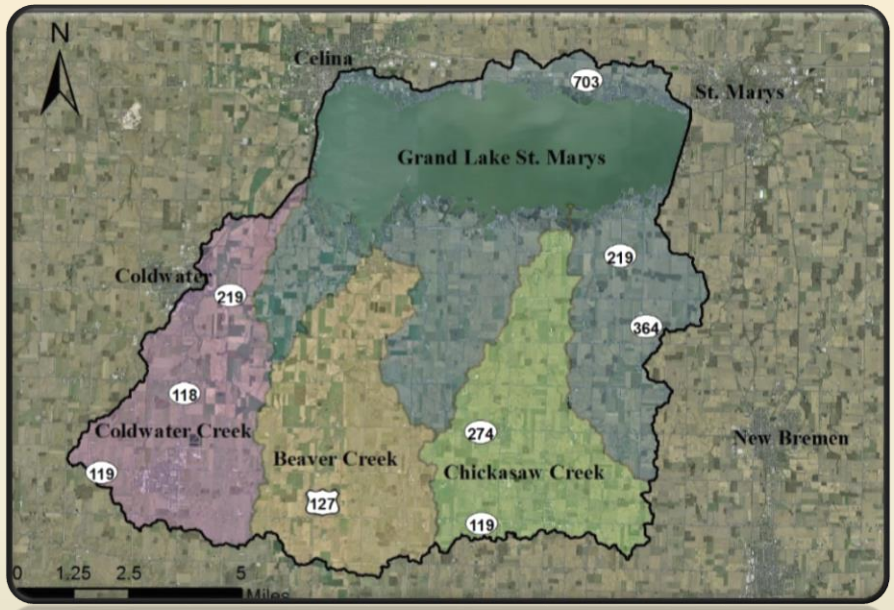
Changes in Water Quality of Grand Lake St. Marys Following a Manure Application Ban



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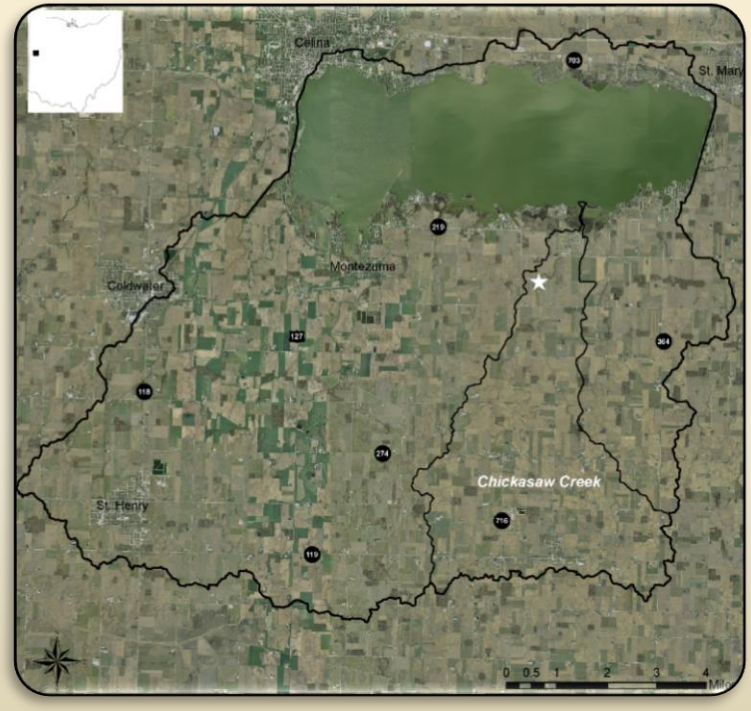
Grand Lake St. Marys Watershed

- Social, economic, and environmental value
- Mercer / Auglaize Counties
- 241 km2 (~60,000 acre) area
- Series of 1st/2nd order tributaries drain into GLSM reservoir
- GLSM constructed 1837-1845
  - large (52 km2), shallow (~1.5m), and mixed (15+km fetch wave length)
- Declines in water quality linked with nutrient rich runoff – exacerbated by physical characteristics
- Tipping point reached in mid 2000s
  - Characterized by HABs
- Region has become a focal area for water quality study and improved understanding



Grand Lake St. Marys Watershed

- Watershed experiences internal and external loading
  - Primarily from nutrient rich agricultural runoff
  - 80-90% row crop
  - Many farms coupled with livestock operations
    - Animal Unit = standard weight relative to beef cow; Filbrun et al. 2013
    - Ohio = 21 AU/km2
    - GLSM = 370 AU/km2 (~250 acres)
  - Among highest soil test P levels in Ohio
  - Nutrient loading in the lake is fed by external loading but dominated at certain points of the year by internal recycling of sediments

A Myriad of Remediation Efforts

- There is no 'one-way' path to remediation
  - Chemical Treatments (e.g. Alum)
  - Dredging
  - Artificial Wetlands (e.g. Treatment Trains)
  - Targeted Nutrient Application and Nutrient Management Plans
  - Aeration Efforts
  - Generating BMPs Watershed Wide
  - Increased Cover Crop / No Till
  - Grass Filter Strips
  - Riparian Restoration
  - State Rules (e.g. Distressed Watershed)

- All require scientific methodologies to assess their efficacy

Research Objective

- Examine trends from 2008-2016 in sediment and nutrient water quality in GLSM watershed for changes concurrent with recent manure application ban (OAC 901:13-1-11) phased in beginning in 2011
  - Distressed watershed declaration 2011
  - Full code on spreading manure took effect in GLSM 2013 –
    - **Effective between Dec. 15 and Mar. 1**

The Importance of Manure and Understanding Potential Problems with Runoff

- Manure application is an important resource
  - Recycled and increases crop yields
  - Use has increased in recent years
  - Synergy between crop and livestock
  - In the US, approximately 5.9 million and 1.8 million tons of N and P are produced in animal based fertilizers
  - Manure helps to build nutrients, reduce soil compaction, and eliminate stock
- However, there is a high potential for runoff – factors which alter likelihood include ground permeability, crop presence, and ambient precipitation
  - What is the importance of identifying risk factors?

