Stream Mesocosm Phosphorus Dose Response Validation Study

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Outline

- Ohio EPA's rebirth of the Total Maximum Daily Load (TMDL) process
- Nutrient criteria in the East Fork Watershed Case Study
- Stream mesocosm nutrient criteria validation studies
  - Set-up and experimental design
  - Response variables
- Nominal and realized water chemistries
- Data analysis approach
- Preliminary results
- Plausible mechanisms linking phosphorous content to biota – hypothesis
- Conclusions and relevance

Ohio EPA's TMDL program

- Total Maximum Daily Load (TMDL) – Defines the maximum load (or amount) of pollution that a waterbody can hand and still be considered healthy and recommends a clean-up plan
- Section 303(d) of the Clean Water Act requires TMDLs for water bodies that are not meeting WQ goals and are considered impaired
- The Supreme Court of Ohio on 3/24/2015 determined that an OEPA TMDL is a "rule" that must follow the rulemaking procedure in R.C. Chapter 119 before being submitted to USEPA for approval and implemented in an NPDES permit
- Because none of OEPA's TMDLs had been adopted as rules the effect of the ruling invalidated all previously approved TMDLS and required a process for the development of a new process for future TMDLs

Ohio Environmental Protection Agency

background load
\+ point source load
\+ nonpoint source load
