources in the Saginaw River Watershed (2004-2006)
Midland
Bay City
Saginaw
Genessee Co.
Montrose
Flint
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
0 10 20 40 60 80 100
Kilometers
Carlo DeMarchi,
NOAA-GLERL

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)



2002 Nitrogen Loading

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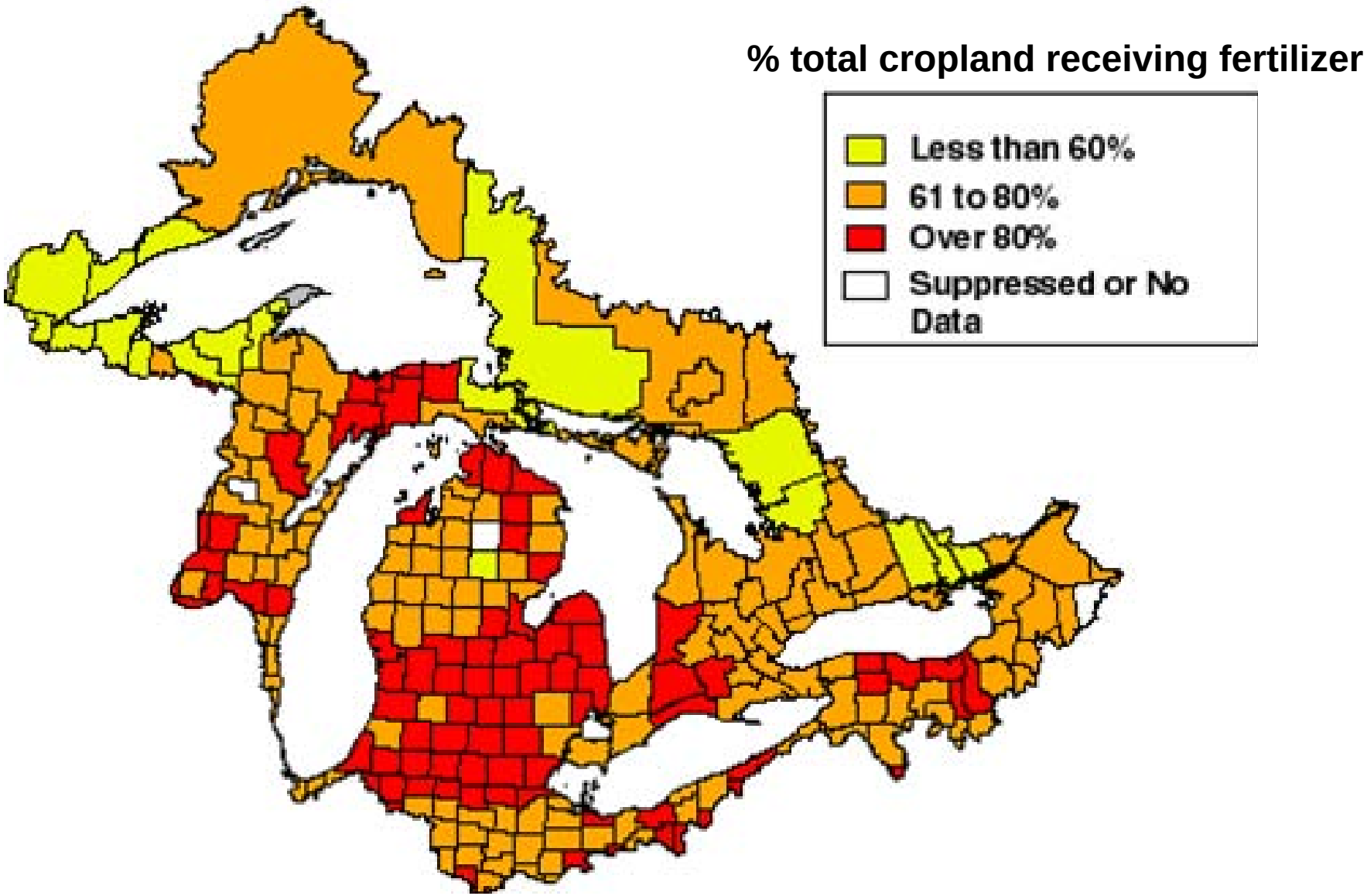
Fertilizer Use



Data from US EPA Great Lakes National Program Office

CSO and WWTP Fraction of Saginaw River TP Annual Load

	CSO/SSO Est. (Met. Ton)	WWTP Effluent (Met. Ton.)	Total P Load MDEQ (Met. Ton)	CSO's Fraction of Load (%)	WWTP Fraction of Load (%)
2000	1.78	--	--	0.50	--
2001	2.43	--	642	0.38	--
2002	3.02	--	513	0.59	--
2003	0.59	--	345	0.17	--
2004	2.98	116	724	0.40	17.2
2005	--	110	288	--	38.2
2006	--	128	--	--	--

