The Ohio State University

Harmful Algal Blooms in Lake Erie

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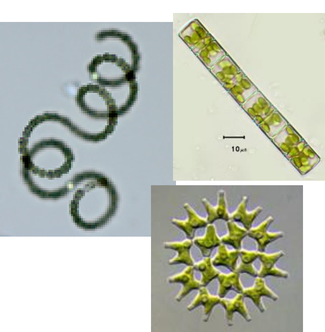
Most algae are not "bad" for lakes

- Algae are tiny plant-like organisms
- 50% of Earth's oxygen produced by algae
  - Every other breath you take, thank algae
- Base of the lake food web
  - "Good" Algae are food for zooplankton
  - Zooplankton are food for small fish

Algae



Food

Oxygen

Zooplankton (small shrimp-like creatures)

Small fish

There are hundreds of species of algae in lakes

Algae need: Sunlight, fertilizers, carbon dioxide

Lake Erie produces the most fish of all the Great Lakes because it has the most algae

- Highest nutrient concentrations
- Warmest water temperature

- Lake Erie
  - 50% of fish
  - 2% of the water
- Lake Superior
  - 2% of fish
  - 50% of water

Too much of the wrong kind of algae is harmful

- Harmful =
  - Has the potential to produce toxins.
  - Harmful impacts on ecosystems
- Algal =
  - Blue-green algae (cyanobacteria)
  - Red tide (dinoflagellates)
- Bloom =
  - Biomass that far exceed normal

Harmful algal blooms are a global problem

- Due to excess nutrients loading from…
  - Fertilizers, manure, lawn care, sewage
  - If it grows plants, it will go algae

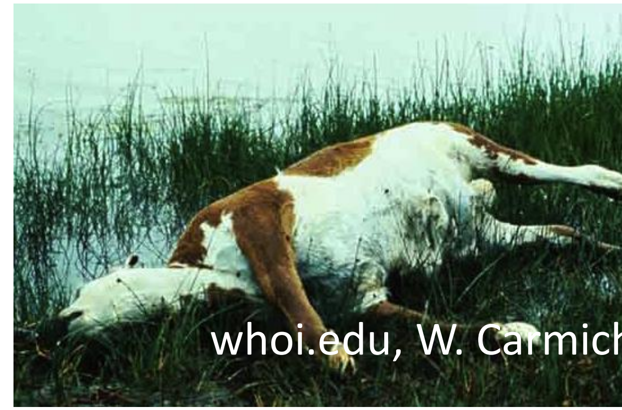
Lake Erie, USA

Lake Taihu, China

Lake Nieuwe Meer, Netherlands

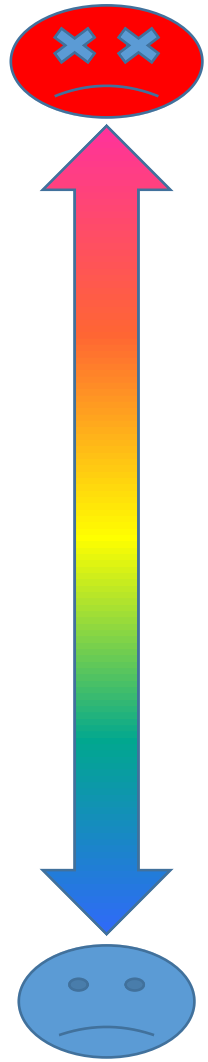
Problems associated blooms

- Produce toxins
- Taste and smell problems
- Negative economic impacts
  - Lake front restaurants and shops
  - 1200 fishing charter captains in Ohio
  - Cedar Point and other tourism
- Property value decreases
  - $2.2 Billion per year in USA (2006 estimate)
- Food web
  - Cyanobacteria not consumed by zooplankton
  - Good algae dies off



Toxicity of Algal Toxins Relative to Other Toxic Compounds found in Water

- **Reference Dose = amount that can be ingested orally by a person, above which a toxic effect may occur, on a milligram per kilogram body weight per day basis.**



Toxin Reference Doses

- Dioxin (0.000001 mg/kg-d
- **Microcystin LR** (0.000003 mg/kg-d)
- **Saxitoxin** (0.000005 mg/kg-d)
- PCBs (0.00002 mg/kg-d)
- **Cylindrospermopsin** (0.00003 mg/kg-d)
- Methylmercury (0.0001 mg/kg-d)
- **Anatoxin-A** (0.0005 mg/kg-d)
- DDT (0.0005 mg/kg-d)
- Selenium (0.005 mg/kg-d)
- Botulinum toxin A (0.001 mg/kg-d)
- Alachlor (0.01 mg/kg-d)
- Cyanide (0.02 mg/kg-d)
- Atrazine (0.04 mg/kg-d)
- Fluoride (0.06 mg/kg-d)
- Chlorine (0.1 mg/kg-d)
- Aluminum (1 mg/kg-d)
- Ethylene Glycol (2 mg/kg-d)

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Microcystin was first termed *"Fast death factor"* in the early 1900s

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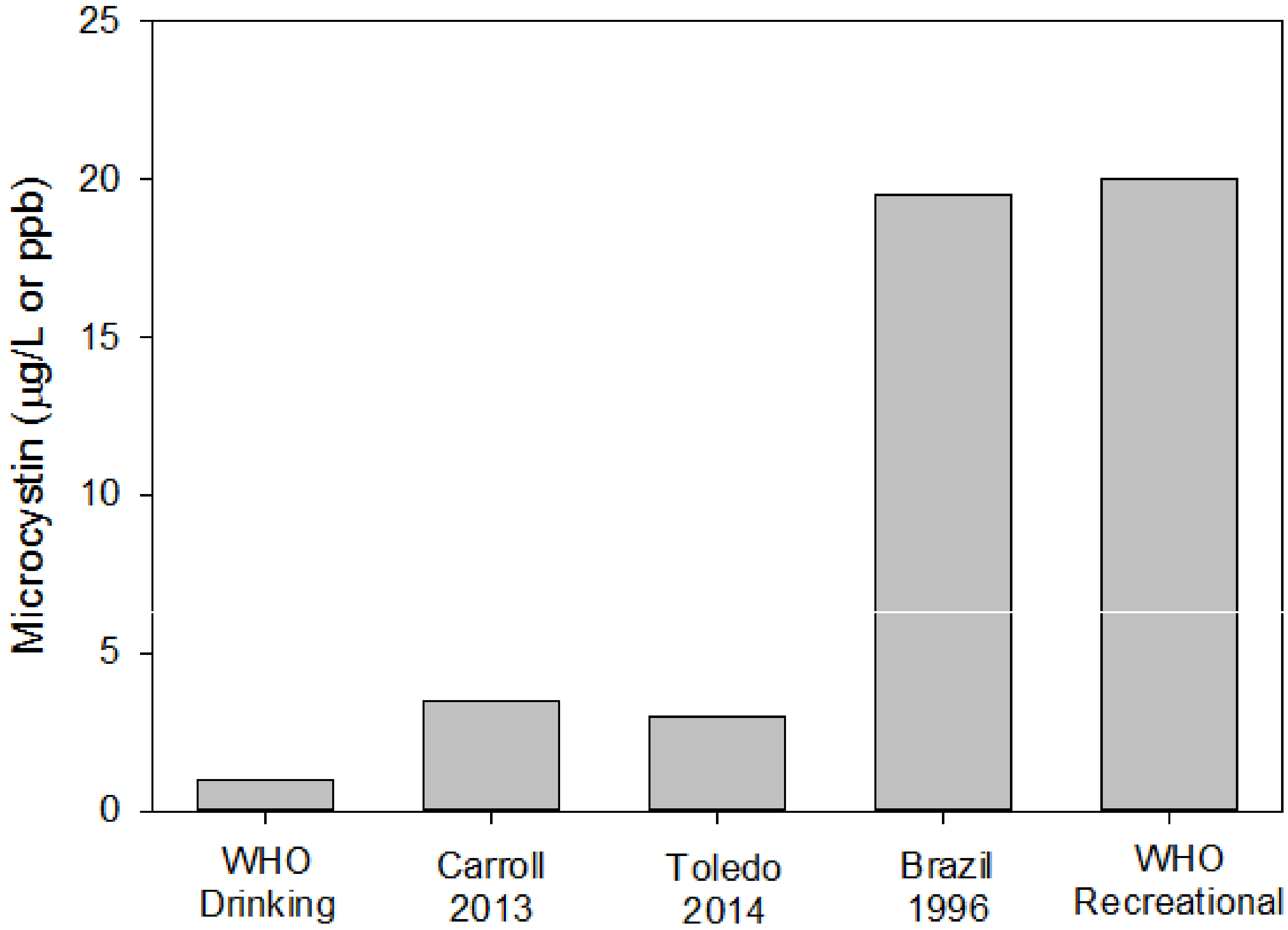
Microcystin

- "Fast Death Factor"
- Responsible for Toledo water crisis
- Produced by cyanobacteria (aka Blue-green algae)
- Targets the liver
  - Fatal at acute high doses
  - Tumor promoter over prolonged exposure
- Early life stages of fish very sensitive
  - Walleye, trout, salmon most sensitive
  - Carp, catfish, sunfish less sensitive

Recent microcystin cases

- Carroll and Toledo Ohio (2013, 2014)
  - Do not drink advisory for 3 days
  - 2000 and 500,000 people
- Wuxi, China (2007)
  - Do not drink advisory for 14 days
  - 2 million people
- Brazil (1988, 1996)
  - 164 Human fatalities due to microcystin in water used for dialysis

Recent microcystin cases



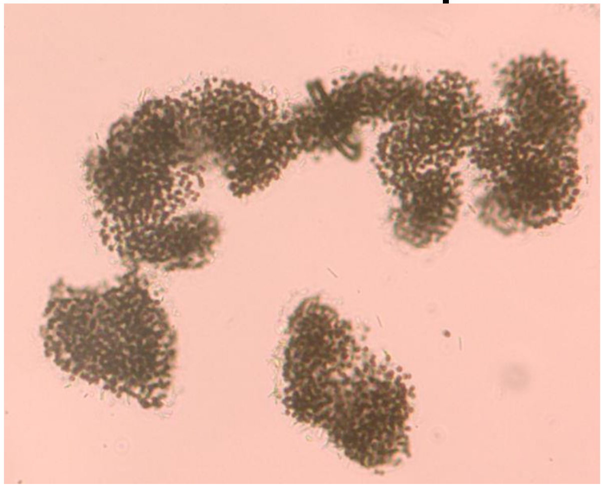
Lake Erie in 2011 had microcystin concentrations that exceeded 1000 ppb

Toledo Water Crisis

- A weekend without safe water
  - Saturday through Monday
  - Half million people without safe water
- Toledo area hospitals cancelled all surgeries during the crisis. – Human Health
- Businesses closed. – Economic impact
- City of Toledo spends an extra $10,000 / day to treat water during blooms. Nearly $1,000,000 during a bad bloom summer.

Lake Erie harmful algal blooms

- Lake Erie blooms are a type of Cyanobacteria called *Microcystis*
  - Also called "blue-green algae"
  - Technically not algae, but are bacteria
  - Require sunlight like algae
- Produce the toxin microcystin that was responsible for Toledo's water crisis



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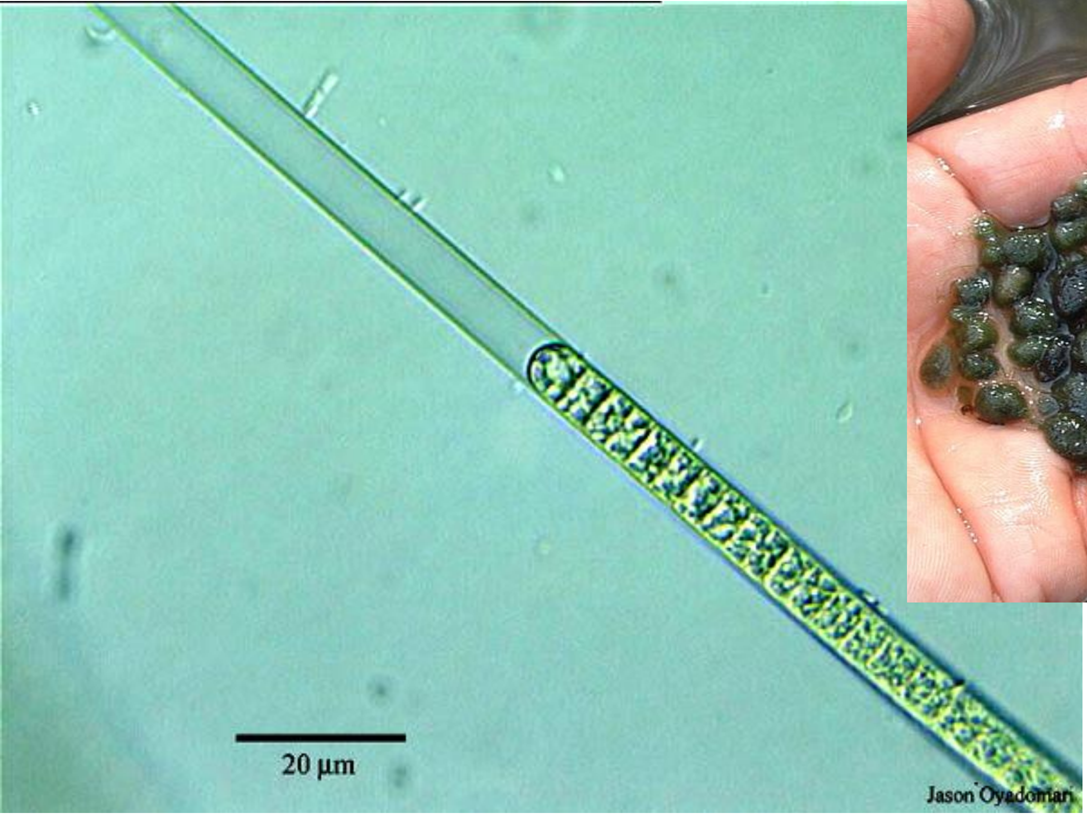
Lyngbya in Put-in-Bay



http://cfb.unh.edu/phycokey/phycokey.htm

Brief Lake Erie harmful algal bloom history

- Mid 1900s: “Dead Lake” by Time magazine
  - Bad blooms, fish kills, burning rivers
- 1980s: Lake recovers
  - Poster child for ecosystem recovery
  - Walleye capital of the world
  - No blooms
- Since 2002: Annual blooms
- 2011: Worst bloom in history (this photo)
- 2014: Toledo water crisis