\+ margin of safety

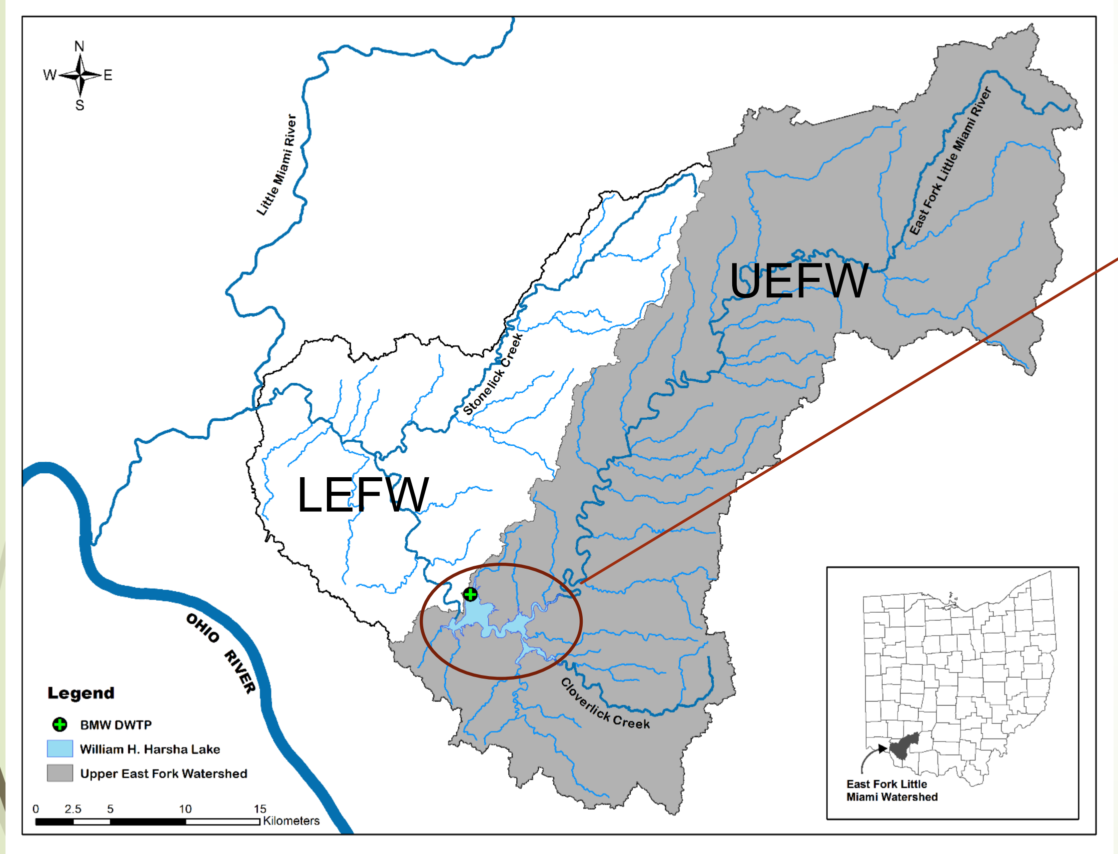
TMDL

Ohio’s New TMDL process

- On 6/30/2017 House Bill 49 was signed into law, included were new requirements for OEPA’s TMDL program including:
  - Reinstatement of TMDLs approved prior to 3/24/2015
  - Challenges to TMDL-based effluent limits occur through the permits appeal process
  - Formalizing stakeholder involvement throughout the TMDL development
  - Additional items of consideration in implementation and wasteload/load allocation
  - Requirement to undertake rulemaking for stakeholder notification and determining significant public interest
- The OEPA will standardize the documentation of:
  - Relative contribution of point and non-point sources, watershed flow dynamics, how reductions will influence attainment, assurances that reductions can be implemented, site impairment relative to source location, how habitat affects impairment, feasibility of available treatment technology, sources of funding, alternative approaches, implementation through scheduled compliance over multiple permit cycles, estimated economic impacts, information submitted by stakeholders.

Enter ORD's East Fork Watershed Study and The East Fork Watershed Cooperative

The East Fork Little Miami River Watershed in Southwestern Ohio



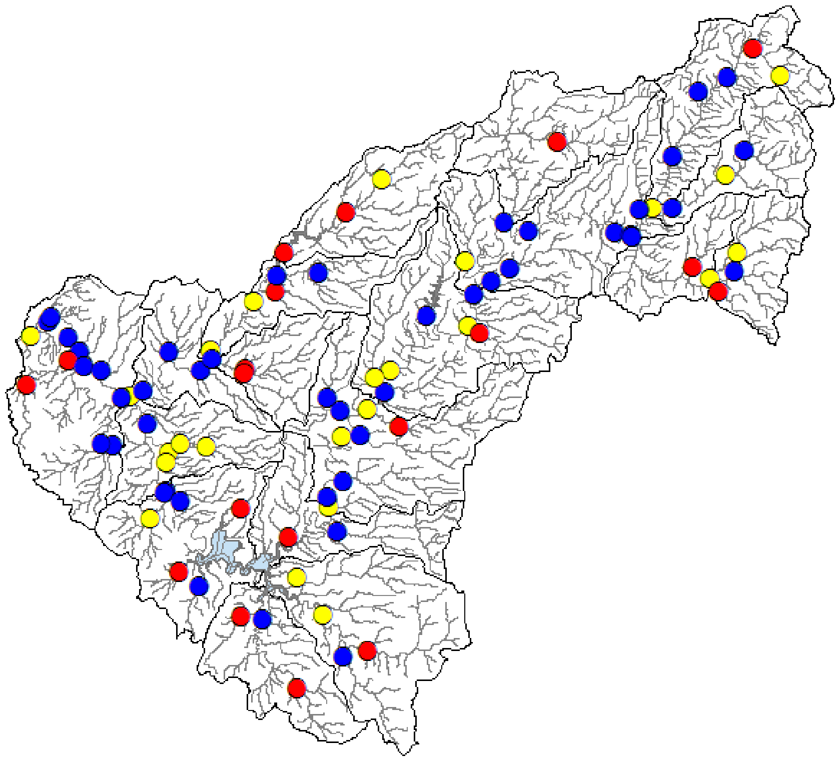
Harsha Lake – Drinking water, recreation, & flood control resource