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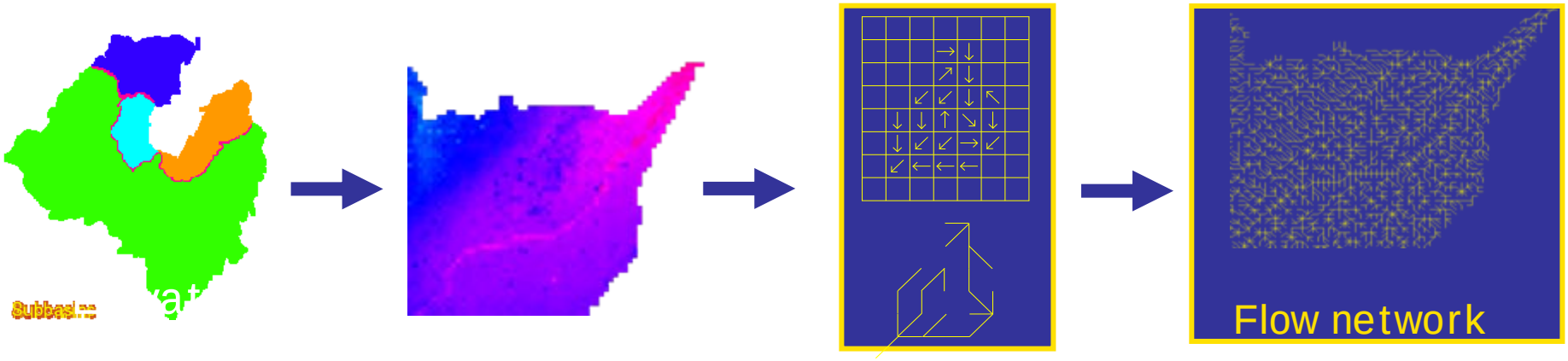
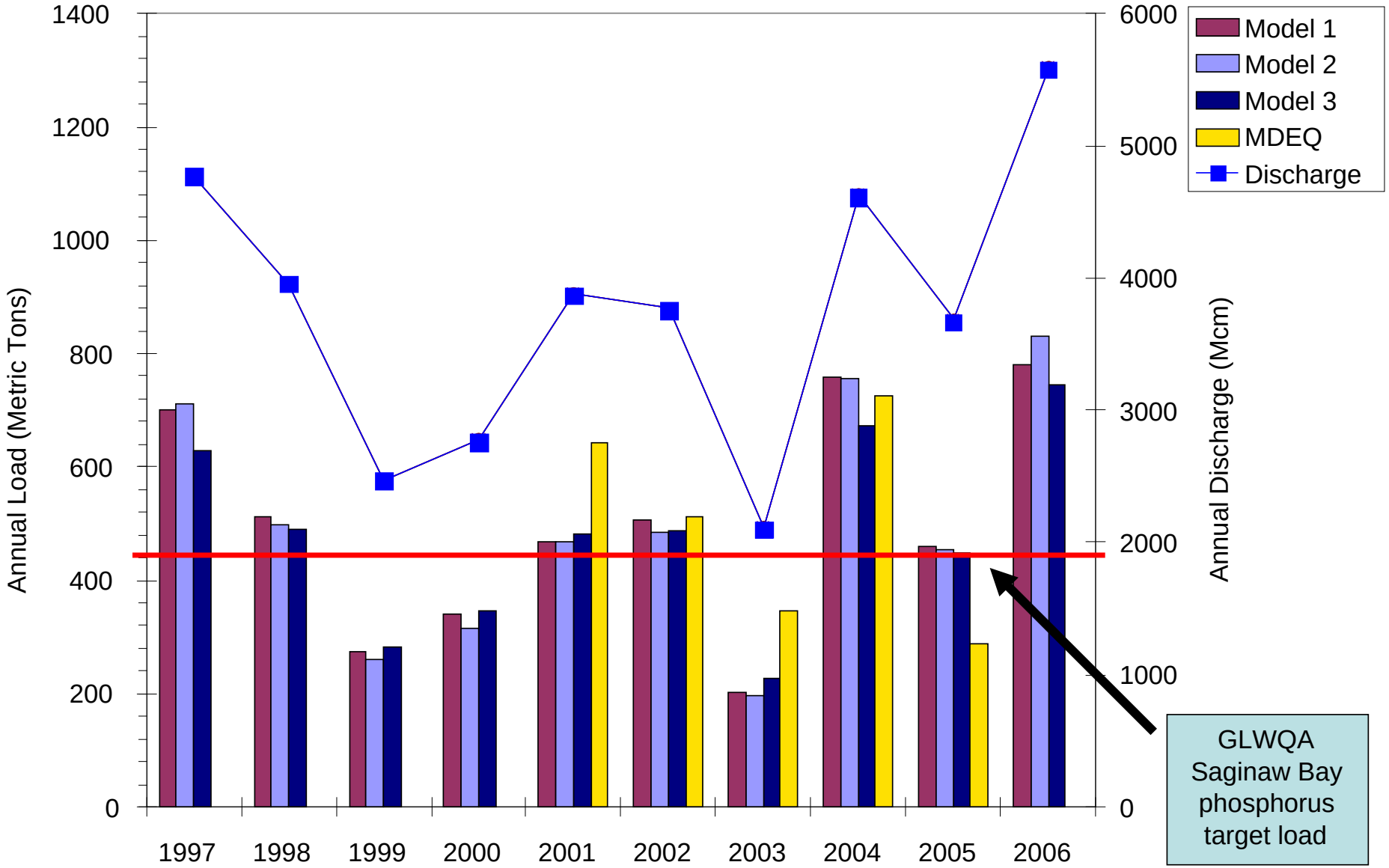
Modeling nutrient loading in Saginaw Bay watershed (DLBRM)

- 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)

