East Fork Watershed Cooperative Meeting: Briefing to local representatives

05/23/2017

With contributions from John McManus[1], Paul Braasch[2], Chris Nietch[3], Matt Heberling[3], Amr Safwat[4], Joel Allen[3], Nate Smucker[5], Jake Beaulieu[3], Tim Neyer[6], Hannah Lubbers[2], Jacob Hahn[1], and Lori Lenhart[8]

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INTRODUCTION

John McManus
&
Paul Braasch

Watershed nutrient trading feasibility research:

The Upper East Fork of the Little Miami River Case Study

Christopher Nietch[1], PhD, Ecologist

Matthew Heberling[1] PhD, Economist

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Case Study System & The East Fork Watershed Cooperative

United States Environmental Protection Agency

- East Fork of the Little Miami River Watershed and William H. Harsha Lake

EFWCoop

Brown County, Ohio, SWCD

Clermont S.W.C.D. Soil & Water Conservation District

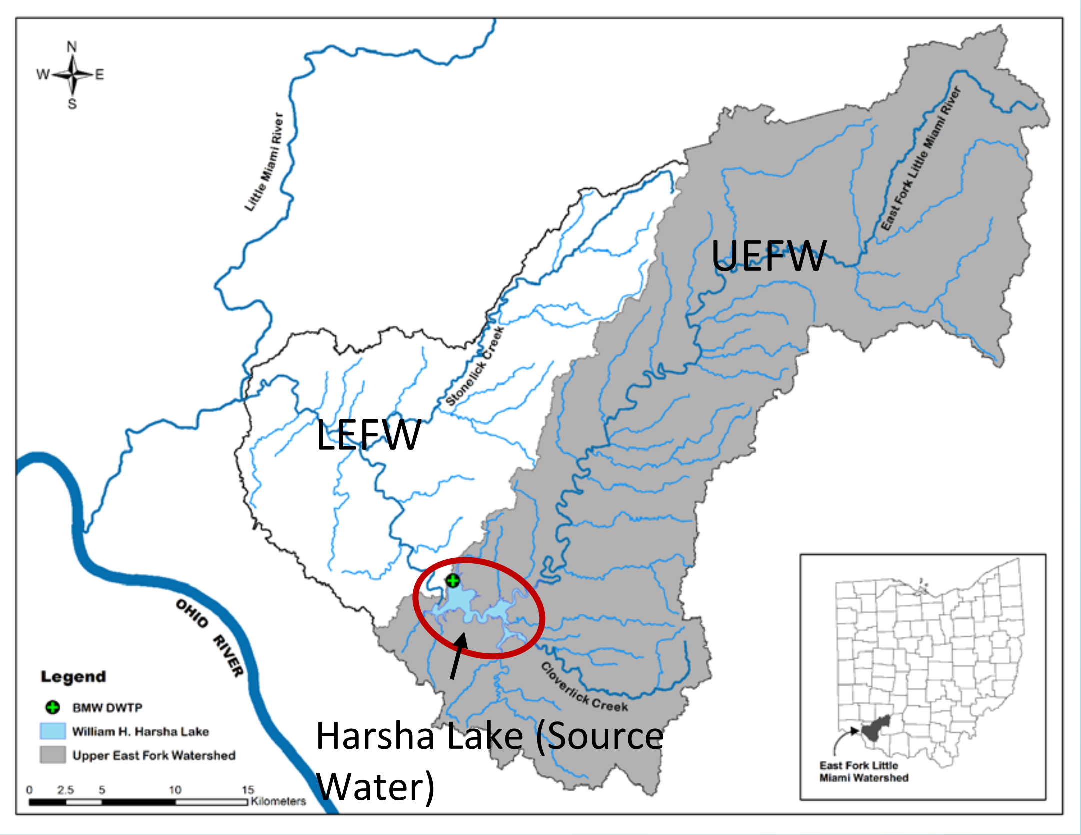
Ohio Department of Natural Resources

USGS science for a changing world

OhioEPA

US Army Corps of Engineers®

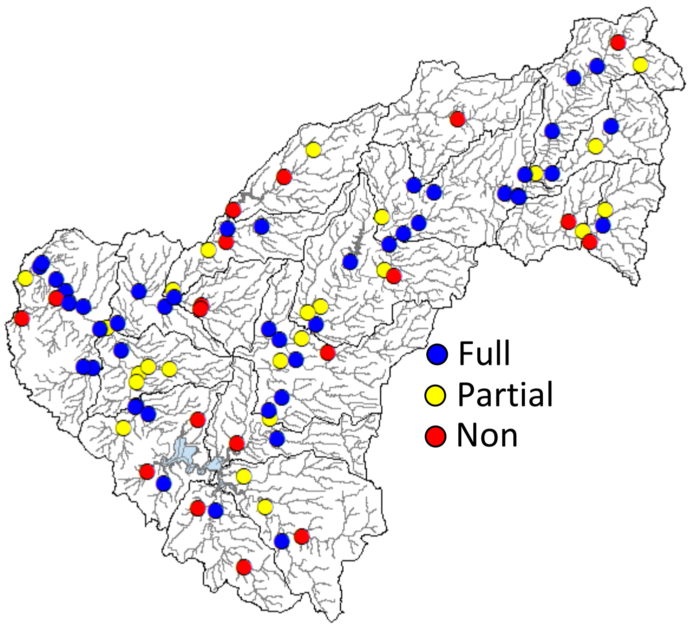
Clermont County, Ohio
Office of Environmental Quality



EPA United States Environmental Protection Agency

Watershed Conditions: Biological attainment, Loading trends, and toxic algae

Biological Attainment Map for the East Fork Watershed from Ohio EPA 2012 Survey

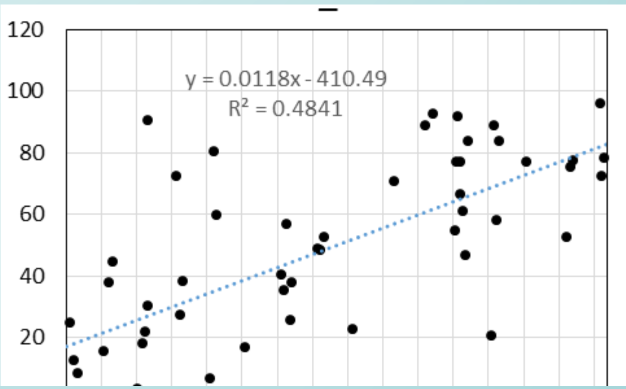


48% of sites non or partial attainment; full attaining sites mostly along mainstem

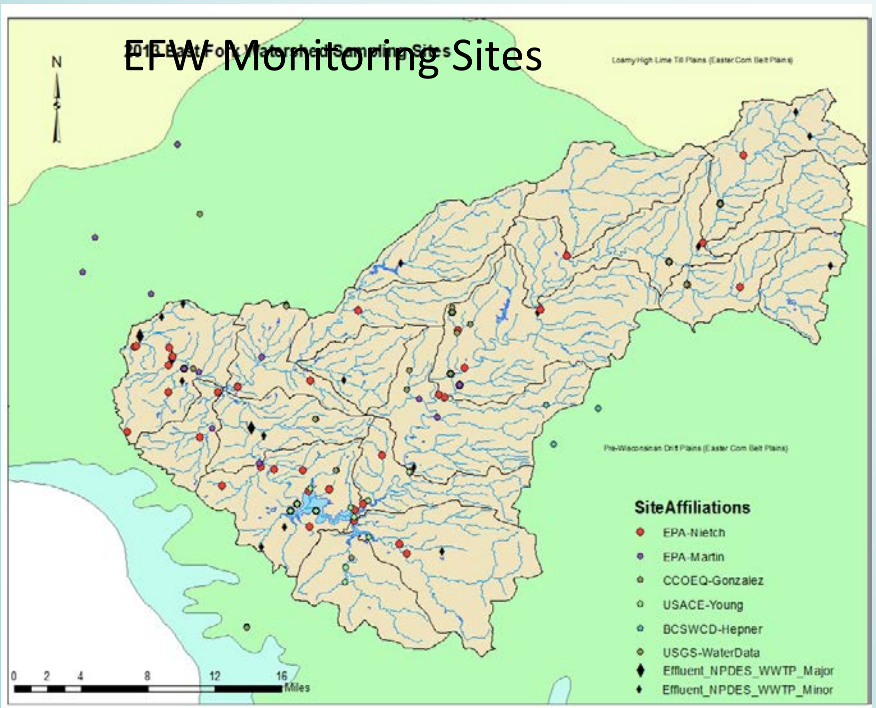
Nutrient Loading Trends to Harsha Lake

Variable	unit	Time Significant?	Direction
Flow	cfs	yes	Increasing
TP	µg/L	yes	Increasing
TRP	µg/L	yes	Increasing
OrgP	µg/L	yes	Increasing
TN	µg/L	yes	Decreasing
TNO23	µg/L	no	-
TNH4	µg/L	yes	Decreasing
OrgN	µg/L	yes	Decreasing
TPLoad	kg	yes	Increasing
TRPLoad	kg	yes	Increasing
OrgPLoad	kg	yes	Increasing
TNLoad	kg	yes	Increasing
TNO23Load	kg	yes	Increasing
TNH4Load	kg	no	-
OrgNLoad	kg	yes	Increasing

Trend for Microcystin-producing cyanobacteria relative abundance (%)



East Fork Watershed: Monitoring Program Design



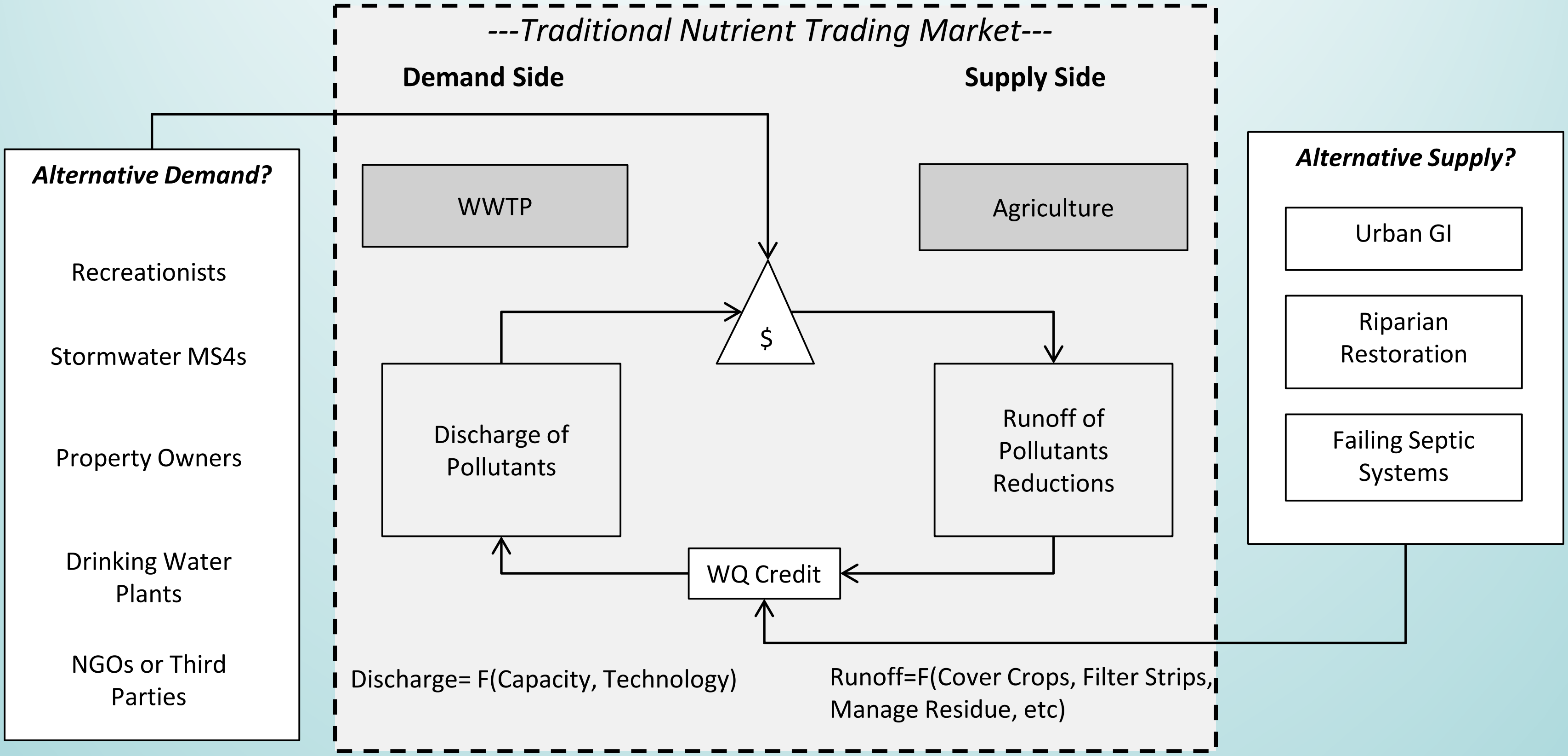
Spatially and temporally dense monitoring program – headwaters to main stem

Härsha Lake sampling sites

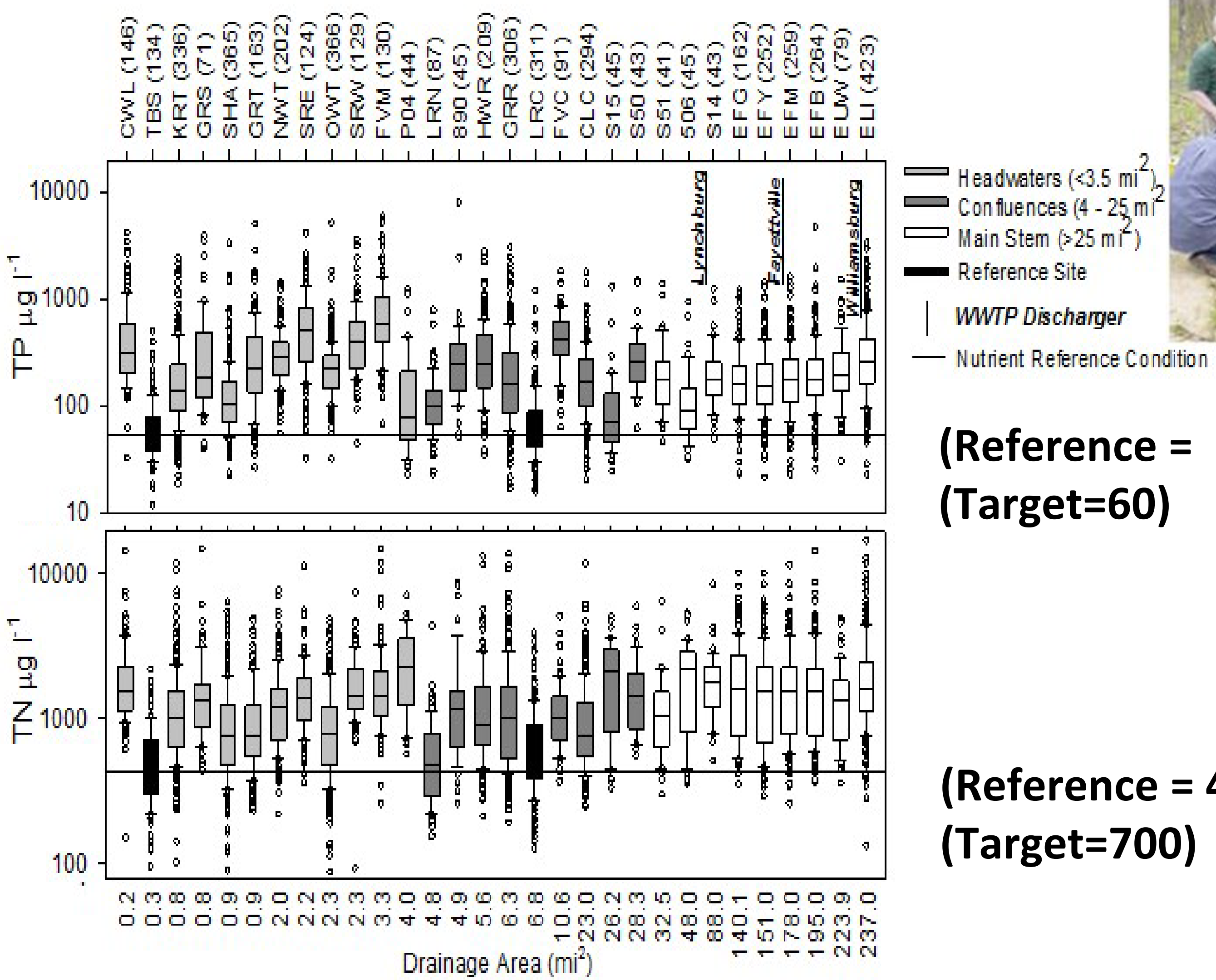
Introduction and Overview

- Theme: Modeling and monitoring for making water quality trading a more viable approach
- Study options for expanding water quality trading market potential:
  1) Determine incentives for alternative participants
  2) explain and decrease uncertainty
  3) increase the adoption rate of agricultural BMPs (agBMPs), and
  4) capture co-benefits
- **Research: Review, evaluate, and validate existing modeling frameworks**
  - **Capture uncertainty in watershed loads and management effectiveness**
  - **Determine advantages and disadvantages of using the Soil Water Assessment Tool (SWAT) as one comprehensive watershed simulation tool**

