Virtual WQS Academy

Nutrient Criteria

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  - Impose any binding requirements.
  - Determine the obligation of the regulated community.
  - Change or substitute for any statutory provision or regulatory requirement.
  - Change or substitute for any Agency policy or guidance.
  - Control in any case of conflict between this discussion and statute, regulation, policy, or guidance.

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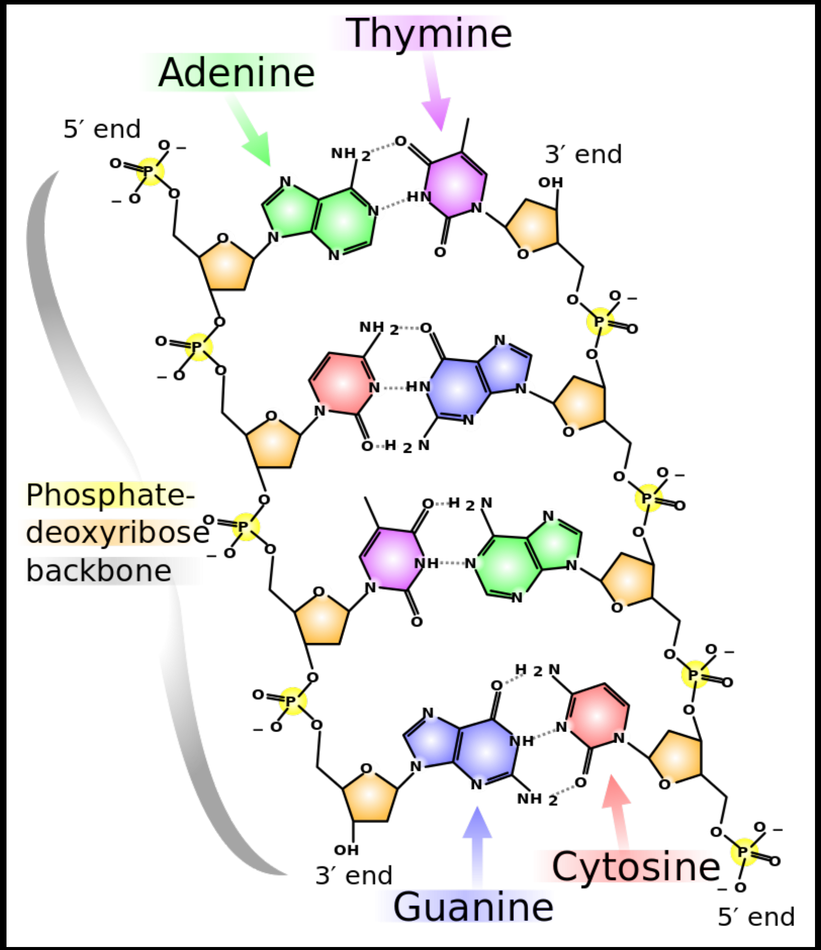
Outline

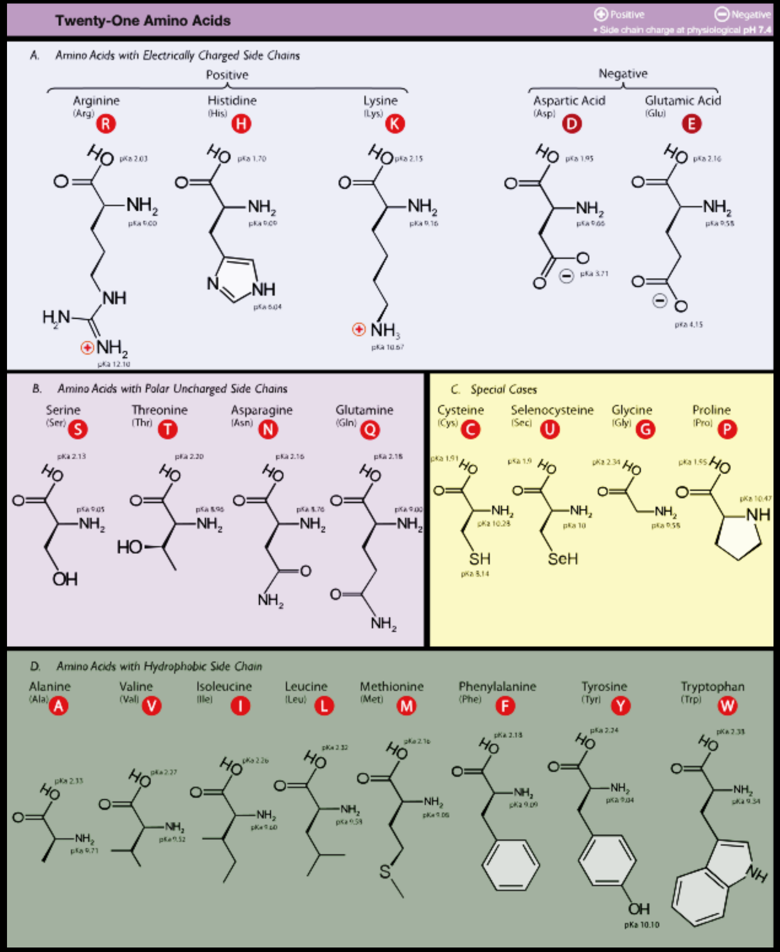
– Pollutants: Nitrogen and phosphorus
– Effects: Widespread degradation of water quality in the U.S.
– Governance: Authorization, regulations, and technical support
– Management: Developing numeric nutrient criteria
– Making a difference: EPA-State partnerships (N-STEPS Program)