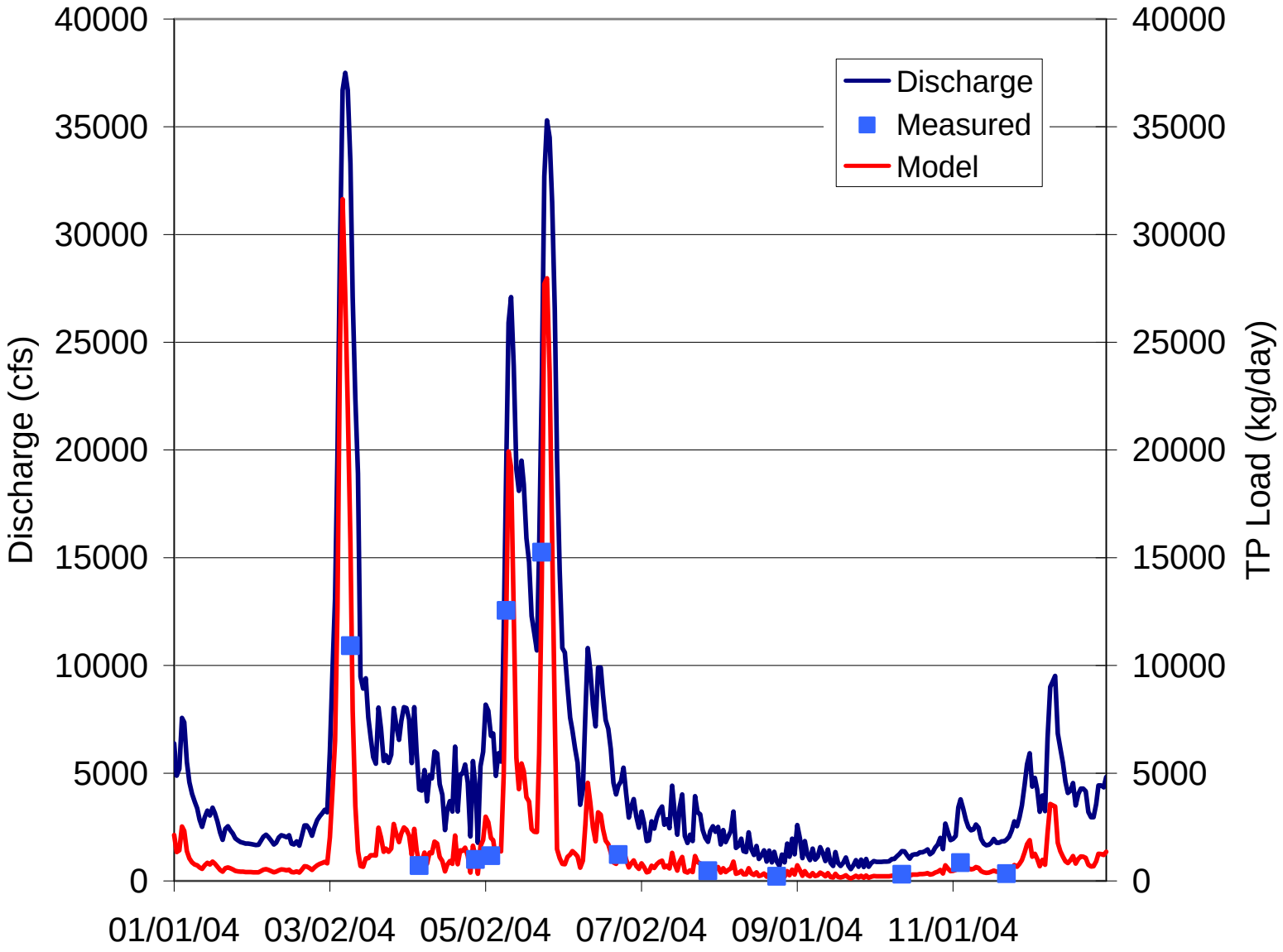


Annual total P load to Saginaw Bay

(Saginaw River watershed only)



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

Basin	Area (km^2)	Area (%)	2004-2006 WWTP Effluent (Met. Ton.)	2004-2006 WWTP Effluent (%.)	2004 Load (Met. Ton)	2005 Load (Met. Ton)	2006 Load (Met. Ton)
Saginaw	16,680	71.6	119	85.6	716	374	788
AuGres/ Rifle	2,777	11.9	4.2	3.0	119	62	131
KawKawlin / Pine	1,409	6.0	5.8	4.0	61	31	67
Pigeon/ Wiscoggin	2,425	10.5	10.3	7.4	104	55	115
Total	23,291		139		999	521	1099

* Average projected values

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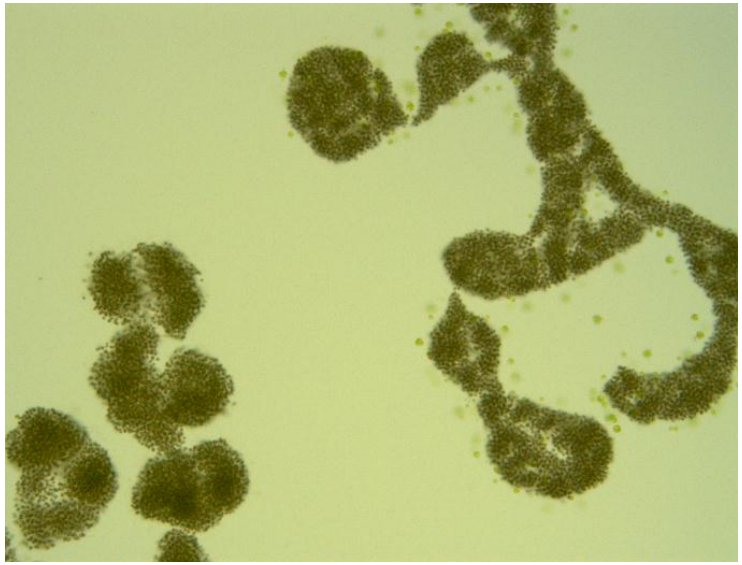
What does impacted water quality look like for Saginaw Bay?

Microcystis blooms

Microcystis in the Great Lakes

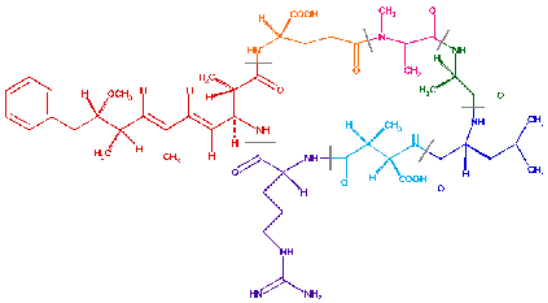
- Colonial harmful algal bloom species (HAB)
- Forms blooms and scums
  - Taste/odor issues
  - Loss of recreational and fishing value to affected waters
  - Hypoxia/anoxia, may lead to mortality in benthic invertebrate community and fish kills