Harsha Lake experiences severe harmful algal blooms

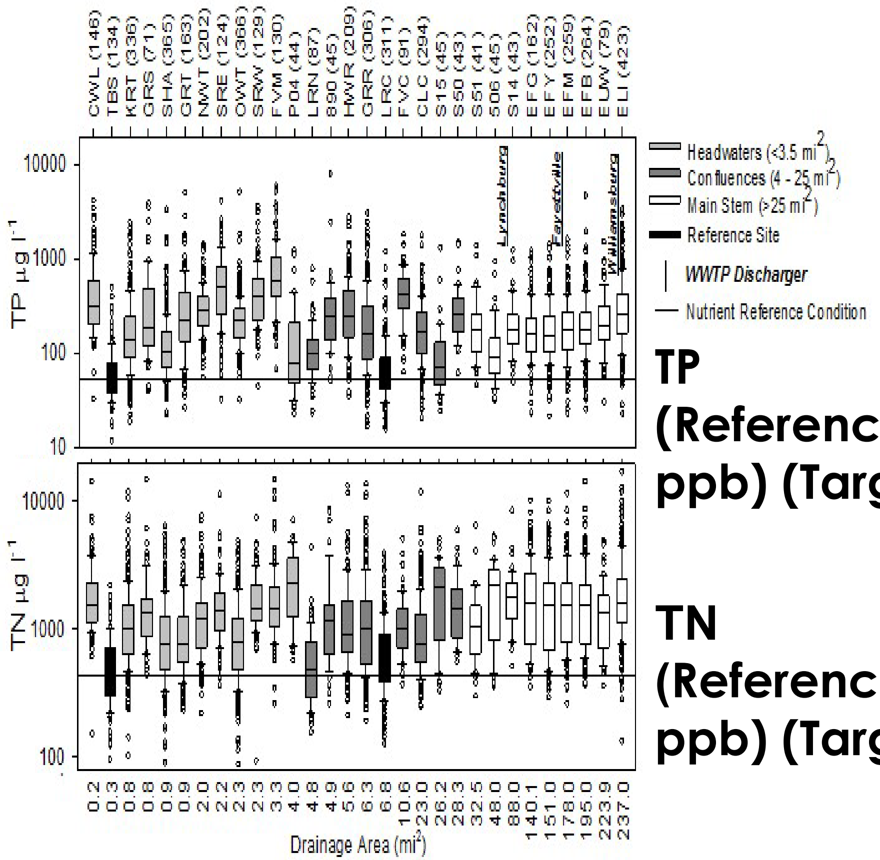
One primary focus of research has been the consideration of market-based approaches to nutrient pollution reduction. Large number of new requirements for TMDL process are in place

East Fork Watershed TMDL: account for impaired streams at HUC12 scale and Lake experience severe HABs

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



TP (Reference = 55 ppb) (Target=60)

TN (Reference = 433 ppb) (Target=700)