Nitrogen and Phosphorus are Important

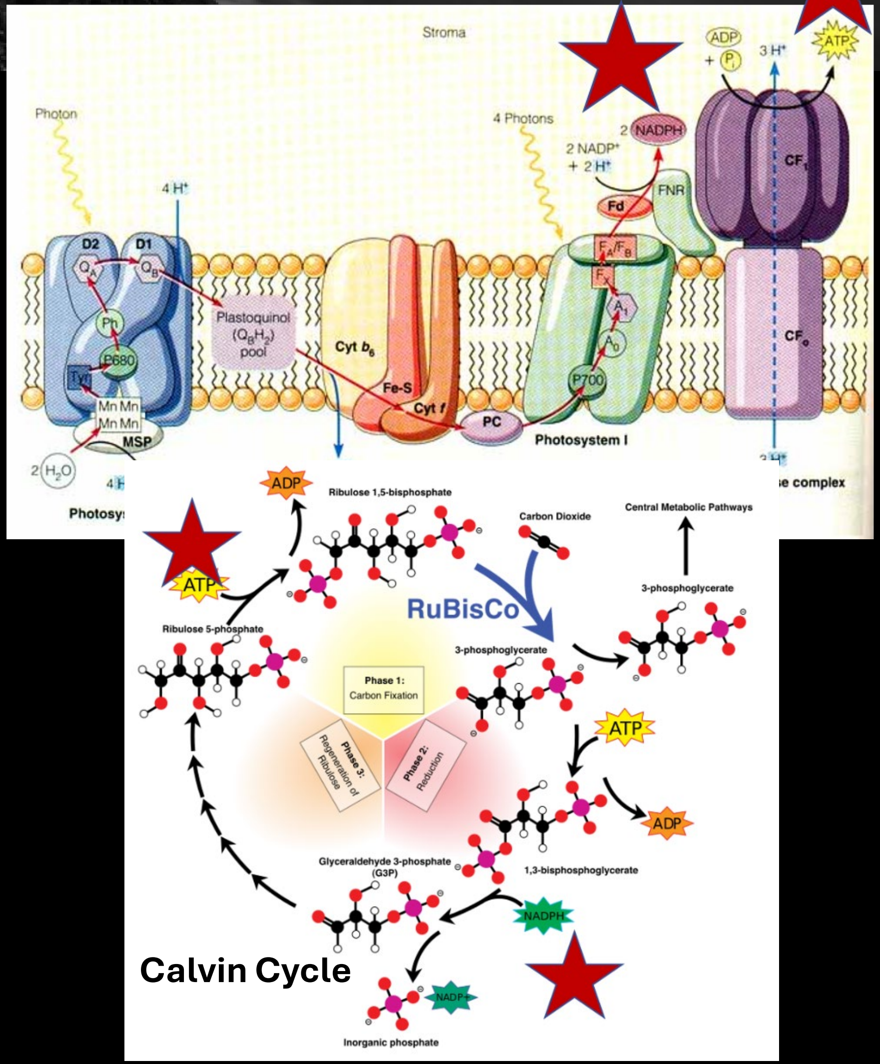
DNA/RNA (P and N rich)



Amino Acids (N rich)