- Prior studies on manure application bans have shown mixed results ranging from 10-20% and 5-15% reductions in N and P, respectively
- However, the majority of these studies are dated and have been shown to be highly dependent on landscape and ambient weather patterns
- This suggests the need for monitoring and innovative analyses to account for variation among individual landscapes to draw conclusions

Testing the Efficacy of the Manure Ban

Do sediment and nutrient concentrations / loads vary with time? Is this related to the implementation of the manure ban?

- **Objective:** Assess trends in Chickasaw Creek to test for manure ban signal
- **Methods**: Use NCWQR (Heidelberg) monitoring data in a general linear model following a gamma (log link) distribution to assess patterns

- Has there been a change in TSS, NO3, TKN, PP, DRP over the past decade?

  - Flow
  - Regulatory Period
  - Manure Ban
  - Interactions

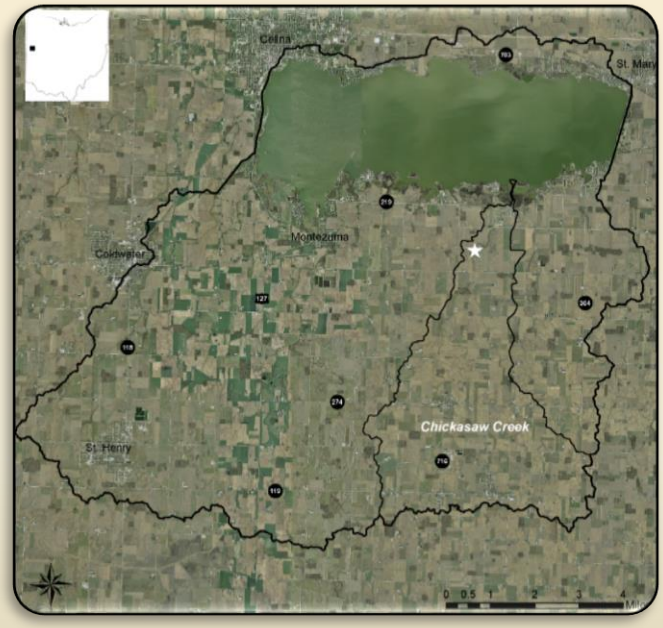
Testing the Efficacy of the Manure Ban

Variables

- TSS = Total Suspended Solids
- NO3 = Nitrate
- TKN = Total Kjeldahl Nitrogen
- PP = Particulate Phosphorus
- DRP = Dissolved Reactive Phosphorus
- Flow = Q (Discharge) → Arranged in Equal Percentiles in Tables/Graphs
- Regulatory Period = Dec. 15 – Mar. 1
- Non-Regulatory Period = Mar. 2 – Dec. 14
  - *Note that regulatory periods also coincide with seasonality: Summer vs. Winter
- Manure Ban Dates = Pre (2008 to 2011) vs Post (2011 to 2016)

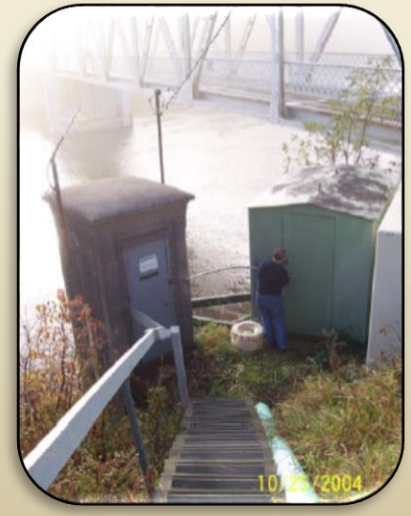
Research Approach

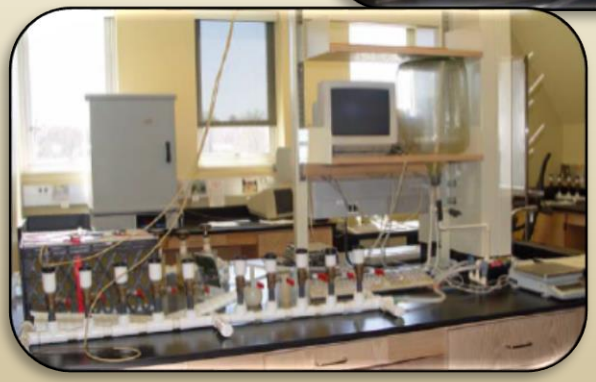
- Assess changes in nutrient concentration and loading over time
  - TSS, NO3, TKN, PP, and DRP
- NCWQR data spanning 2008 to 2016
- Use flow weighted mean concentration
- Test for specific changes concurrent with manure application ban (beginning with Phase I of implementation – 2011)
- Correct for non linear flow relationships
- GLM model with Gamma Distribution
- Visualize and breakdown by flow percentiles for management inference