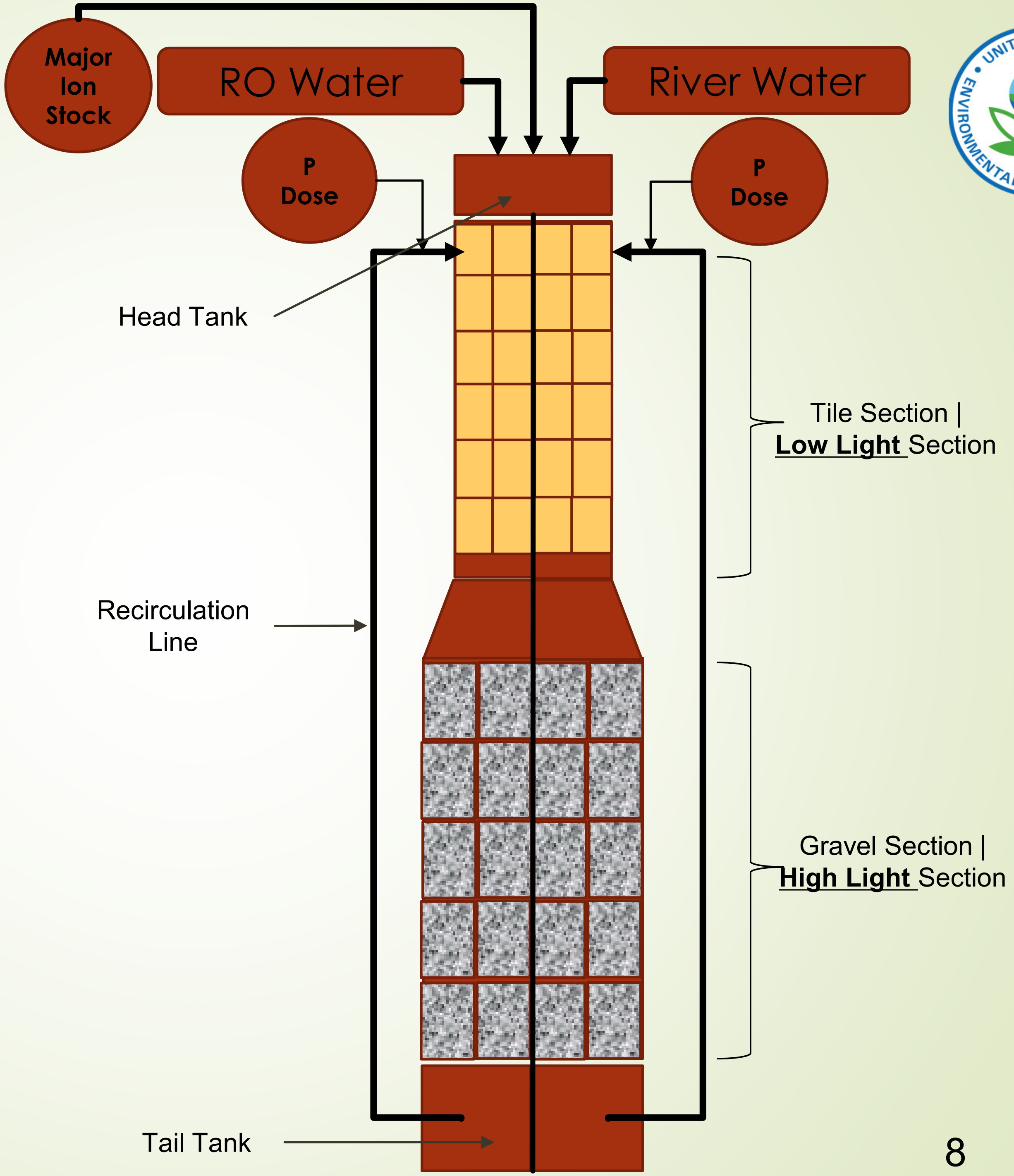
ORD's Nutrient Criteria established for research purposes

Stream mesocosm studies

- Validate nutrient criteria
  - EPA's experimental stream facility resides in the East Fork Watershed
  - Colonizing biota and water chemistry conditions can be configured to be highly relevant to the TMDL development
- Use mesocosm approach to better understand the linkages between nutrients and stream biotic structure and function
  - Characterizing mechanisms lends confidence to the nutrient criteria
  - Presently the linkages among nutrients and biota are weaker than expected and confusing (e.g. strongest correlate with macroinvertebrate impairment is organic Nitrogen (Miltner 2014)

Mesocosm Set-up

- Dose Response Design
- Ecotoxicology Approach
- ~ 1 month colonization period followed by 2 month dosing period
- Individual Experiments
  - Nitrate Dose
  - Phosphate Dose
  - N+P Dose
  - Etc.