Proposal: Augmenting nutrient trading markets with non-traditional participants



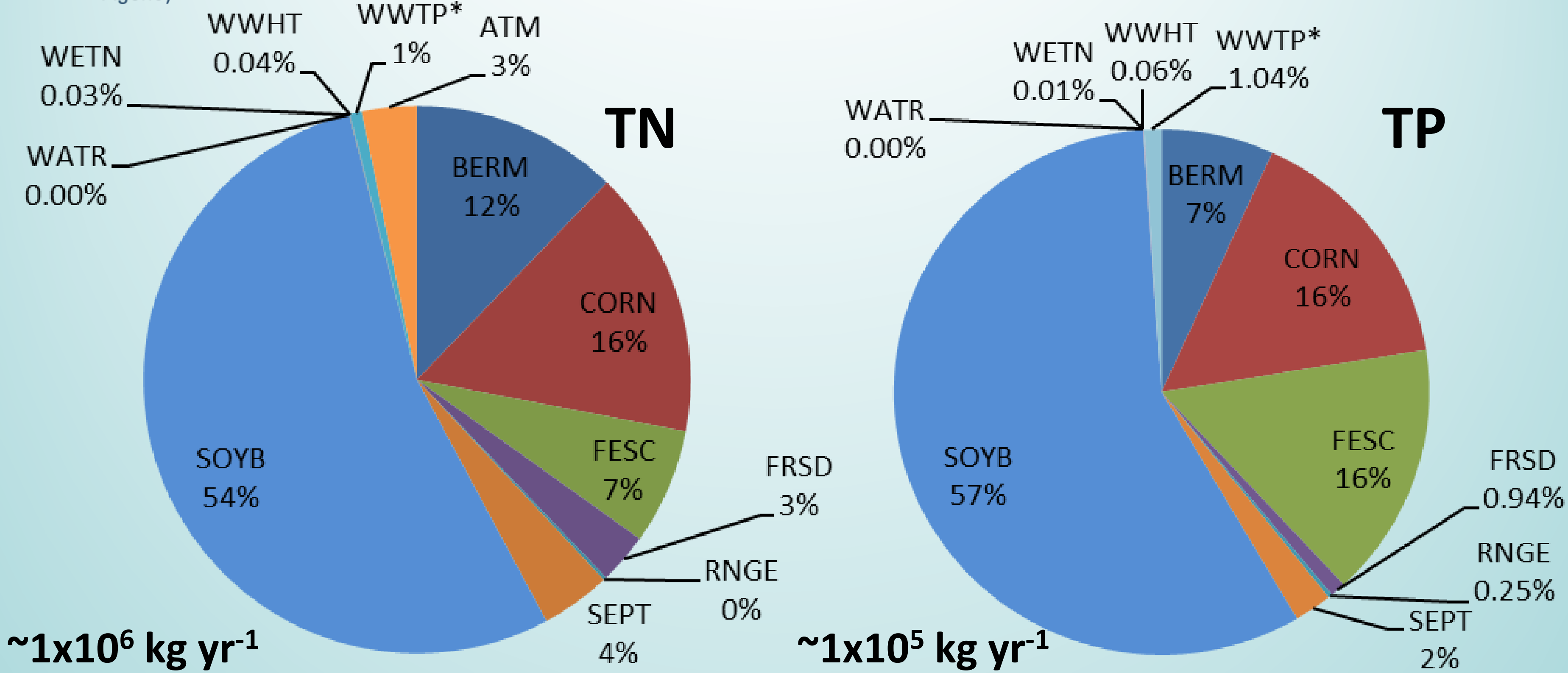
Existing Conditions and WQ Targets – Upper Watershed



(Reference = 55 ppb)
(Target=60)

(Reference = 433 ppb)
(Target=700)

Modeling Results – Source distribution for loads to Lake Harsha



- **Soil and Water Assessment Tool (SWAT)**
  - simulates many crop types and management options. Incorporates point sources and septic systems
- **SWAT- Calibration and Uncertainty Program (CUP)** for <u>uncertainty</u> analysis

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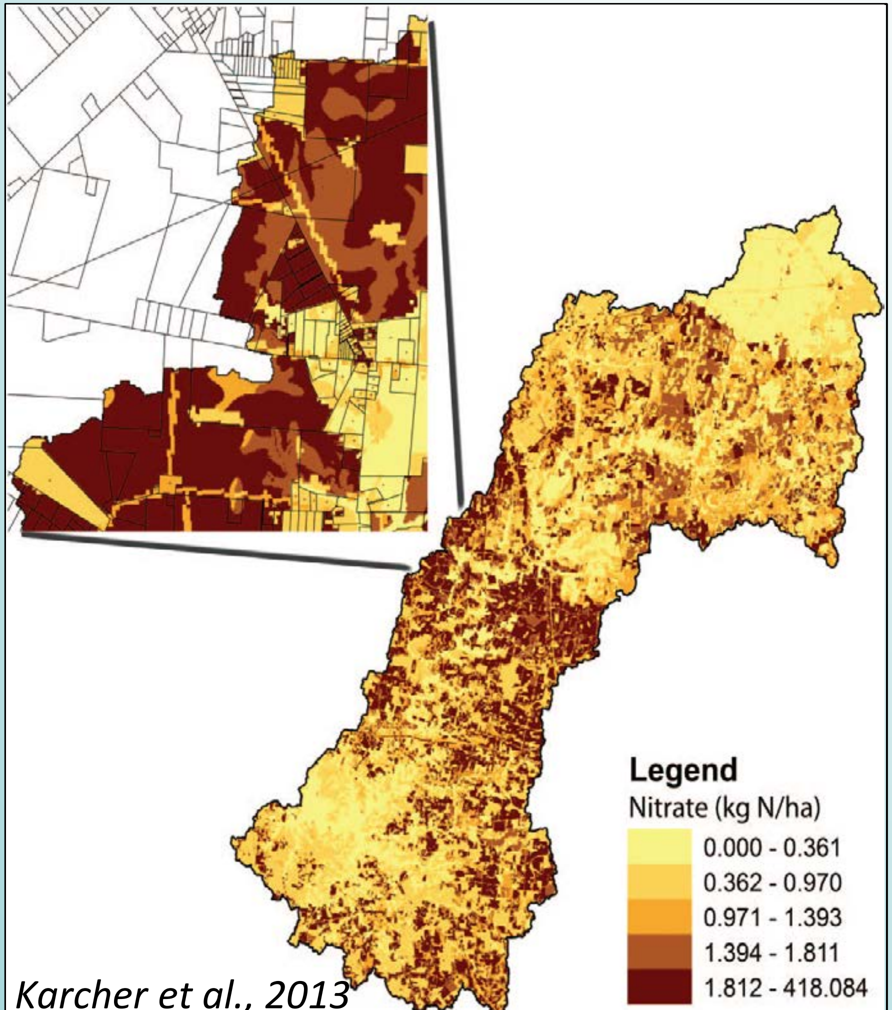
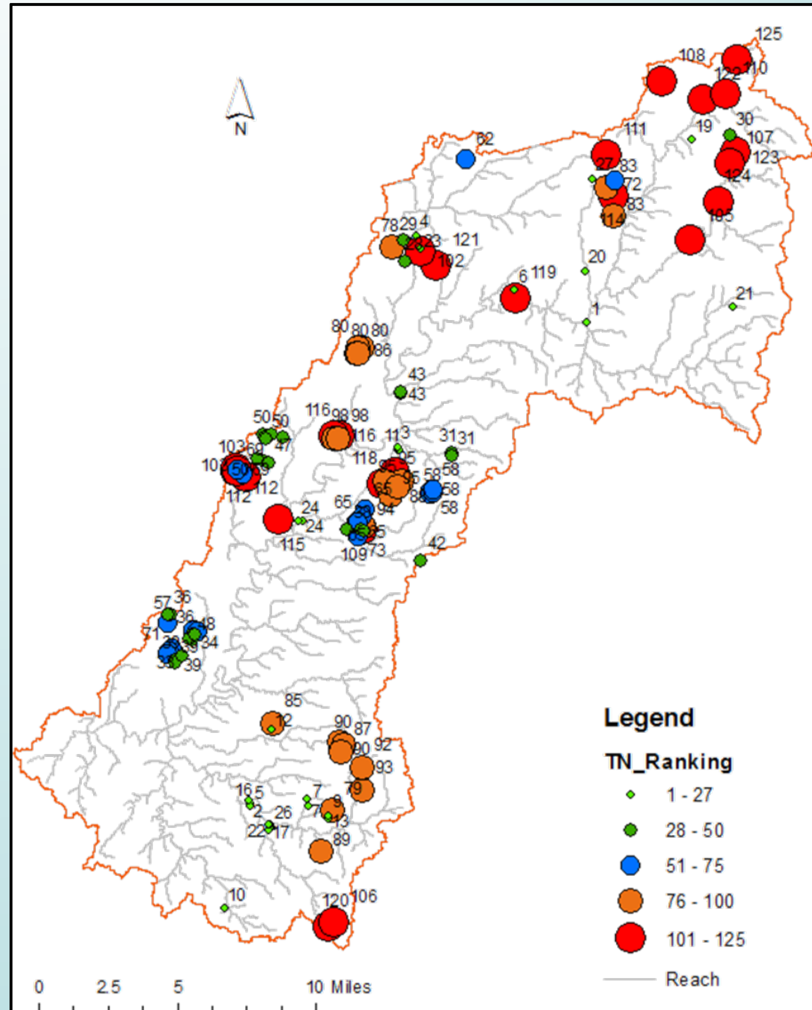
The UEFW SWAT Application



Karcher et al., 2013

Spatial Resolution for Nitrogen loading – Lot-level loads can be elucidated



Ranked TN Loads among farmer's fields applying for agBMP funding

Fixing the Nutrient Problem – Point Sources?

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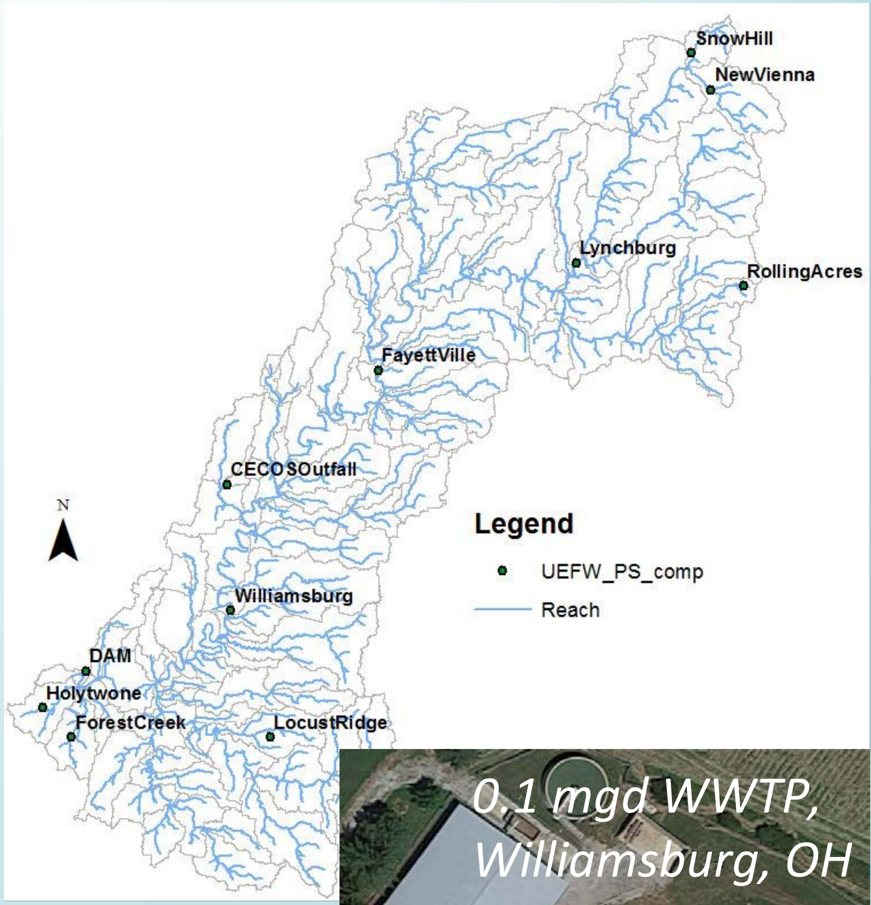
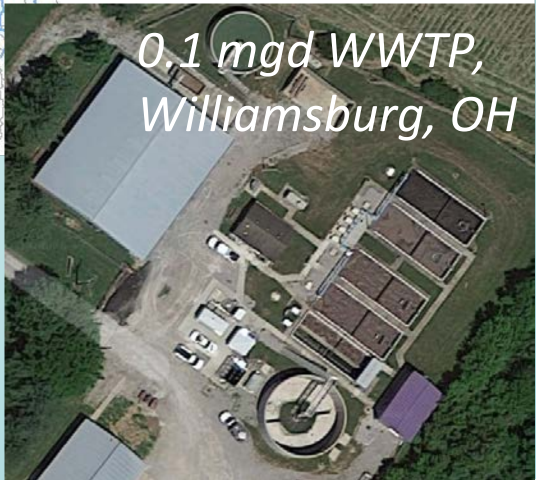
- **85K kg·yr^{-1} TP and 800K kg·yr^{-1} TN reduction needed watershed wide**
  - from WWTP upgrades, agBMPs and septic system repairs
- **9 WWTPs in the UEFW**
  - **1768** kg TP·yr^{-1} reduction needed
  - **6433** kg TN·yr^{-1} reduction needed
- WWTPs nutrient reduction accounts for **at most 2%** of the nutrient reduction needed
- **but, allowing WWTPs to purchase nutrient credits**
  - establishes a market,
  - increases agBMP adoption, and
  - provides avenue for alternative participants

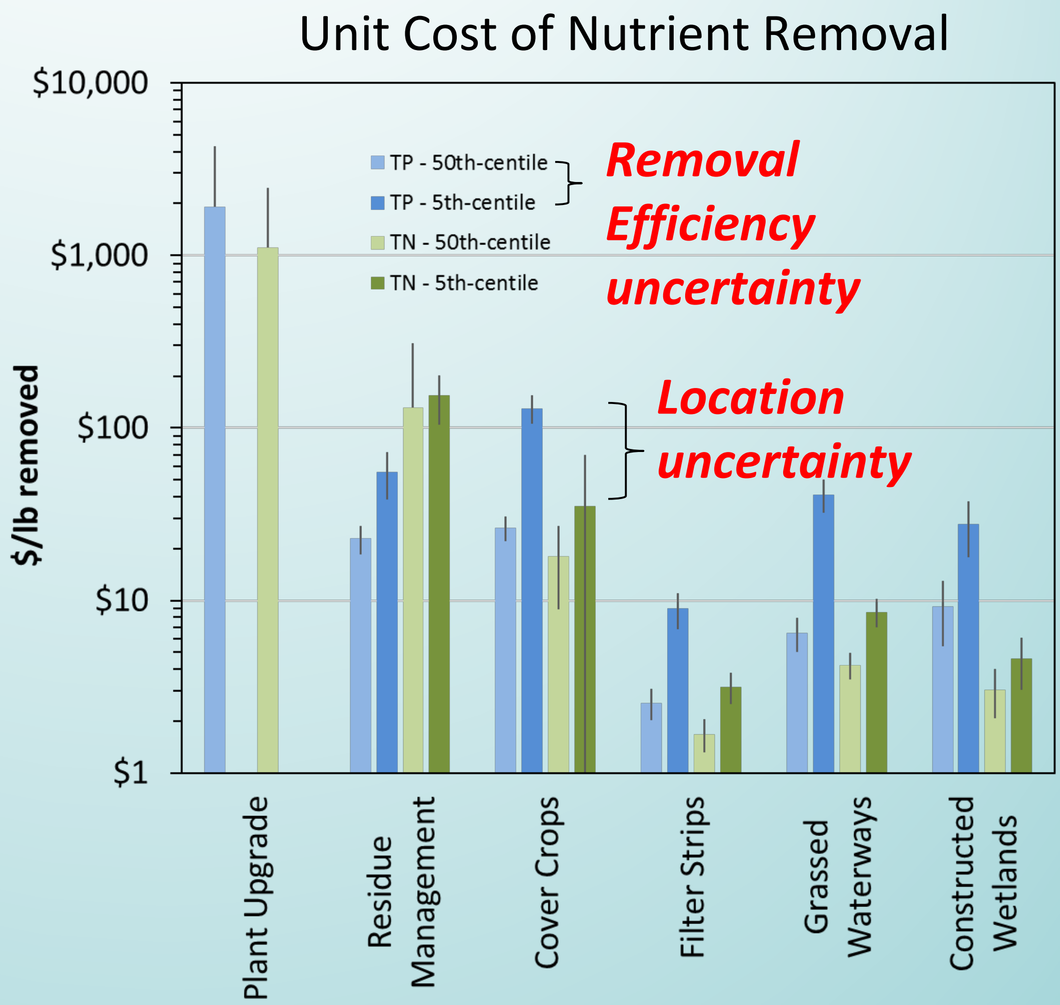




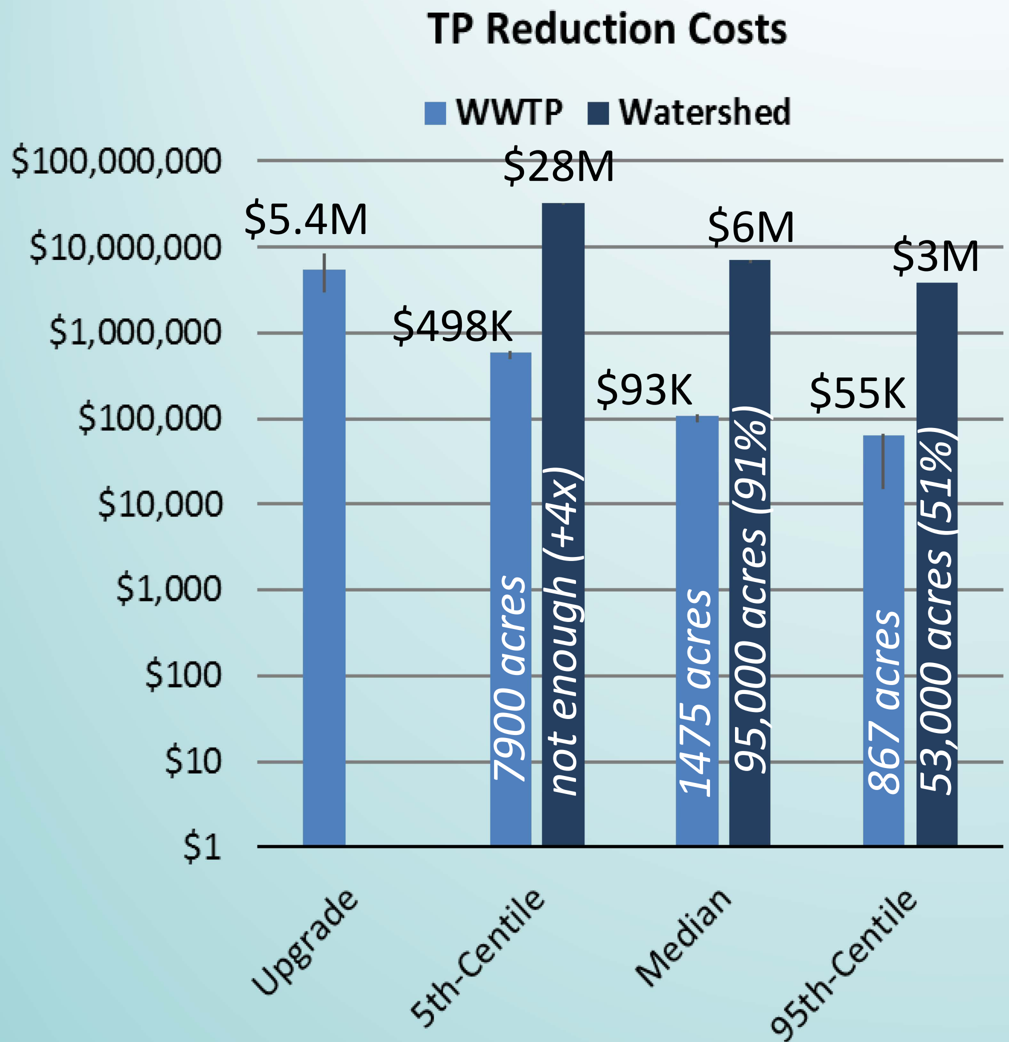
0.1 mgd WWTP, Williamsburg, OH

Plant upgrades vs. agBMP costs

- **agBMPs scenarios:**
  - Residue Management, Cover Crops, Filter Strips, Wetlands, Grassed Waterways, and Septic Repair
  - Septic Repair >> WWTP upgrade >> agBMPs
- **Costs differences among agBMP types are not trivial**