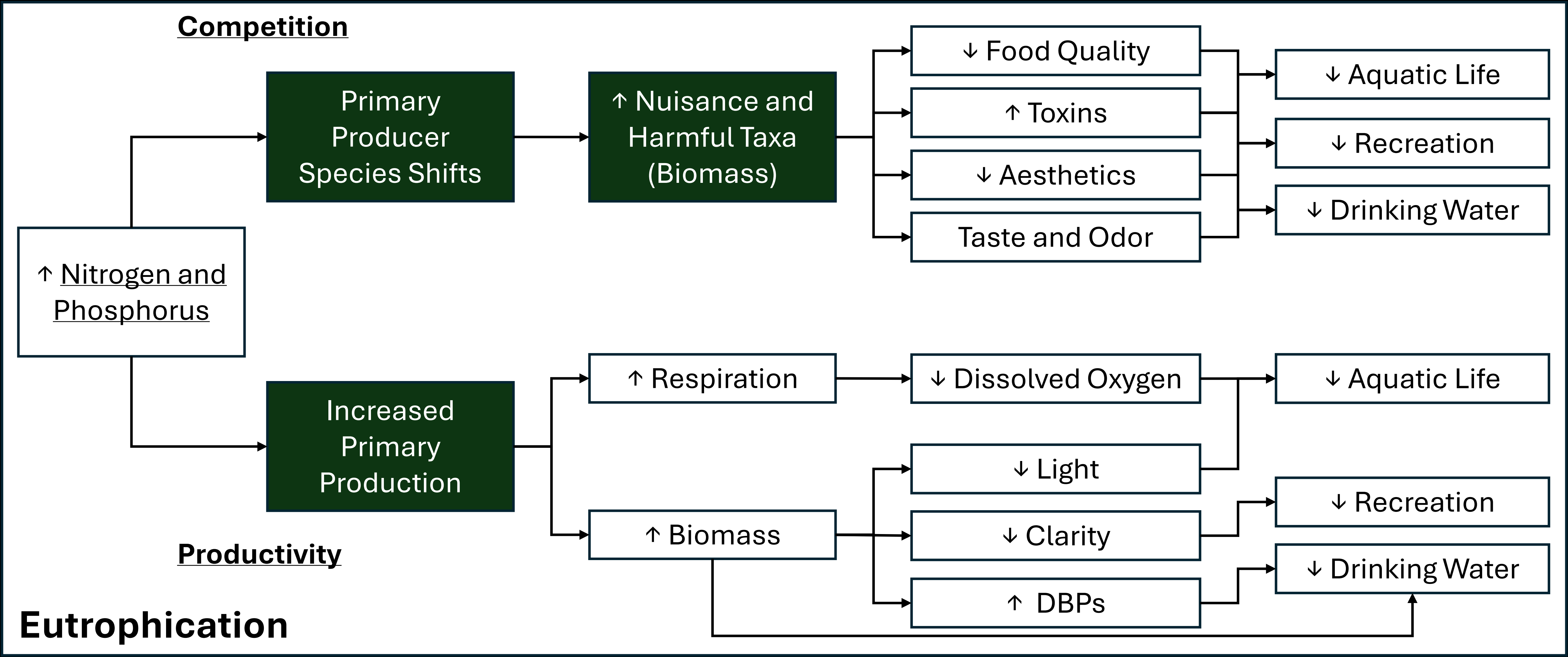


Photosynthesis: phospholipid bilayer

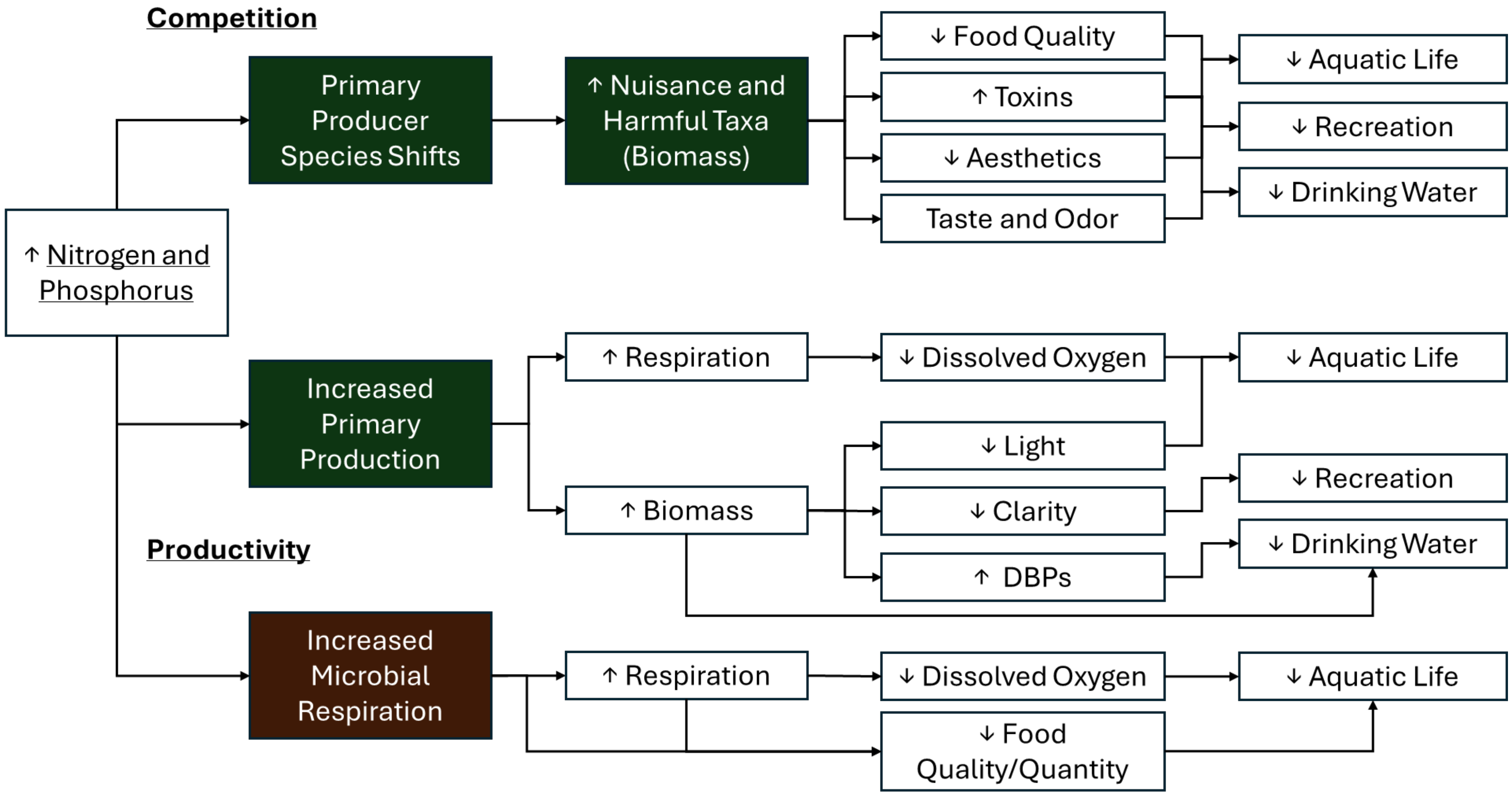


Photosynthesis: P rich energy molecules

Too much of anything though...

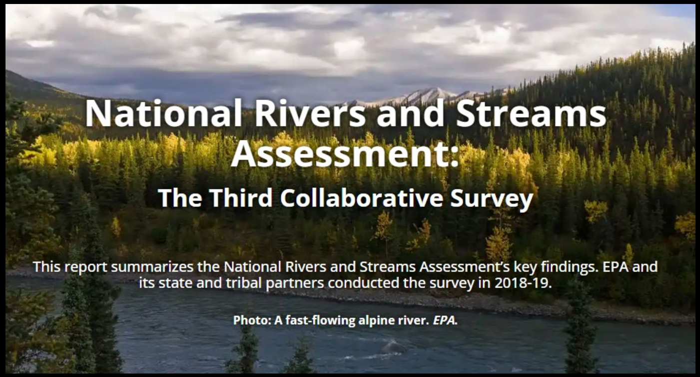


Don't forget brown pathways too.



Effects: Widespread degradation of water quality in the U.S. (1)

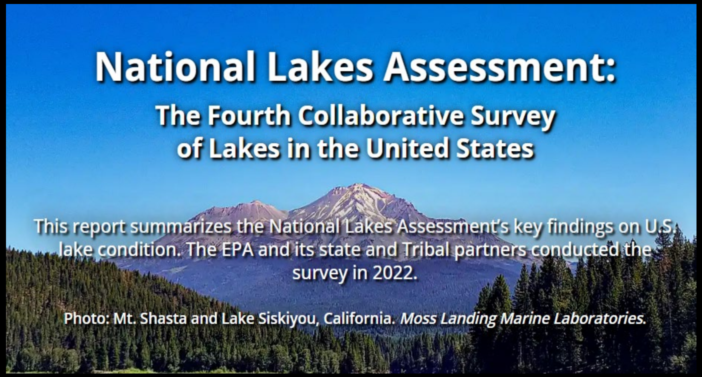
U.S. EPA 2024



"Nutrients (phosphorus and nitrogen) were the most widespread stressors"