Response Variables

Variable / Variable Class
Macroinvertebrates - Insect Emergence
Macroinvertebrates - taxa drift, dry weight, LOI
Macroinvertebrates - gravel benthos
Periphyton, gravel & tile (tile/gravel extraction days) _ BenthoTorch biomass
Periphyton - tile - low and high light sections - BenthoTorch biomass trend
Periphyton - tile - short term growth rate - BenthoTorch biomass
Periphyton - tile - reciprocal transplant study - BenthoTorch biomass
Periphyton - nutrient diffusing substrate - BenthoTorch biomass
Periphyton - nutrient diffusing substrate - specific DO metabolism
Periphyton - gravel/tile/nutrient diffusing substrate - chlorophyll extraction
Periphyton - gravel/tile/nutrient diffusing substrate - AFDM
Periphyton - gravel/tile/nutrient diffusing substrate - CNP
Periphyton - gravel/tile - algal taxonomy (300)
Periphyton - gravel/tile - diatom taxonomy (500)
Periphyton - gravel/tile - DNA metabarcoding
Periphyton - cyanotoxins - ELISA tests
Leaf Litter - Lirodendron tulipifera - Dry Weight, LOI, CN&P
Nutrient Uptake - whole mesocosm - short term study
Single Species Toxicity - N. triangulifer Mortality and Growth - WET Format
Single Species Toxicity - H. azteca- WET Format
Single Species Toxicity - C. dubia - WET Format
Single Species Toxicity - larval P. promelas - WET Format
Single Species Toxicity - N. triangulifer Mortality and Growth - ExSitu Format
Single Species Toxicity - H. azteca Mortality and Growth - ExSitu Format
Single Species Toxicity - C. fluminea, survival and growth - In-situ Format
Single Species Toxicity - adult P. promelas Survival and Fecundity - In-situ Format

Gravel/Litter

Drift

Periphyton

Emergence

Ex-situ

In-situ bivalves

In-situ Fish

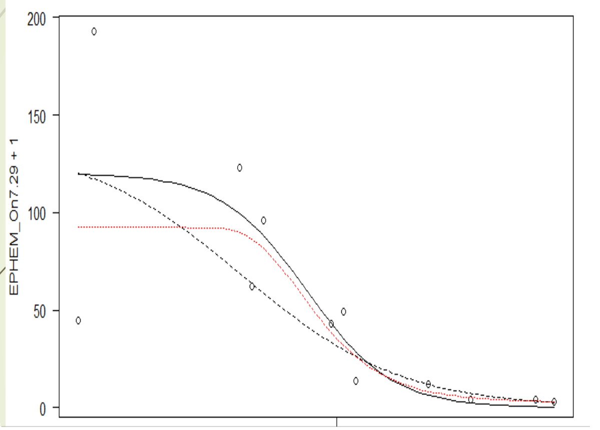
Lab assay

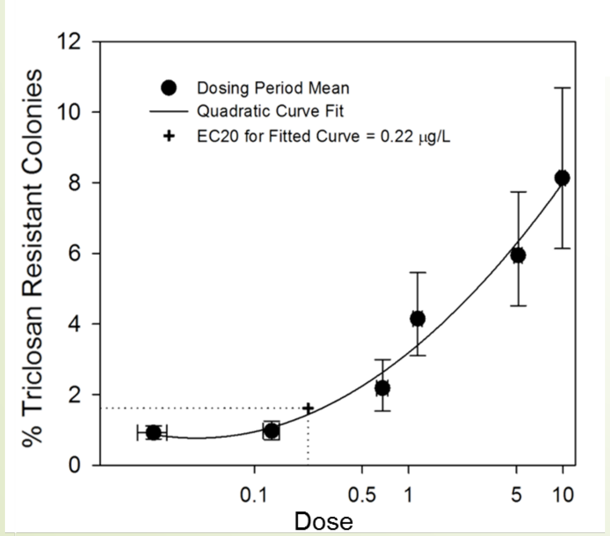
Water Chemistries – Phosphate Dosing Period