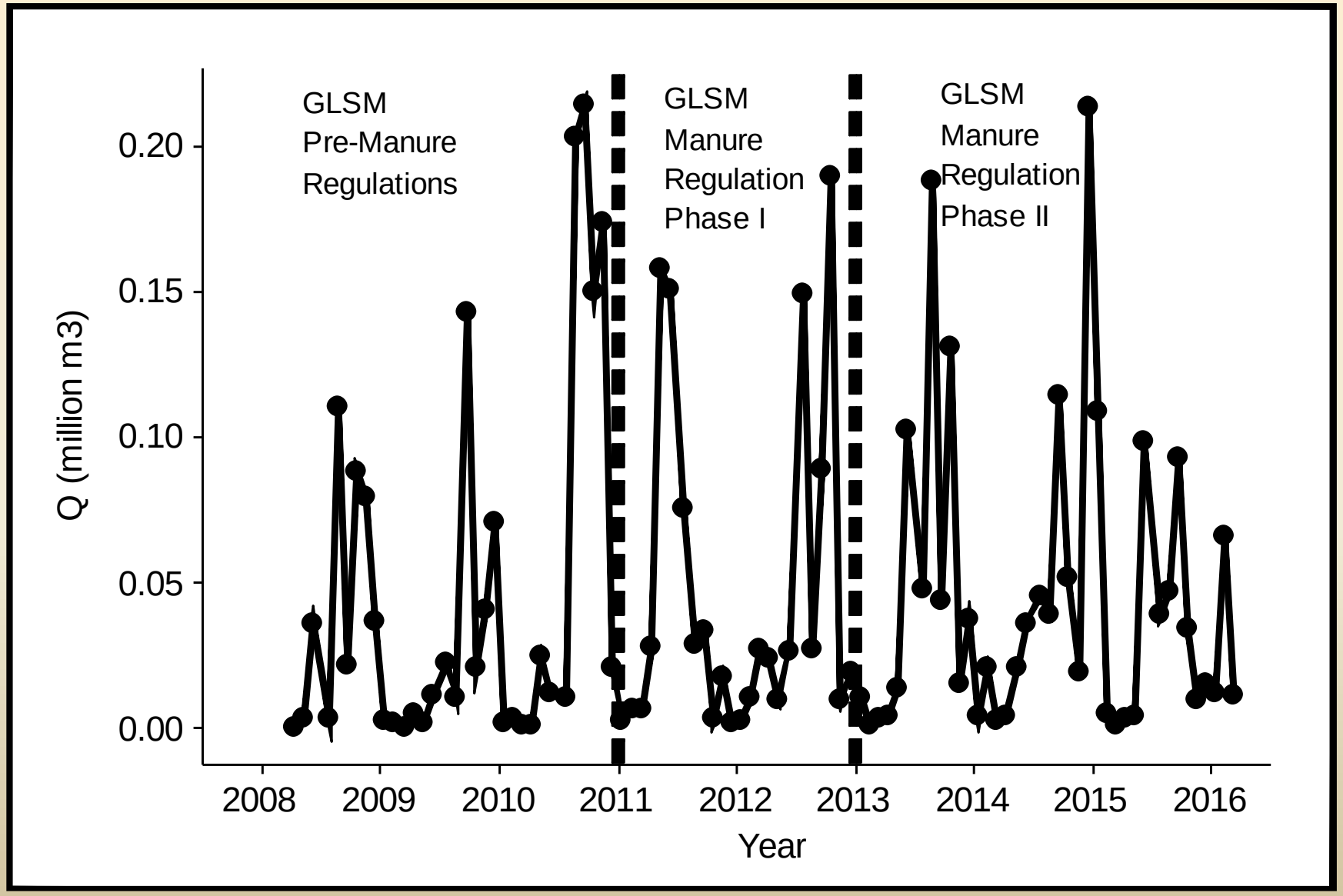
Sediment and Nutrient Analyses

- Water Quality Stations
  - Collect Auto Samples (3x/day)
  - Transported back to NCWQR
- Water Quality Analysis
  - Colorimetry for TP, DRP, and TKN
  - Ion Chromatography for NO3
  - Gravimetric Methods for TSS