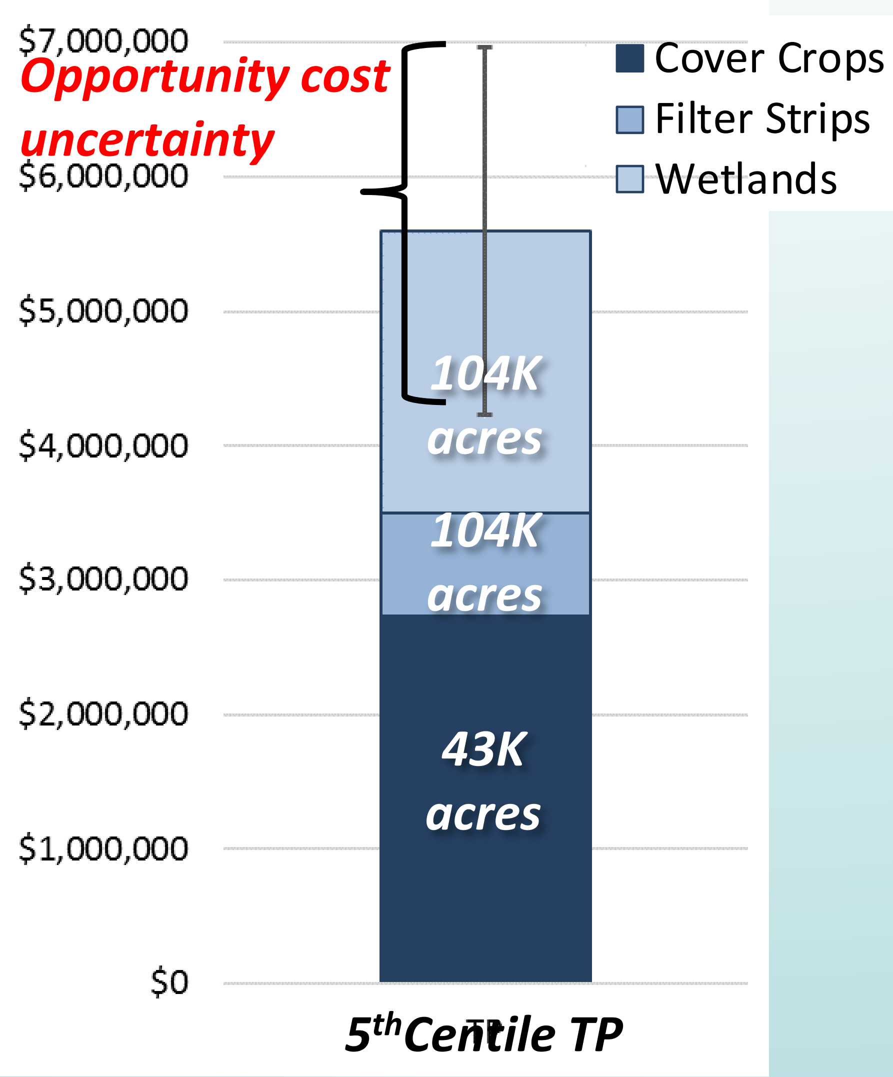


Plant Upgrades vs. Cover Crop Costs



- **To account for 2% reduction from WWTPs - $5.4 million** for WWTP upgrades vs. **$498K** for cover crops over **7900** acres.
- Factoring in uncertainty = a factor of 9 difference in annual cost.
- **To account for all the reduction needed at watershed scale**:
  - The TP problem cannot be fixed with cover crops alone at 5th centile removal efficiency

Watershed Nutrient Reduction Costs



- **\$4.2 – \$7.0Mil annually** to fix **TP** in the watershed at the 5th centile removal efficiency, needs 3 BMPs.
- 46% to 100% of the **TN** enrichment problem would be accounted for pending efficiency
- **For context, the DWTP spends ca. \$700K yr^{-1} for granulated activated carbon to keep drinking water safe**

Understanding a drinking water utility's incentive to protect source water

Michael Elovitz; Kelly H. Birkenhauer; Srinivas Panguluri; Balaji Ramakrishnan; Eric Heiser; Tim Neyer

Background

- Concerns about water quality and drinking water safety
  - Wichita, KS constructed an ozone treatment facility to address taste and odor problems caused by algae in the source reservoir (KDHE 2011)
  - Celina, OH incurred considerable costs, including testing treated water for microcystins, as a result of severe toxic algal blooms (Davenport & Drake 2011)
  - Denver, CO incurred considerable treatment and watershed restoration costs following wildfire induced sediment loading (Gartner et al. 2013)
  - Toledo, OH, residents told not to drink water due to toxins from harmful algal blooms (HABs) in Lake Erie (Snider 2014)
  - Waco, TX installed a dissolved air flotation plant and ozone treatment to, in part, address persistent taste and odor problems caused by algal blooms (Dunlap et al. 2015)
  - Des Moines Water Works suit seeks to make agricultural drainage districts address nitrate problems (Hanson et al. 2016)

Motivation

- Assess whether source water protection is cost-effective and determine whether drinking water treatment plant (DWTP) has incentive to participate in water quality trading (WQT) program as demander of nutrient abatement from agriculture
  - States and Agencies want WQT to work because it is cost-effective compared to command-and-control, but there are barriers.
  - **E.g., thin markets (too few participants)**

- Understanding how treatment costs are affected by changes in source water quality is essential to understanding tradeoffs between natural and built infrastructure
  - Can provide evidence whether it is less expensive to invest in natural infrastructure than pay for treatment on site
  - **Important knowledge gap for municipalities and DWTPs** (Gartner et al. 2013)

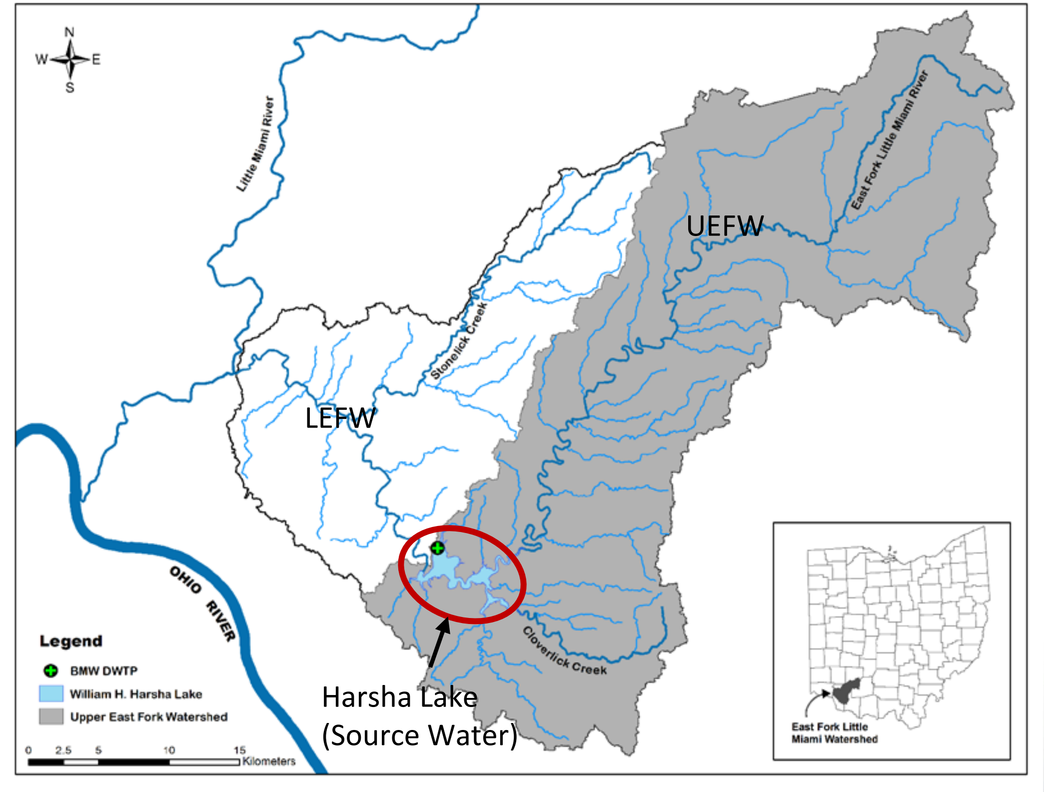
General Framework for DWTPs

1. Link changes in source water quality to changes in treatment costs
2. Understand how source water quality is impacted by changes in watershed load reductions (through land use change or preservation)
   - Requires connecting watershed variables to variables governing costs of drinking water treatment process (e.g., turbidity or TOC). When treatment variables differ from watershed variables (nitrogen, phosphorus, sediment), this translation needs to be made.
3. Estimate costs of the land use change (e.g., best management practices [BMPs]) or preservation that leads to the watershed load reductions

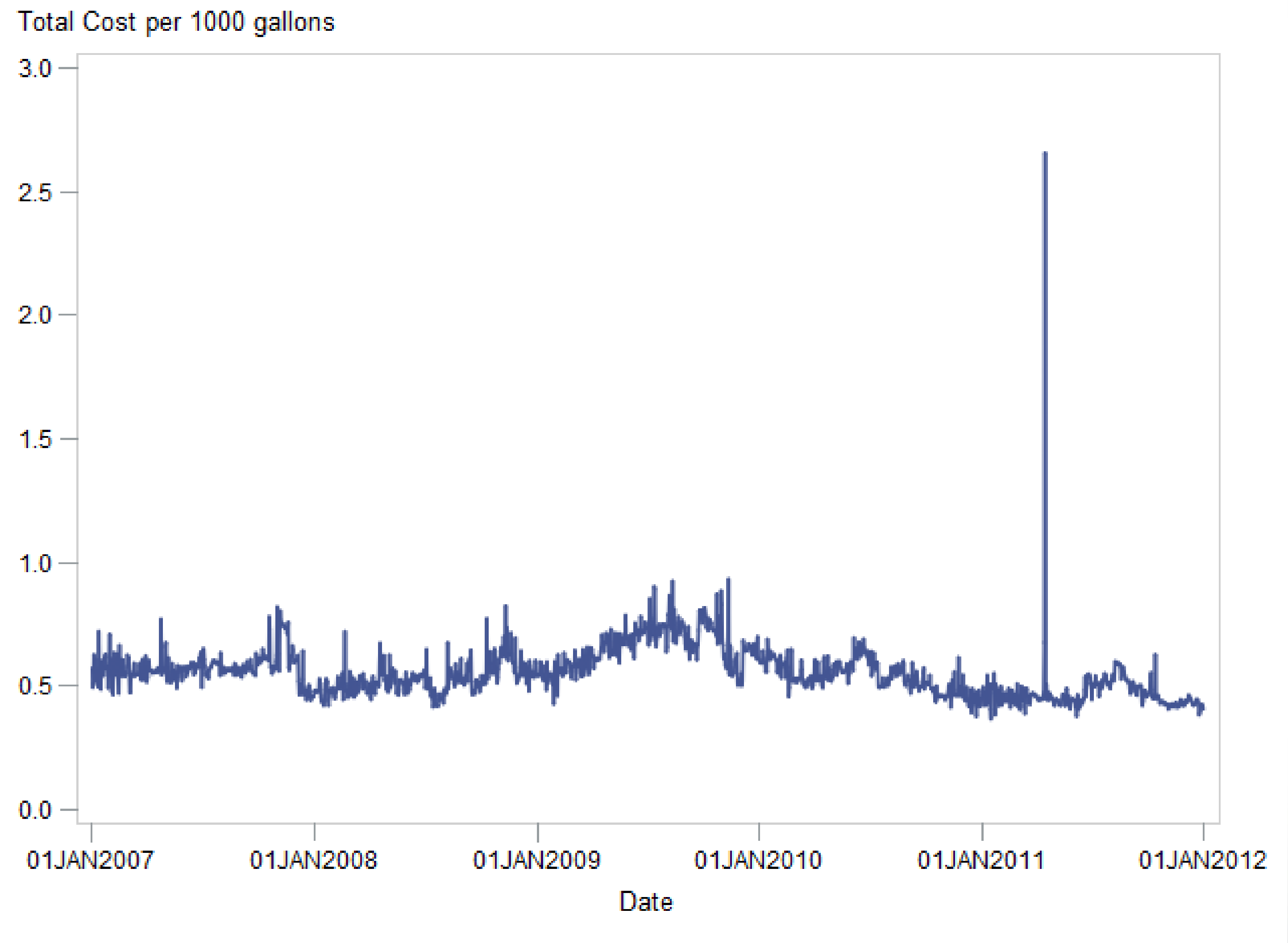

Drinking Water Plant Intake Structure on Lake Harsha

Case Study

- Bob McEwen Water Treatment Plant (BMWTP), Batavia, OH
  - Clermont County Water Resources Dept. (operator logs, paper records, invoices)
  - US Army Corps. (reservoir characteristics)
  - Time series: 1826 daily observations, 2007-2011



Total Cost per 1000 Gallons of Finished Flow (Aug 2012$)



Time Series Model

- Analyze daily costs using Error Correction Model (ECM).
  - Several commonly used time series models ignore the long-run equilibrium relationships predicted by economic theory.
  - Changes in one independent variable can have immediate effect on treatment costs, a long-run effect, or both.

$$\frac{Cost}{1000\ gallons} = f\begin{pmatrix} FINAL, RAWTOC, TURB, pH, \\ GCPOOL, \\ TEMP, ActualTOC, \\ SPRSUM, CY07 - CY10, PROCESS \end{pmatrix}$$

Time Series Results

- Cost of treating turbid water depends on current turbidity and water previously treated

- 1% decrease in TURB(≈0.11NTUs) leads to an immediate decrease of 0.02% in TC/1000 gal. with another 0.1% decrease over future time. Total effect is 0.11%

- Approximately $0.09 decrease in costs per million gallons immediately and another $0.53/MG into future days

- 1% decrease in turbidity, leads to $1120 annual decrease in treatment costs

Link Water Quality to Load Reductions

- How does total phosphorus (TP) load impact turbidity in source (raw) water?
  - Chose TP load because its affinity for natural clay particles and its link to harmful algal blooms
  - Ideal: Link daily nutrient/sediment results to daily turbidity (TURB)
  - TP load is weekly measurement of daily grab sample

- Time series analysis (polynomial distributed lag model)
  - TURB=f(TPLOAD, GCPOOL, SPR, CY09, CY10)

- 1% reduction in TPLOAD (≈10.74 lbs/day) leads to 0.15% decrease in turbidity over the long-run (5 weeks)
  - $168 in treatment cost savings from 1% annual reduction in TP load
  - Cost to control 10.74 lbs/day for a year using cover crops=$11763--$105867
  - Price/lb=$3—$27; 10.74*365*price

Conclusions

- Case study revealed no incentive to purchase abatement, but there are lower costs with lower turbidity and TP
  - DWTPs with other treatment processes/locations may have incentives
  - Limitations: uncertainties in lake, not having right/enough data obscures incentives
- Future research:
  - Does treatment process change lead to different incentives?
    - BMWTP built granular activated carbon building, new study (2013-2016)
  - New data/models
    - Data on algal communities, algal toxins, pesticides, and other chemicals in agriculture
    - Lake modeling could improve link to source water quality

EPA

Office of Research and Development

SAFE AND SUSTAINABLE WATER RESOURCES RESEARCH PROGRAM





Cyanotoxin occurrence associated with cyanoHAB events on Harsha Lake

Joel Allen

2017-05-23

Statutes and States

- Public Law 113–124 Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014
  - Ecology and impacts of freshwater harmful algal blooms
  - Forecasting and monitoring of and event response to freshwater harmful algal blooms in lakes, rivers, estuaries (including their tributaries), and reservoirs
- Public Law 114–45 Drinking Water Protection Act
  - Establish guidance regarding cyanotoxin analytical methods, monitoring frequency
  - Provide technical assistance to affected States and public water systems
- State Interactions
  - Ohio, Indiana, Kentucky
  - Ohio River Sanitation Commission,
  - Upper Mississippi River Basin Association
- Federal Partners
  - USGS, USACOE
- Local/Stakeholder Partners
  - Clermont County Ohio

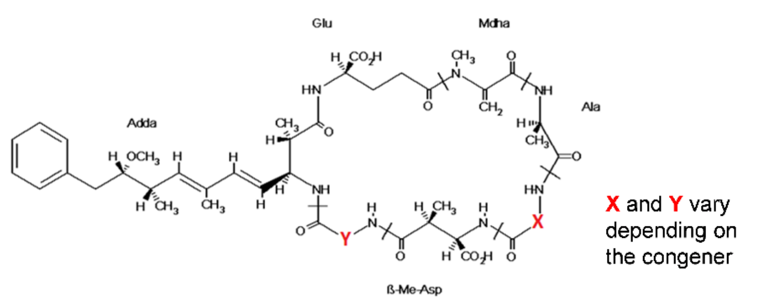
ORD HABs Research – Lake Harsha

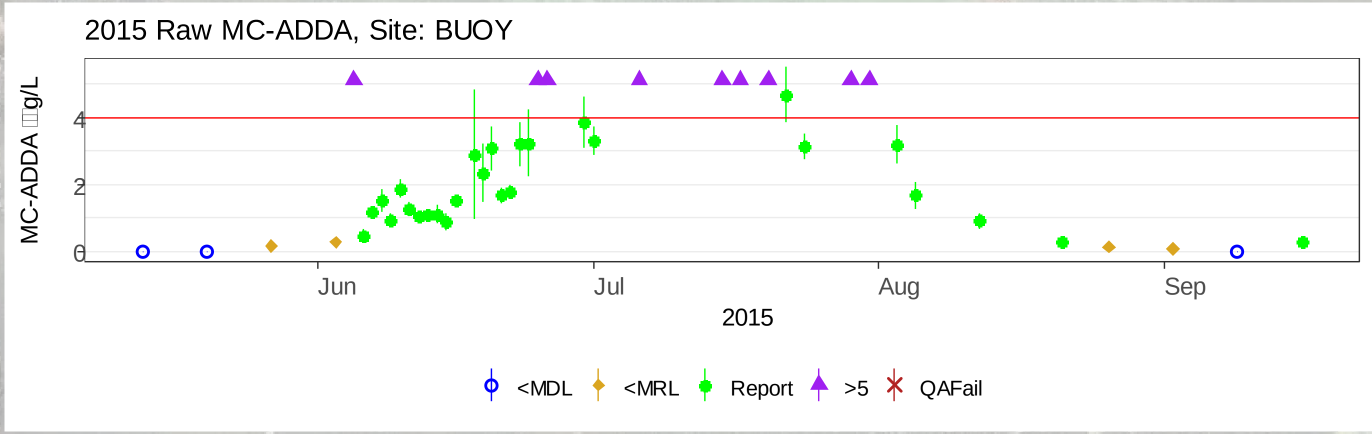
- **Inland HAB Management**
  - Monitoring and modeling using high frequency data to predict and assess HAB and cyanotoxin intensity
- **Modeling Reservoir Algal Community Dynamics**
  - Link Watershed to Drinking Water Treatment and Recreation Uses
- **Ecological contributors to cyanoHABs**
  - Investigate if specific sediment areas act as seed beds for initial cyanobacterial stocks
- **Sorption and Recovery of Total Phosphorous on Reactive Media**
  - Evaluate innovative solid media, developed at EPA, to remove phosphate and ammonia from waste water.
- **Optimizing early stages of the water treatment process**
  - Oxidants and PAC for the removal of seasonally occurring contaminants
- **Removal of Cyanotoxins using Granular Activated Carbon**
  - Studies at various cyanotoxin concentrations to assess removal efficiency and carbon usage rate.