"Reducing nutrient pollution could improve biological condition"

U.S. EPA 2024

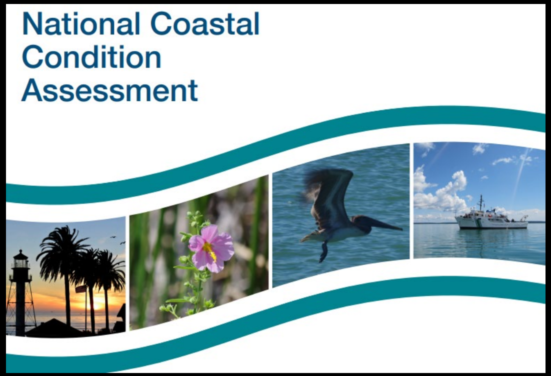


"Nutrient pollution was the most widespread stressor measured"

"High levels of algae and cyanobacteria growth were observed"

"Poor biological condition was more likely when lakes were in poor condition with respect to nutrients"

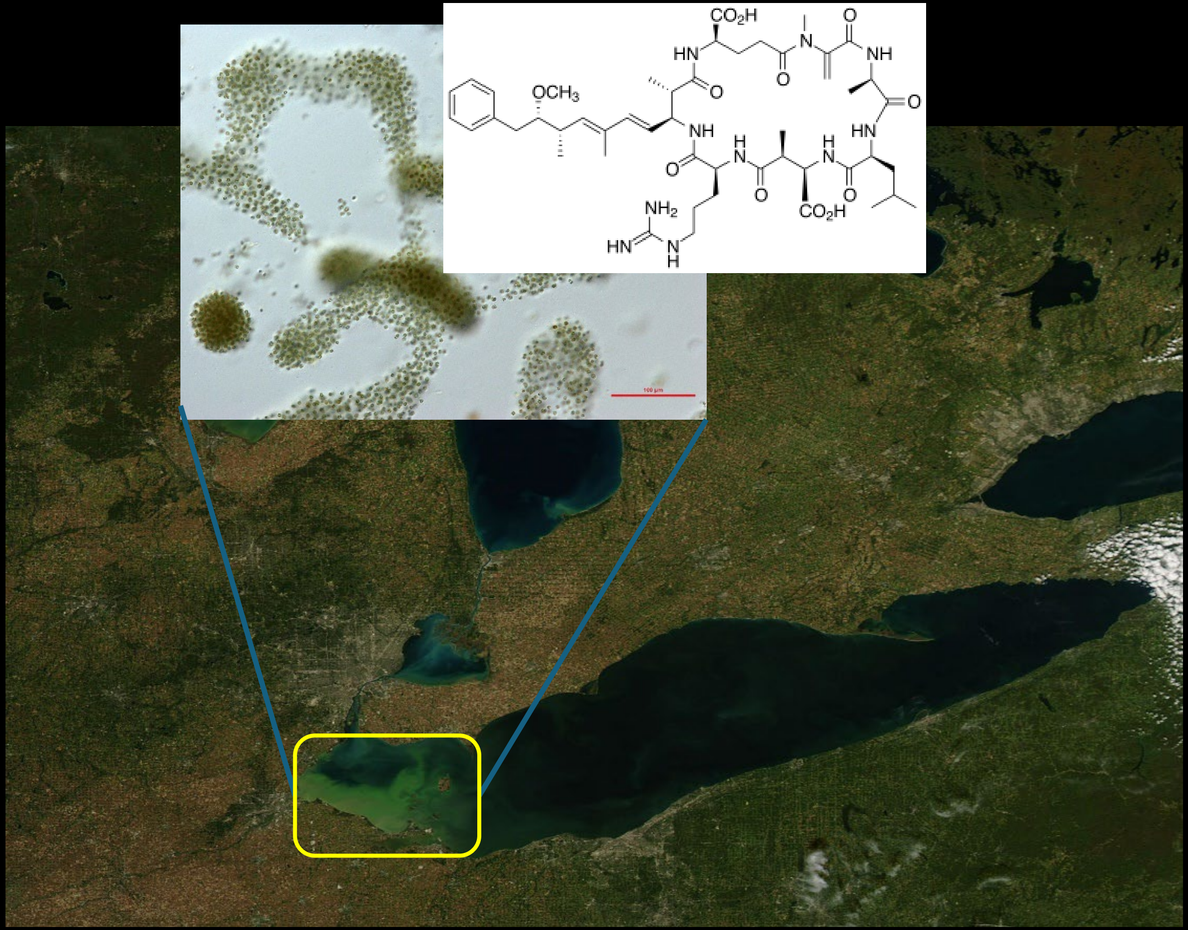
U.S. EPA 2021

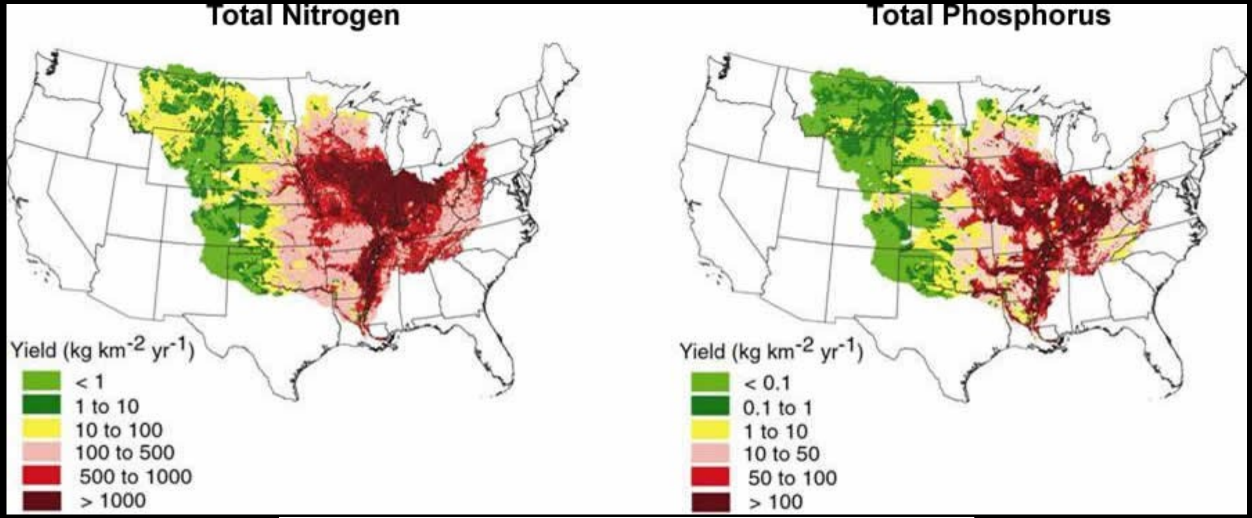


"Nutrient pollution is widespread in the nation's estuaries"

"Nutrient pollution is widespread in the Great Lakes"

Effects: Widespread degradation of water quality in the U.S. (2)





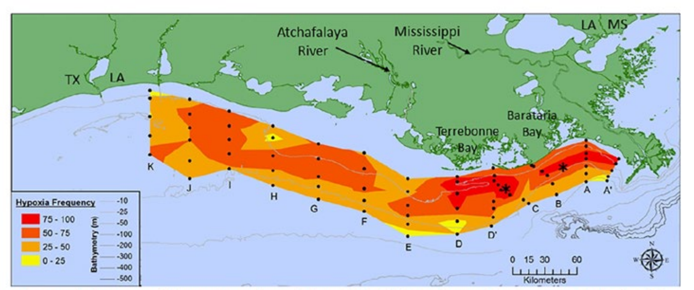


FIG. 1. The frequency of bottom-water hypoxia from shelf-wide hypoxia mapping (1985–2014) (updated from Rabalais et al. (2007b); frequency is determined from stations for which there are data for at least half of all cruises. Asterisks (*) indicate locations of near-bottom oxygen meters; transects C and F identified. Data source: N. N. Rabalais and R. E. Turner.