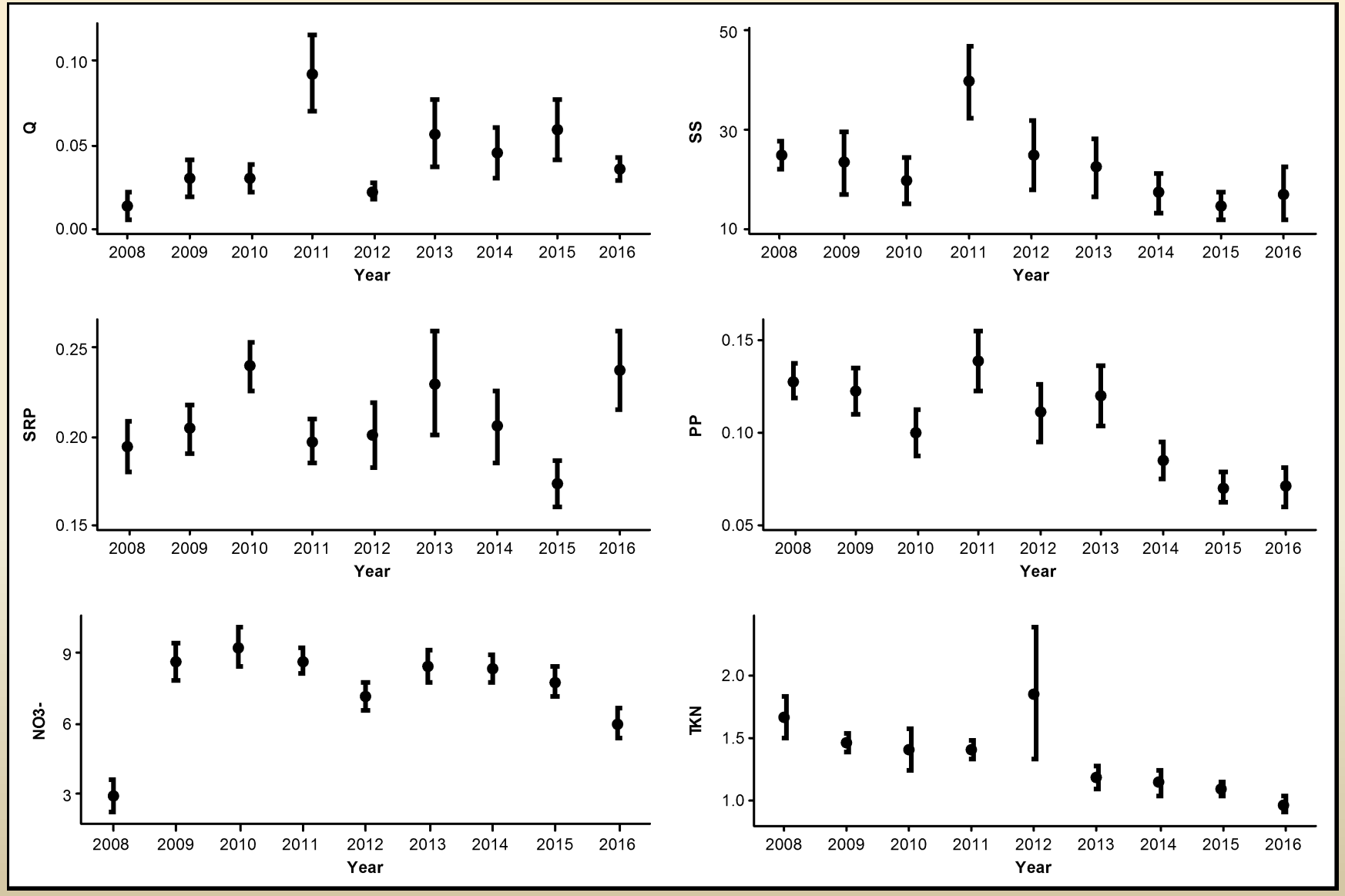




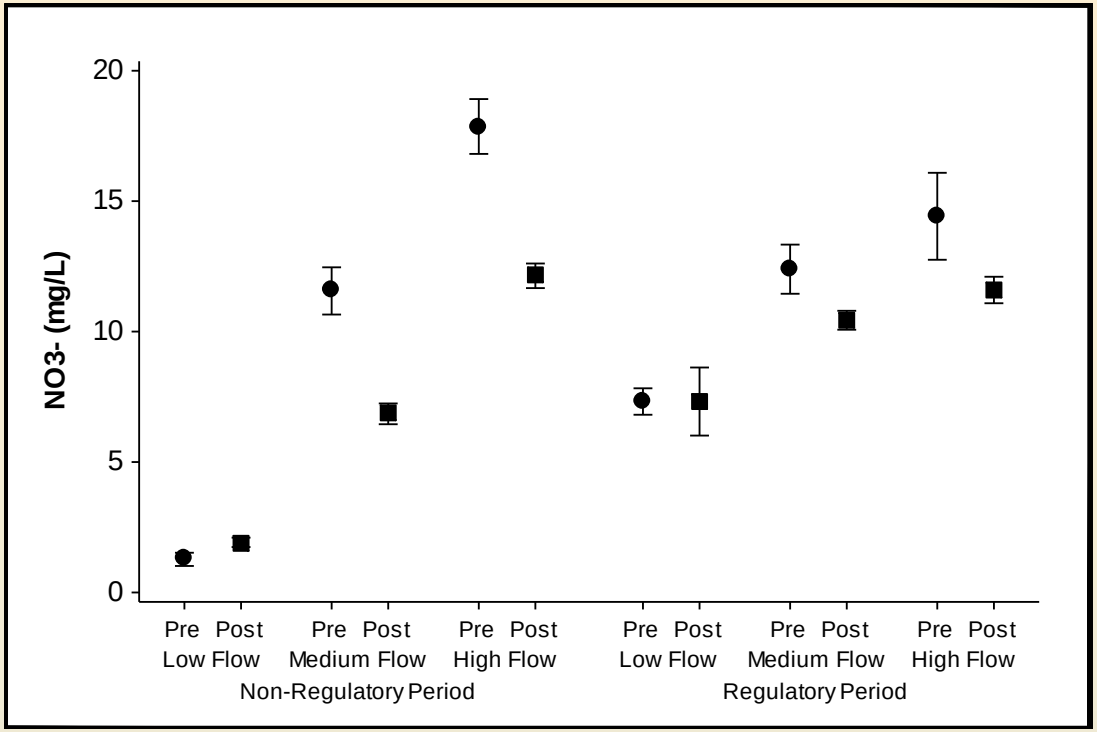
Annual Flow and Nutrient Summary



Annual Flow and Nutrient Summary

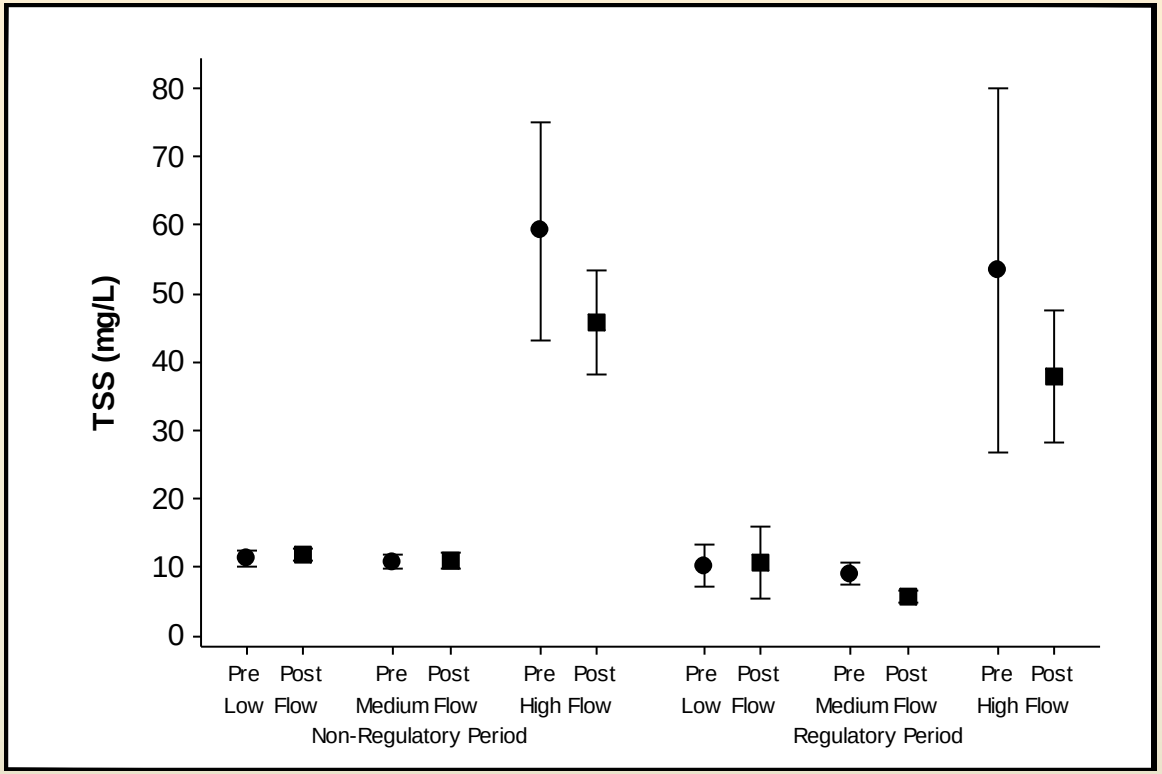


Nitrate



	Non-Regulatory Period (Mar. 2 - Dec. 14)									Regulatory Period (Dec. 15 - Mar. 1)							
	Pre Regulation			Post Regulation						Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)		N	Mean	SE	N	Mean	SE	Change	Change (%)
Nitrate									Nitrate								
Low Flow	334	1.2	0.13	524	1.8	0.1	0.6	50	Low Flow	75	7.3	0.25	27	7.2	0.64	-0.1	-1
Medium Flow	167	11.6	0.46	560	6.8	0.2	-4.8	-41	Medium Flow	68	12.4	0.48	174	10.4	0.2	-2	-16
High Flow	152	17.85	0.52	533	12.12	0.24	-5.73	-32	High Flow	44	14.4	0.82	222	11.6	0.26	-2.8	-19