POC: Joel Allen allen.joel@epa.gov

CyanoHABs in Source Waters

- **Drinking Water Guidelines for microcystins**
  - **World Health Organization: 1µg/l**
  - **US EPA/Ohio/Oregon: 0.3µg/l (10-day, sensitive populations)**
  - **Minnesota: 0.1µg/l**
  - **Vermont: 0.16µg/l**
- **Recreational Contact**
  - **US EPA draft guidance: 4µg/l**
  - **States 0.8-20µg/l**

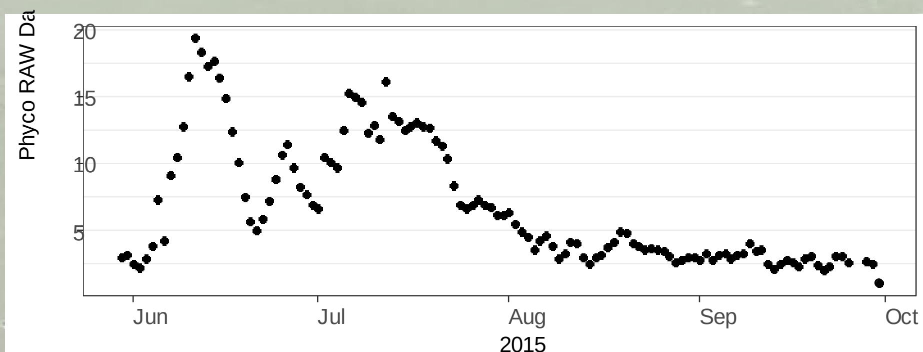




CyanoHAB Source Water Monitoring

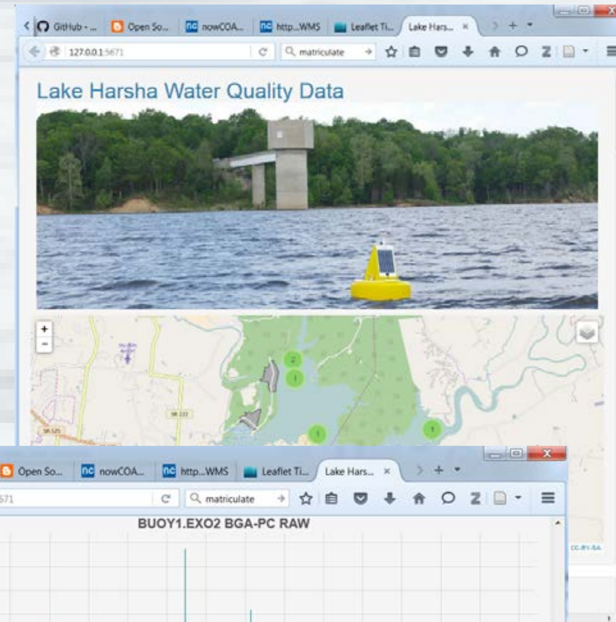
- **Source Water Monitoring**
  - **Bloom prediction**
    - **Biotic/abiotic factors driving cyanobacterial ecology?**
    - **Surrogates indicating impending blooms and cyanotoxin production?**
  - **Potential opportunities of reservoir hydrological management**
- **Temporal scale is critical to understand ecological context**
  - **Sampling should reflect the time-scale at which relevant processes occur**

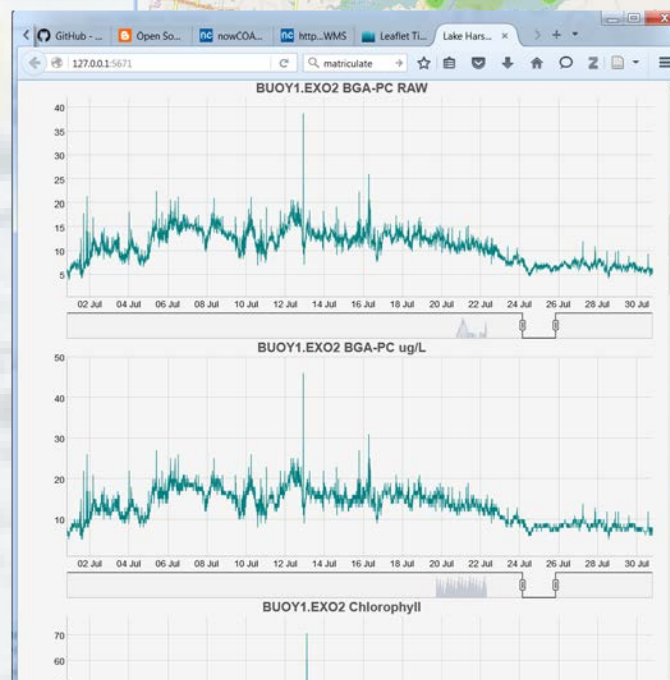
- **HF Physico-chemical**
  - **Water Quality**
  - ***In-vivo* Fluorescence**
  - **Photosynthetically Active Radiation**
  - **Weather**
- **Temporally Relevant Sampling**
  - **Cyanotoxin Concentration**
  - **Nutrient Chemistry**
  - **Molecular Markers**

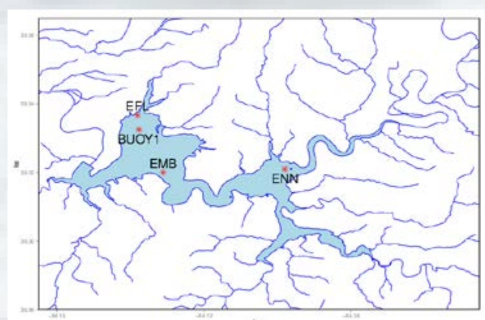


2017 Research

- Continue temporally dense sampling/monitoring
- Buoy to be deployed at ENN with EXO2 sonde and temperature string
- 24 hour profiling to assess vertical migration and optimal sampling approach
  - 2 hour intervals
  - Sample collection at 1m increments from surface to thermocline
- Automated ELISA analyzer
  - MC-ADDA
  - Anatoxin
  - Saxitoxin
- Predictive model development



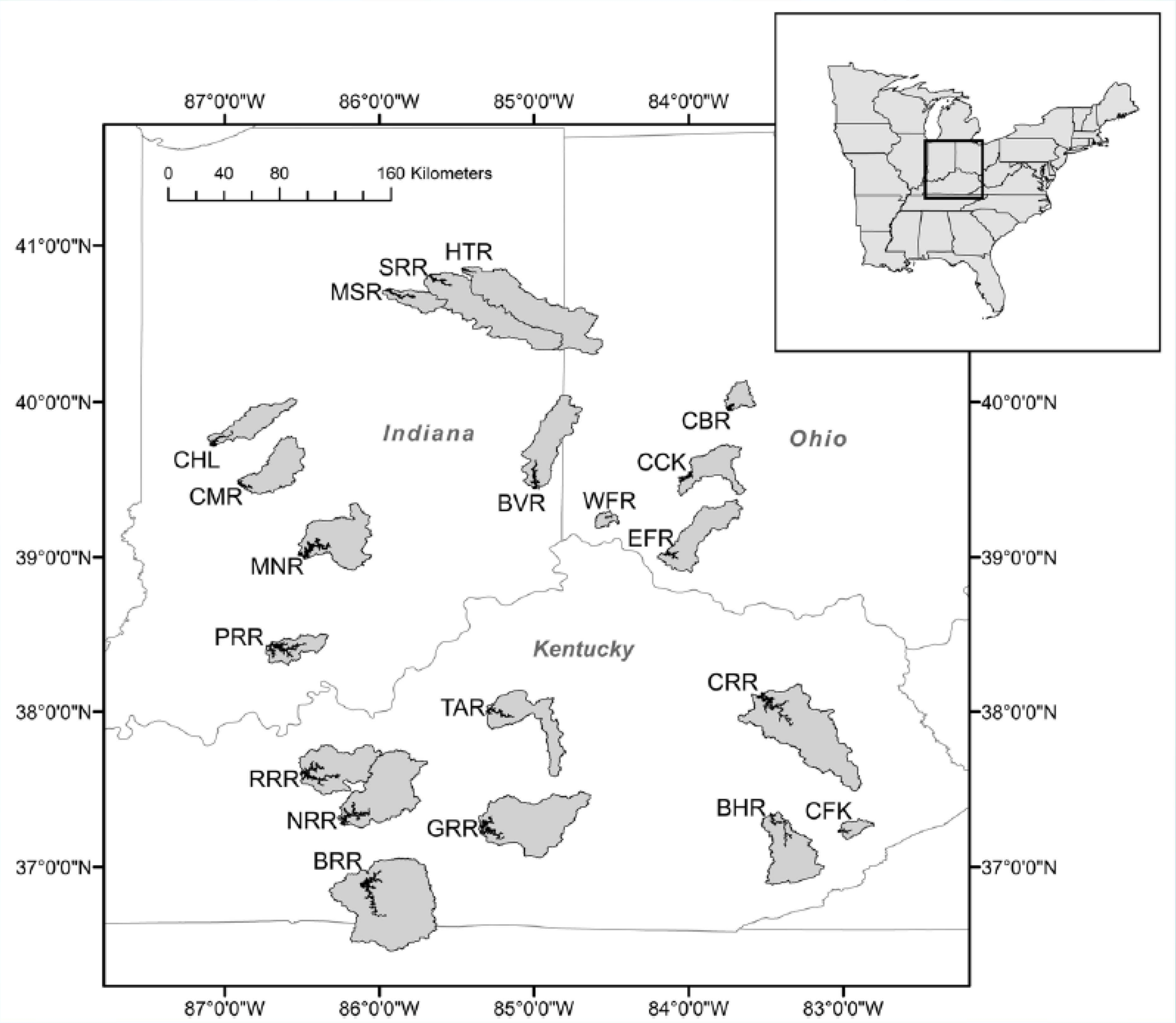




Cyanobacteria historical trend in USACE Louisville District Reservoirs

Nate Smucker,
Jake Beaulieu,
Chris Nietch

United States Environmental Protection Agency



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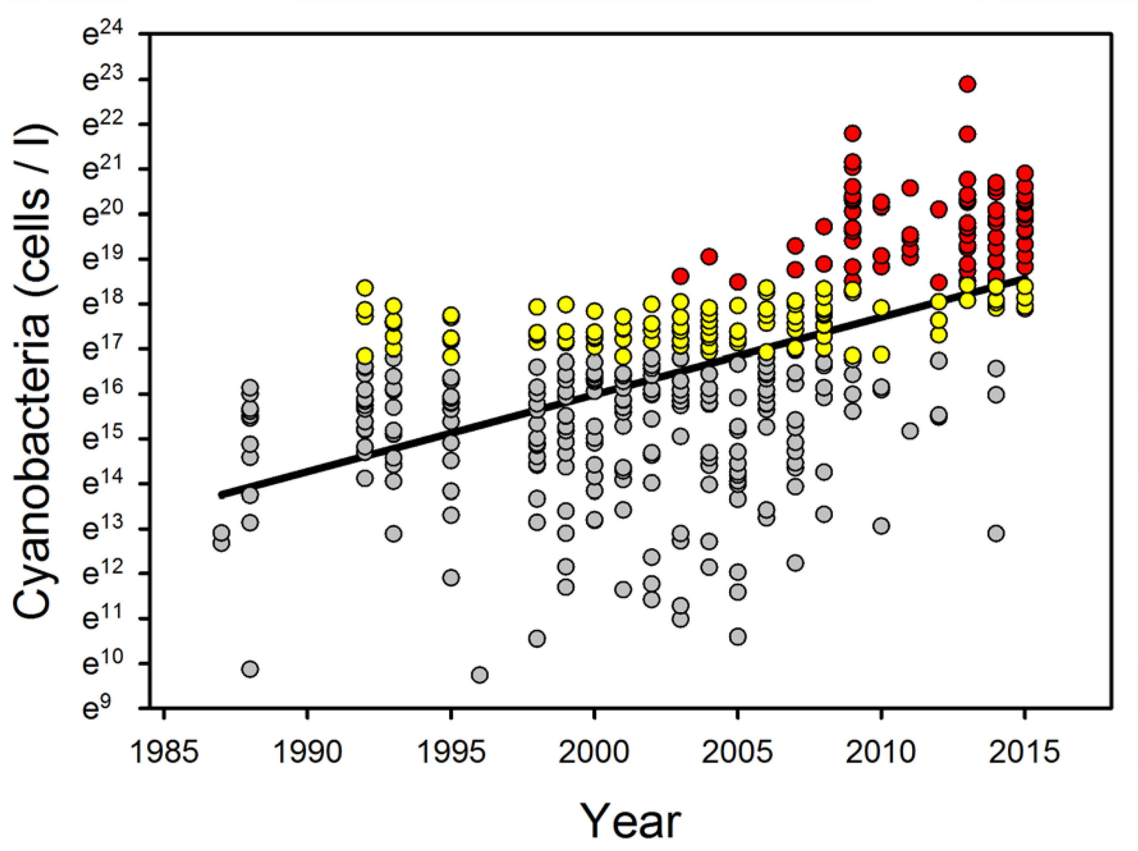
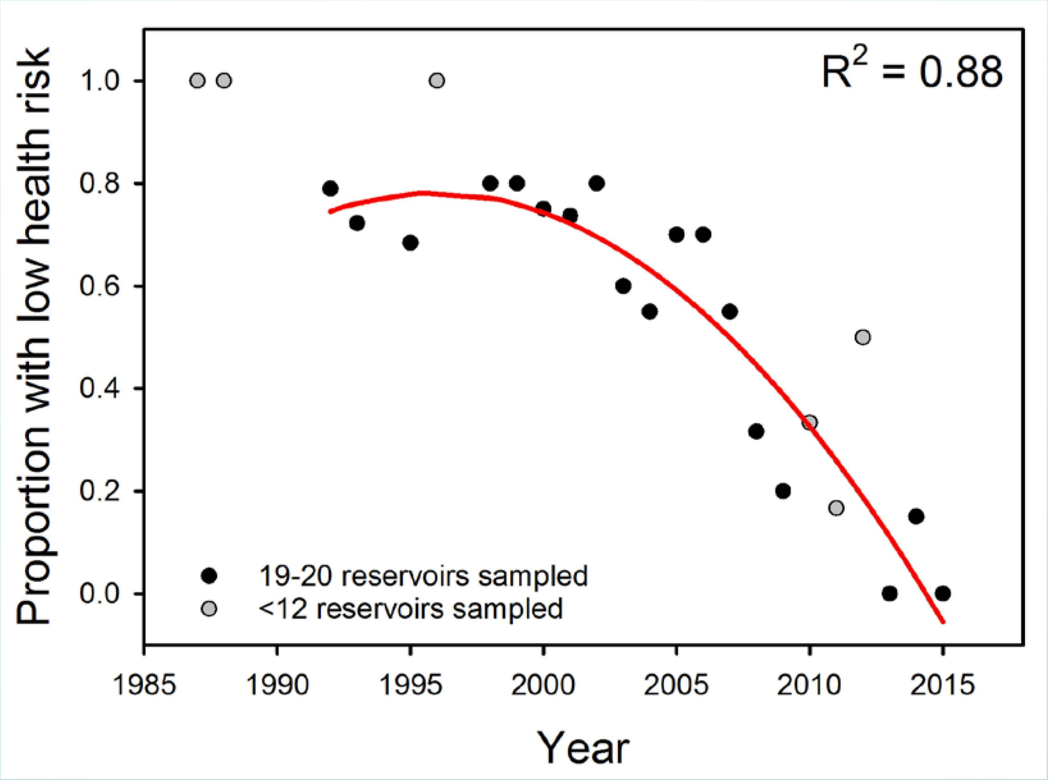
Yearly maximum densities of cyanobacteria in 20 reservoirs

- Maximum densities of cyanobacteria observed during the summer have been increasing in general
- Seeing more reservoirs experiencing conditions with moderate to high risk to human health