National Geographic

Lake Erie *Microcystis* in 2011

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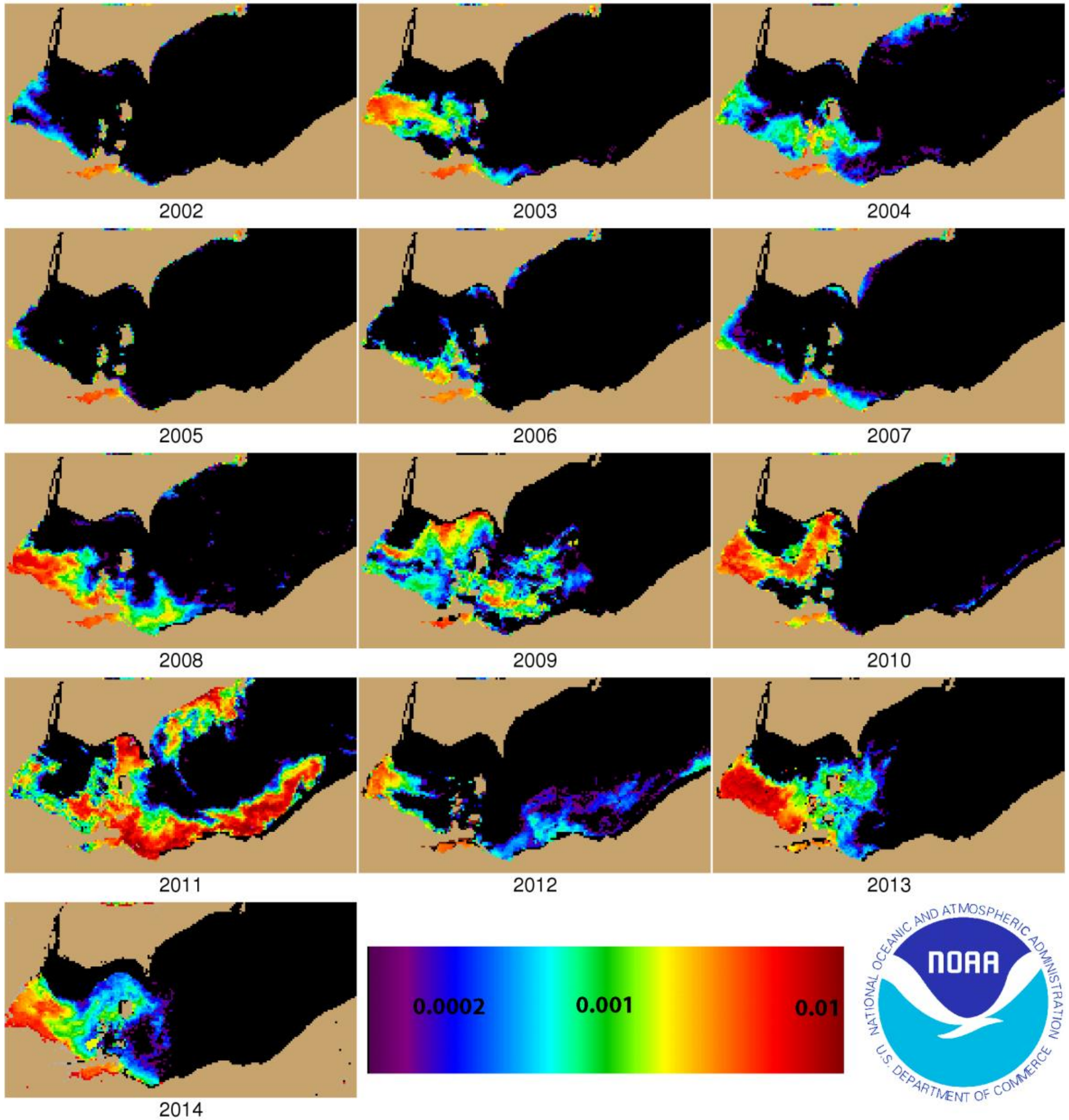
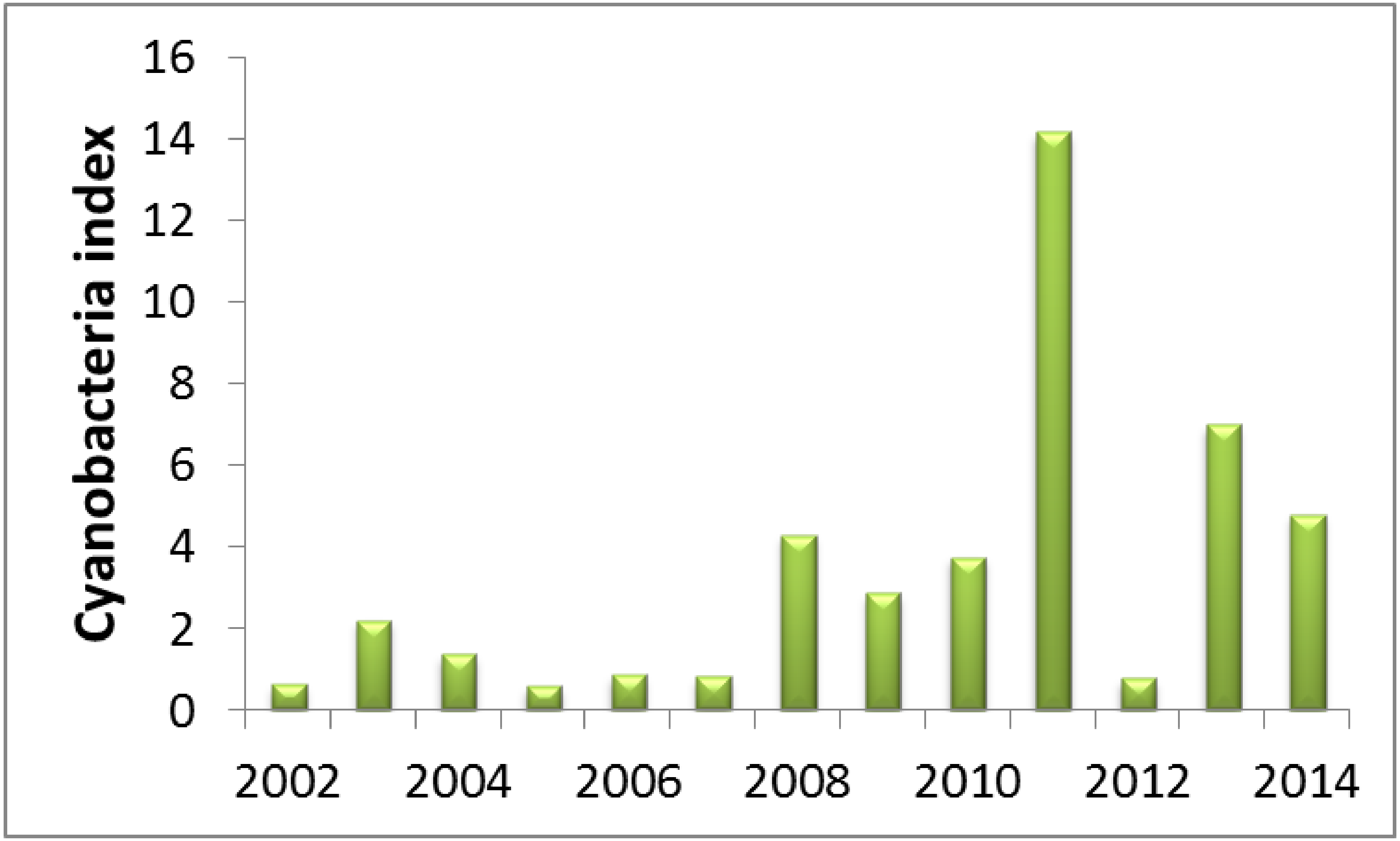
13 Years of Satellite Bloom Data

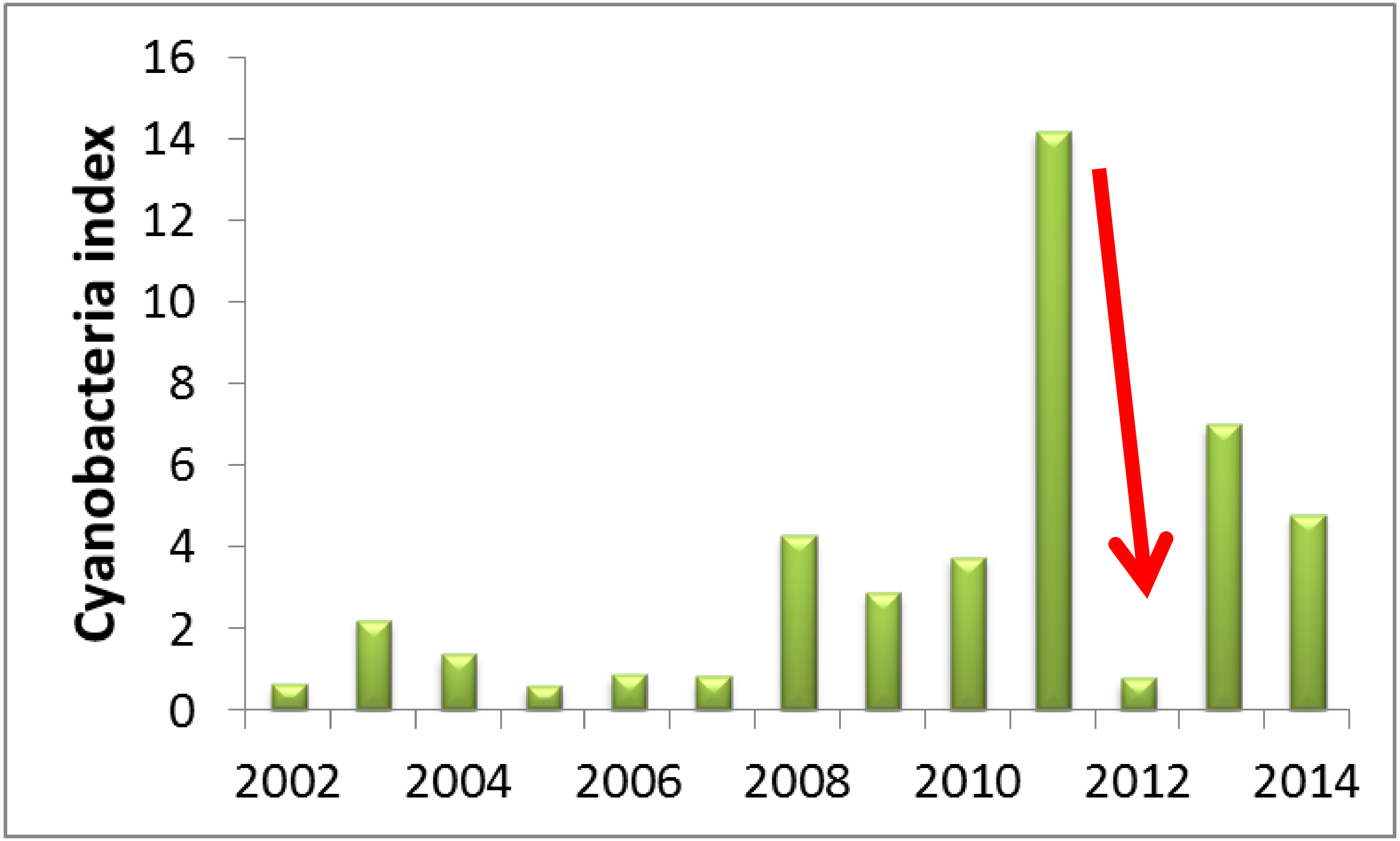


Cyanobacteria in Lake Erie



Stumpf et al. 2012
PLoS One

Lake Erie can recover from blooms in one year!



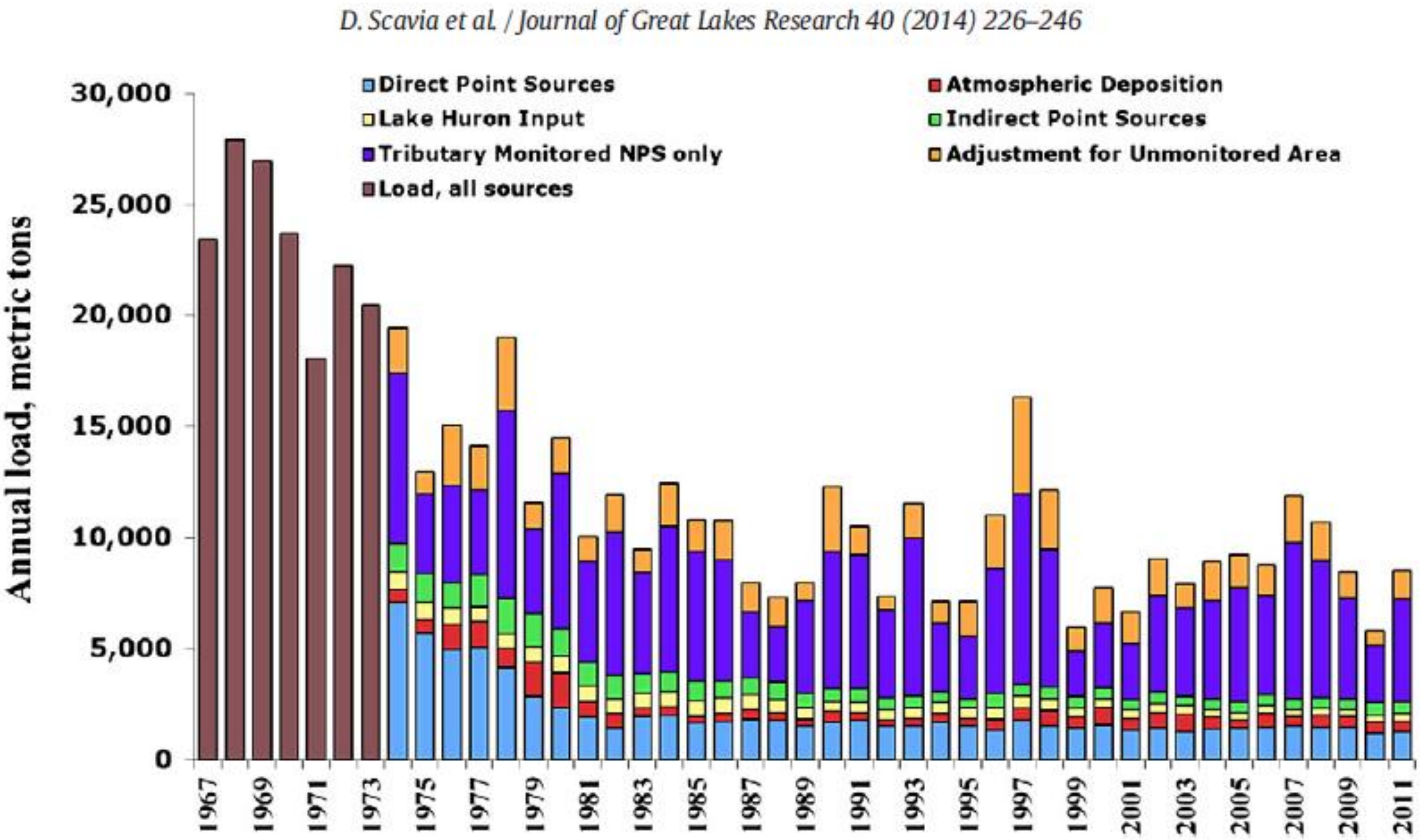
High phosphorus concentrations are required for harmful algal blooms