Microcystis

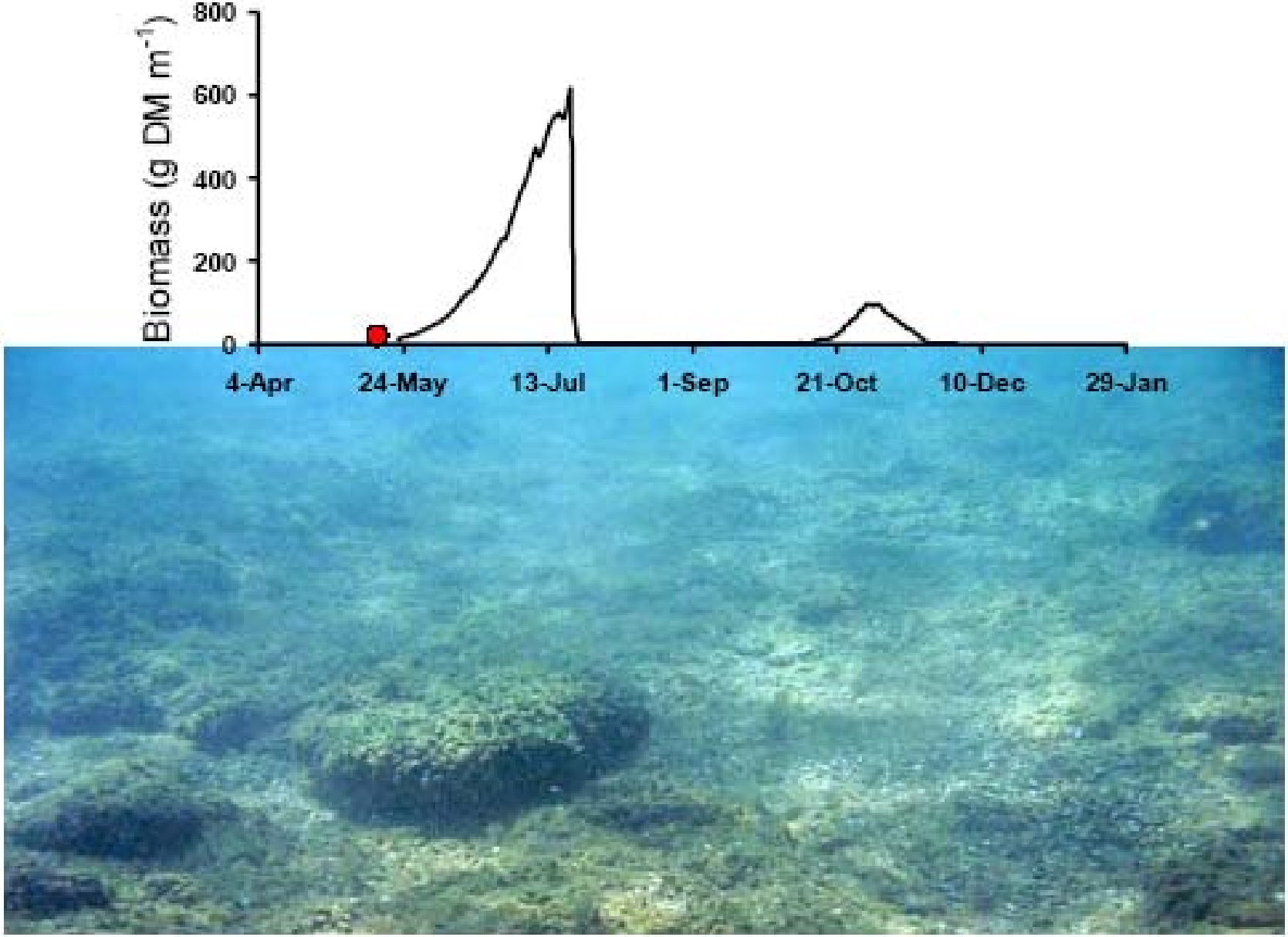
Put-In-Bay, August 2004

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



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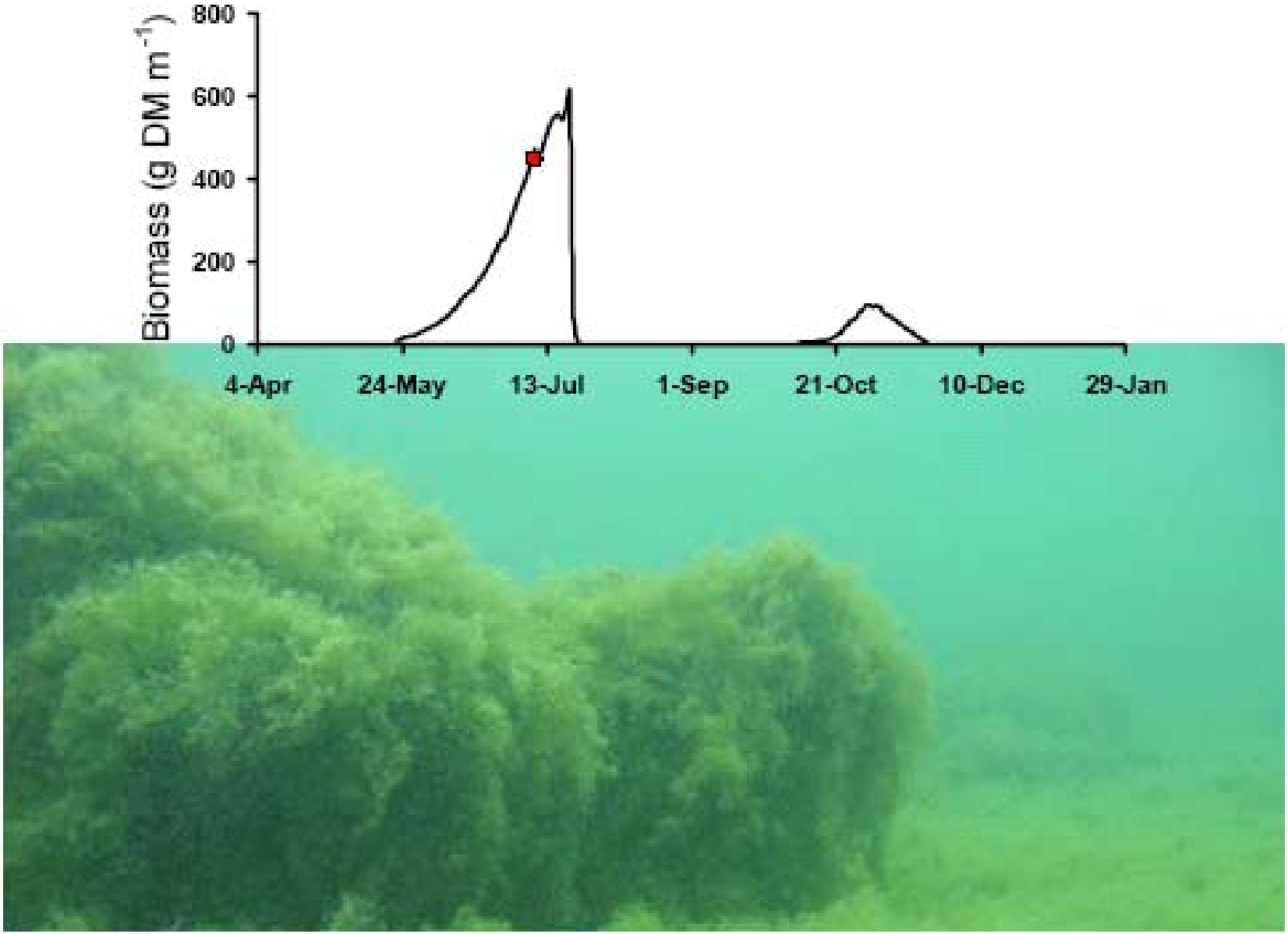