Decline in the number of reservoirs having no moderate to high health risks



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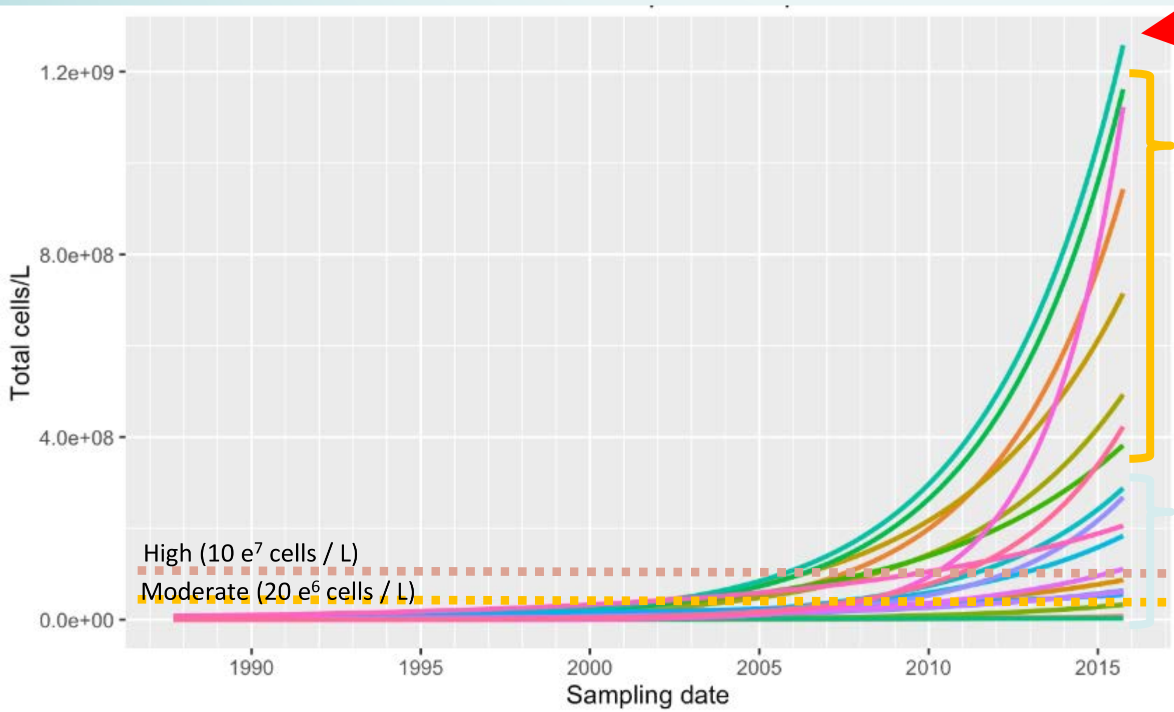
Trends of increasing summer maximums of cyanobacteria densities for 20 reservoirs



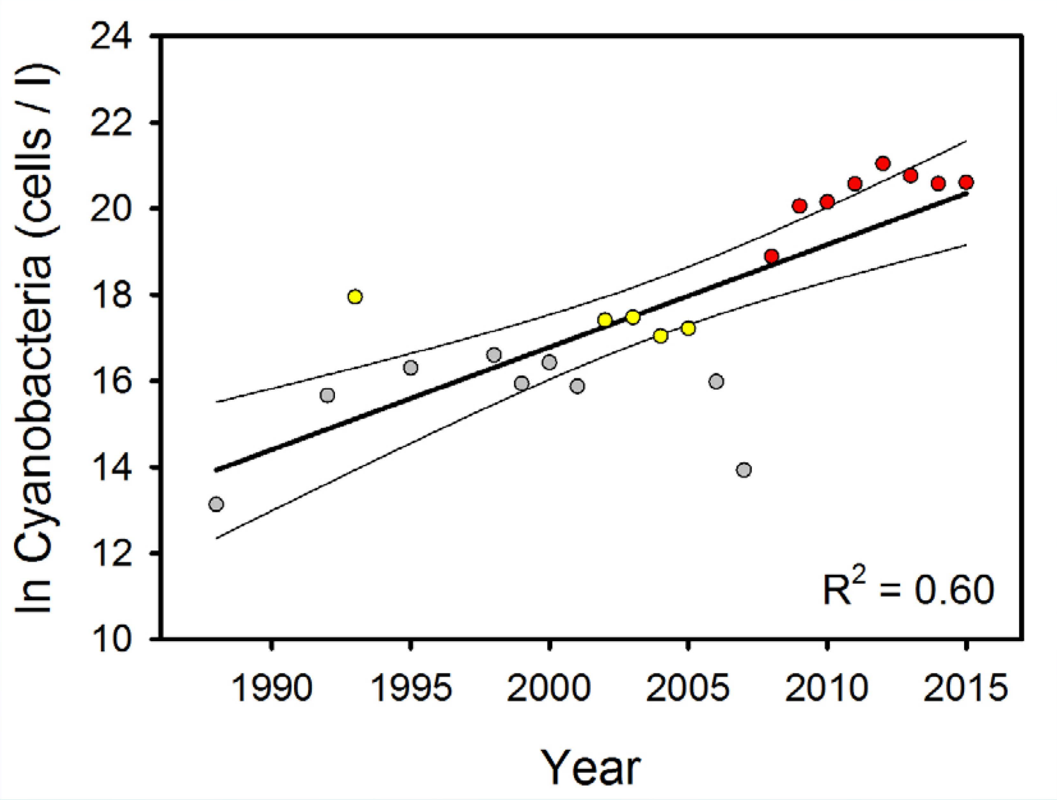
Lake Harsha

Harden (13% forest)
West Fork (1% forest)
Brookville (23% forest)
C.J. Brown (9% forest)
Caesar Creek (13% forest)
Salamonie (9% forest)
Cagles (22% forest)

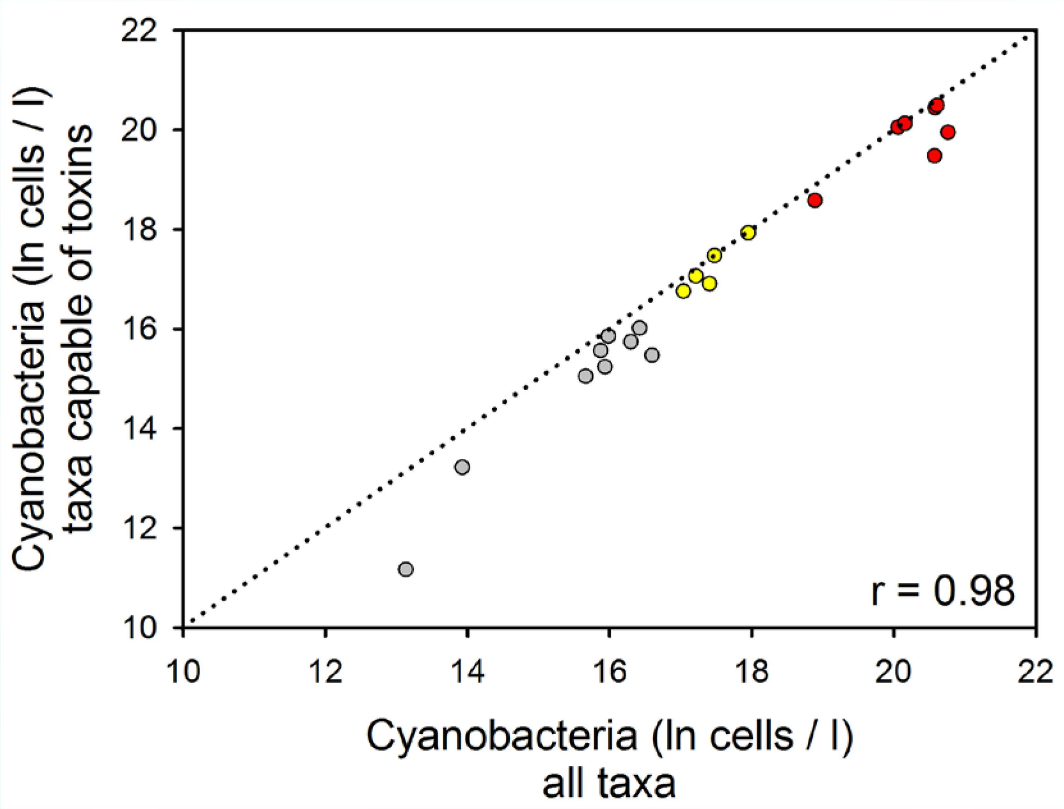
Green River (61% forest)
Nolin (46% forest)
Taylorsville (45% forest)
Roush (7% forest)
Rough River (51% forest)
Barren River (39% forest)
Mississinewa (14% forest)
Patoka (67% forest)
Monroe (82% forest)
Carr Creek (76% forest)
Buckhorn (84% forest)
Cave Run (78% forest)

13 reservoirs in high risk category
5 reservoirs in moderate risk category
2 reservoirs in low risk category

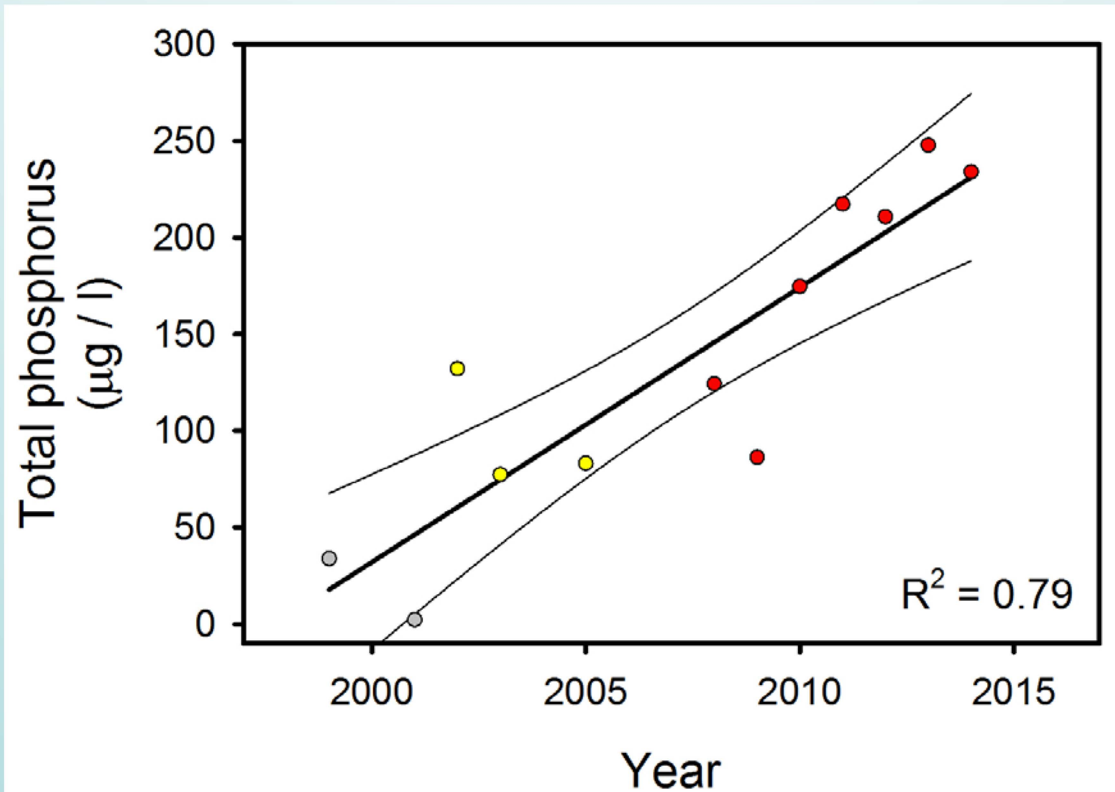
Observed annual maximums of cyanobacteria cell densities in Harsha



Taxa capable of producing toxins typically dominate cyanobacteria cell densities in Harsha



Phosphorus concentrations have increased since 1999



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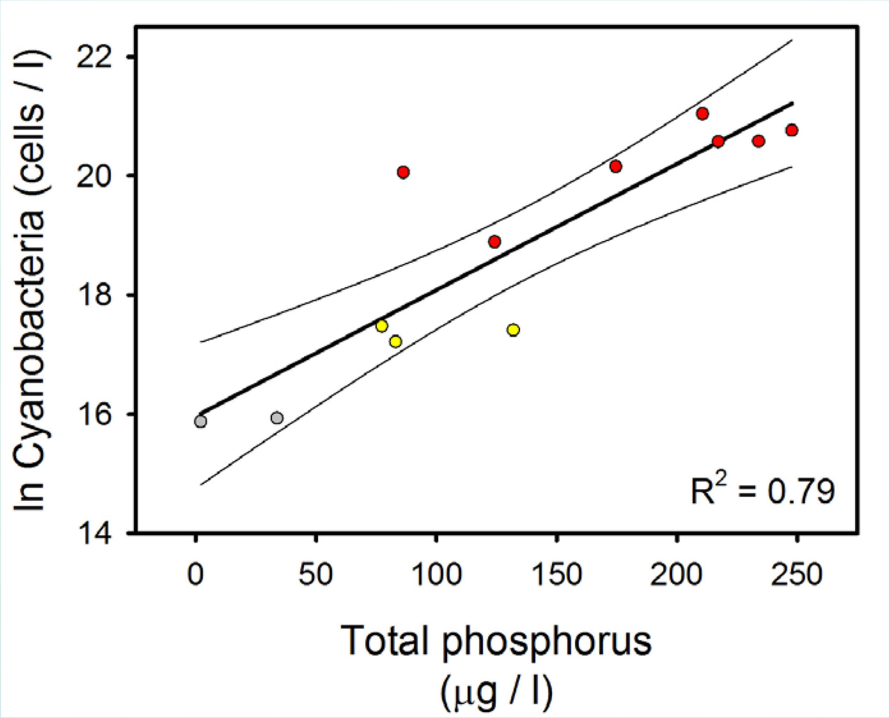
Increased phosphorus concentrations are associated with greater summer maximum densities of cyanobacteria



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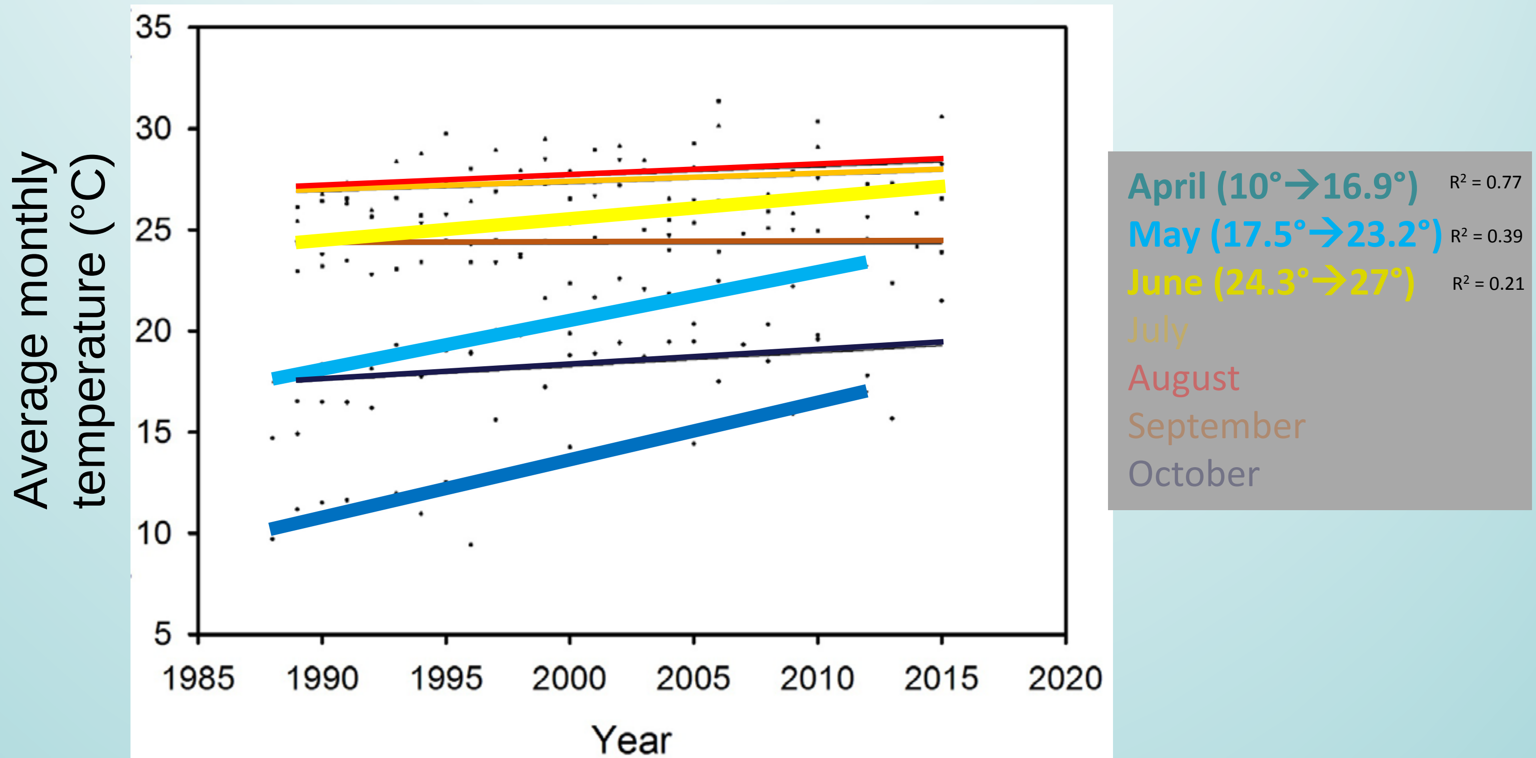
Harsha surface temperatures have been increasing earlier in the year