+ Carbon
+ Nitrogen
+ Phosphorus
Dense algal bloom

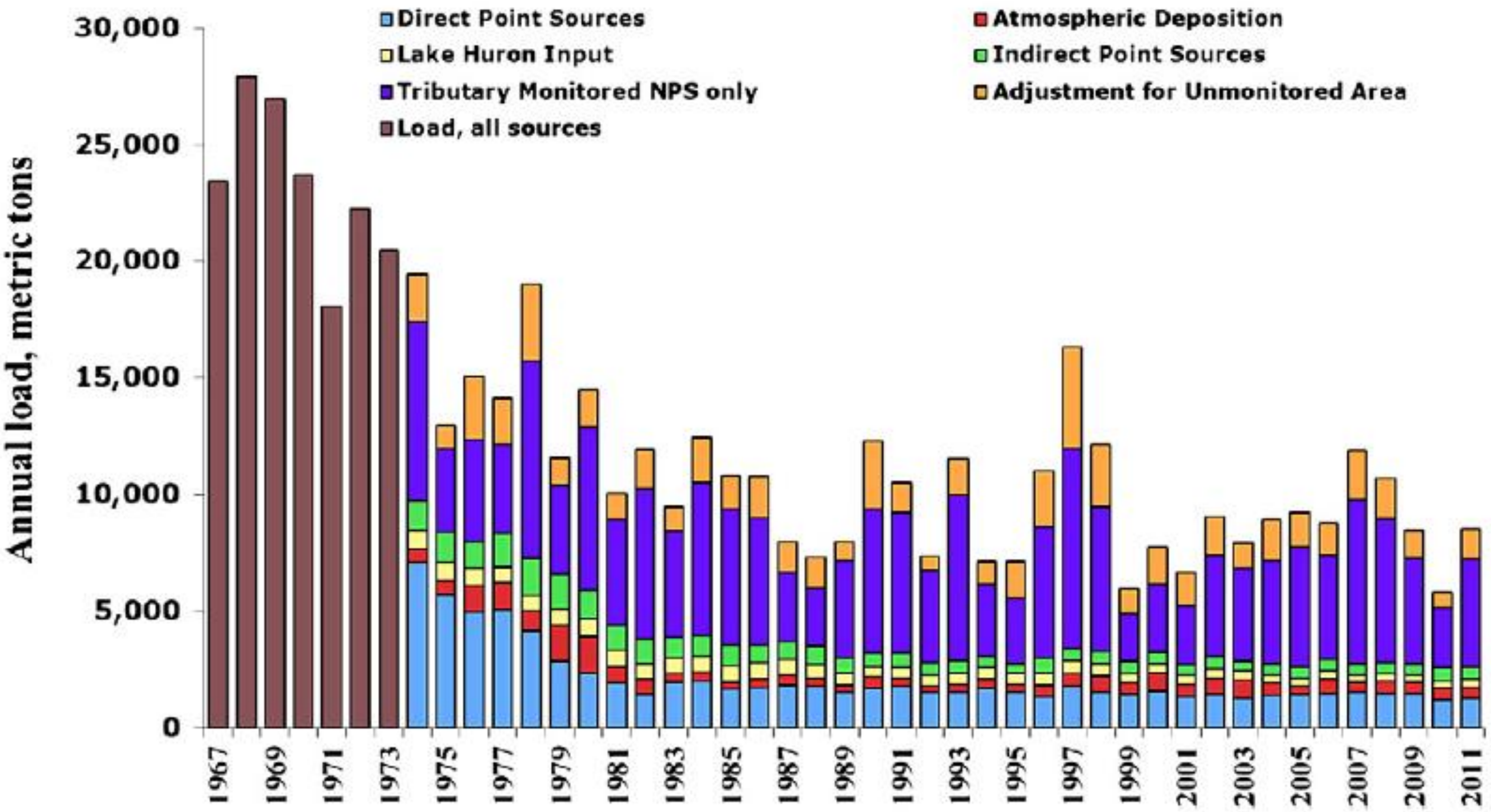
+ Carbon
+ Nitrogen
No Phosphorus added
No algal bloom

Schindler 1974. Science

Where does Lake Erie get its phosphorus from?

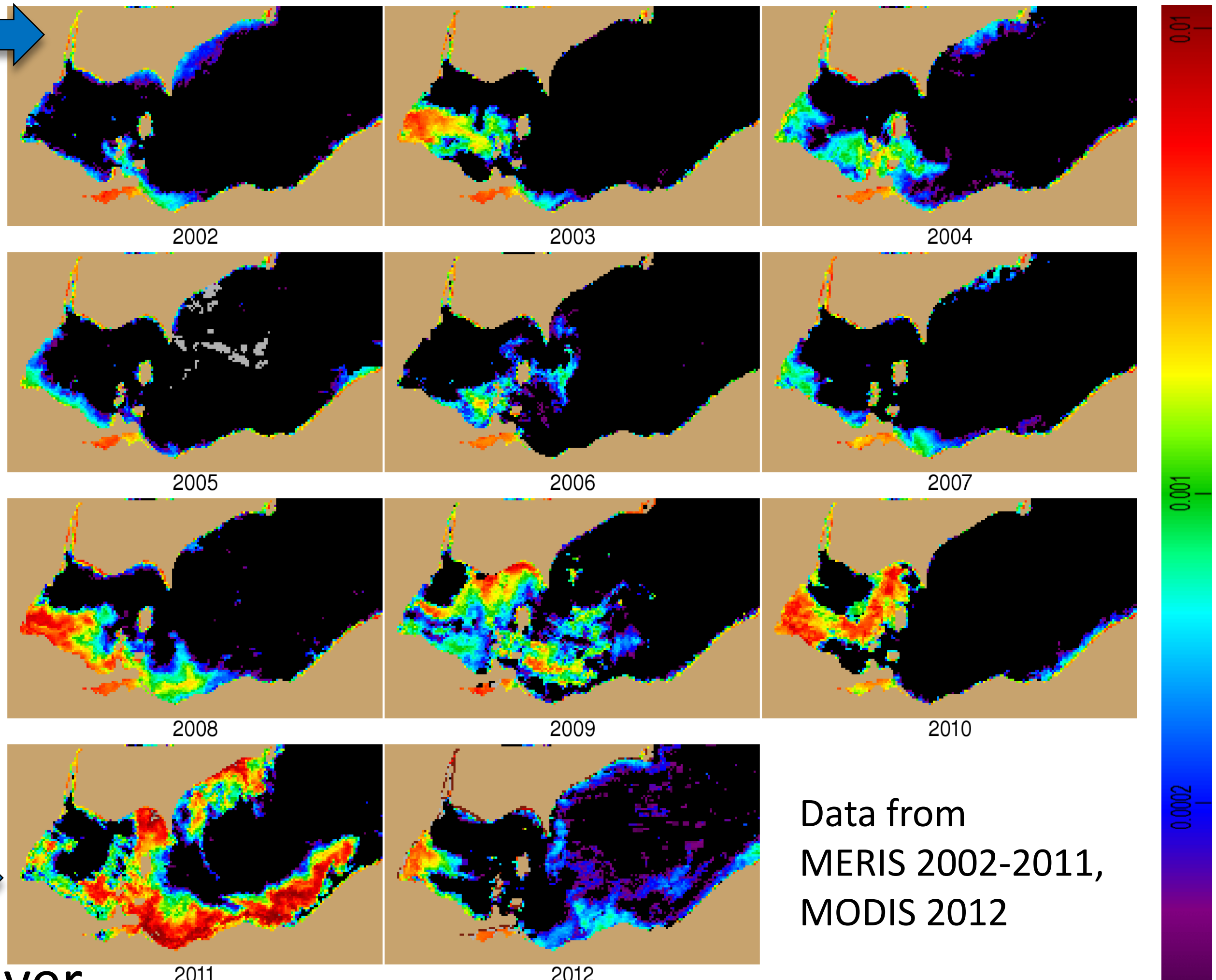


Point sources unchanged since early 1980s. Non-point sources change with year.



Blooms form near mouth of Maumee River, *NOT the Detroit River*

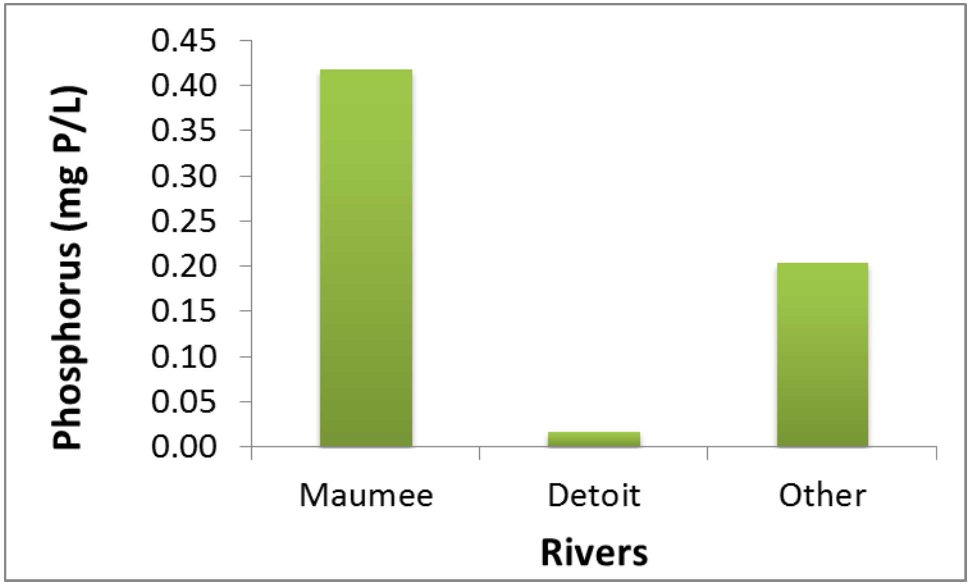
Detroit River



Maumee River

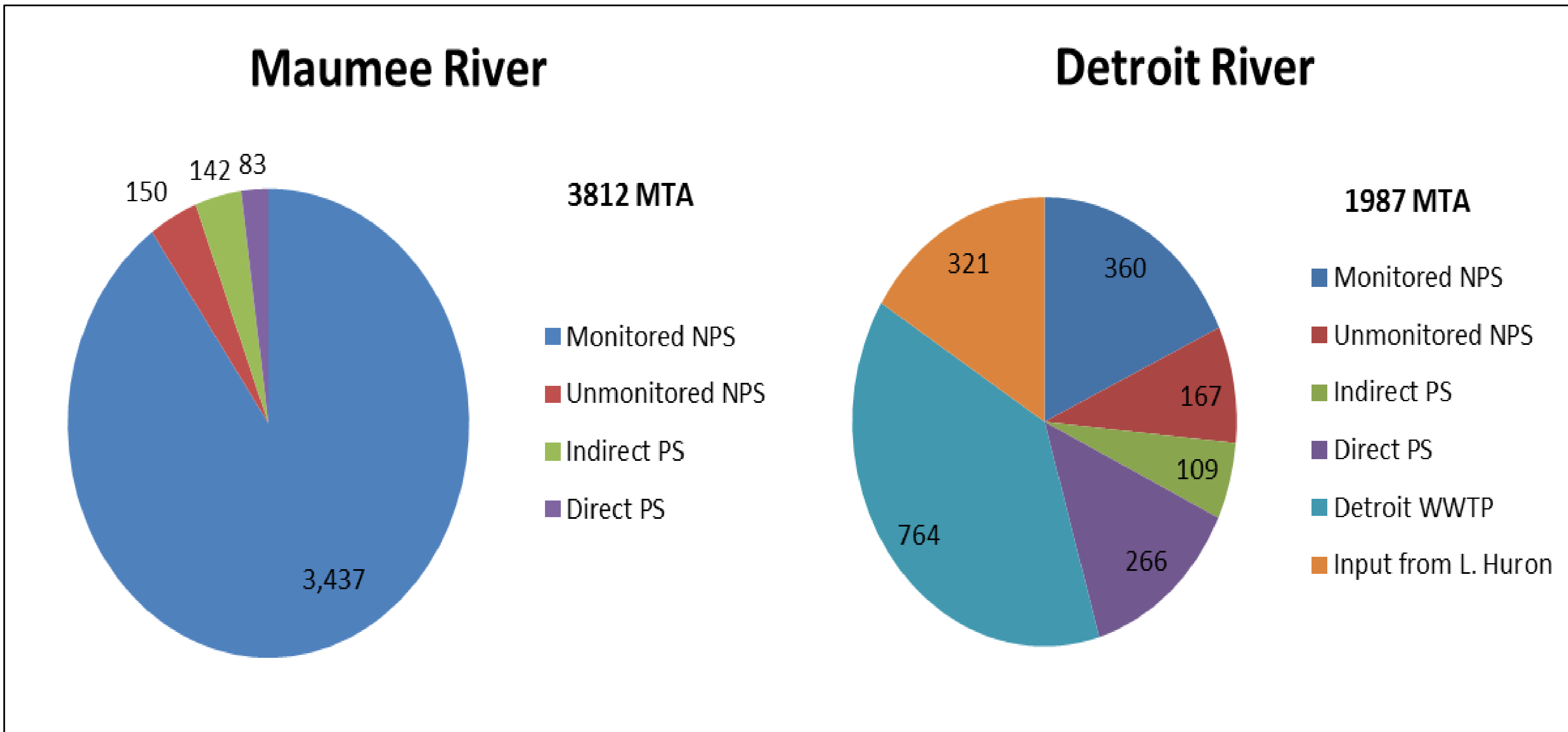
Data from MERIS 2002-2011, MODIS 2012

Phosphorus concentrations in Maumee River are very high, whereas very low in the Detroit River