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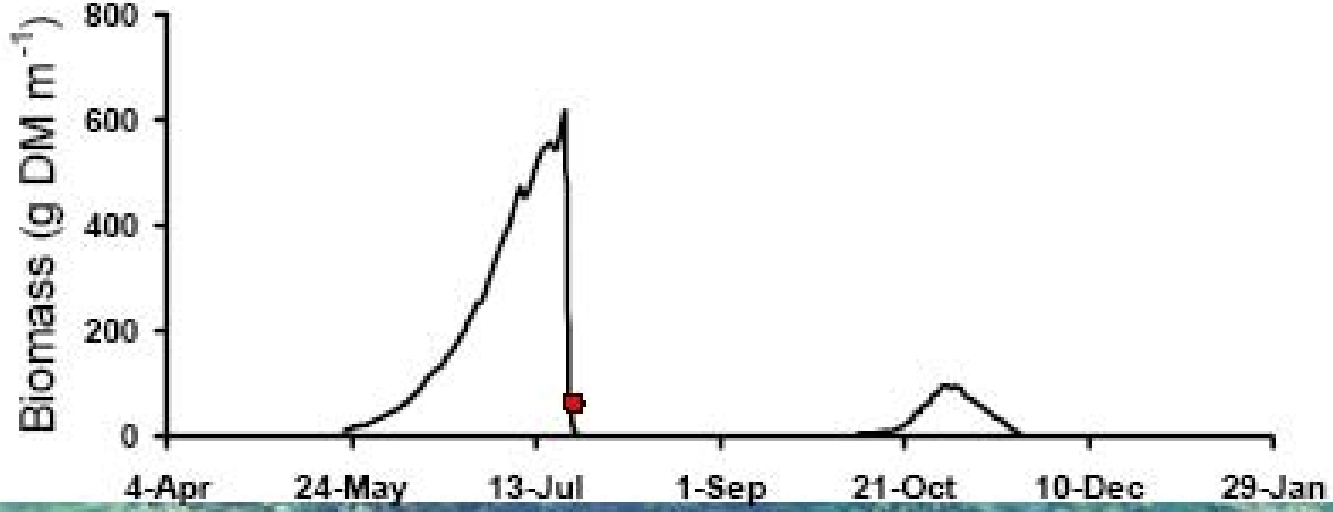