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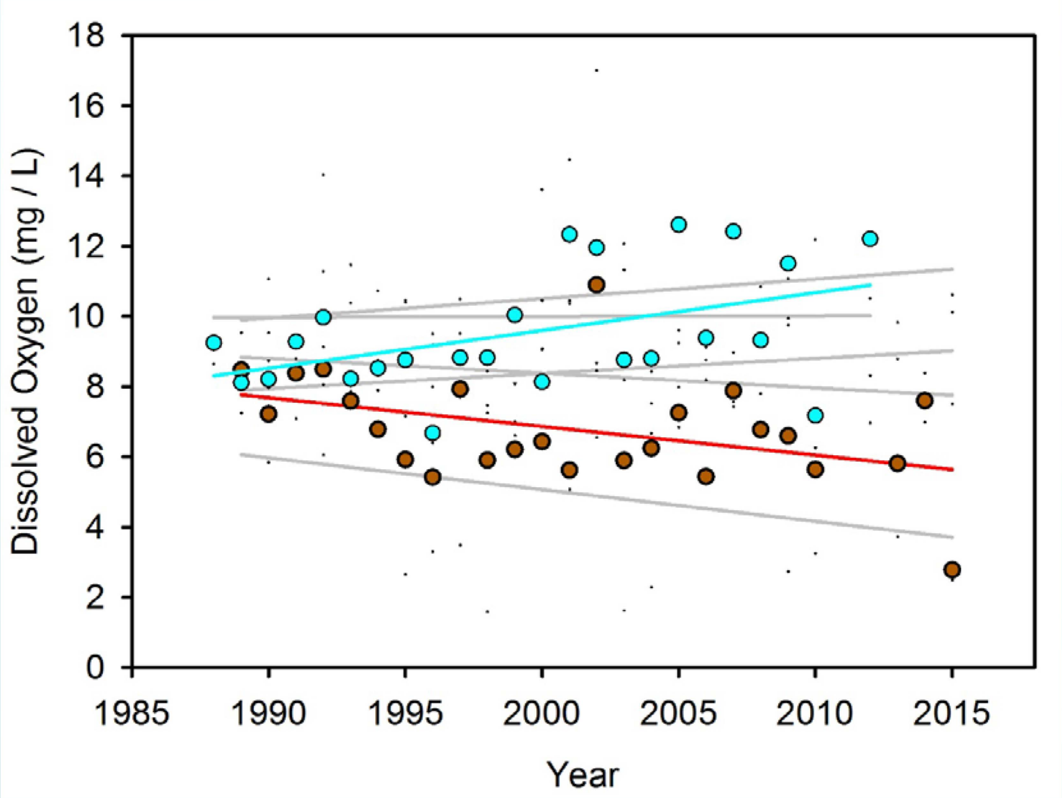
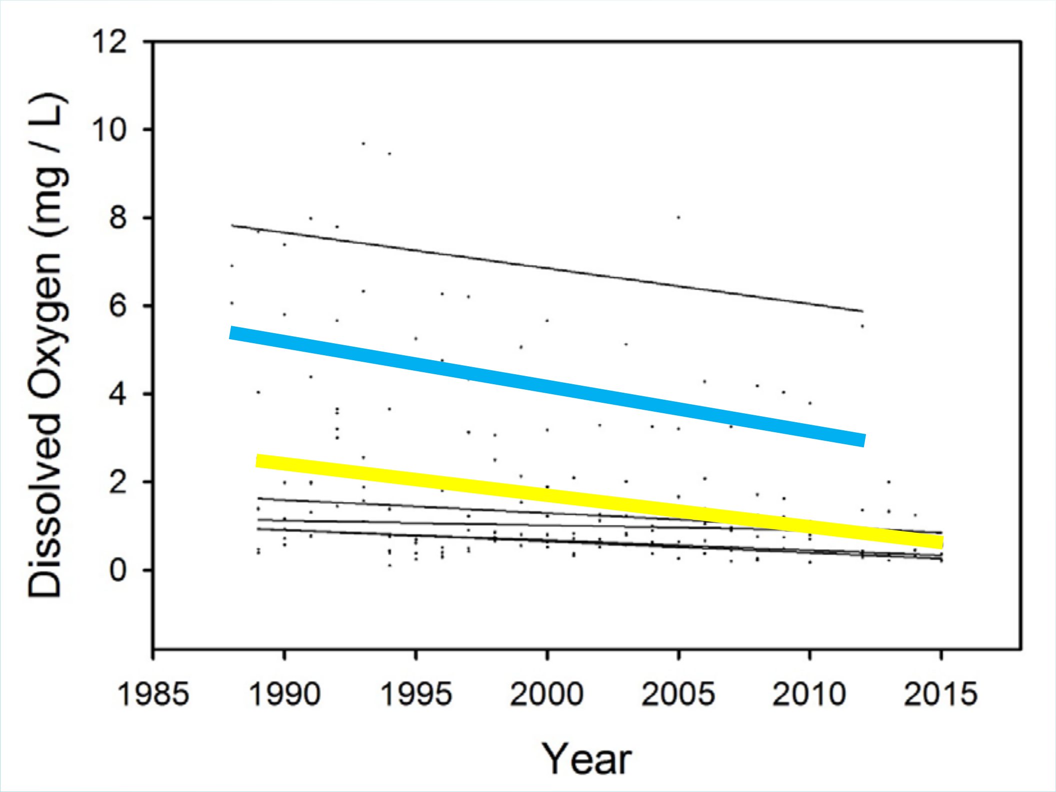
In the epilimnion, average and maximum observed dissolved oxygen (DO) have increased in May whereas average DO and minimum DO decreased in September



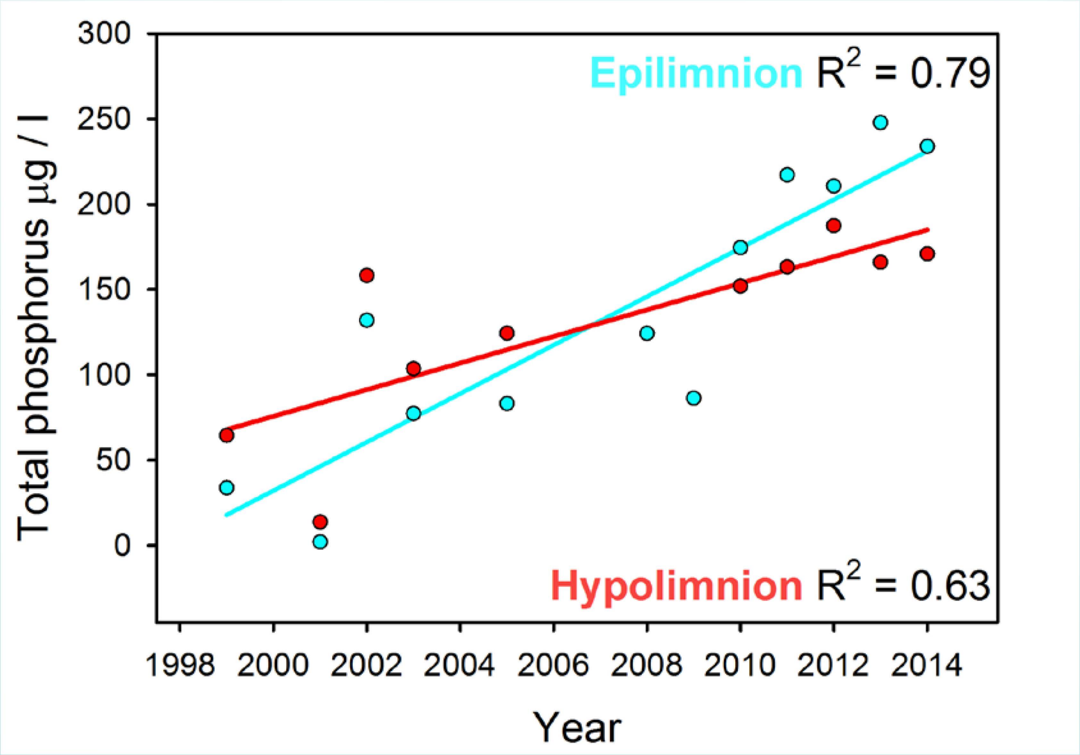
Apr (R² = 0.00)
May **(R² = 0.20) – 8.3 → 10.8 mg / L (Max DO [+]: R² = 0.32)**
Jun (R² = 0.03)
Jul (R² = 0.07)
Aug (R² = 0.09)
Sep **(R² = 0.17) – 7.7 → 5.6 mg / L (Min DO [–]: R² = 0.24)**
Oct (R² = 0.09)

In the hypolimnion, average dissolved oxygen has decreased in May and June



Apr (R^2 = 0.15)
May **(R^2 = 0.41) – 5.4 → 2.9 mg / L**
Jun **(R^2 = 0.40) – 2.5 → 0.6 mg / L**
Jul (R^2 = 0.21)
Aug (R^2 = 0.10)
Sep (R^2 = 0.02)
Oct (R^2 = 0.11)

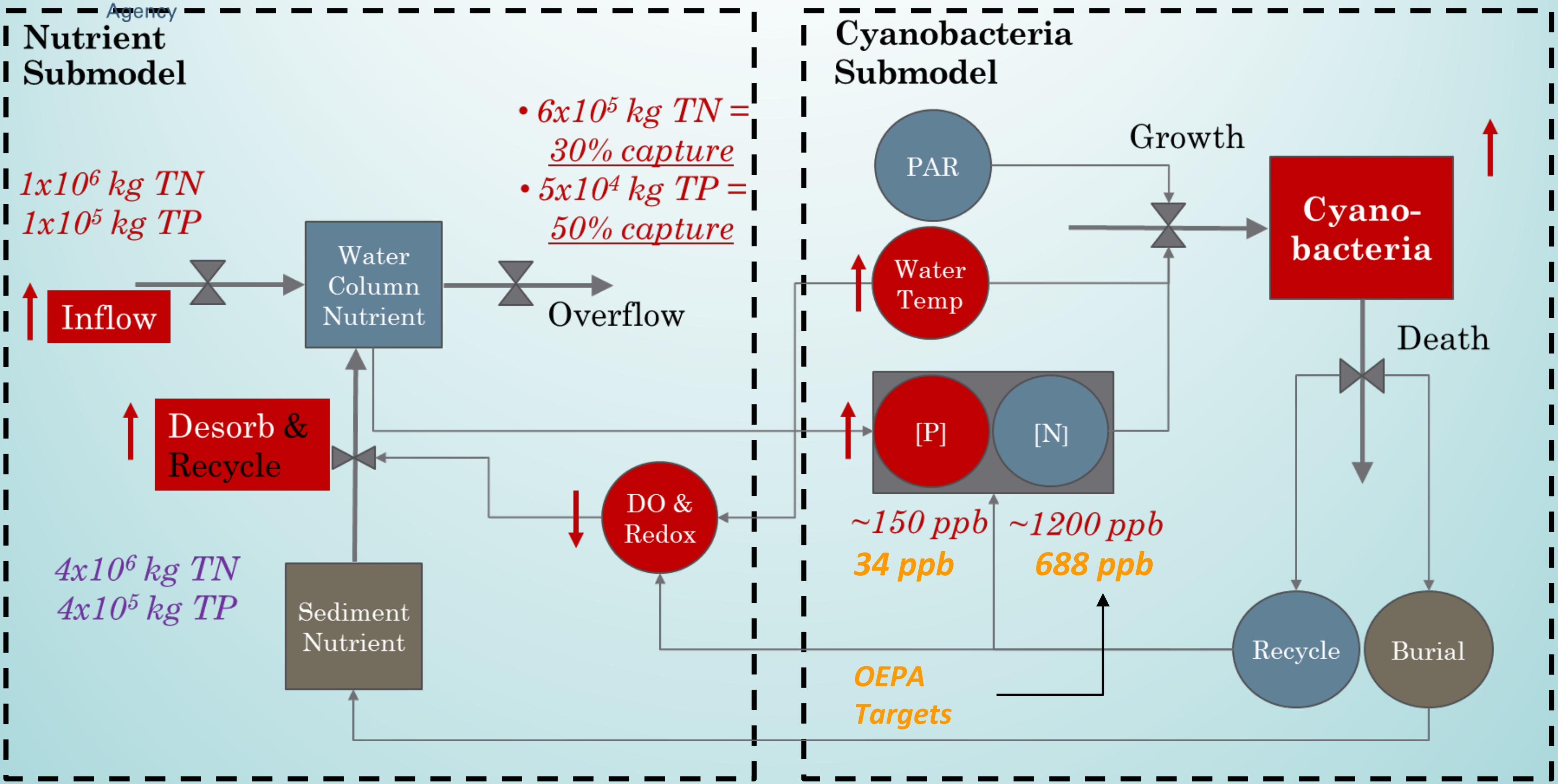
Phosphorus concentrations during May have increased since 1999



This slide is a placeholder to make a summary figure showing the story of the previous slides:

Phosphorus and temp up, algae/cyano up, epilimnion DO up in spring, down in fall, hypolimnion goes anoxic earlier, phosphorus in hypolimnion increases

Lake Algae - Nutrients Linkage – Model



❖Will the watershed nutrient load reduction fix the algae problem in Harsha Lake: How long will it take?

- *Depends on the role of lake sediments and other internal nutrient cycling processes*
- *Market participation depends on this understanding*

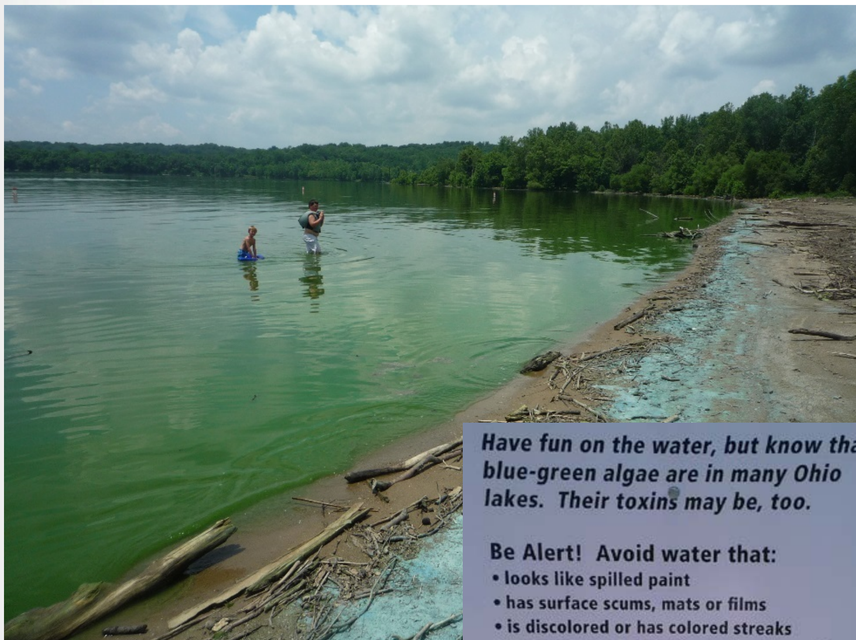
Watershed-climate interactions regulating biogenic gases in reservoirs