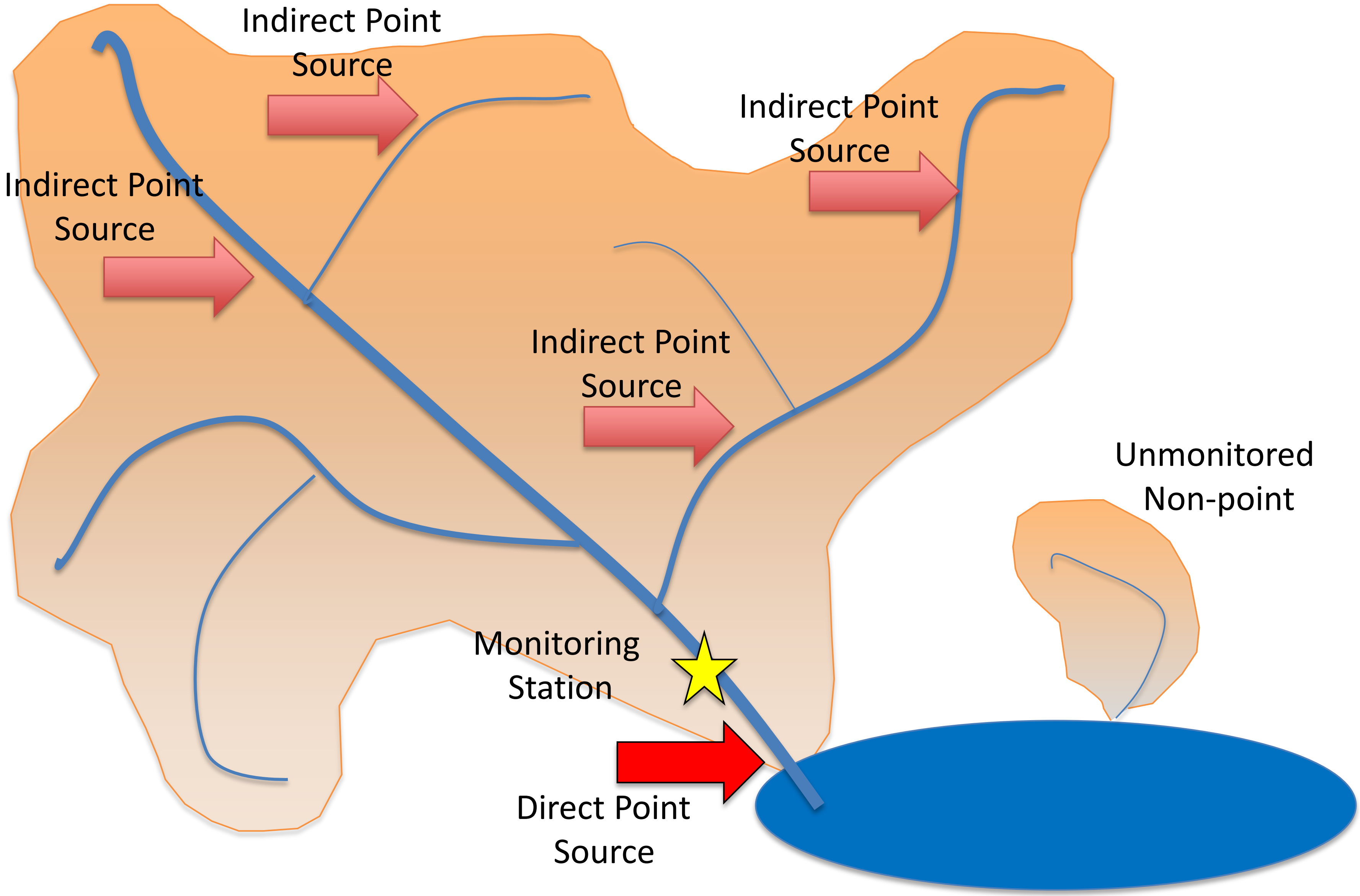


2010 – 2013 Average

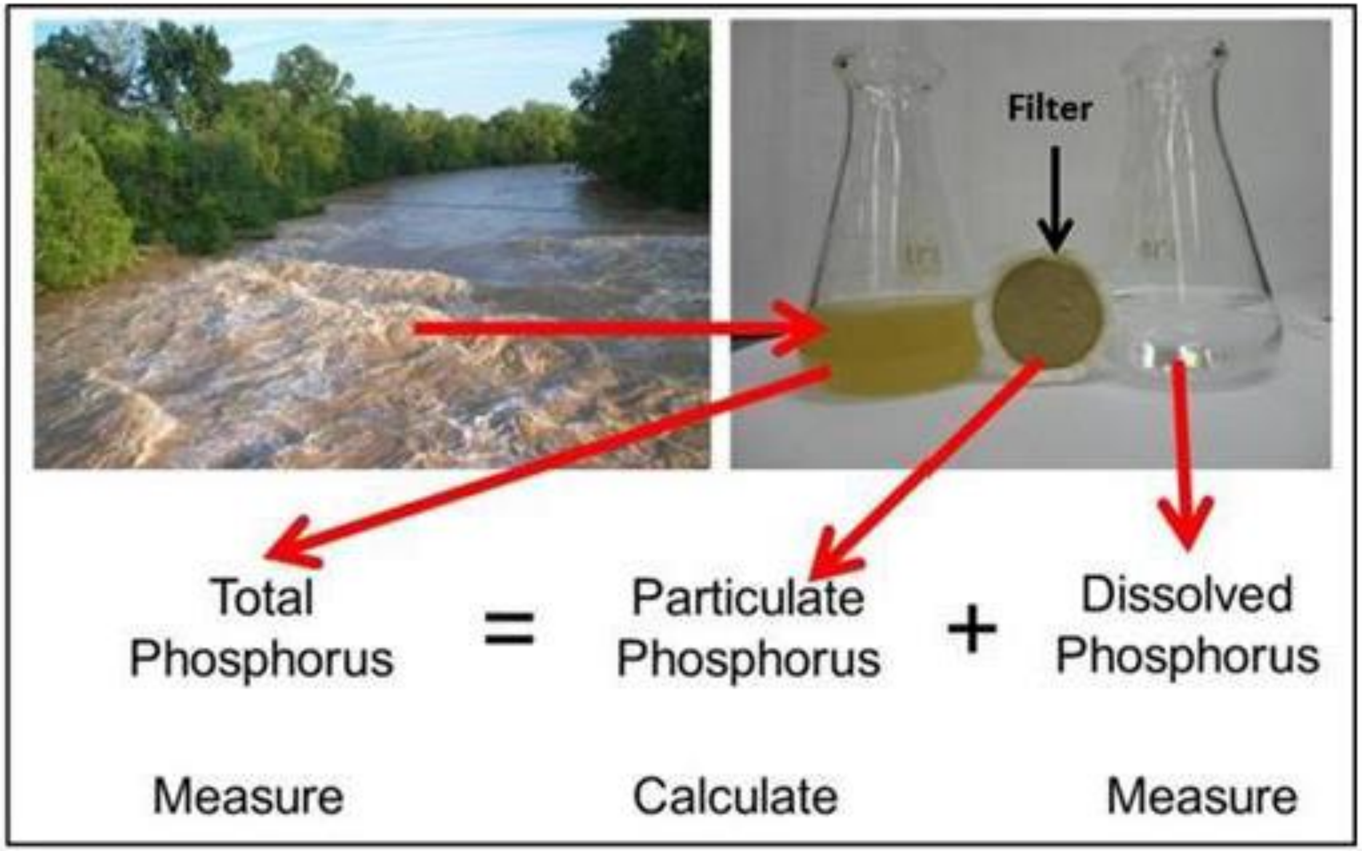
Distribution of annual TP load for the 2008 water year from the Maumee and Detroit Rivers by source category (Maccoux unpublished data).



Non-point load = Total load (*measured*) minus Point load (*measured and reported*)

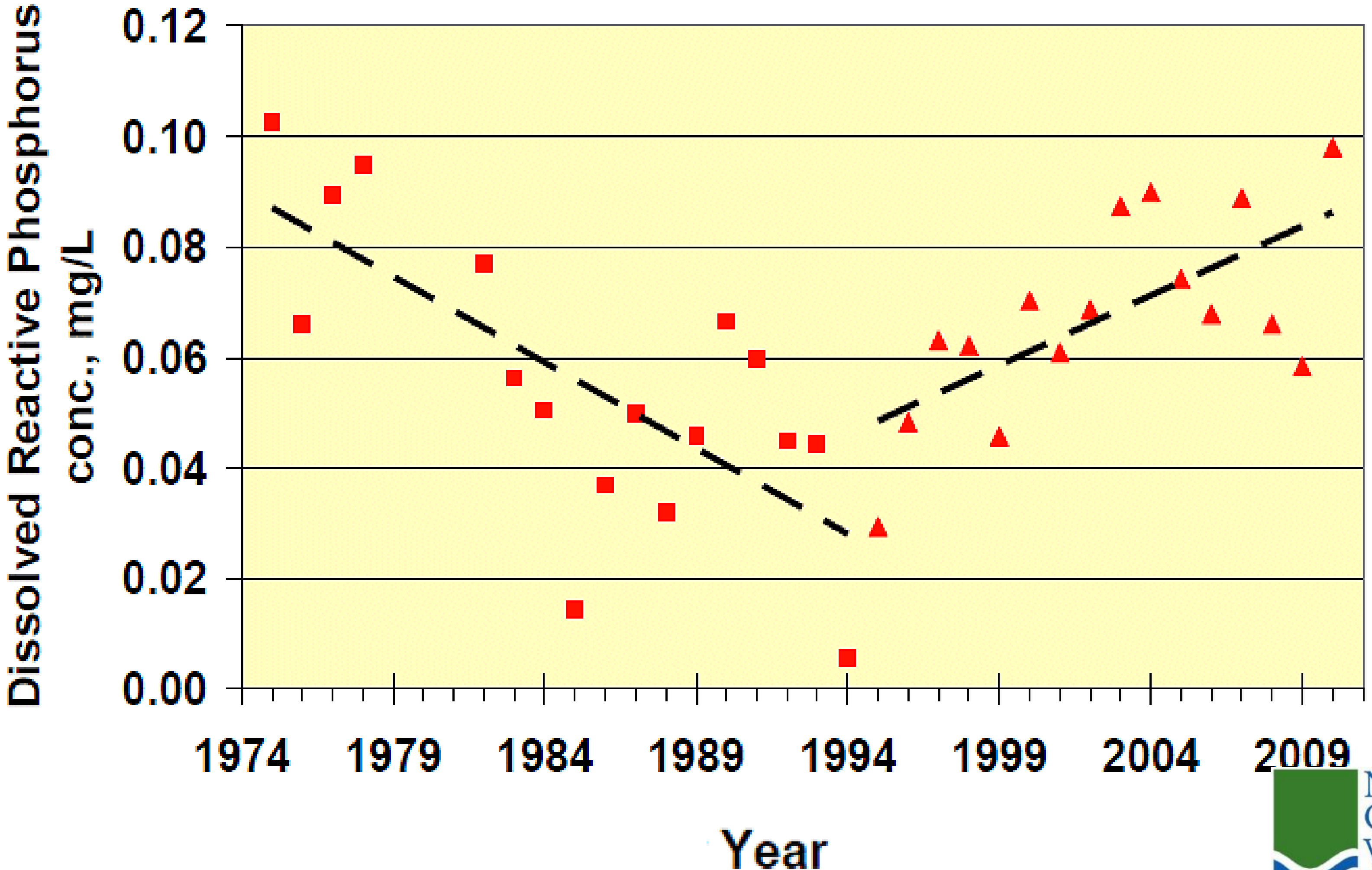


Total Phosphorus vs. Dissolved Phosphorus



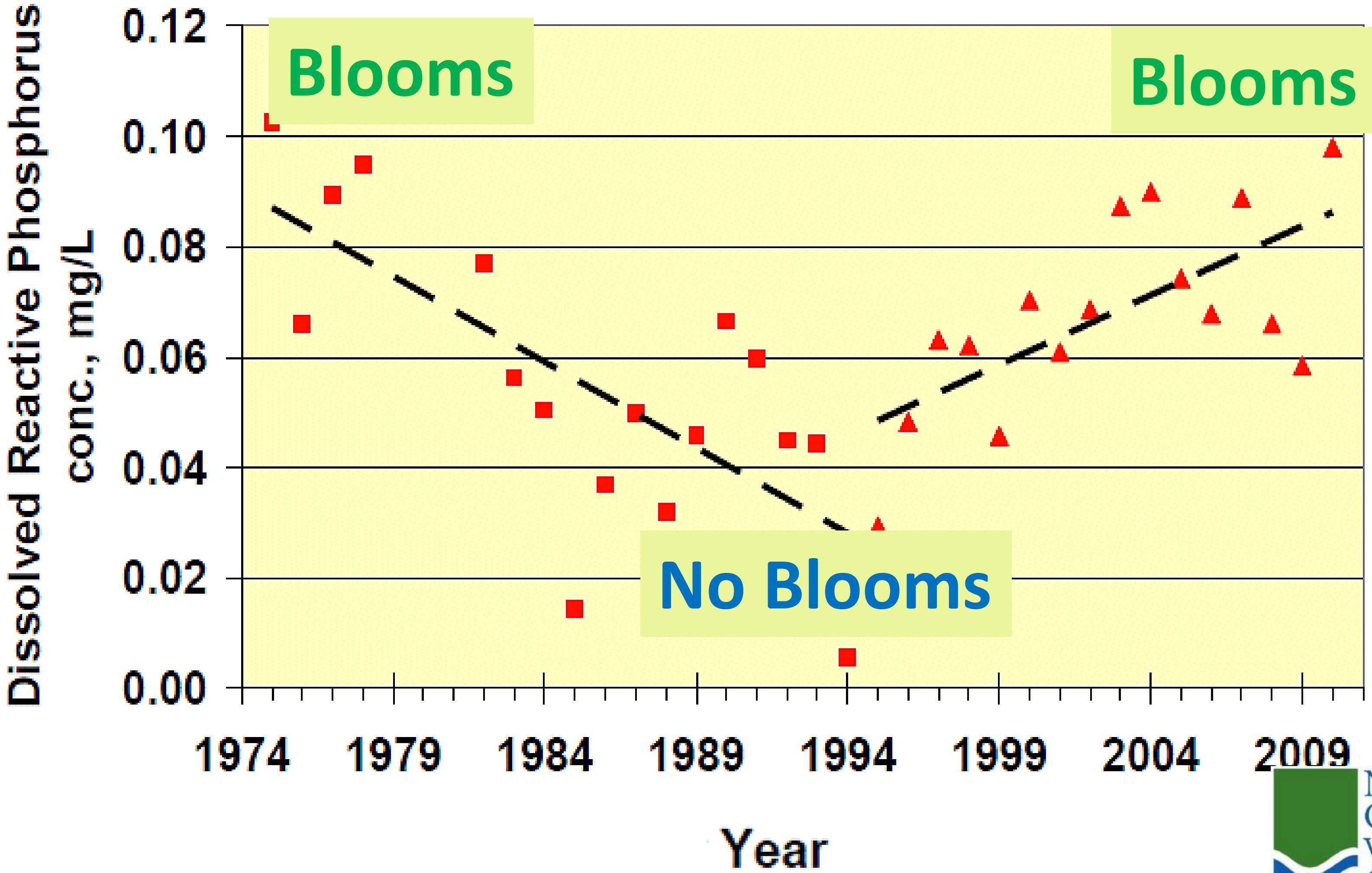
- Particulate P is P in sediments, rock, and algae
- Dissolved P is P that passes through a filter and is 100% available to support algae growth