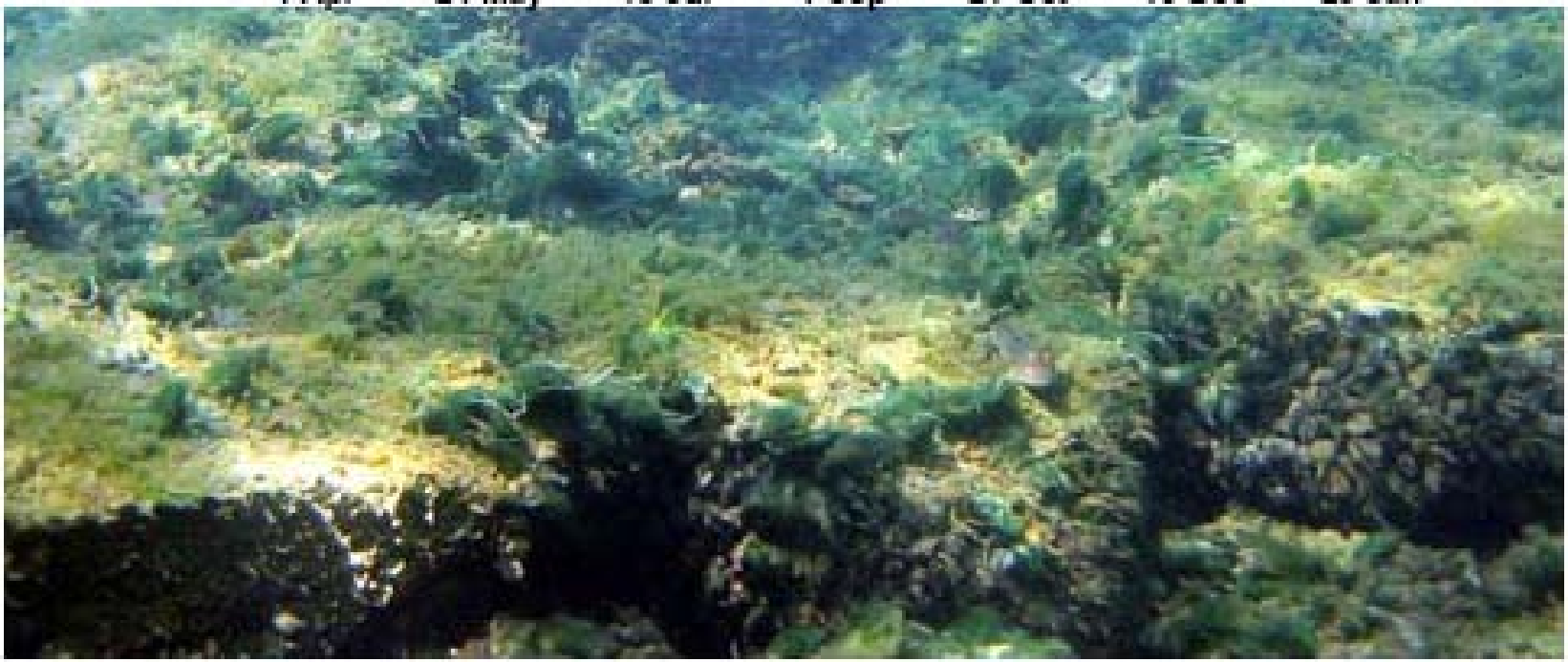

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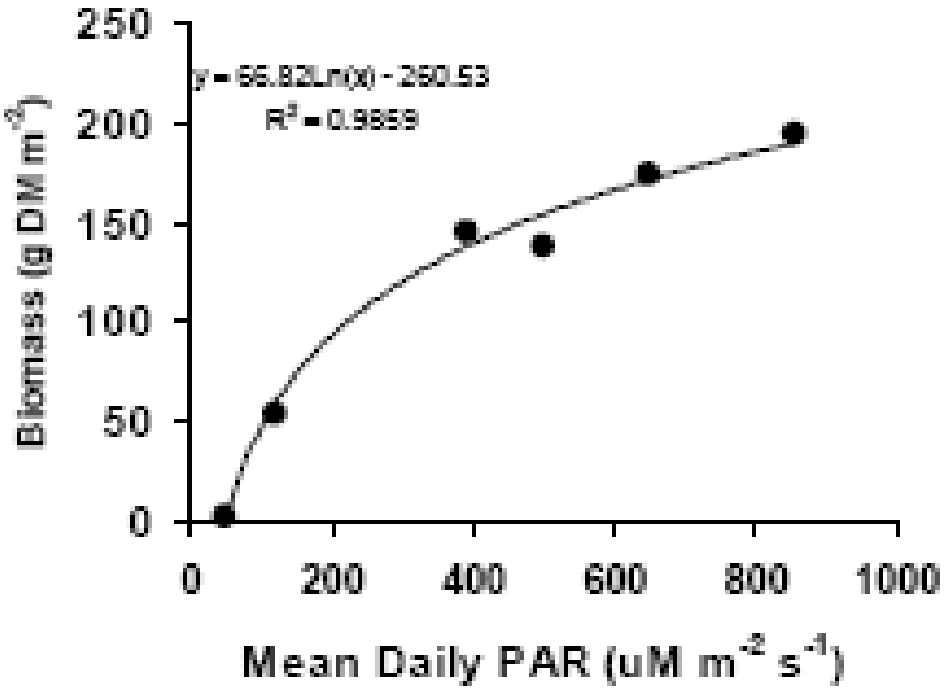
Limits of *Cladophora* distribution

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



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In situ Phosphorus Additions

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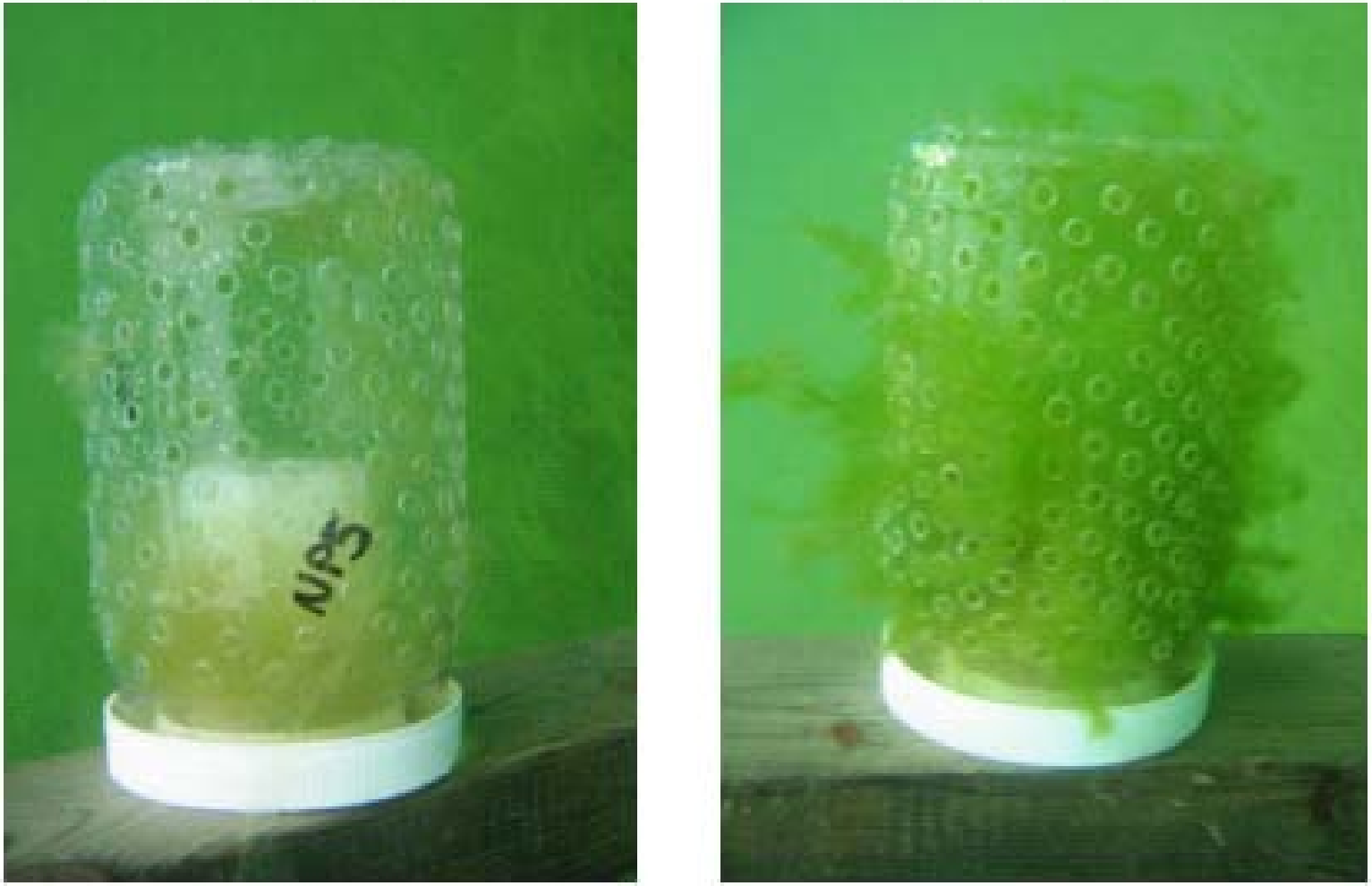
No P Added **P Added**



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.