Jake Beaulieu

US EPA, Office of Research and Development

Water Quality Issues at Harsha Lake

Algal Blooms

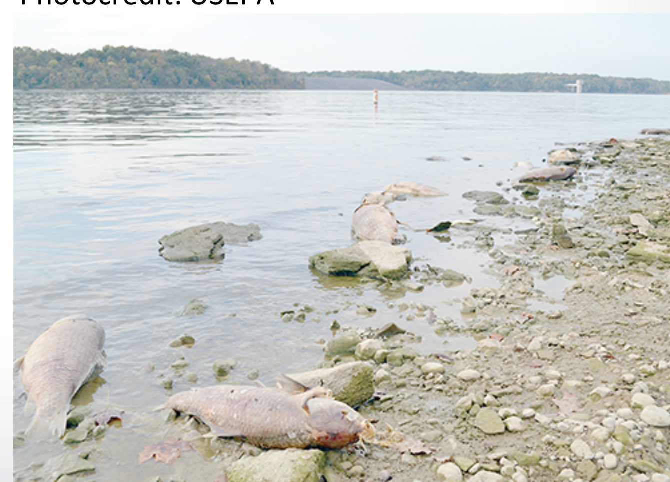


Photocredit: Clermont County

Photocredit: USEPA

Oct 2015 Fish Kill

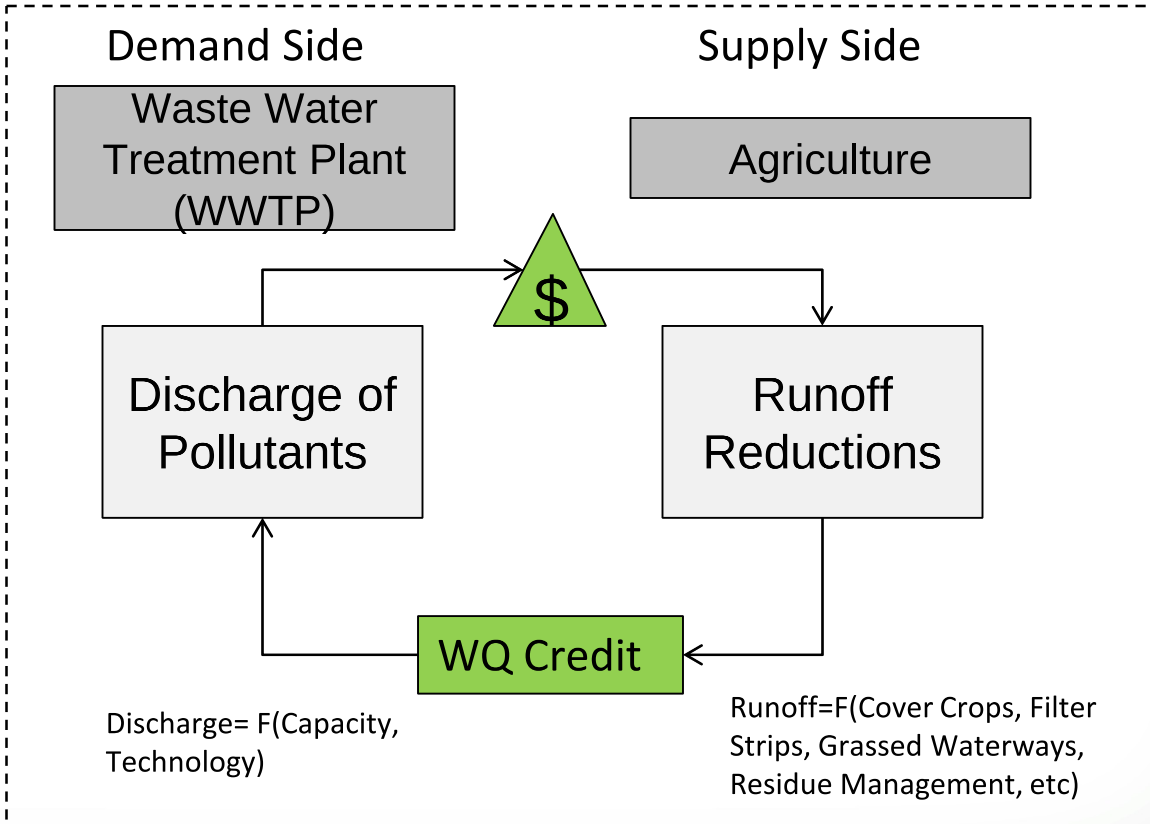
Photocredit: USEPA



Photocredit: Clermont Sun

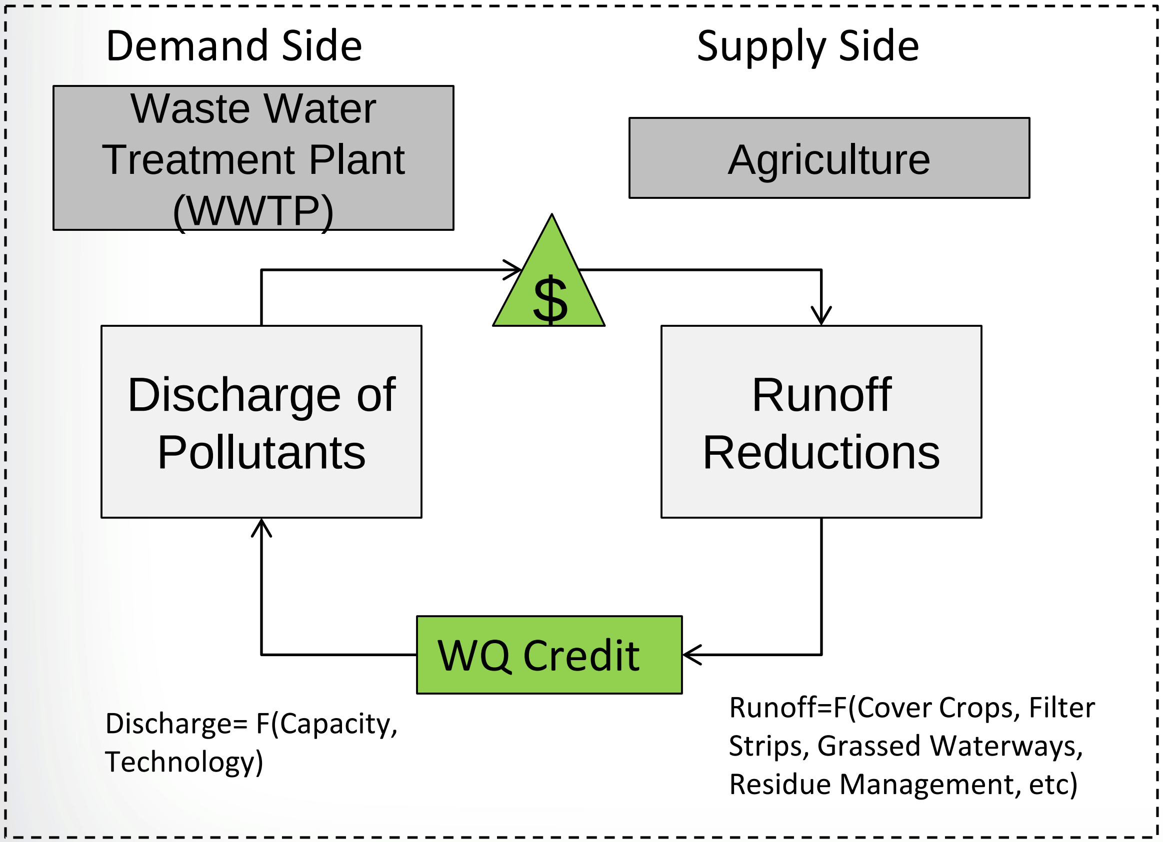
Water Quality Trading

Traditional WQT Market



Co-benefits of Water Quality Trading

Traditional WQT Market

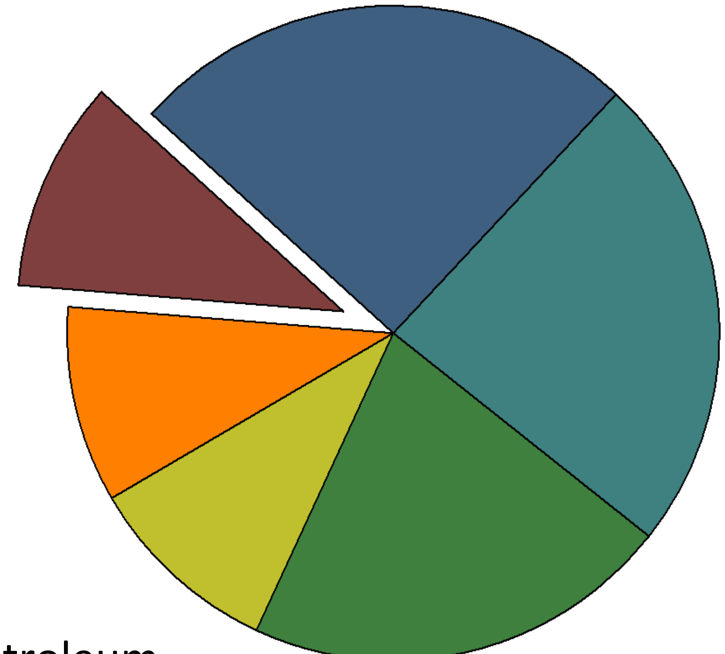


Co-benefits

- Wildlife habitat
- Enhanced property values
- Improved recreational opportunities
- C storage in created wetlands or riparian buffers
- GHG reductions from soils
- GHG reductions from waterways

US Anthropogenic CH_4 Budget

Natural Gas
7.0 Tg/yr

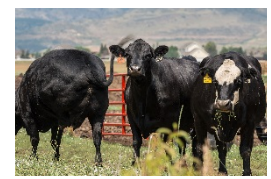


Reservoirs
~2.9 Tg/yr
Beaulieu et al (2014)

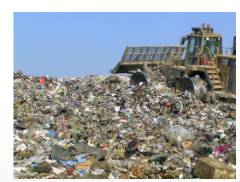
Coal Mining
2.7 Tg/yr

Petroleum
2.7 Tg/yr

Ruminants
6.6 Tg/yr



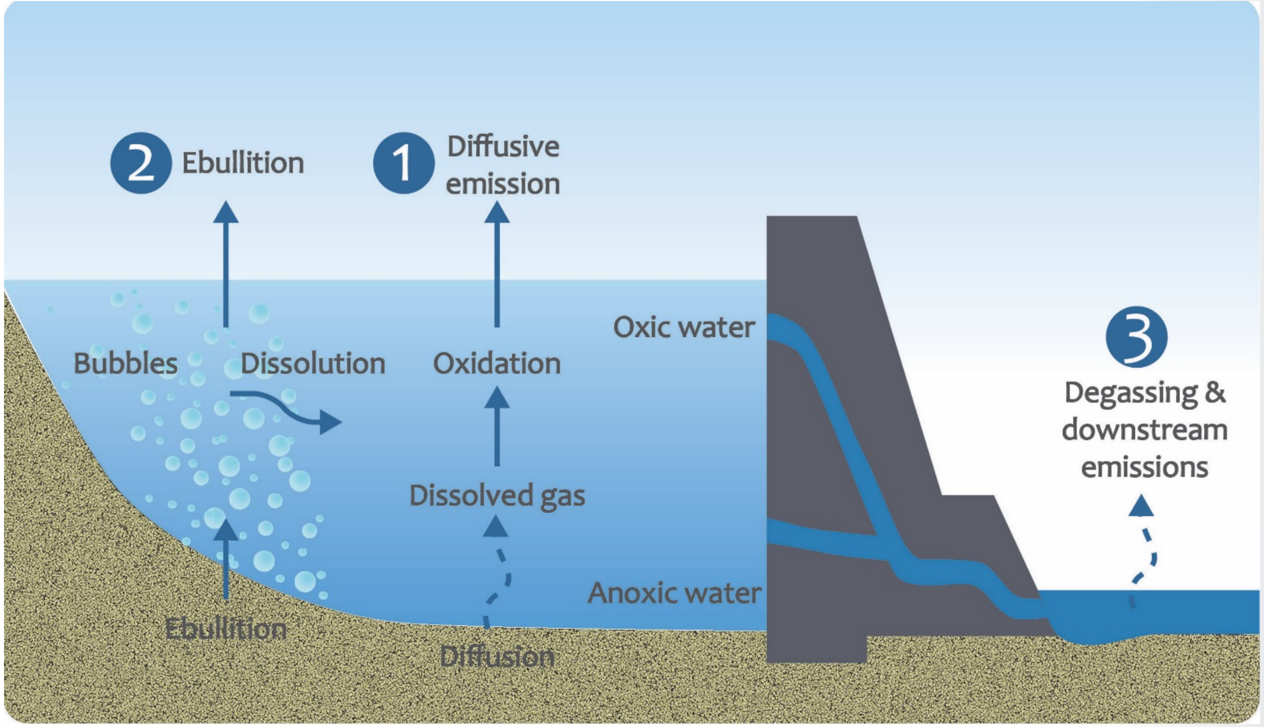
Landfills
5.9 Tg/yr



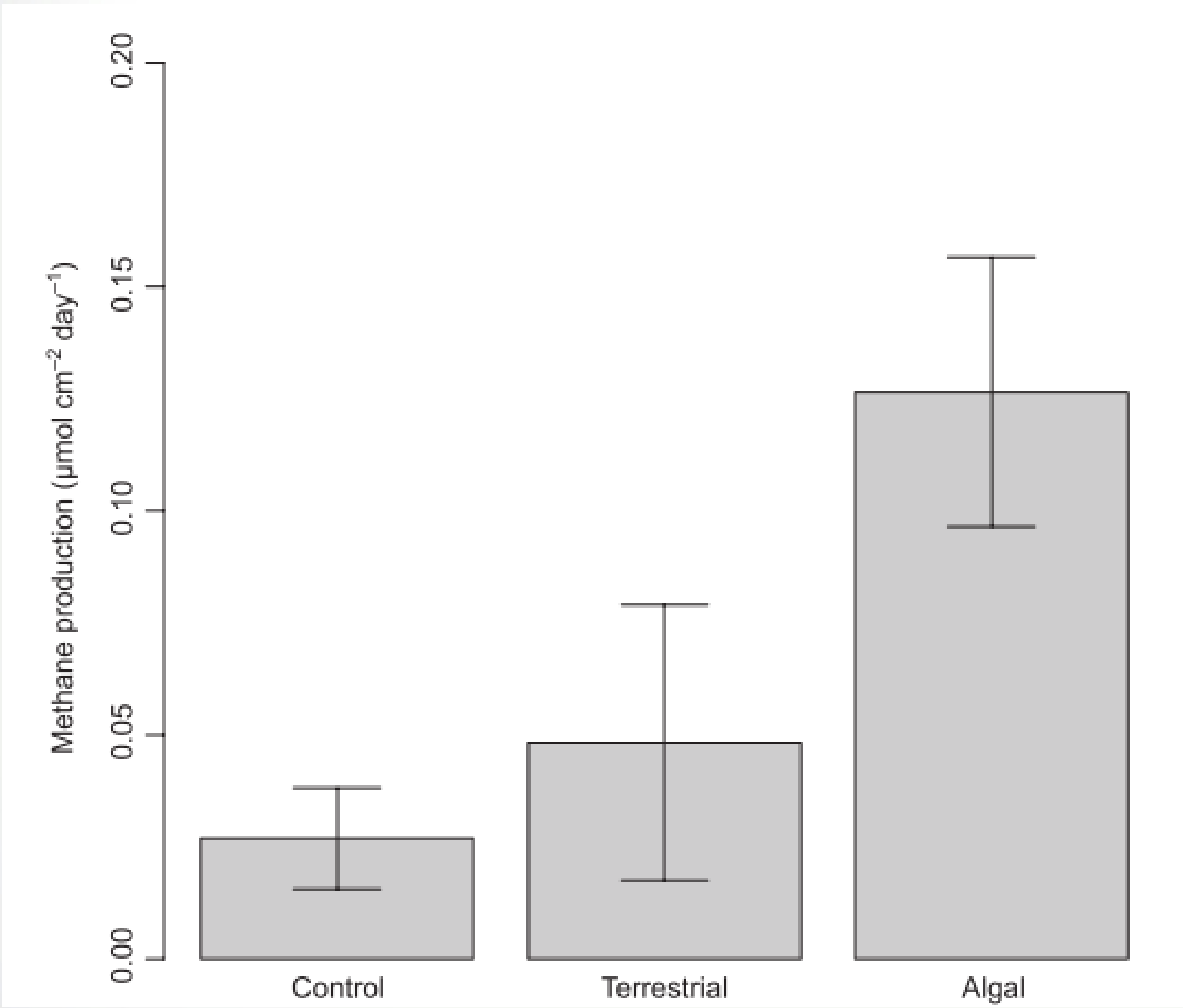
2014 Inventory of US Greenhouse Gas Emissions and Sinks

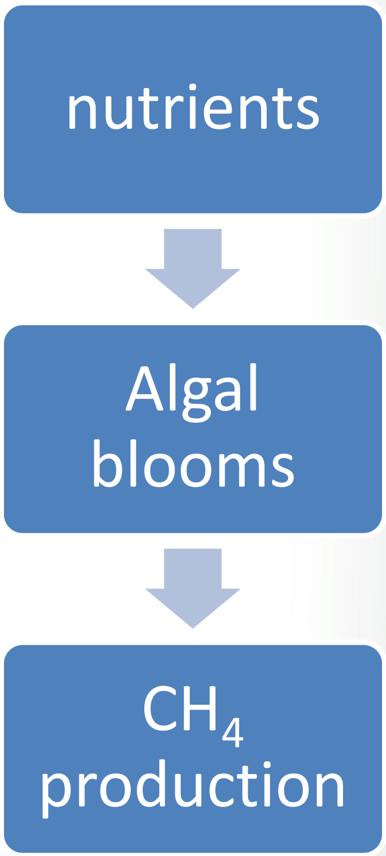
EPA

Methane and Water Quality



Methane and Water Quality



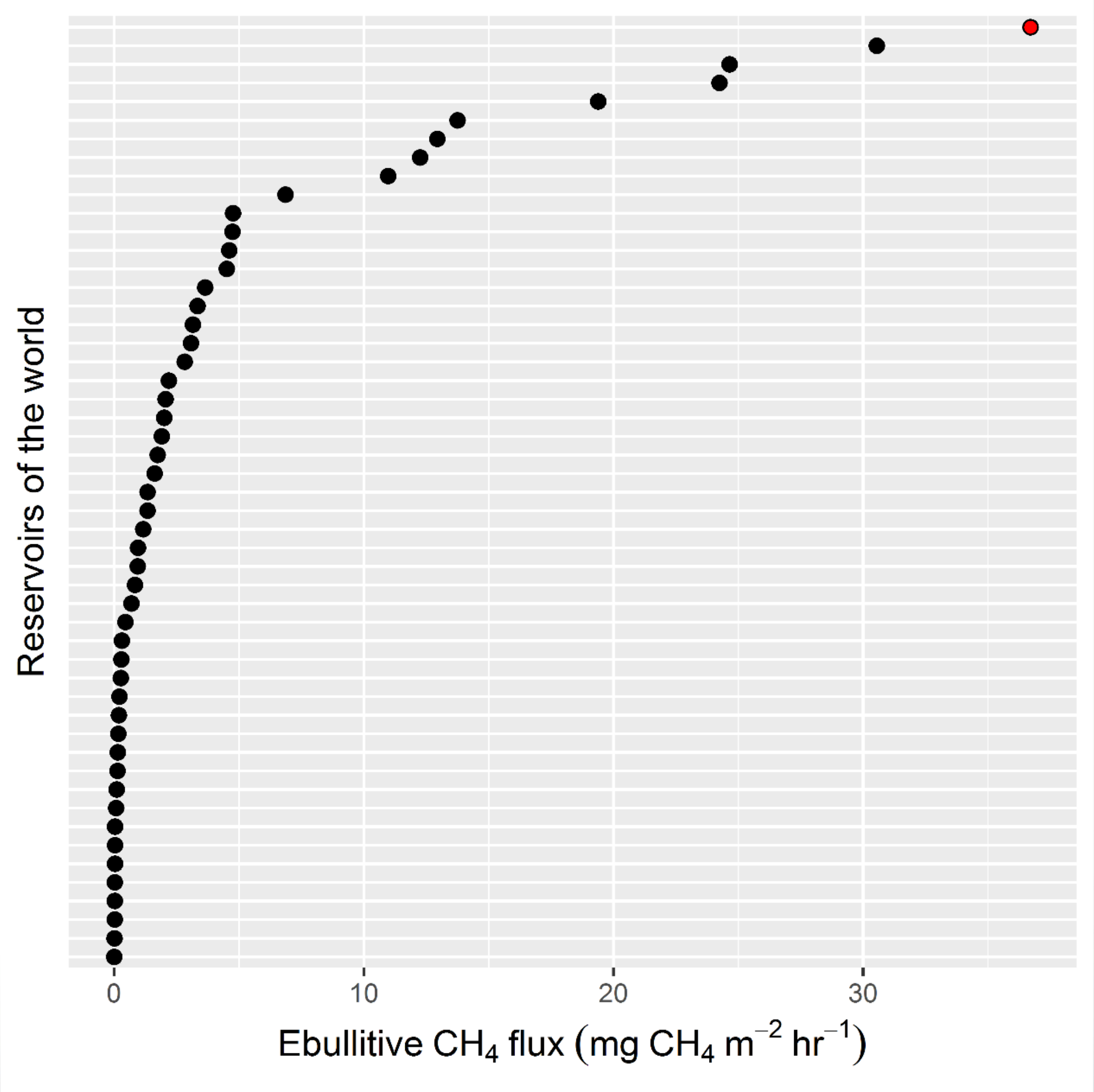


West et al. 2012

Lots of Methane from Harsha Lake

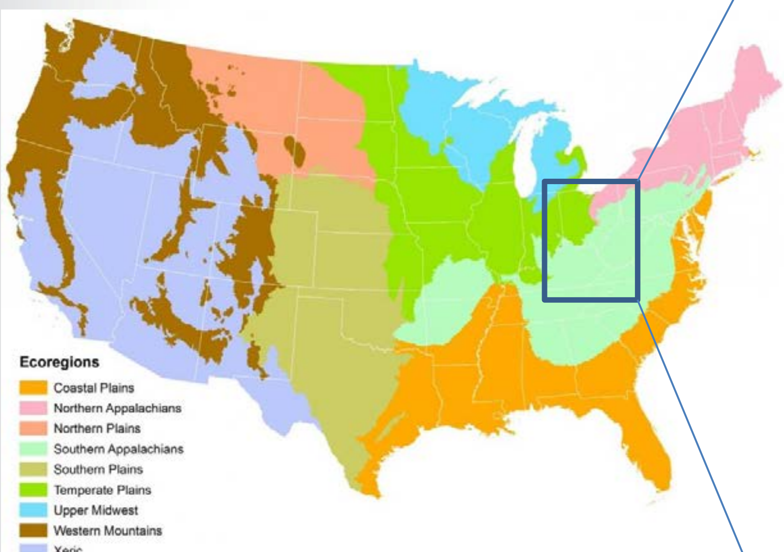
Eastman-1 Reservoir, Quebec, Canada. Photo credit: HydroQuebec