Dissolved phosphorus concentrations in Maumee River



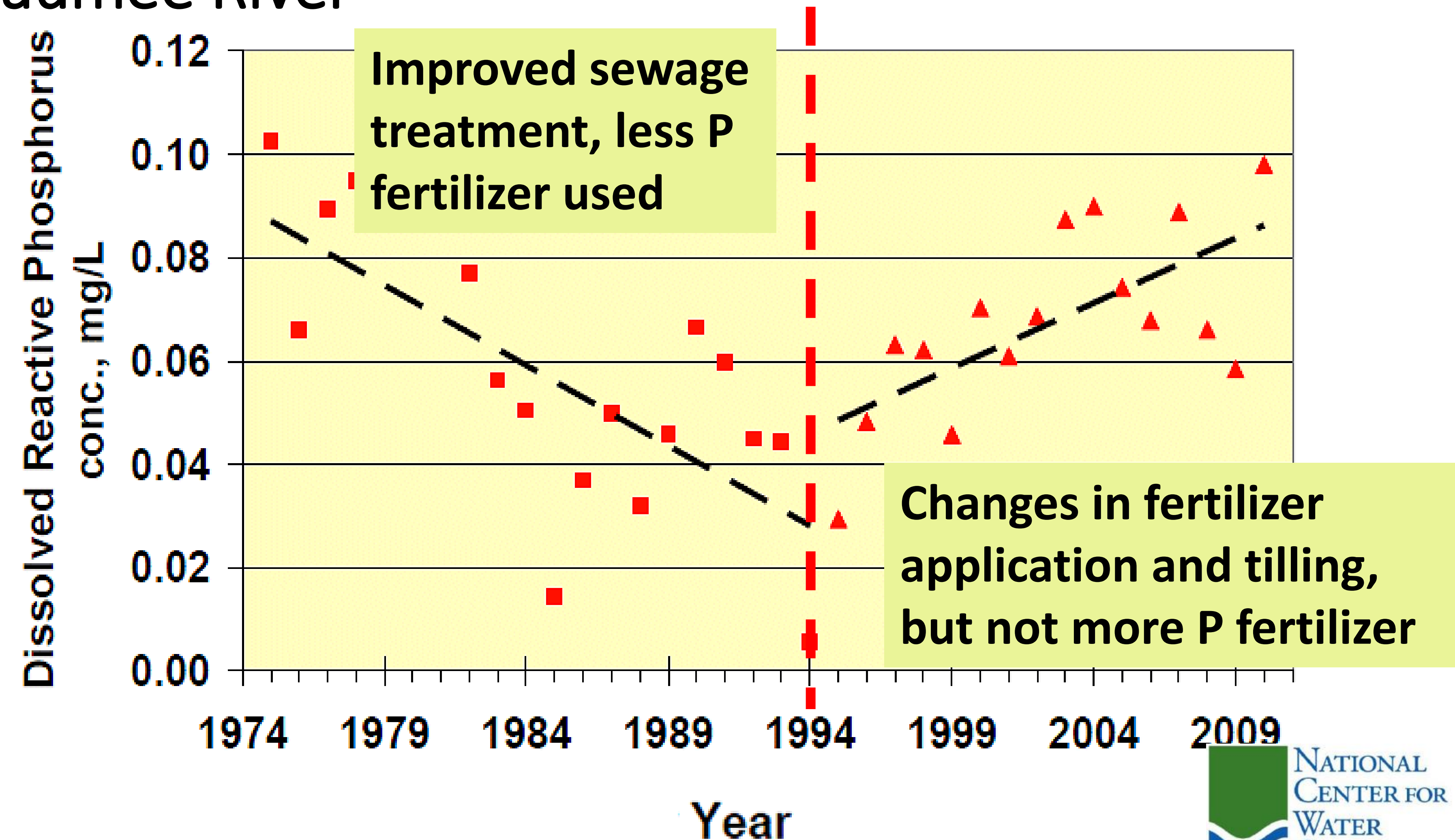
NATIONAL CENTER FOR WATER QUALITY RESEARCH

Dissolved phosphorus concentrations in Maumee River



National Center for Water Quality Research

Dissolved phosphorus concentrations in Maumee River



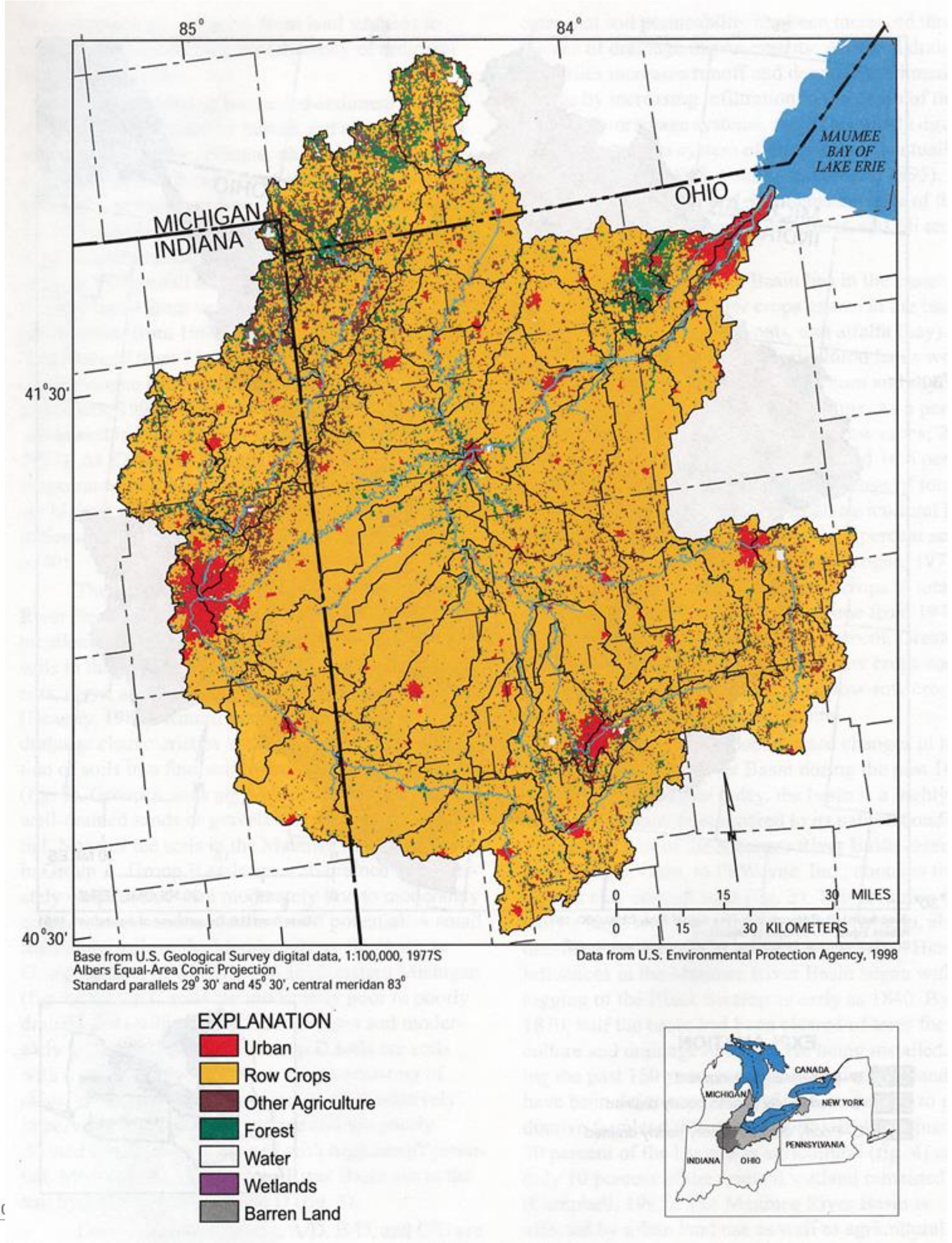
National Center for Water Quality Research