Effects: Widespread degradation of water quality in the U.S. (3)

Diagnosis
Impaired waters[1] (303(d) list)

Wetlands: 672,924 acres
Rivers and streams: 588,173 miles
Lakes, reservoirs, ponds: 13,208,917 acres
Bays and estuaries: 44,625 miles^2

Diagnosis
Nutrient-Impaired waters[1]

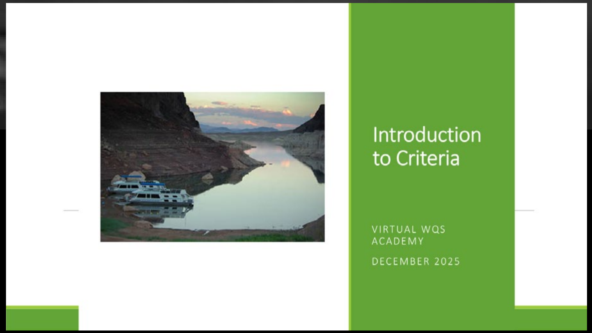
Wetlands: 10%, 67,849 acres (6th)
Rivers and streams: 20%, 118,831miles (3rd)
Lakes, reservoirs, ponds: 30%, 3,943,395 acres (2nd)
Bays and estuaries: 40%, 18,279 miles^2 (2nd)

Remediation

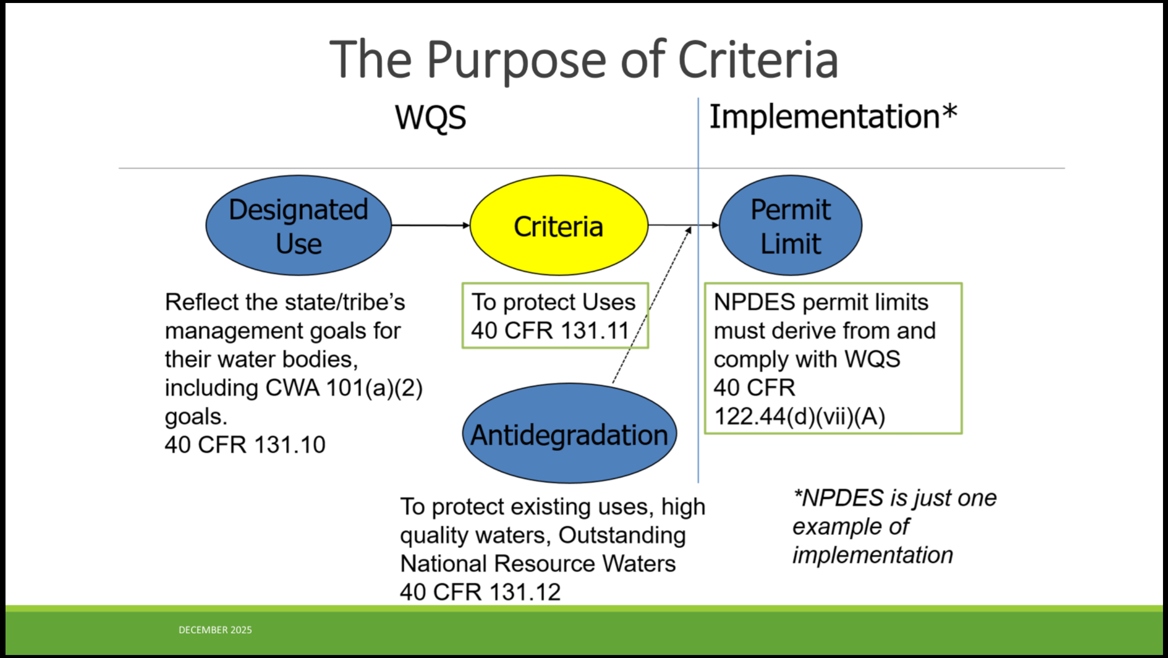
Total maximum daily loads[1] (TMDLs) = 74,001

Nutrient TMDLs[1] = 6,685 (4th)

Governance: Authorization, regulations, and technical support (1)



- Quick reminders
  - Designated uses and criteria to protect uses - serve CWA objectives
  - Sound scientific rationale
  - Narrative and numeric forms



Governance: Authorization, regulations, and technical support (2)

State Regulations: Narrative Criteria

"Plant nutrients from other than natural causes shall not be present in concentrations which will produce ***undesirable aquatic life*** *or result in a* ***dominance of nuisance species*** *in surface waters of the state."*

–*State of New Mexico Standards for Interstate and Intrastate Surface Waters* (Subsection E of 20.6.4.13 NMAC)