Balbina Reservoir, Brazil. Photo credit: Eduardo M. Venticinque

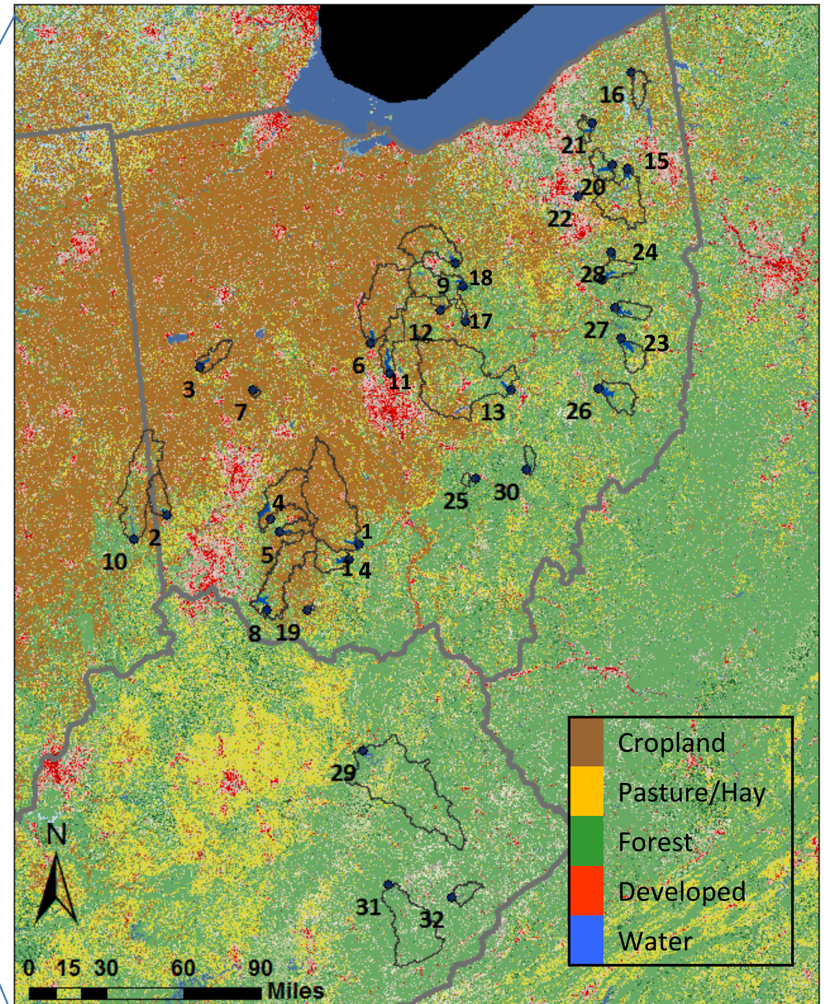


Regional Survey

Surveyed Reservoir Locations and Watersheds:

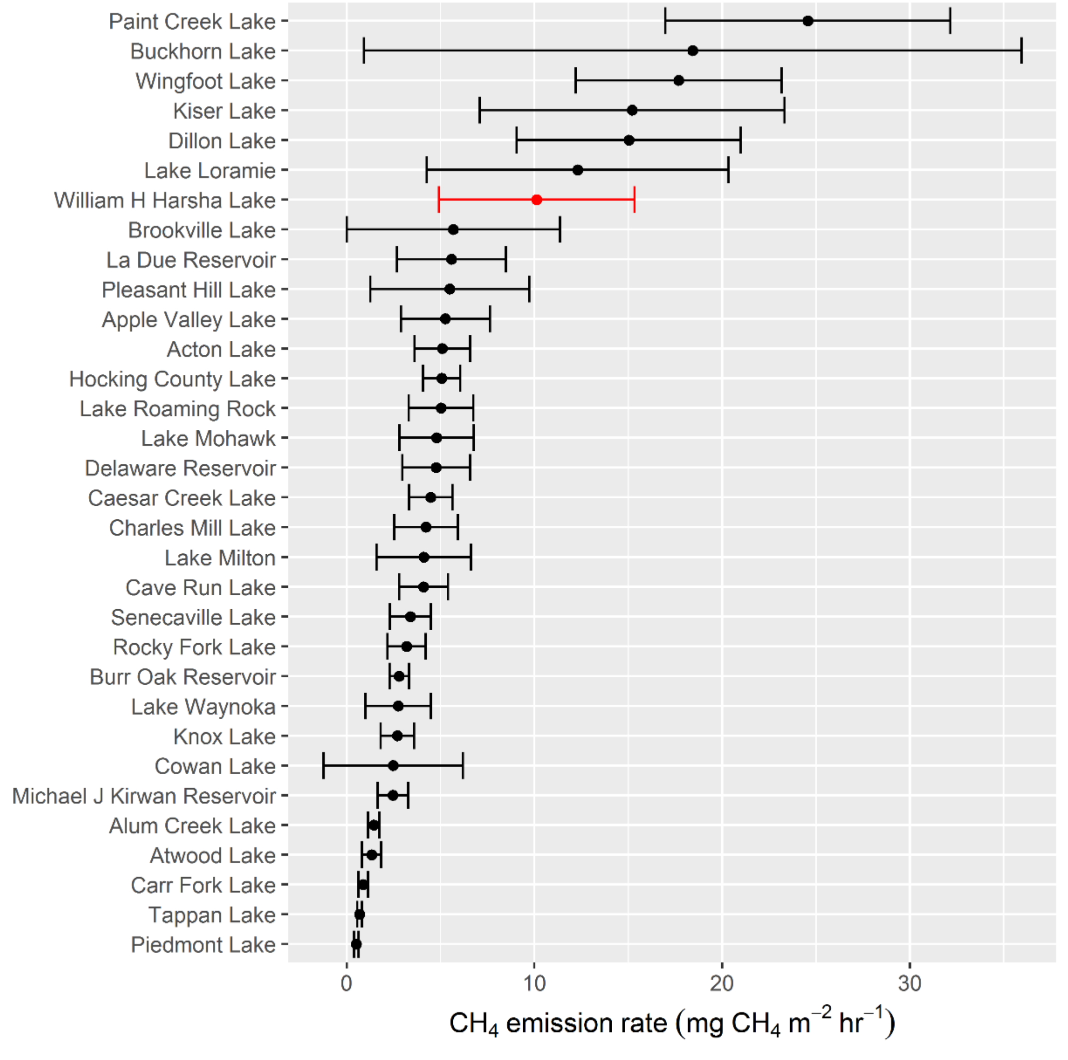


https://www.epa.gov/national-aquatic-resource-surveys/ecoregional-results-national-lakes-assessment-2012

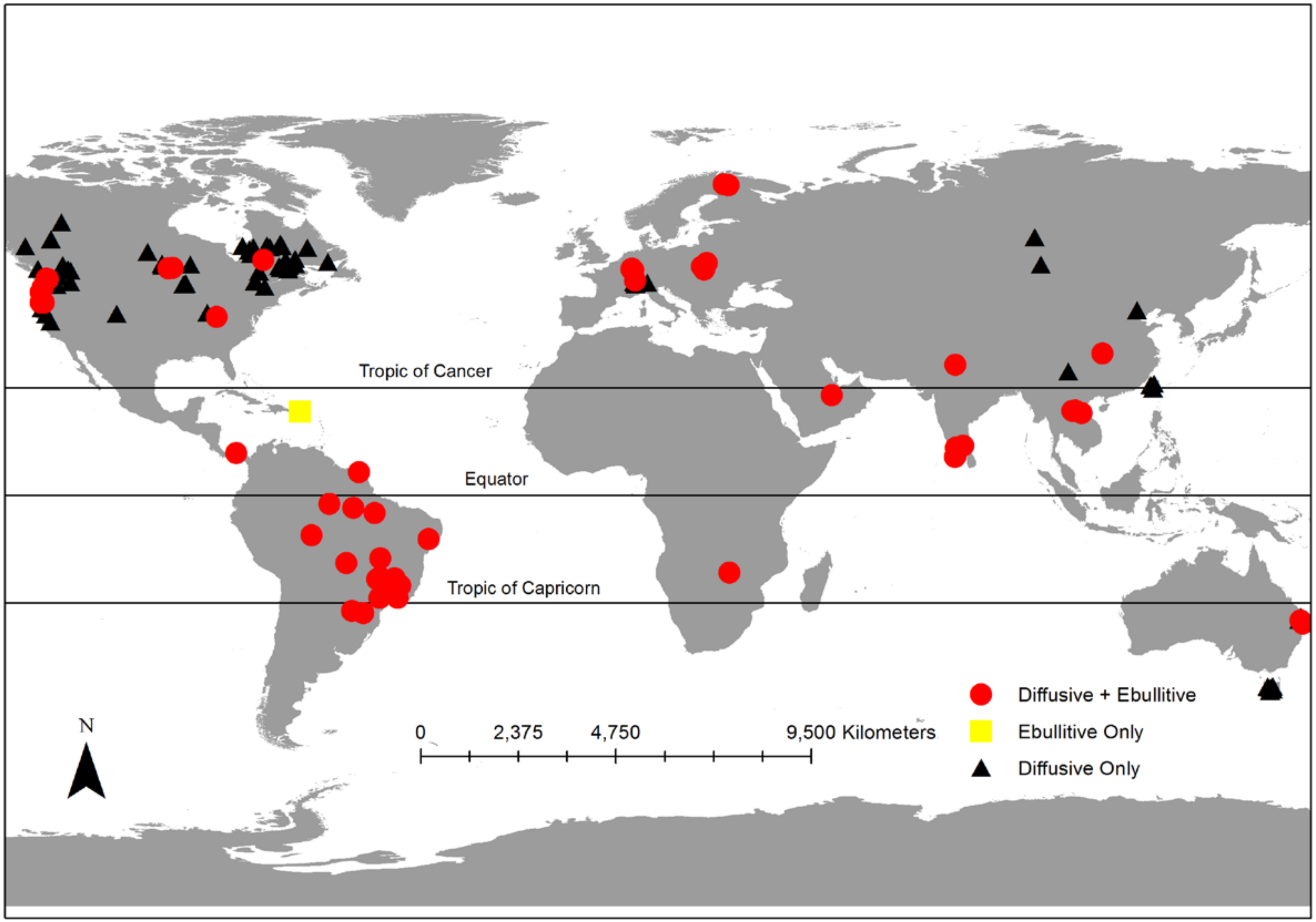


Land cover data from:
http://www.mrlc.gov/nlcd2011.php

Results: CH_4 emissions

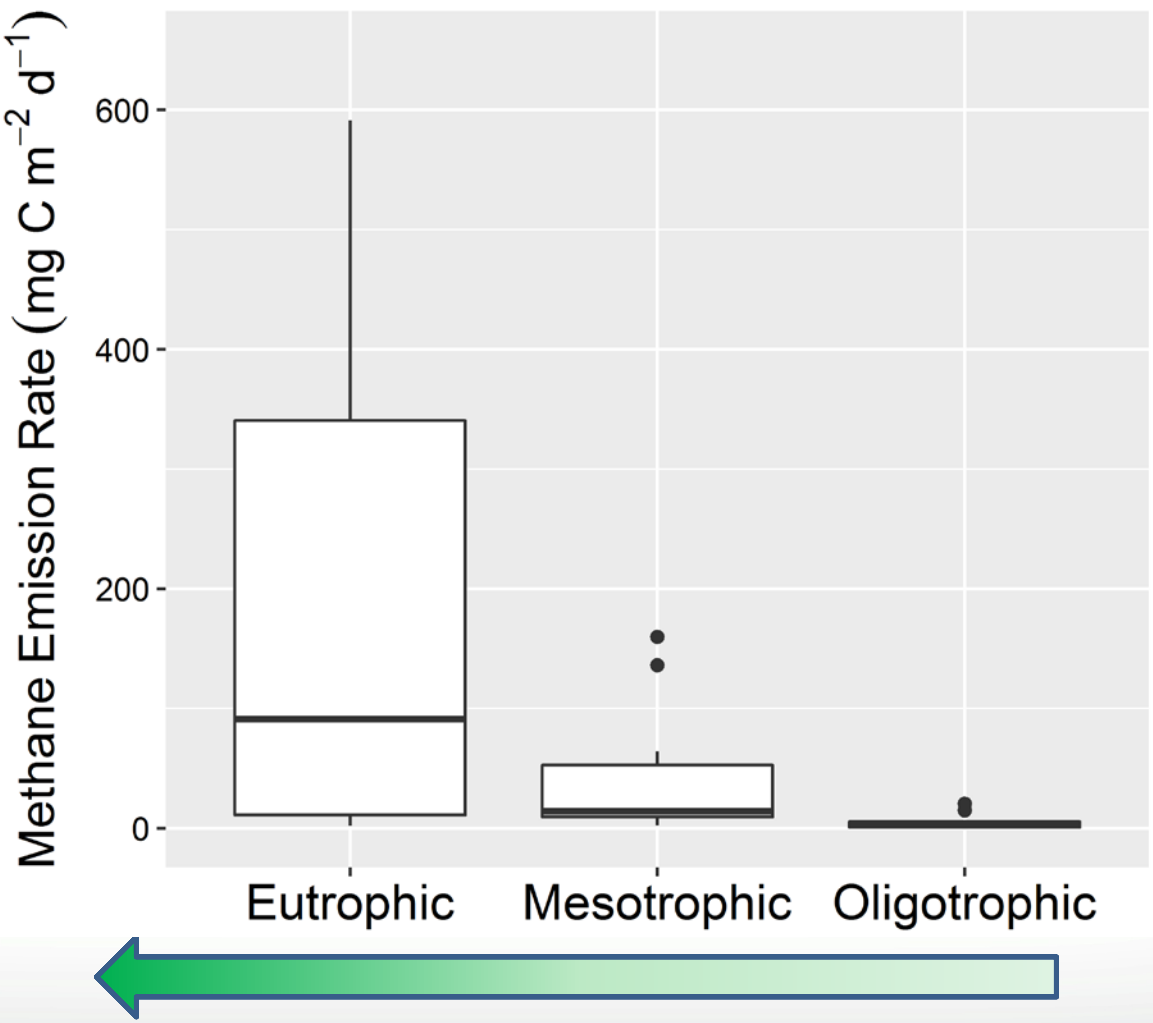


Methane and Water Quality



Deemer et al. 2016. Bioscience

Methane and Water Quality



Conclusions

- Harsha lake, and other productive reservoirs in Ohio/Indiana, support very high CH_4 emission rates.
  - Methane emissions are correlated with reservoir productivity.
  - Nutrient and algal reductions achieved through WQT could result in the co-benefit of reduced methane emissions.

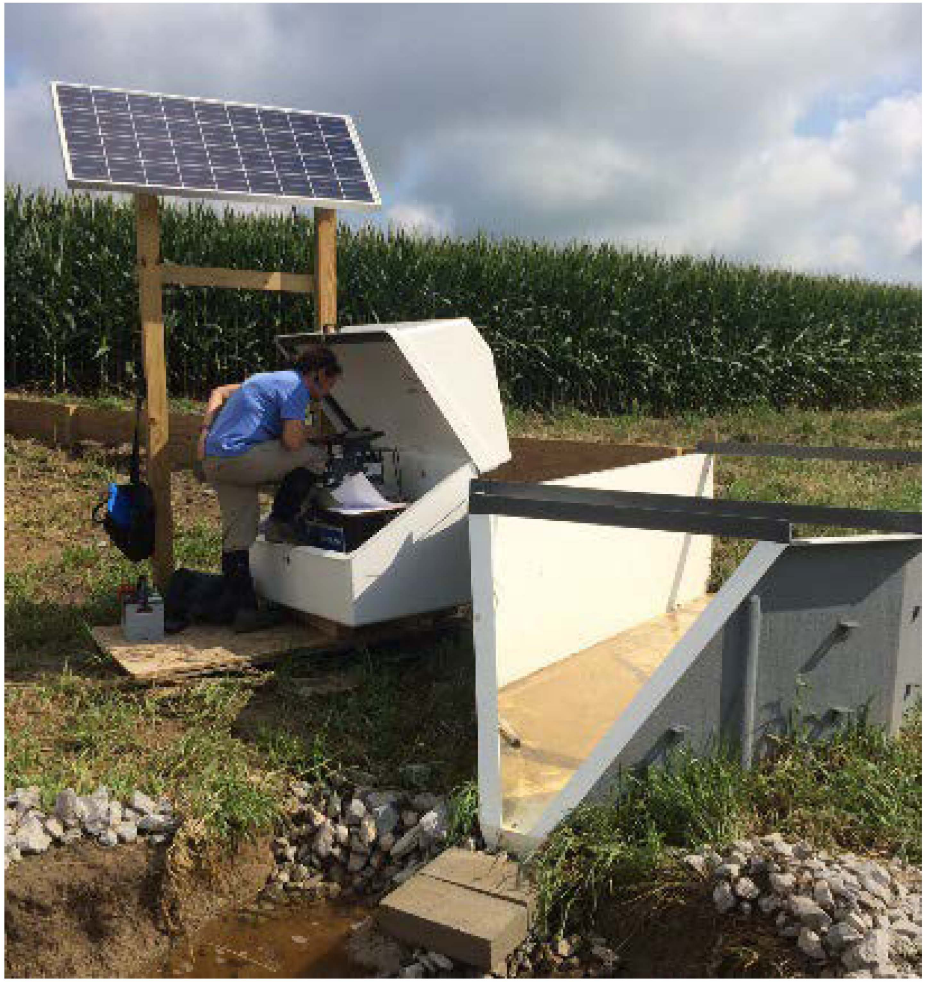
MJ Kirwan, Ohio. Photocredit: USEPA

- Future research:
  - Develop methane ~ algae model for area reservoirs.
  - Expand study to 1200 reservoirs across the country

Carr Cr, KY. Photocredit: USEPA

WATER QUALITY MONITORING PARTNERSHIPS

- **Clermont County Water Resources Department**
- **Clermont and Brown County SWCDs**
- **Clermont County OEQ**
- **USACE, Louisville District;**
- **USGS, Ohio Water Science Center;**
- **University of Cincinnati**
- **Northern Kentucky University**



AGBMP MONITORING

Hannah Lubbers and Jacob Hahn

Lori Lenhart and John McManus

FUNDING AGRICULTURAL BMPS

5/23/2017 – Tuesday

NEXT MEETING

ATTENDEES

- Chris Nietch