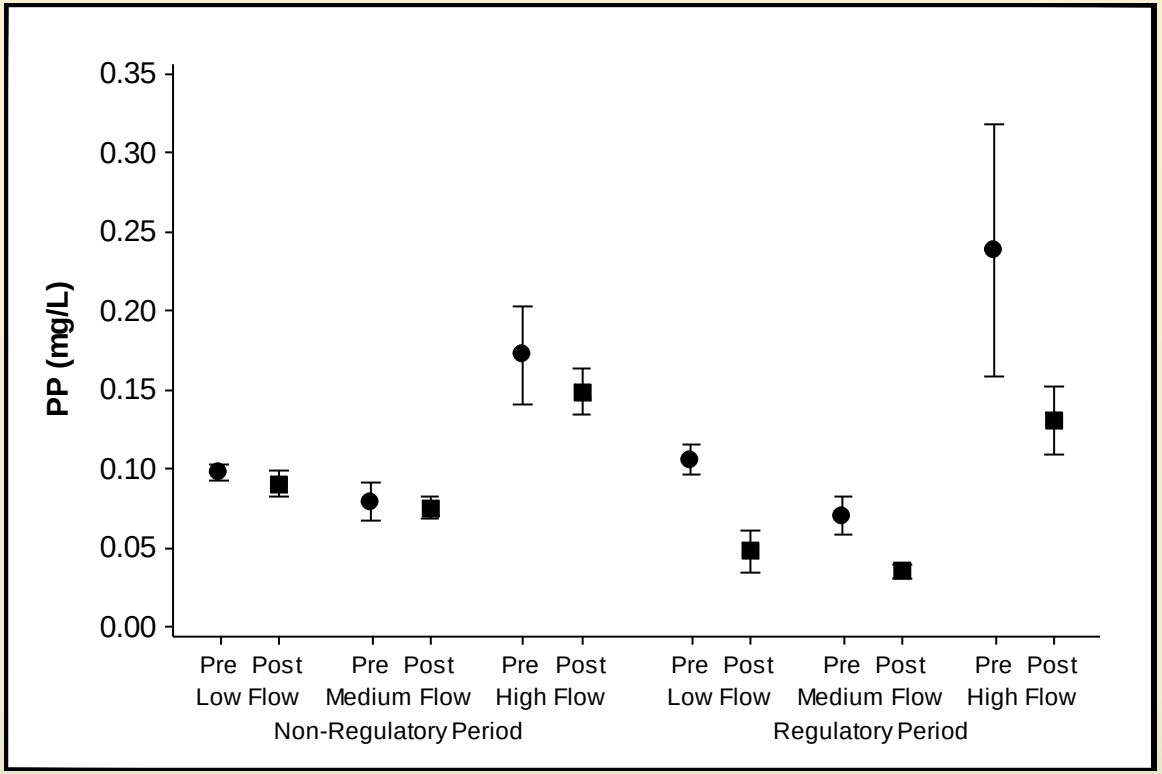
Total Suspended Solids



	Non-Regulatory Period (Mar. 2 - Dec. 14)							
	Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)
Total Suspended Solids								
Low Flow	334	11.4	0.6	524	11.9	0.5	0.5	4
Medium Flow	167	10.9	0.58	560	11.03	0.6	0.13	1
High Flow	152	59.2	8.1	533	45.7	3.4	-13.5	-23

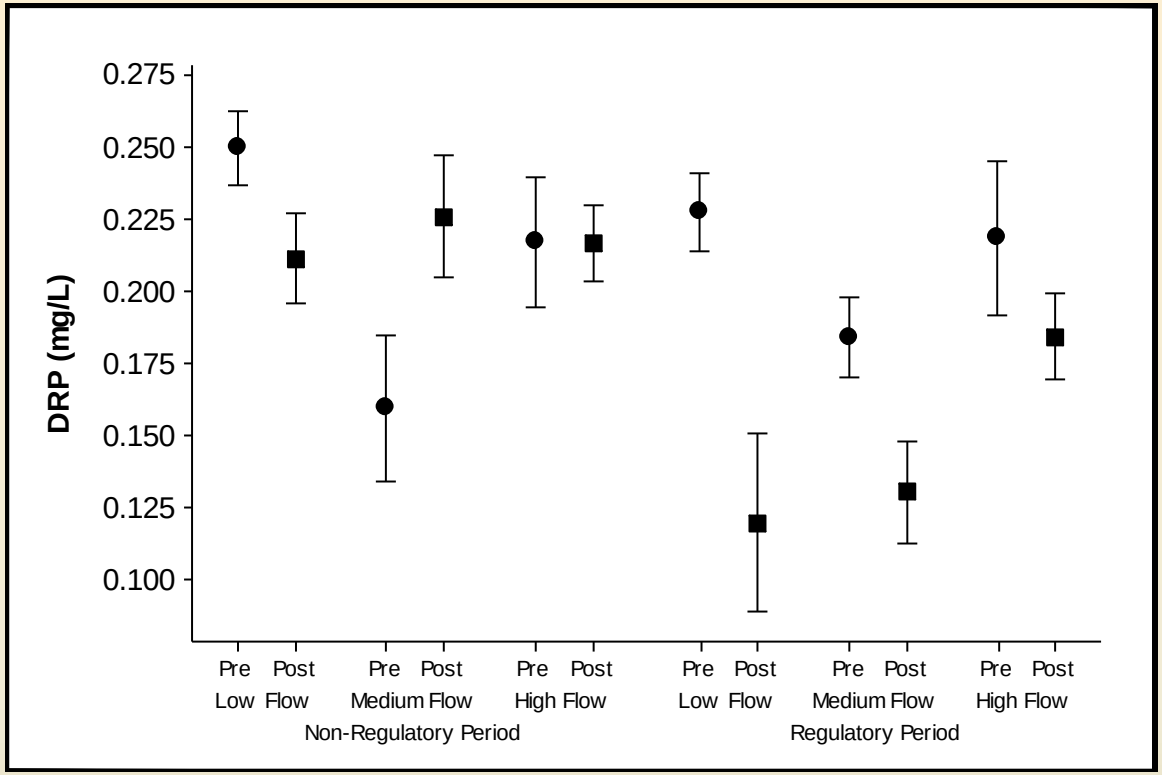
	Regulatory Period (Dec. 15 - Mar. 1)							
	Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)
Total Suspended Solids								
Low Flow	75	10.4	1.6	27	10.6	2.6	0.2	2
Medium Flow	68	9.1	0.8	174	5.8	0.4	-3.3	-36
High Flow	44	53.5	13.1	222	37.8	4.9	-15.7	-29

Particulate Phosphorus



	Non-Regulatory Period (Mar. 2 - Dec. 14)									Regulatory Period (Dec. 15 - Mar. 1)							
	Pre Regulation			Post Regulation						Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)		N	Mean	SE	N	Mean	SE	Change	Change (%)
Particulate P									Particulate P								
Low Flow	334	0.1	0.002	524	0.09	0.004	-0.01	-10	Low Flow	75	0.11	0.005	27	0.05	0.01	-0.06	-55
Medium Flow	167	0.08	0.01	560	0.07	0.003	-0.01	-13	Medium Flow	68	0.07	0.01	174	0.03	0.002	-0.04	-57
High Flow	152	0.17	0.02	533	0.15	0.01	-0.02	-12	High Flow	44	0.24	0.04	222	0.13	0.01	-0.11	-46