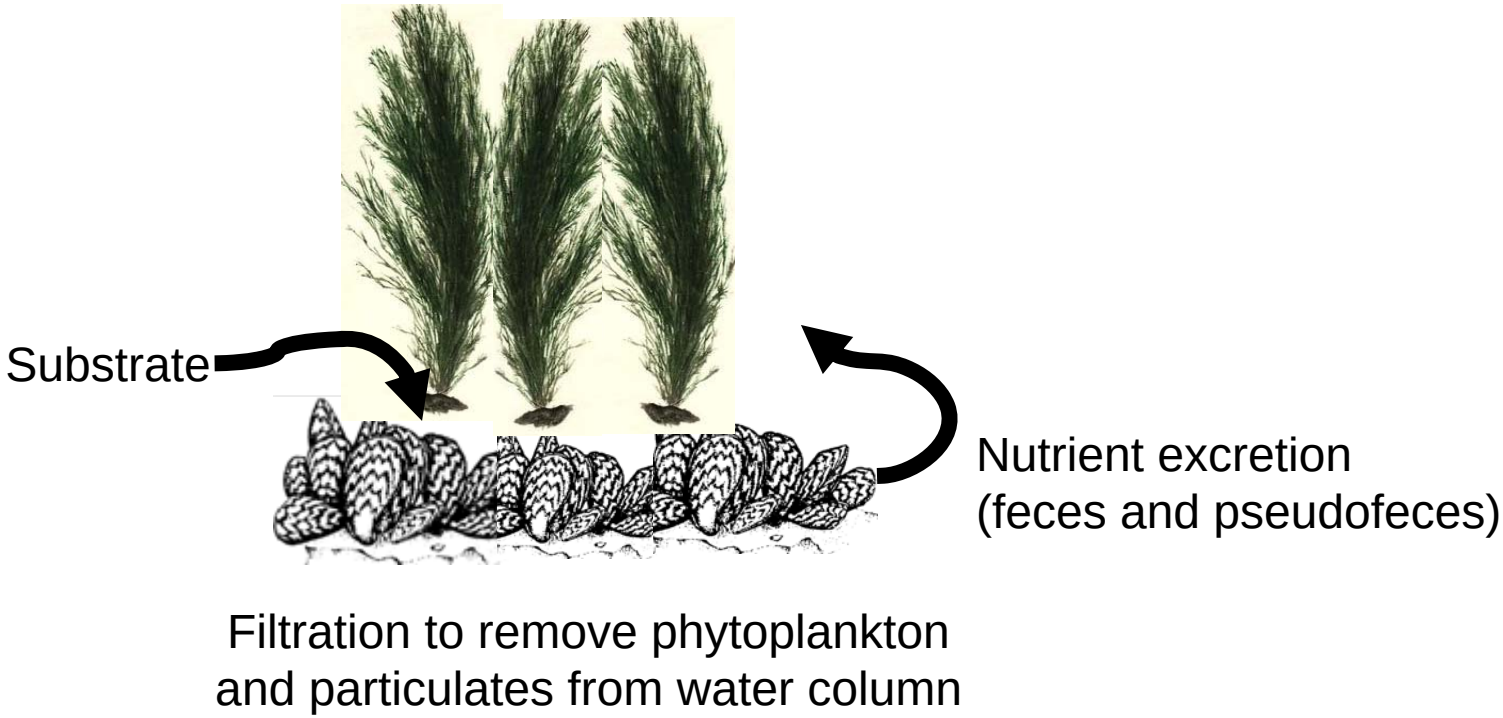
Sean Mechelen

DISTINGUISHING FEATURES

year. They also multiply rapidly and consume

Mussels promote benthic algal growth

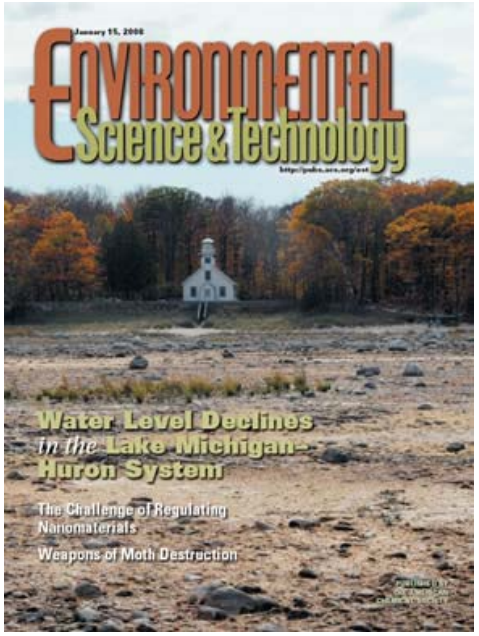
- Improves water clarity for increased light penetration
- Provide hard substrate for attachment
- Localized nutrient excretion
  - remineralization of N, P
  - more rapid nutrient cycling



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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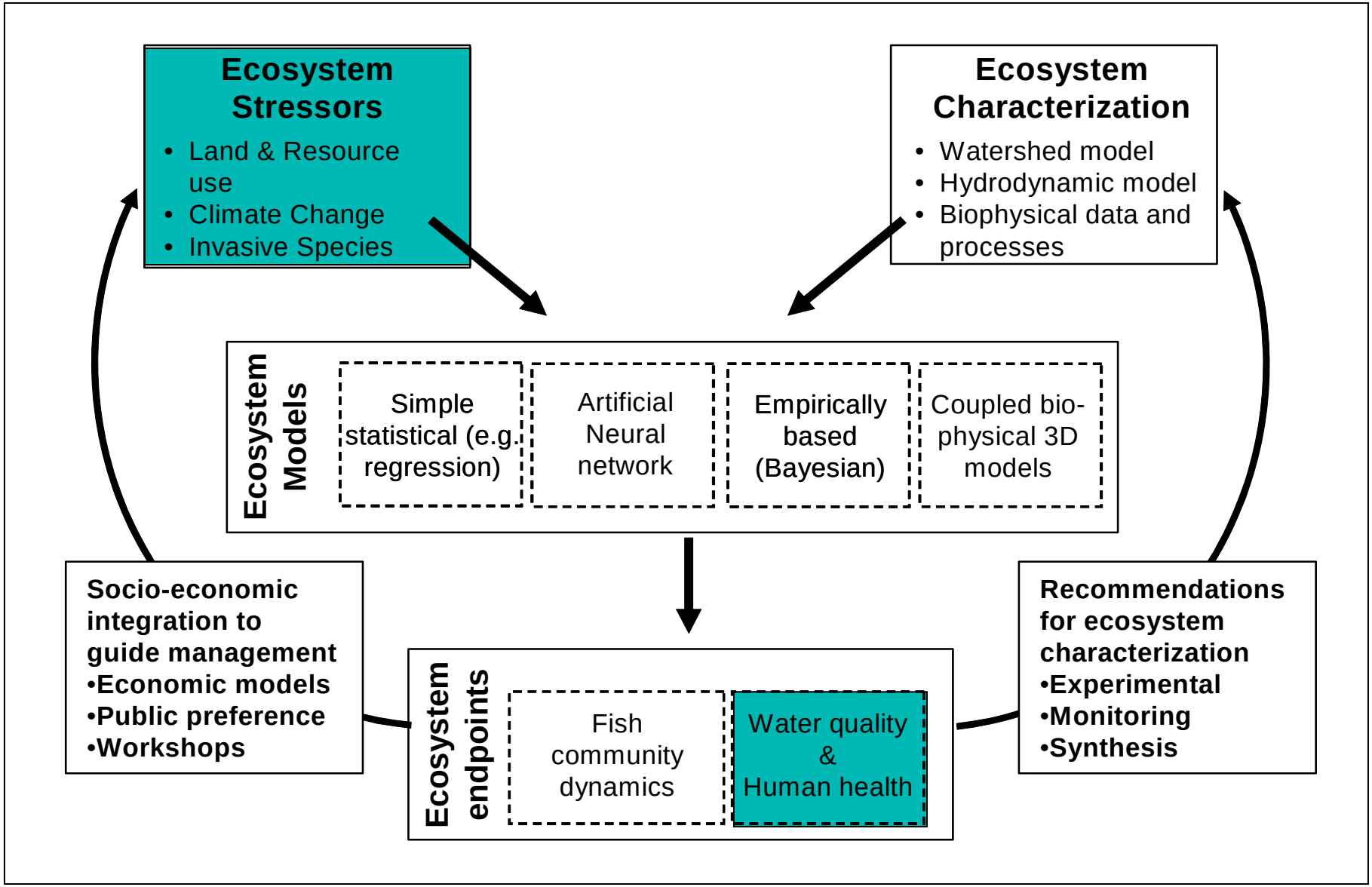
Adaptive Integrated Framework (AIF): a new methodology for managing impacts of multiple stressors in coastal ecosystems