Sea Grant

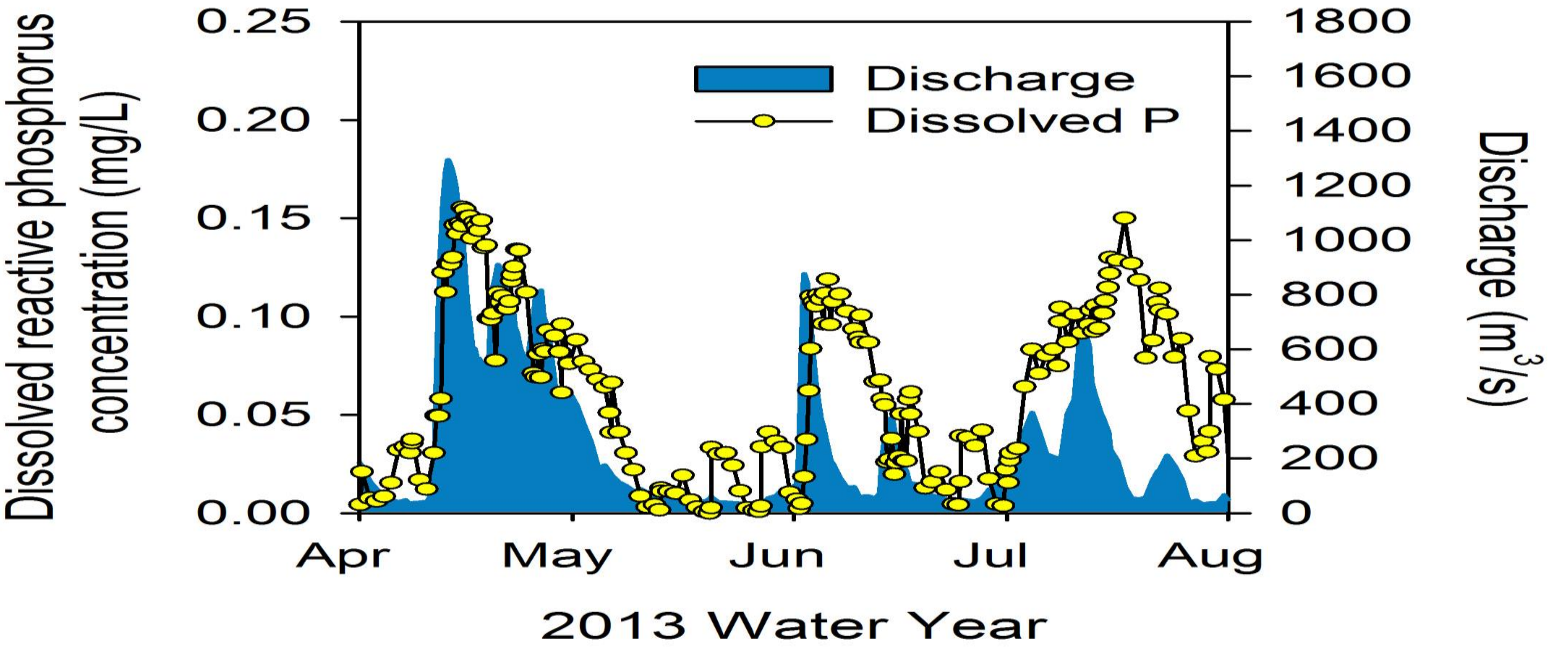
The Ohio State University

Maumee River watershed: >80% agricultural

Largest watershed in the Great Lakes



Highest Phosphorus concentration in Maumee River occur after rain storms



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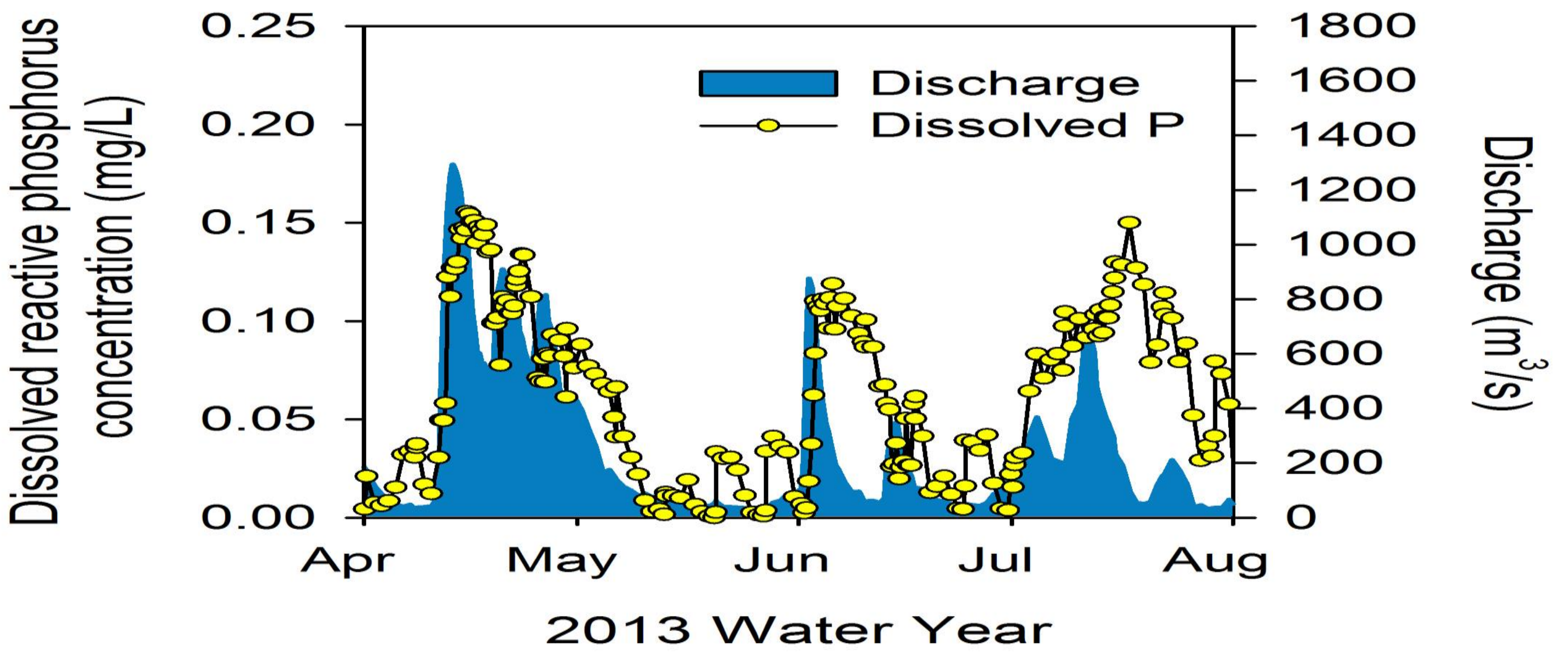
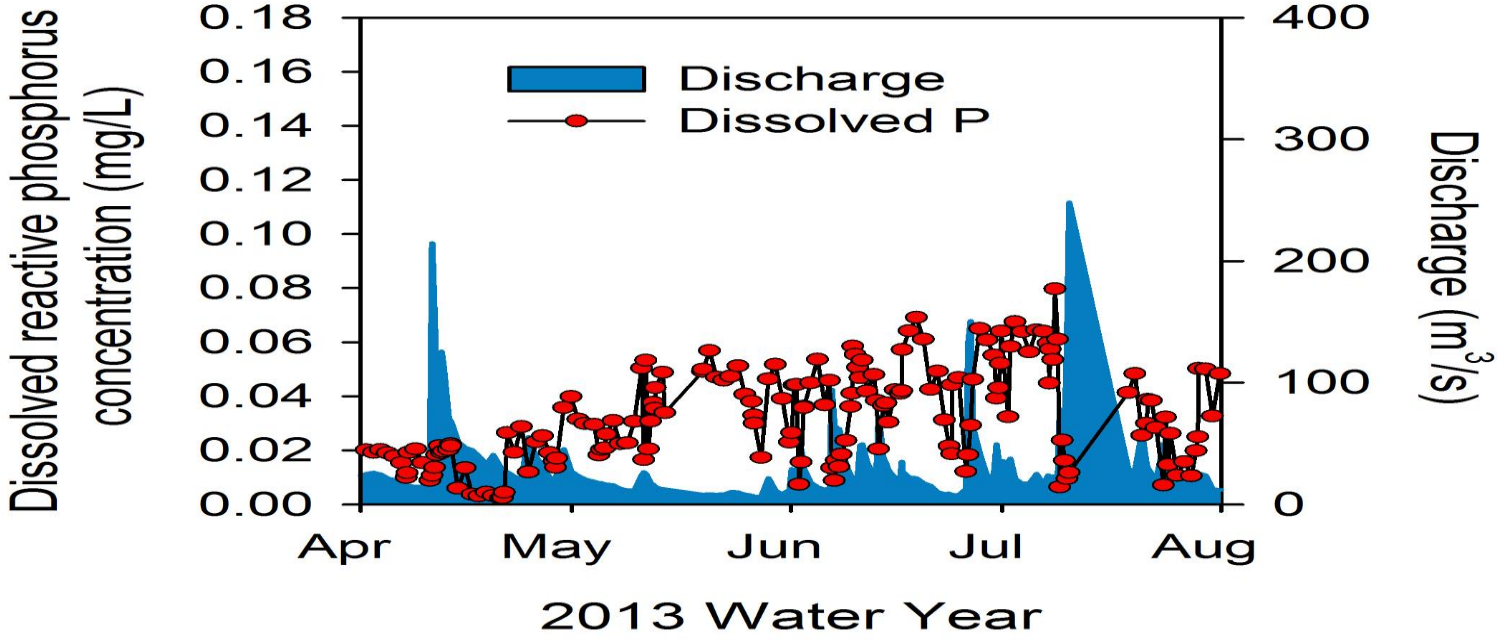
Discharge X P concentration = P load



Highest Phosphorus load from Maumee River occur after rain storms… run off

Rain water dilutes P in urban rivers (Cuyahoga River)



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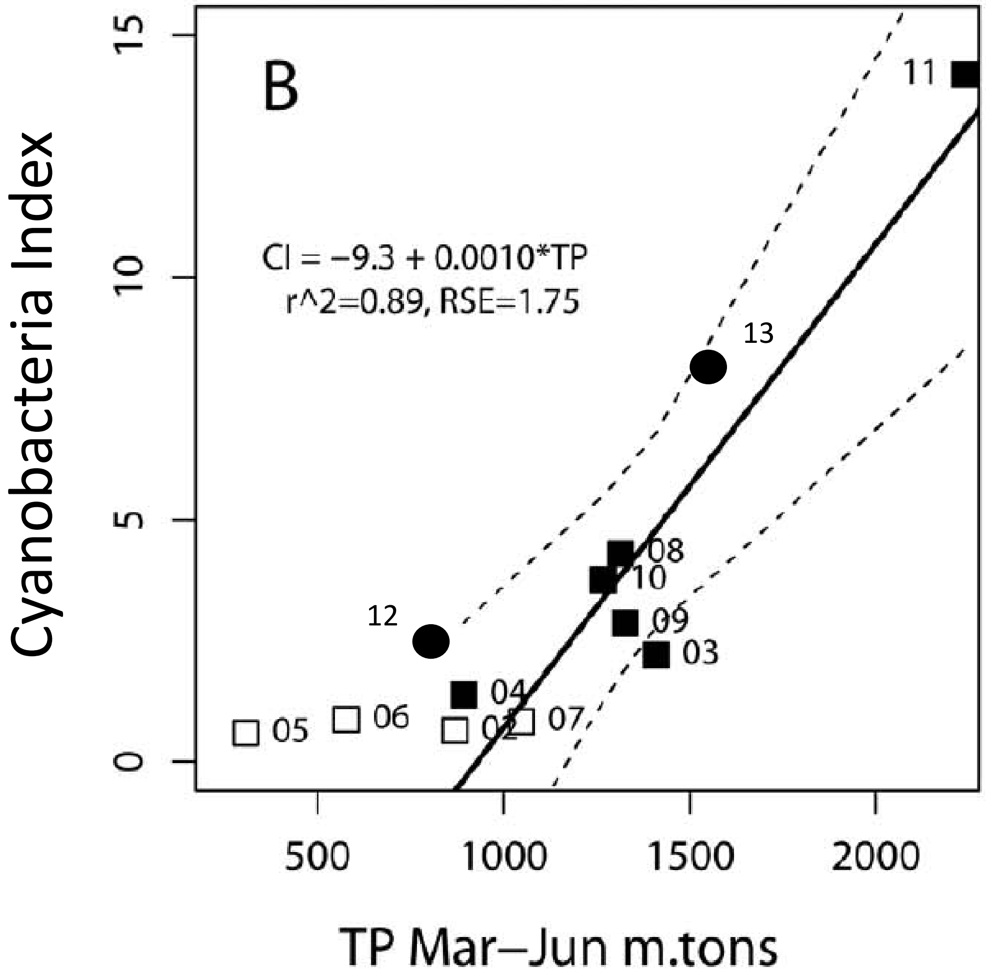
Sea Grant
THE OHIO STATE UNIVERSITY

Lake Erie

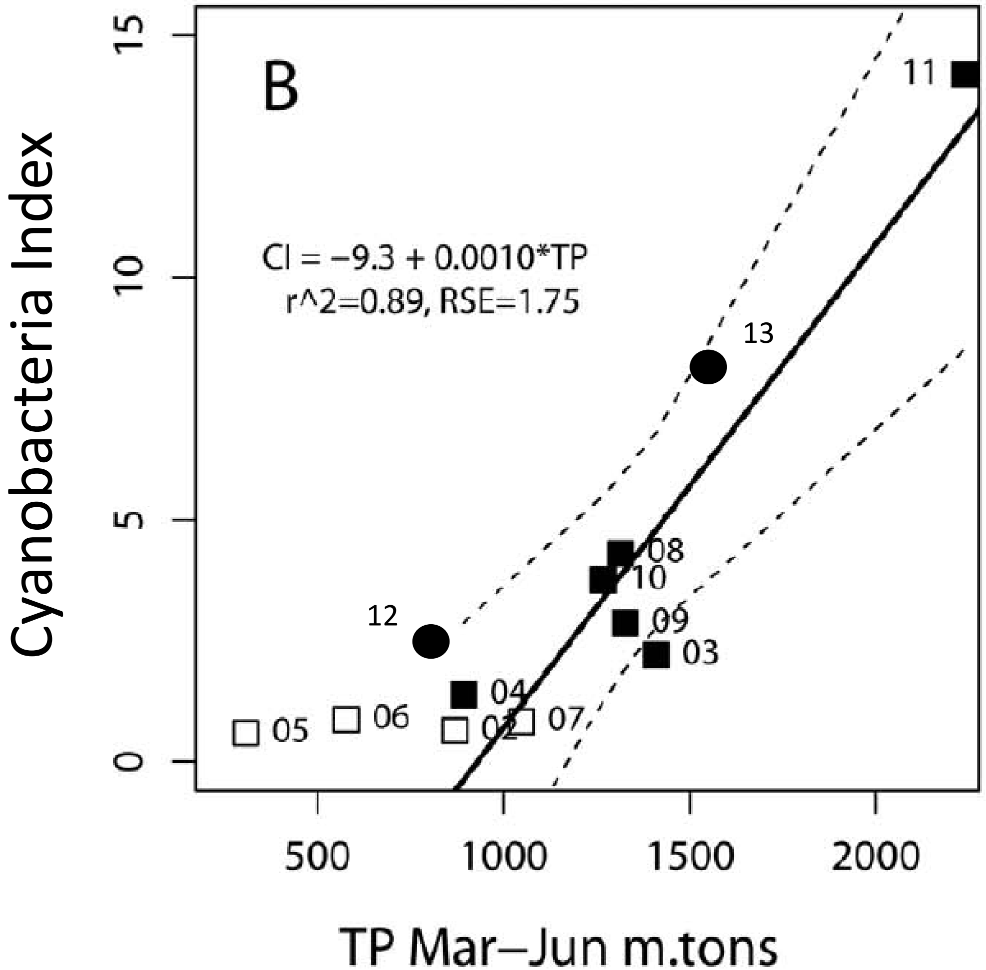
- We know how much cyanobacteria biomass is in the Lake every summer
  - Satellite data
- We measure river phosphorus concentration and discharge
  - Load = concentration X discharge
- What is the relationship between cyanobacteria biomass and P load?