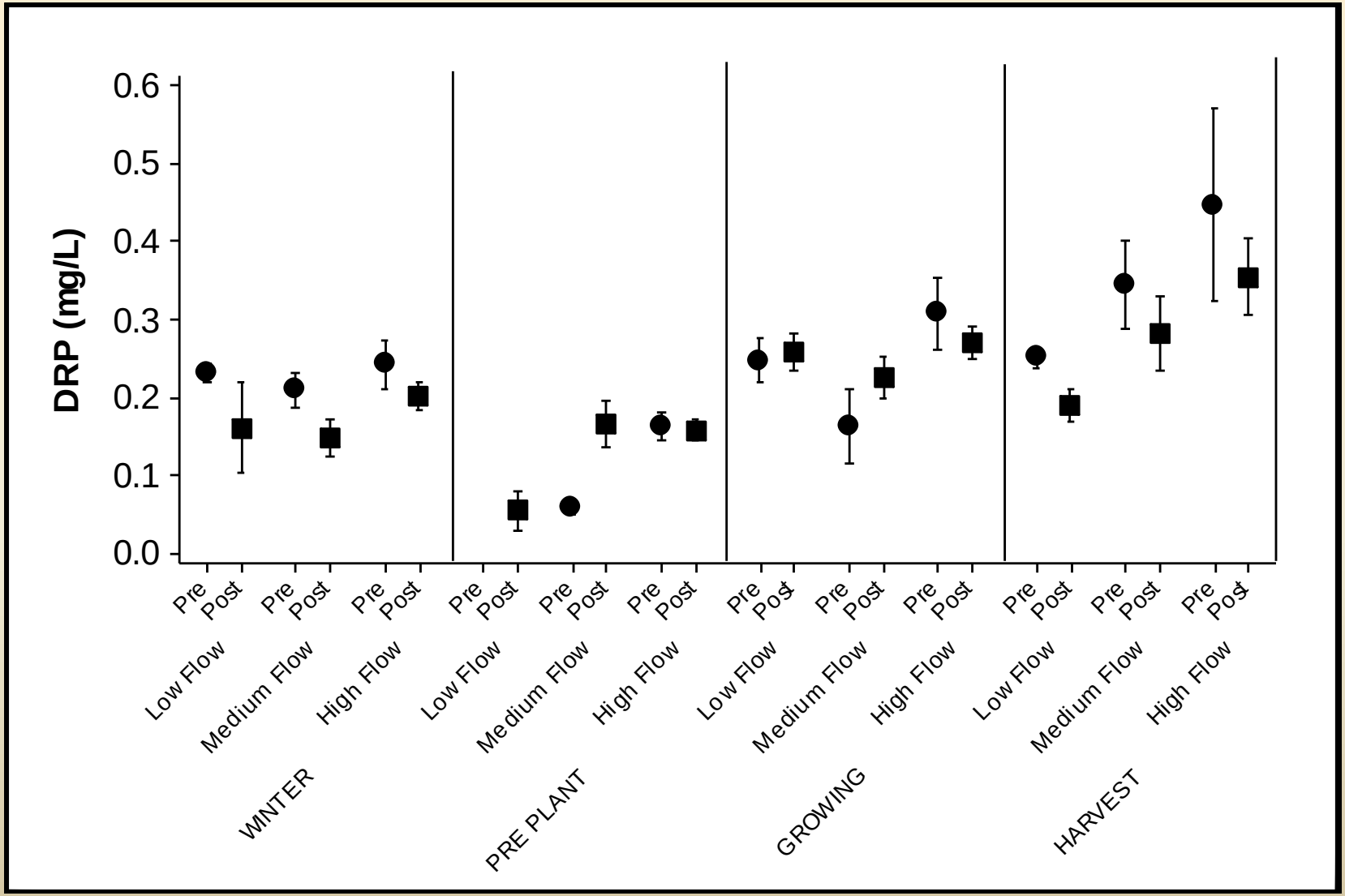
Dissolved Reactive Phosphorus



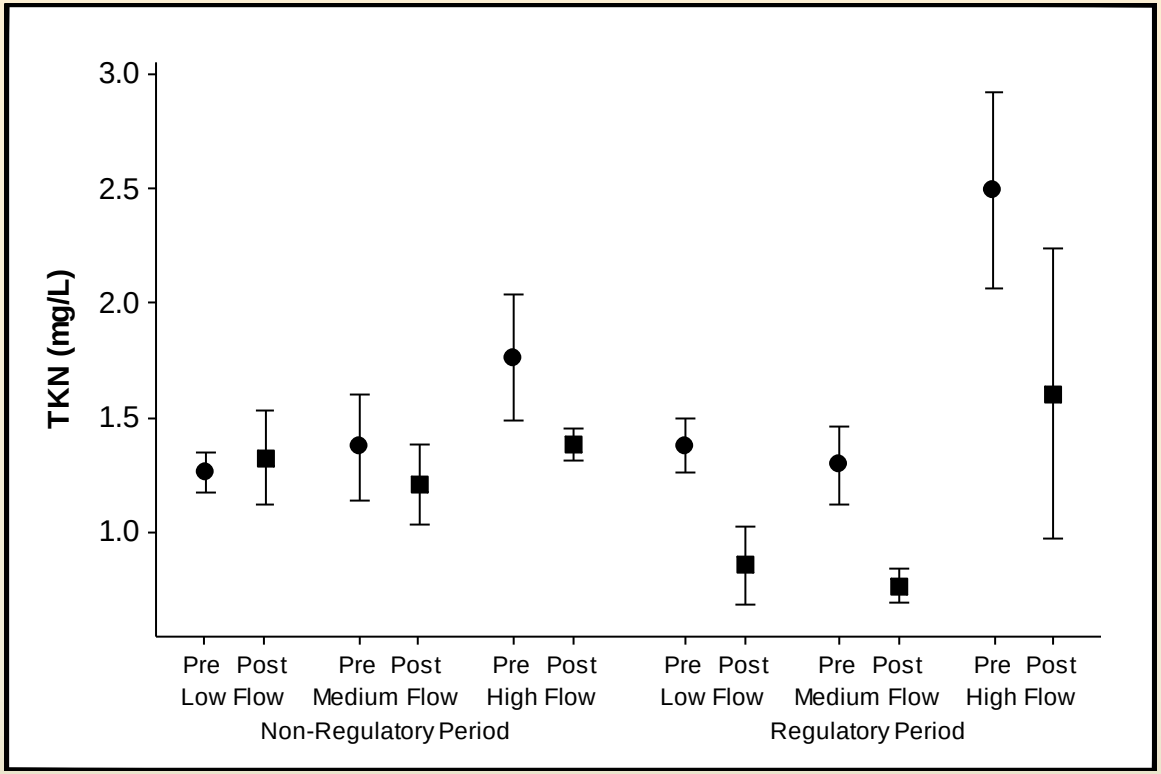
	Non-Regulatory Period (Mar. 2 - Dec. 14)							
	Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)
Dissolved Reactive P								
Low Flow	334	0.25	0.006	524	0.21	0.007	-0.04	-16
Medium Flow	167	0.16	0.01	560	0.23	0.01	0.07	44
High Flow	152	0.22	0.01	533	0.22	0.01	0	0

	Regulatory Period (Dec. 15 - Mar. 1)							
	Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)
Dissolved Reactive P								
Low Flow	75	0.23	0.01	27	0.12	0.02	-0.11	-48
Medium Flow	68	0.18	0.01	174	0.13	0.01	-0.05	-28
High Flow	44	0.22	0.01	222	0.18	0.01	-0.04	-18

DRP Concentration and Loading Timing



Total Kjeldahl Nitrogen



	Non-Regulatory Period (Mar. 2 - Dec. 14)							
	Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)
Total Kjeldahl Nitrogen								
Low Flow	334	1.26	0.04	524	1.3	0.1	0.04	3
Medium Flow	167	1.4	0.12	560	1.2	0.09	-0.2	-14
High Flow	152	1.8	0.14	533	1.4	0.04	-0.4	-22

	Regulatory Period (Dec. 15 - Mar. 1)							
	Pre Regulation			Post Regulation				
	N	Mean	SE	N	Mean	SE	Change	Change (%)
Total Kjeldahl Nitrogen								
Low Flow	75	1.4	0.06	27	0.85	0.08	-0.55	-39
Medium Flow	68	1.3	0.09	174	0.76	0.04	-0.54	-42
High Flow	44	2.5	0.21	222	1.6	0.32	-0.9	-36

Overarching Conclusions

- Clear reductions in external loading of TSS, PP, NO3, and TKN following ban
- Interesting patterns with DRP were noted
  - Potentially due to excessively high STP in the watershed (highest in Ohio)
  - Legacy effect? In fields and in stream channels
  - Interesting result at low flows – may be result of slow winter melt waters
  - Additional analyses needed to fully disentangle relationships
- More time – continued monitoring efforts are needed. Interestingly, both seasons were affected – even though ban is during winter