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

Saginaw Bay
Multiple Stressors


Ecosystem Stressors
• Land & Resource use
• Climate Change
• Invasive Species
Ecosystem Characterization
• Watershed model
• Hydrodynamic model
• Biophysical data and processes
Ecosystem Models
Simple statistical (e.g. regression)
Artificial Neural network
Empirically based (Bayesian)
Coupled bio-physical 3D models
Socio-economic integration to guide management
•Economic models
•Public preference
•Workshops
Ecosystem endpoints
Fish community dynamics
Water quality & Human health
Recommendations for ecosystem characterization
•Experimental
•Monitoring
•Synthesis

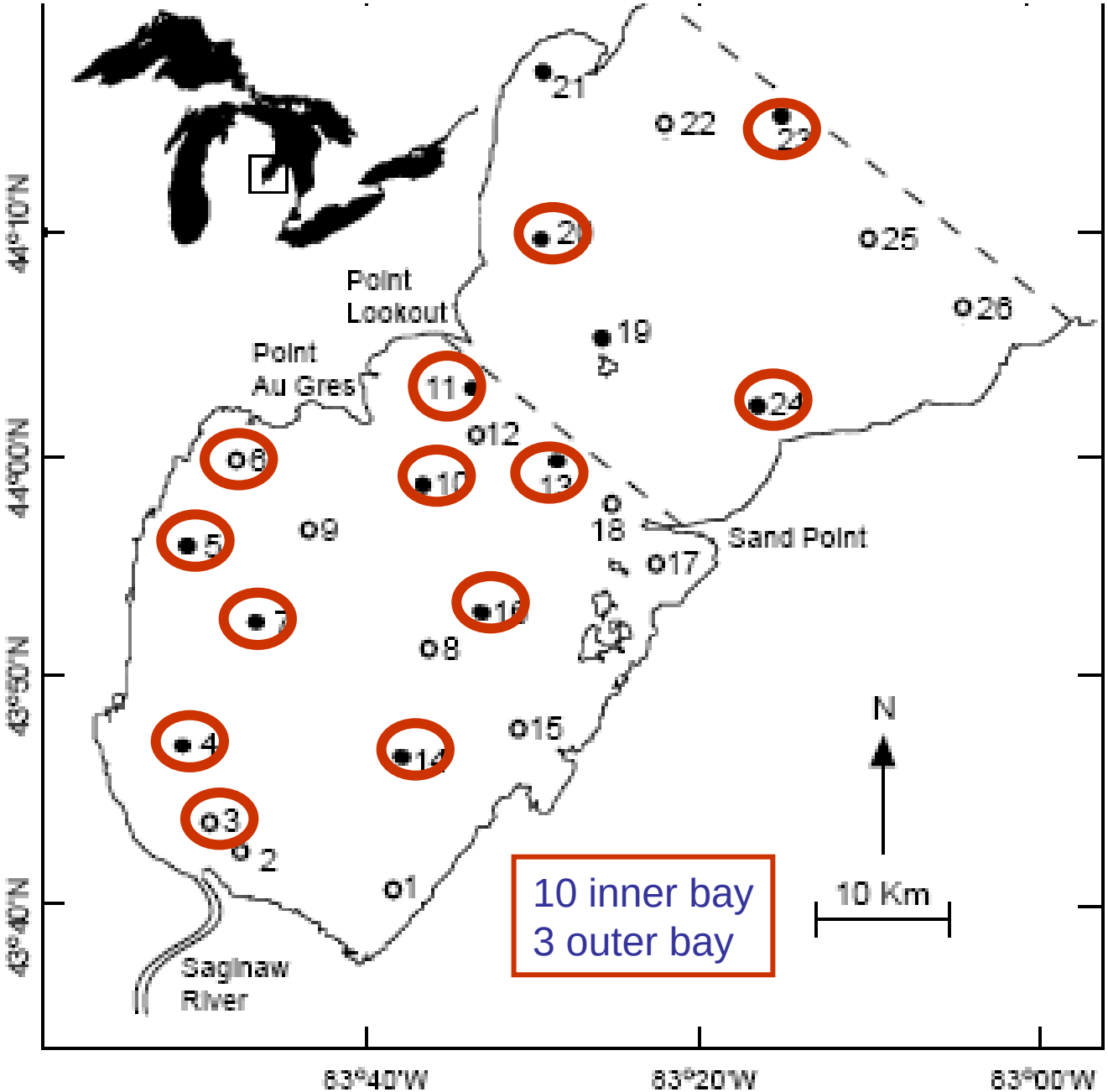
Goals of Multiple Stressors project

- 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



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

NOAA


Thank you!