Set-up				Major Ions and Nutrients (mg/l)										Nutrient Ratios		Flow-Throuh rate to ESF Discharge (l/min)
Mesocosm	Nominal P as Phosphate Target (ppb)	Chem Tank	Stock Tank Vol (gal)	Cl-	SO4-	Ca	Na	Mg	K	N as TN	N as NO3	P as TP	P as OrthoP	Ing N:P	TN:TP	
E03.2	15	9	300	46.38	31.35	34.55	20.62	8.04	4.11	0.114	0.098	0.019	0.013	7.65	5.87	2.73
E07.1	15	9	300	46.38	31.35	34.55	21.62	9.04	4.11	0.114	0.098	0.019	0.013	7.83	5.65	2.73
E08.1	15	9	300	46.38	31.35	34.55	22.62	10.04	4.11	0.114	0.098	0.019	0.013	7.83	5.65	2.73
E01.2	40	1	125	46.38	31.35	34.55	23.62	11.04	4.11	0.114	0.098	0.050	0.043	2.31	2.20	2.73
E03.1	40	4	125	46.38	31.35	34.55	24.62	12.04	4.11	0.114	0.098	0.050	0.043	2.31	2.20	2.73
E04.2	40	4	125	46.38	31.35	34.55	25.62	13.04	4.11	0.114	0.098	0.050	0.043	2.31	2.20	2.73
E02.2	100	2	125	46.38	31.35	34.55	26.62	14.04	4.11	0.114	0.098	0.110	0.103	0.97	1.00	2.73
E05.1	100	8	125	46.38	31.35	34.55	27.62	15.04	4.11	0.114	0.098	0.110	0.103	0.97	1.00	2.73
E08.2	100	8	125	46.38	31.35	34.55	28.62	16.04	4.11	0.114	0.098	0.110	0.103	0.97	1.00	2.73
E07.2	300	7	125	46.38	31.35	34.55	29.62	17.04	4.11	0.114	0.098	0.310	0.303	0.33	0.35	2.73
E05.2	300	3	125	46.38	31.35	34.55	30.62	18.04	4.11	0.114	0.098	0.310	0.303	0.33	0.35	2.73
E06.1	300	7	125	46.38	31.35	34.55	31.62	19.04	4.11	0.114	0.098	0.310	0.303	0.33	0.35	2.73
E01.1	600	5	300	46.38	31.35	34.55	32.62	20.04	4.11	0.114	0.098	0.610	0.603	0.17	0.18	2.73
E04.1	600	5	300	46.38	31.35	34.55	33.62	21.04	4.11	0.114	0.098	0.610	0.603	0.17	0.18	2.73
E06.2	1200	6	300	46.38	31.35	34.55	34.62	22.04	4.11	0.114	0.098	1.210	1.203	0.08	0.09	2.73
E02.1	1200	6	300	46.38	31.35	34.55	35.62	23.04	4.11	0.114	0.098	1.210	1.203	0.08	0.09	2.73
River Water	na	na	na	28.25	21.00	44.70	14.60	10.25	4.50	1.94	1.28	0.23	0.17	7.63	8.34	1892.50
osms -Coloniz	na	na	na	46.38	31.35	34.55	11.08	7.80	4.11	0.11	0.10	0.02	0.01	7.83	5.65	43.69