Maumee River spring phosphorus load explains the size of the bloom



Stumpf et al. 2012 PloS One

Spring phosphorus load depends on weather

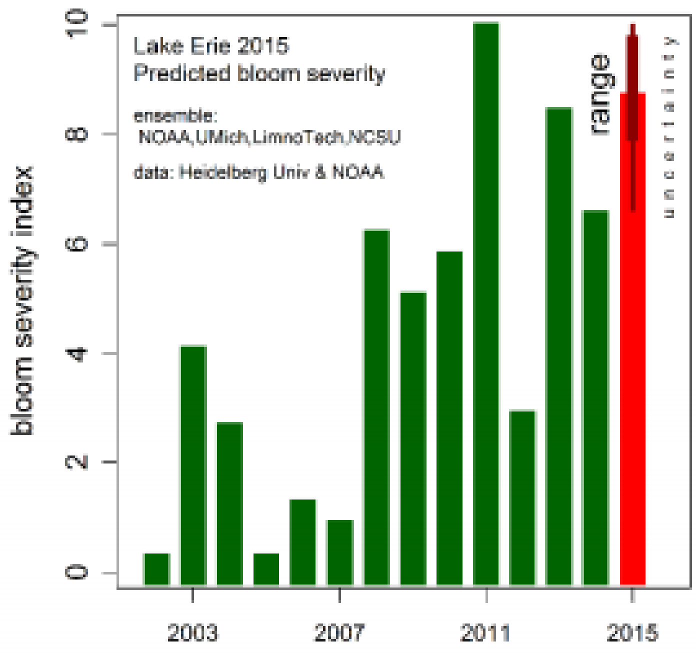


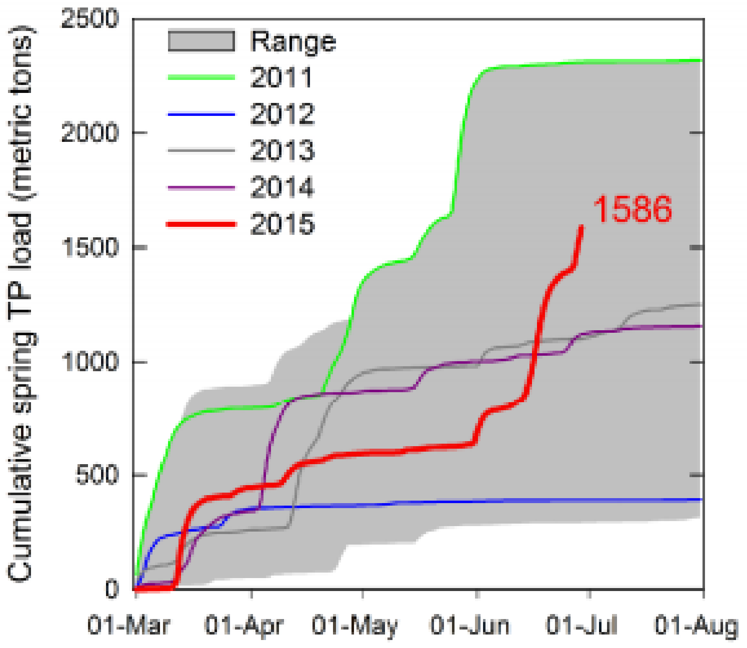
2011 & 2013 = Wet spring

2012 = Drought

Stumpf et al. 2012 PloS One

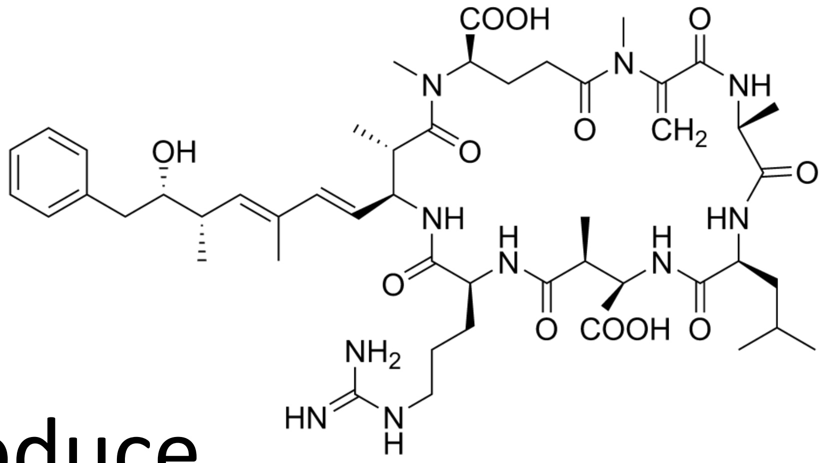
2015 bloom prediction



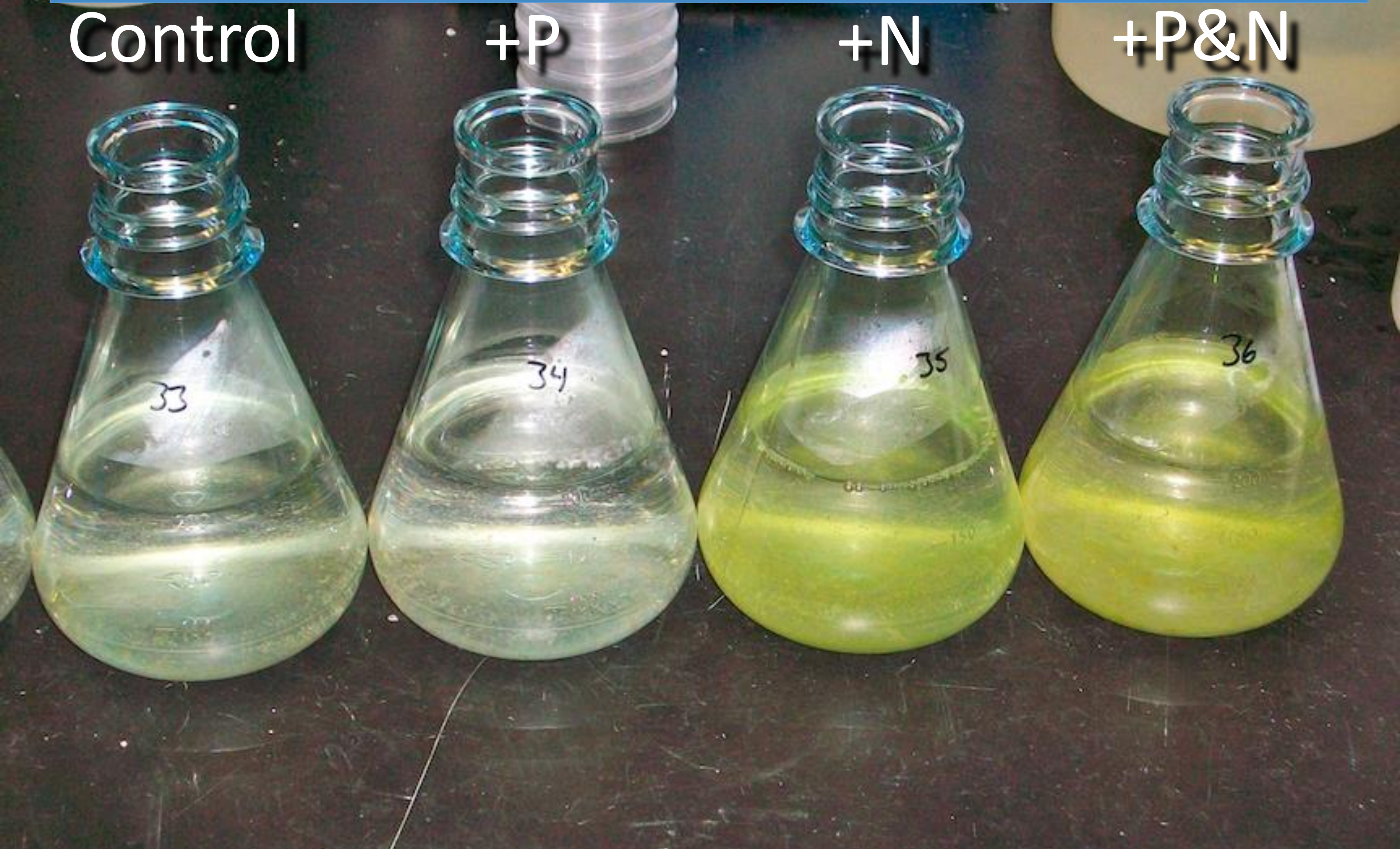


Excessive nitrogen loads exacerbate blooms

- **Toxicity**
- Microcystin LR is 14% nitrogen (mass).
- *Microcystis* cannot produce microcystin without combined nitrogen (such as nitrate, ammonia, or urea)



Nitrogen limits Lake Erie cyanobacteria abundance in August and September



Conclusions: What is driving Lake Erie harmful algal blooms?

- Blooms require very high phosphorus concentrations
  - Maumee River = very high P concentration
  - Detroit River = very low P concentration
- Phosphorus from non-point sources depends on rainfall
  - Wet year = more P load (2011 and 2013, for example)
  - Drought = less P load (2012, for example)
  - P from point sources to Lake Erie has not changed since 1980s
- Timing of phosphorus load from Maumee matters
  - March through June is the critical period
- Size of bloom depends on rainfall.
  - *Challenge: Keep P out of lake during heavy rain springs*
- 2014 bloom will be very serve.
- Toxicity depends on nitrogen
  - Lake Erie can recover in one year if extra phosphorus is kept out of the lake

Other environmental factors required for cyanobacterial blooms

- **Warm water temperatures (> 65F)**
  - Blooms only during summer
- **Nitrogen**
  - *Microcystis* needs nitrogen to produce toxins.
  - No nitrogen = no microcystin
- **Calm water**
  - Allows *Microcystis* to float and access sunlight, whereas good algae sink into darkness

Microcystis floats, good algae sink

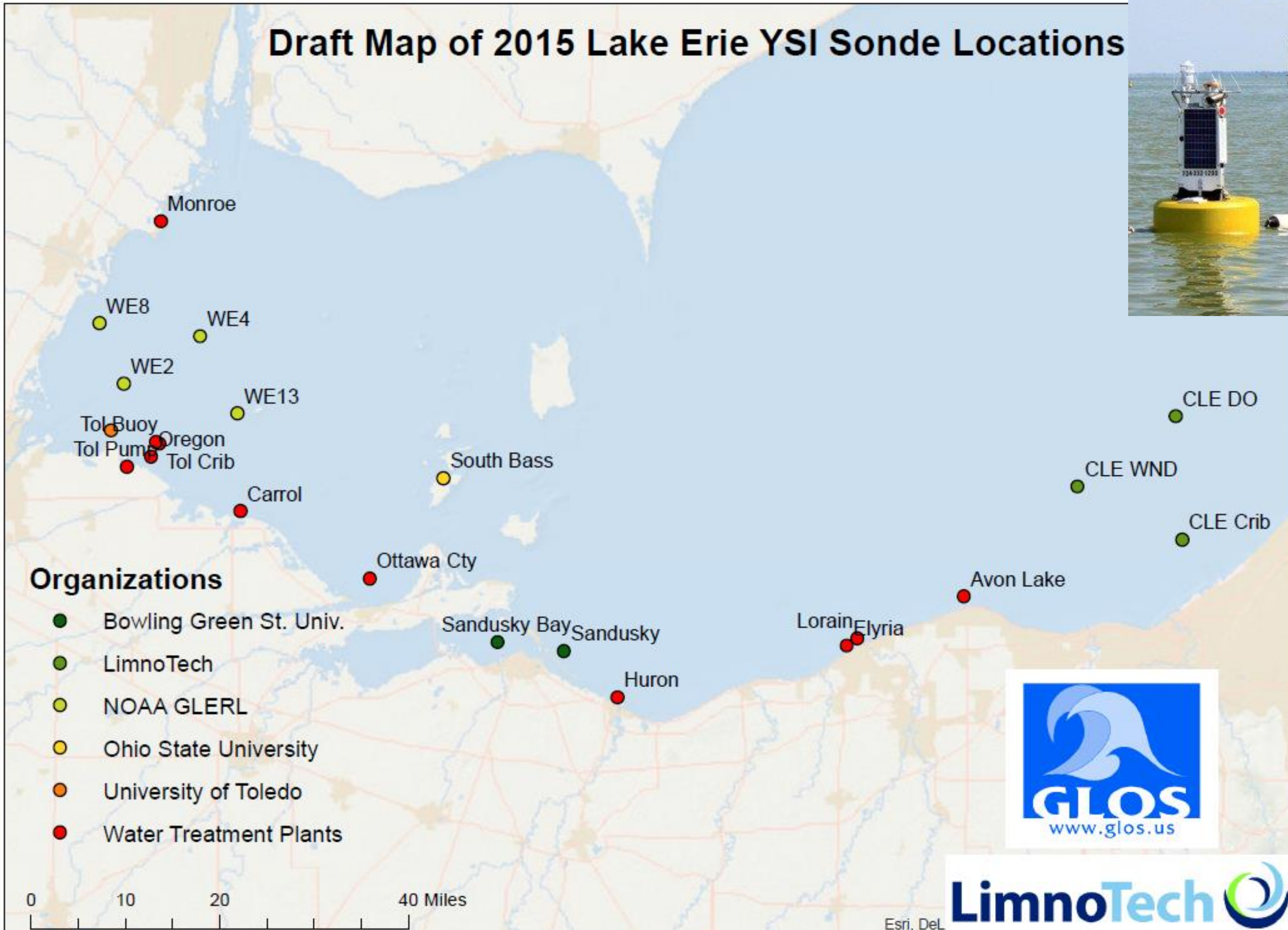
Calm sample

Mixed sample

Calm and muddy waters also exacerbate blooms

Photo credit: Roger Knight

Tracking blooms with buoys



Walleye are safe to eat

- Charter boat captains provide Stone Lab with walleye fillet samples during 2013 and 2014
- Ice fisherman provided fillet samples February 2015
- Mean microcystin in walleye was 85 ng/g
  - 92µg per 1 pound of walleye
- WHO guidelines based on human body weight:
  - 0.04 µg/kg lifetime, 0.4 µg/kg seasonal, 2.5 µg/kg single
  - In Ohio, a 110 lb person could safely consume 125 µg
  - A 110 lb person could consume 1 lb of walleye (if possible)

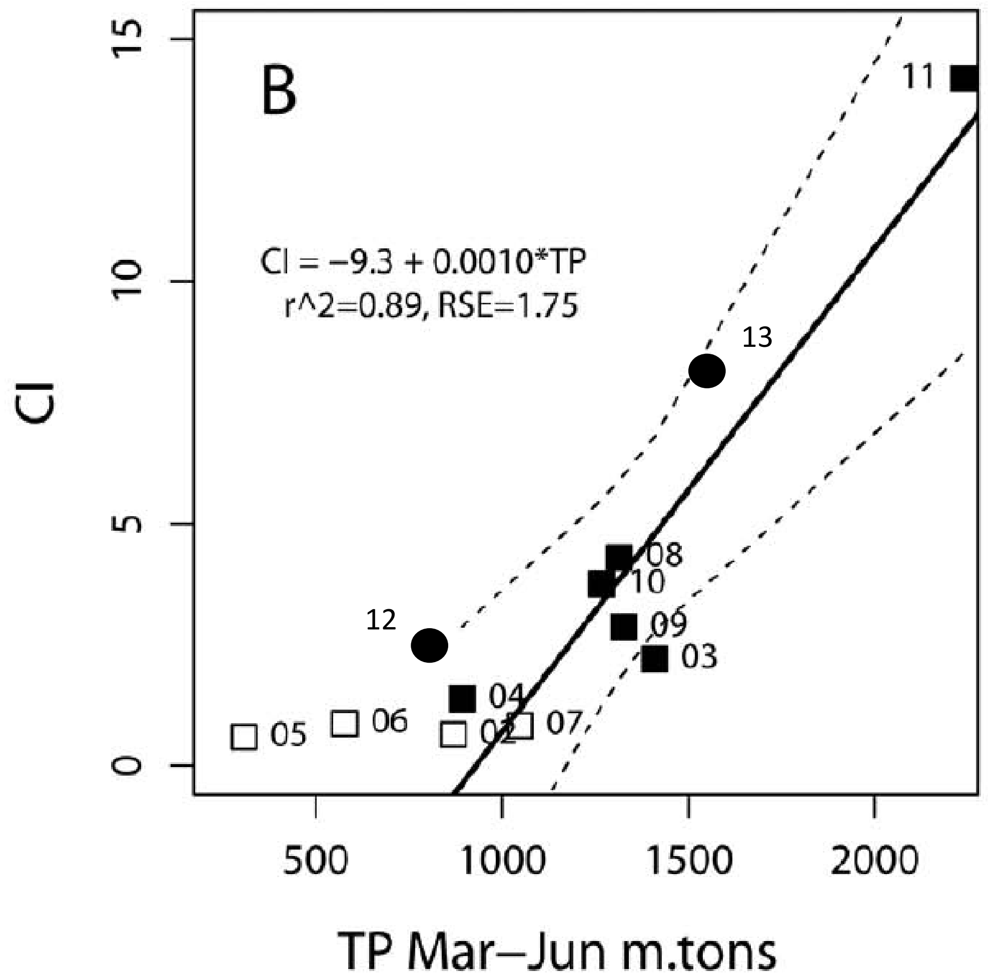
What is being done to stop blooms?

- **Arm water treatment plants with better technology to remove microcystin**
  - Optimizing activated carbon treatment
  - Investigating other treatment methods
    - Ozone, UV light, others
- These only address the problem in the short-term. Long-term goal is preventing blooms before they start.