    - Summer = largest effects at high flows
      - May be due to other management requirements (OAC 901)
    - Winter = largest effects at low to medium flows
- Anecdotally, no negative yields reported to local SWCD / ODA offices
- Timing may be an issue in early spring given potential for winter manure stock piling
- Results provide potential future template for management strategies
- Nothing works without cooperation – this is a success story!

Continuing Efforts

- Continue ban on winter manure application
- Continue to maintain current nutrient management plans for all livestock farms, with an emphasis on recordkeeping and soil testing
- Look at potential projects to reduce legacy-P in the soil
  - Harvest 2 crops per year, or conversion to alfalfa/grass
  - Provide an incentive for farmer
- Continue efforts of Ag Solutions
  - Alternative methods of manure management
  - Reducing/removing/dewatering manure nutrients
  - Several ongoing pilot projects and potential for large-scale projects
- Research and provide incentives for new nutrient reduction practices
  - Retention ponds
  - Saturated buffers
  - Tile bioreactors
  - Blind inlets
- Continue Education Efforts!

Implications for Freshwater Biodiversity

- Freshwater comprises only 0.01% global H_2O
- Houses >100,000 species (~6% described global diversity)
- Taxa are imperiled globally largely resultant of anthropogenic influences – up to 20% freshwater fish are extinct
- We have an obligation to study and preserve for future

Thank You

A SPECIAL THANK YOU TO ALL OF THE AGRICULTURAL PROFESSIONALS IN THE REGION THAT HELPED FACILITATE THESE CHANGES.

Wright State University
Lake Campus

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