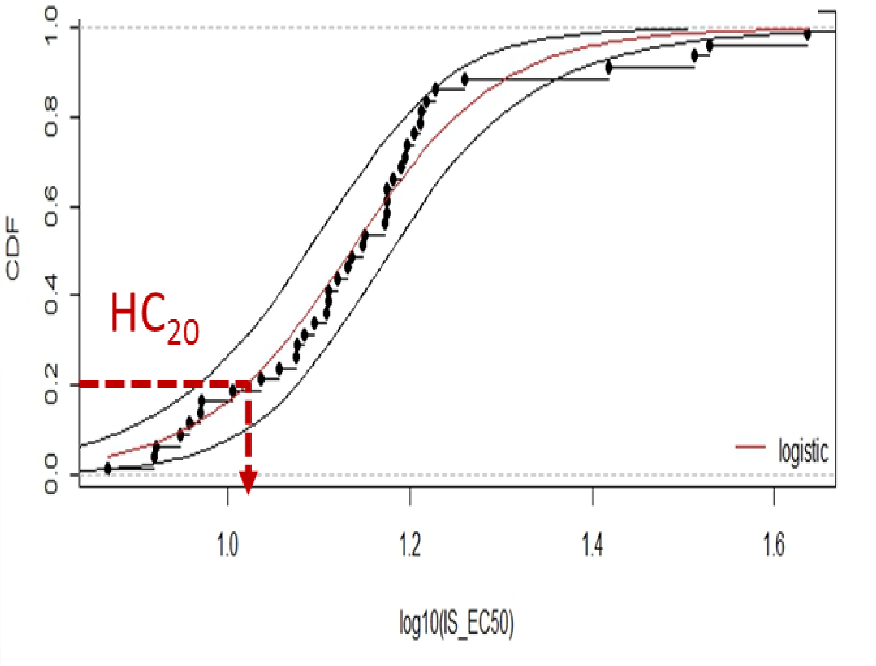
Characterizing Responses – Data analysis objectives – Ecotox "SSD" approach

Dose – Response for Effective Concentration





Response Sensitivity Distribution for Hazard Concentration Determination

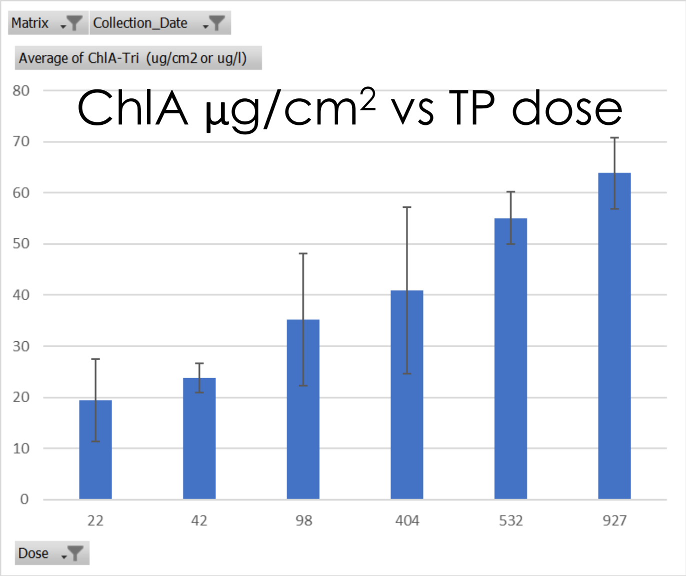


Summary of results compiled to date

- All mesocosms were N-limited
- Macroinvertebrate responses varied by group, most non-significant – but chironomids show a threshold response (EC20=140 ppb)
- Hysteresis in specific periphyton colonization rate as well as macroinvertebrate drift response
- By the end of the study Cyanobacteria biomass is decreasing with increasing TP while Chlorophyll content of periphyton increases (EC20 ~ 60 ppb)