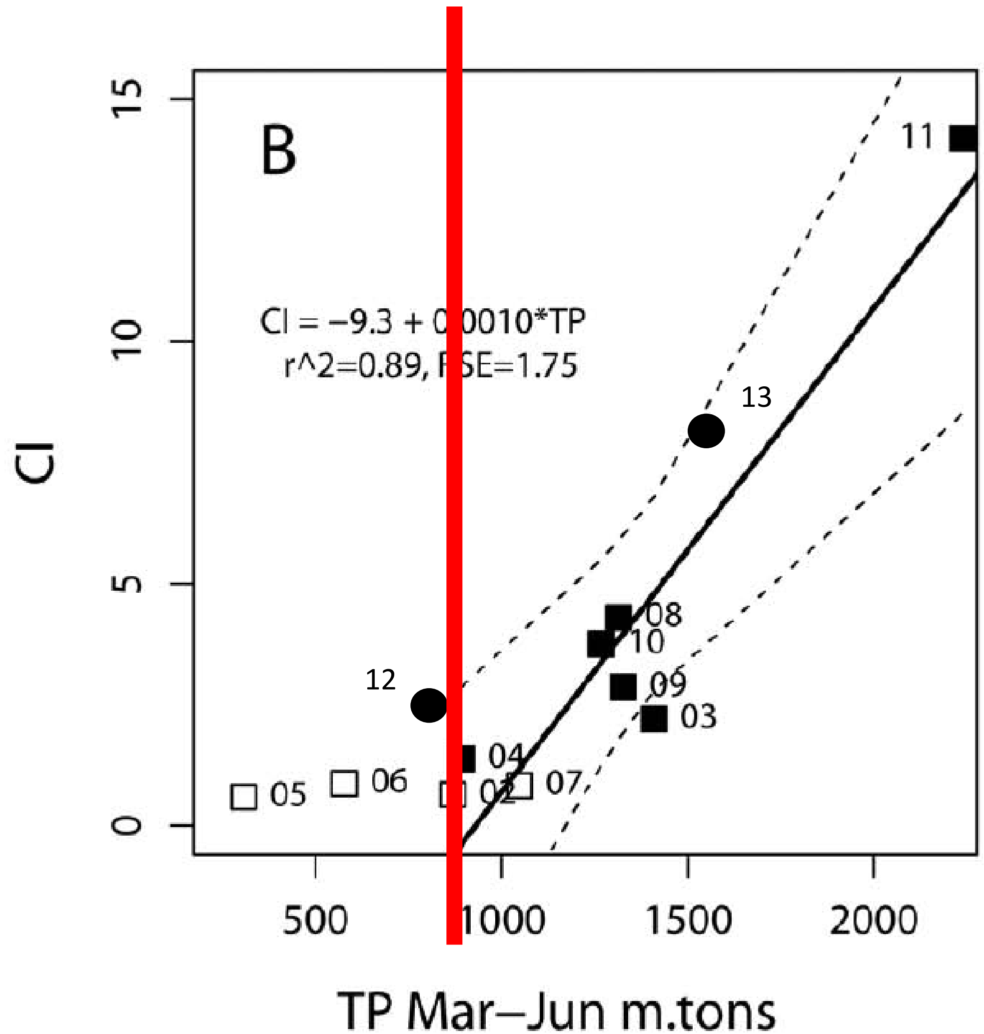
What is being done to stop blooms?

- **Set new phosphorus loading target**
  - New target will include a spring-time target from Maumee River

New Phosphorus loading target: 800 m.tons from Maumee River March - June



New Phosphorus loading target: 850 m.tons from Maumee River March - June



What is being done to stop blooms?

- **Keeping phosphorus on fields during wet springs**
  - Placement of fertilizer in soil near roots
  - Timing of fertilizer of application
    - Not on frozen ground, not before rain (*new law in State of Ohio.* Senate Bill 1)
  - Field soil phosphorus tests
    - Apply right amount to each field and within a field
  - Better land use practices
    - Buffer strips, cover crops, fertilizer placement, 2-stage ditch
    - Not a one size fits all approach
    - Factor in soil type, slope, crop need

What is being done to stop blooms?

- **Farmers already taking action**
  - Survey of farmers in Maumee River watershed:
    - 77% agree that fertilizer lost from their fields have negative impacts down stream.
    - 70% willing to do at least one more practice to keep fertilizer on their fields
  - Ohio Farm Bureau
    - Ohio Farm Bureau is working with reporters to draw their attention to agriculture's commitment to accept responsibility and act responsibly. http://ofbf.org/news-and-events/news/3999/
    - List of steps farmers already taking: http://ofbf.org/media-and-publications/news-room/569/

What is being done to stop blooms?

- **Improve waste water treatment**
  - Eliminating combined sewer overflow
    - Separating storm flow and sewer.
  - Reduce P levels coming out of waste water treatment plants
  - Very costly for improvements

What is being done to stop blooms?

- **Phosphorus removed from lawn care**
  - Scott's brand lawn care products are all phosphorus free, except start up fertilizers
    - 20:0:10, for example
  - Send less water to treatment plant
    - Rain barrels
    - Low flow showers

Questions & Discussion

MODIS. October 2011

How Gardeners Can Help Reduce Lake Algae

Reduce Run-off

- Improve compacted/clay garden soil every year by adding peat moss, compost, or leaf mold to soil.
- Aerate compacted lawns every few years.

Reduce Run-off

- Plant buffer zone of native plants at edge of lawn along shoreline to catch nutrients

Increase green mass on your property

- Preserve existing trees

- Increase plants and green mass on your property

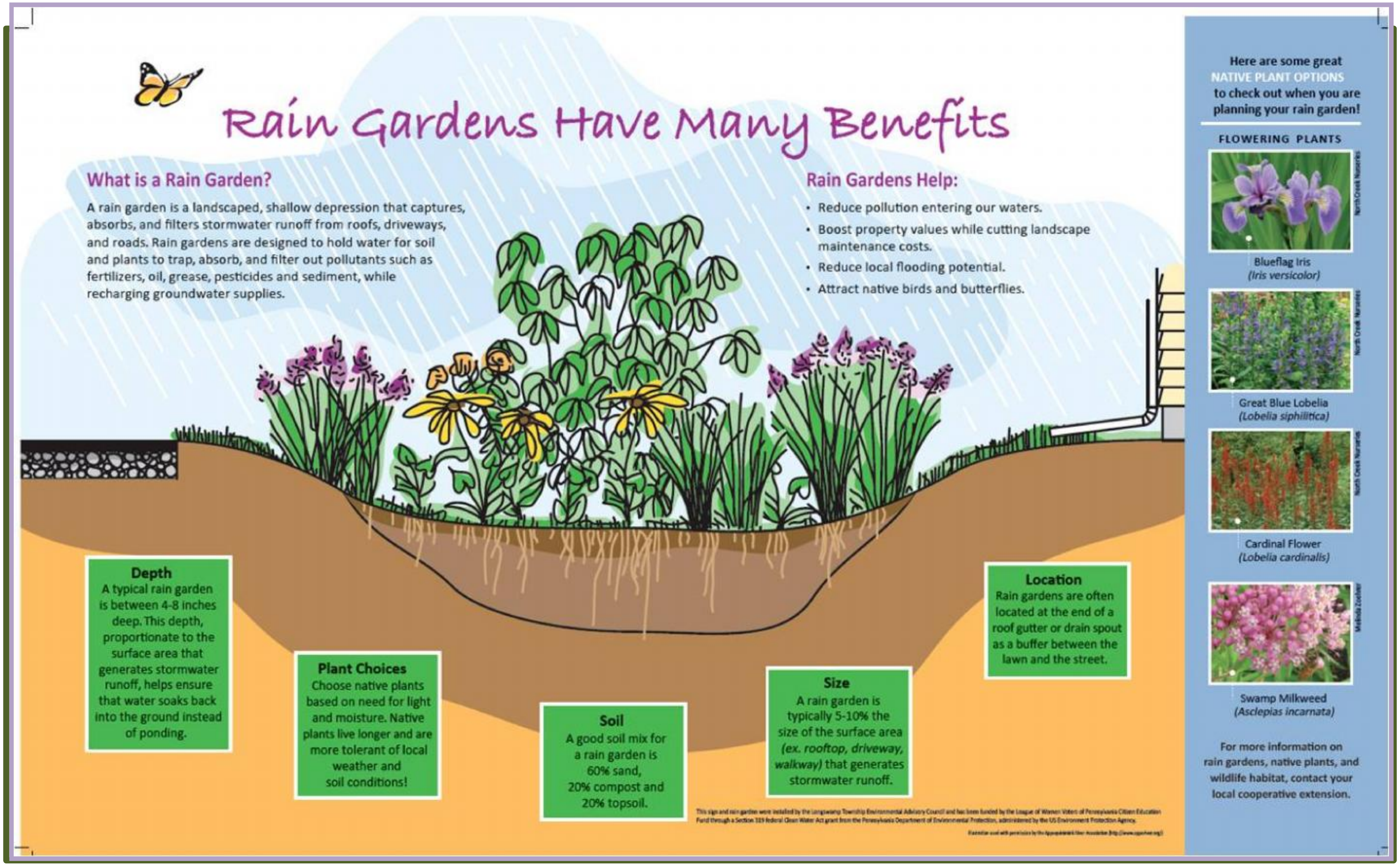
Reduce Hardscape on your Property

Consider porous, permeable pavements.

Encourage water percolation

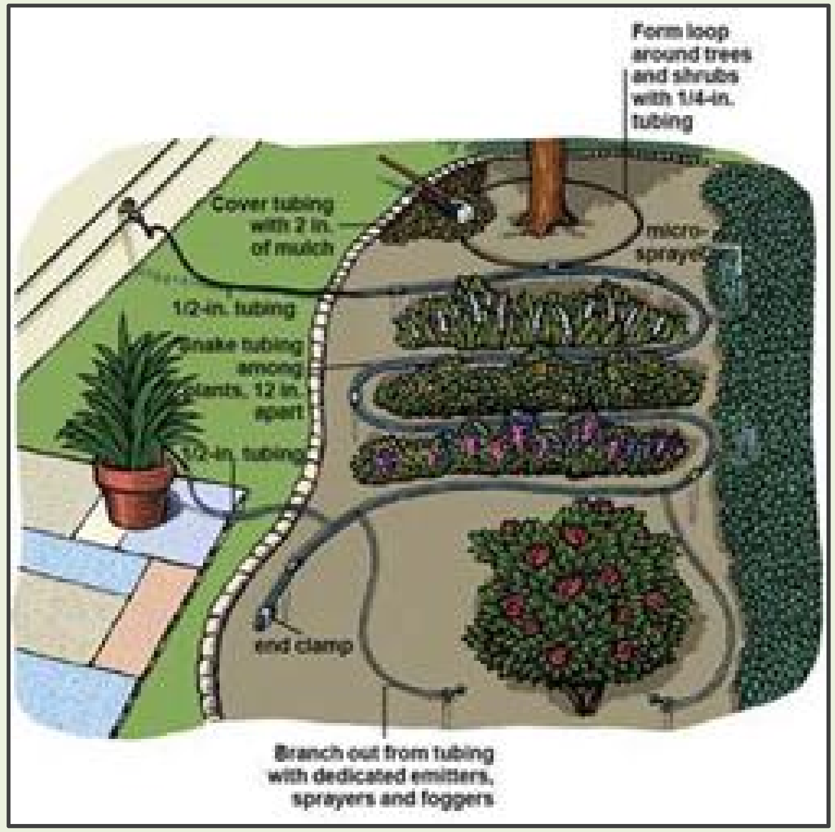
- Install **rain gardens** to trap and absorb water and filter out pollutants.

Encourage water percolation



Minimize water use

- Install drip irrigation to water roots directly
- Install timers on watering systems



Minimize water use

- Use rain gauge to measure 1”water/week
- Allow lawns to go dormant in dry conditions

Reuse water

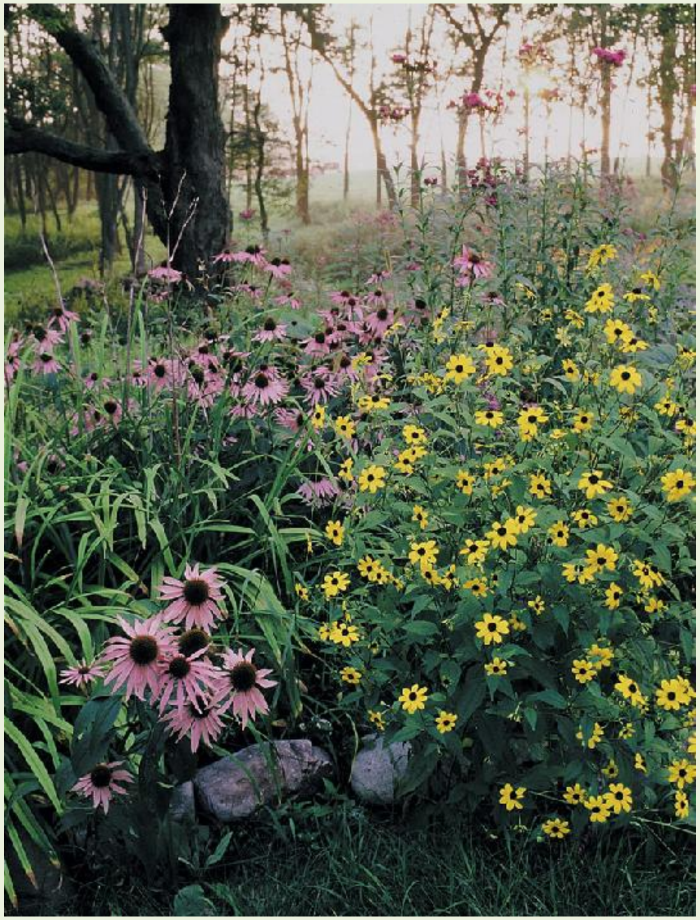
- Install rain barrels and use water collected for garden care

Reduce use of chemicals in lawn and garden care

- Use phosphate-free fertilizers
- Minimize applications on lawns
- Explore alternatives to chemicals
- Only use nutrients and controls you need!

Keep it Simple

- Reduce need for fertilizers and sprays by using native plants in your landscape



Lake Erie Algae and how Lakeside Gardeners Can Help

Reduce Run-off

Improve compacted soil with peat, compost, leaf mold

Aerate lawn every few years

Plant buffer zone of native plants alone shoreline

Increase green mass on property

Preserve existing trees

Increase plants and shrubs

Reduce hardscape on property

Use porous, permeable pavements

Encourage Percolation

Install rain gardens to trap, absorb, and filter water

Minimize water use

Drip irrigation systems

Install timers

Rain gauge (1”per week)

Allow lawns to go dormant

Reuse water

Install rain barrels to catch and reuse downspout water

Reduce use of chemicals in lawn/garden care

Phosphate-free lawn fertilizer

Minimize lawn applications

Explore alternatives to chemicals

Use only nutrients and chemicals you need!

Keep it simple

Use native plants in landscape