Nutrient Diffusing Substrate Samplers

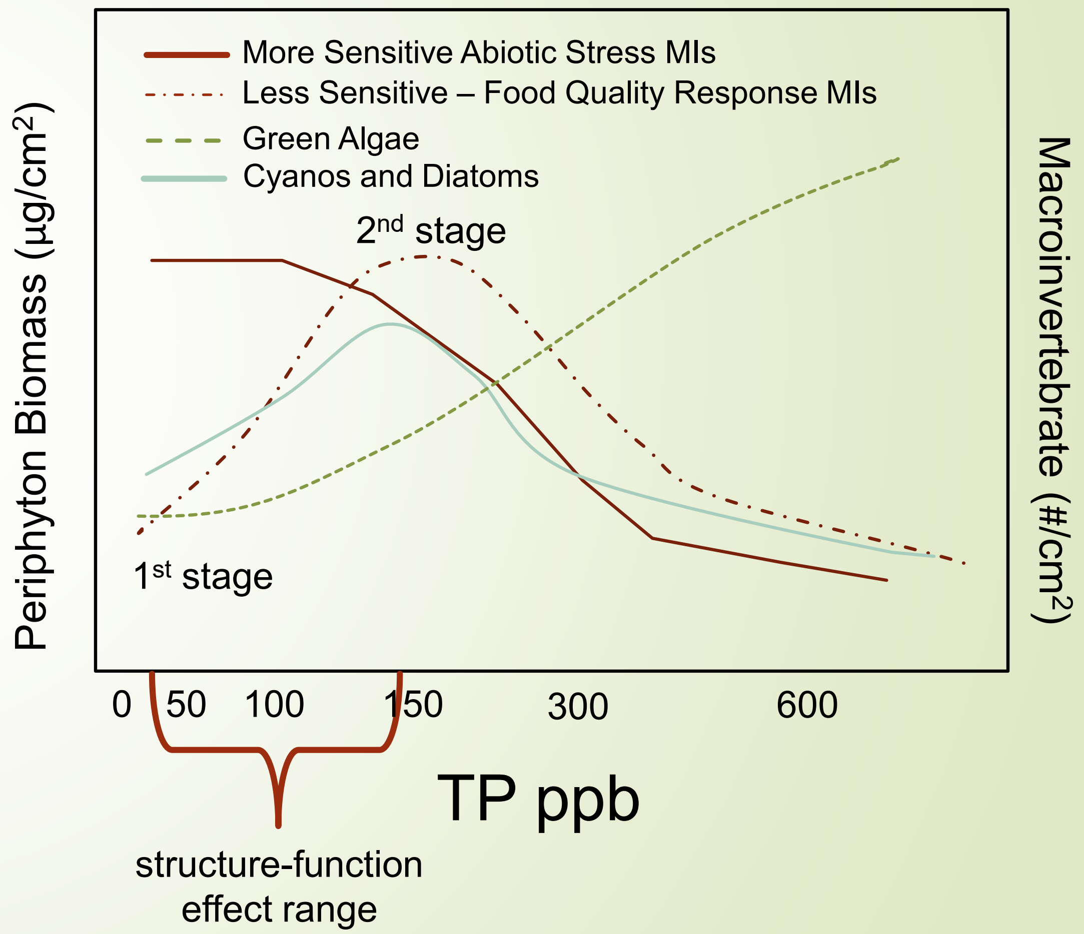
Control +N +P +NP



Plausible Mechanisms

- Intermediate [P] (i.e. ca. 100 ppb) increases food quality, but N-stressed system overloads biofilm biomass to sequester N (i.e. TN higher in IG) – causing stress to some macroinvertebrates sensitive to D.O. variability
- At higher [P] (i.e., > 300 ppb), system saturates and less palatable periphyton species favoring high P become dominant, producing an overall decline in macroinvertebrate diversity and biomass
- Hypothesis: 2 stage threshold response at the community scale when N is low and P is in excess

Conceptual model of P effects



Conclusions and Relevance

- Results thus far tend to support the current criteria (i.e., 60 ppb target)
- This appears to correspond to a P threshold where food quality is effected increasing the relative abundance of macros less sensitive to abiotic stress posed by excess biofilm biomass
- Considering responses for a single nutrient, don't make much ecological sense, but are relevant to policy makers
  - N concentrations were very low, albeit not completely irrelevant based on monitoring data in the EFW
- Experiments like these are needed to indicate the plausible mechanisms that lend credence to proposed criteria