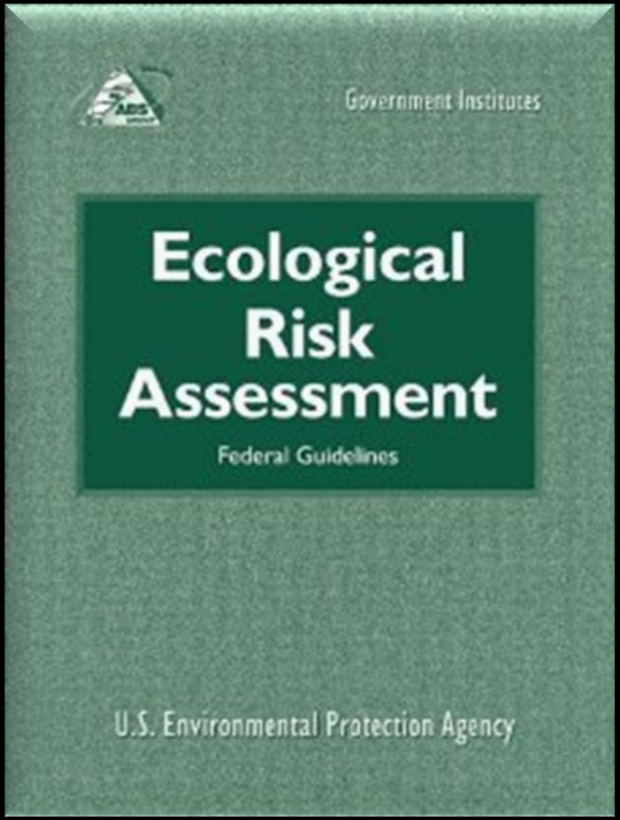
EPA Strategy and Technical Support

National Strategy for the Development of Regional Nutrient Criteria (1998)

Technical support documents (pursuant to 33 USC 1314, CWA Section 304)

- Nutrient criteria = nitrogen, phosphorus, chlorophyll-a, and water clarity
- Waterbody-specific technical support documents (2000, 2001, 2006)
- Recommended criteria for most lakes/reservoirs, rivers/streams (2000-1)
- Stressor-response approaches (2010)
- Revised recommendations for lakes and reservoirs (2021)

Management: Developing numeric nutrient criteria (1)

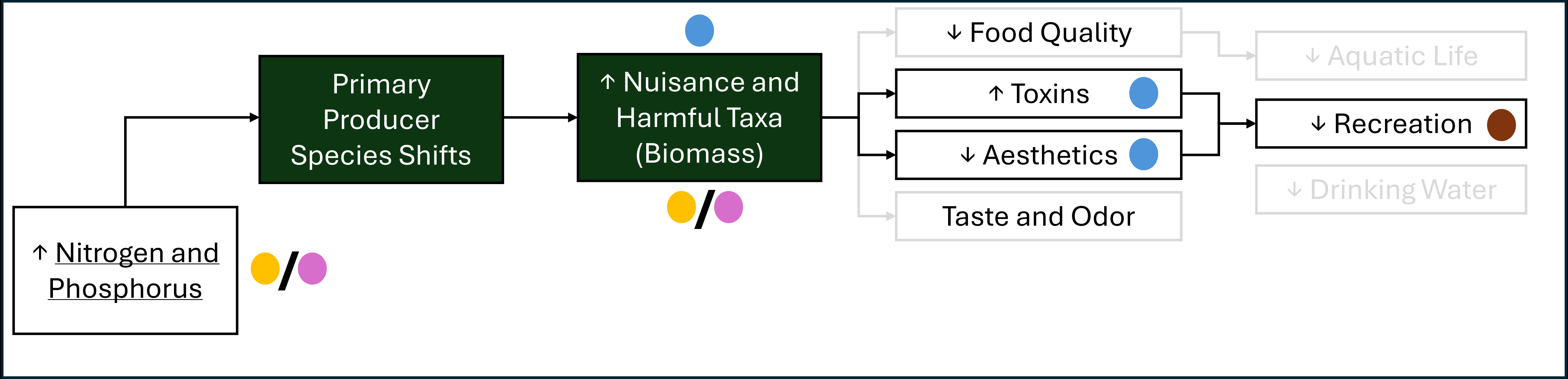


Term	Definition
Management Goal	Narrative reflective of protecting a designated use
Assessment Endpoint	Ecological entity/attribute to be protected
Measure	Measurable attributes of an assessment endpoint
Water Quality Target	Numeric value reflecting management goal attainment

Management: Developing numeric nutrient criteria (2)

- Range of waterbody types
- Conceptual models
- Data
  - Surveys vs. experiments (spatial and temporal scales)
  - Discrete vs. continuous (data quantity)
- Analysis
  - Classification: Parsimonious techniques to reduce variability
  - Stressor-response models (empirical)
  - Reference condition models (empirical)
  - Mechanistic numerical models (deterministic)
  - Nutrient criteria duration and frequency

Management: Developing numeric nutrient criteria (3)



Recreation

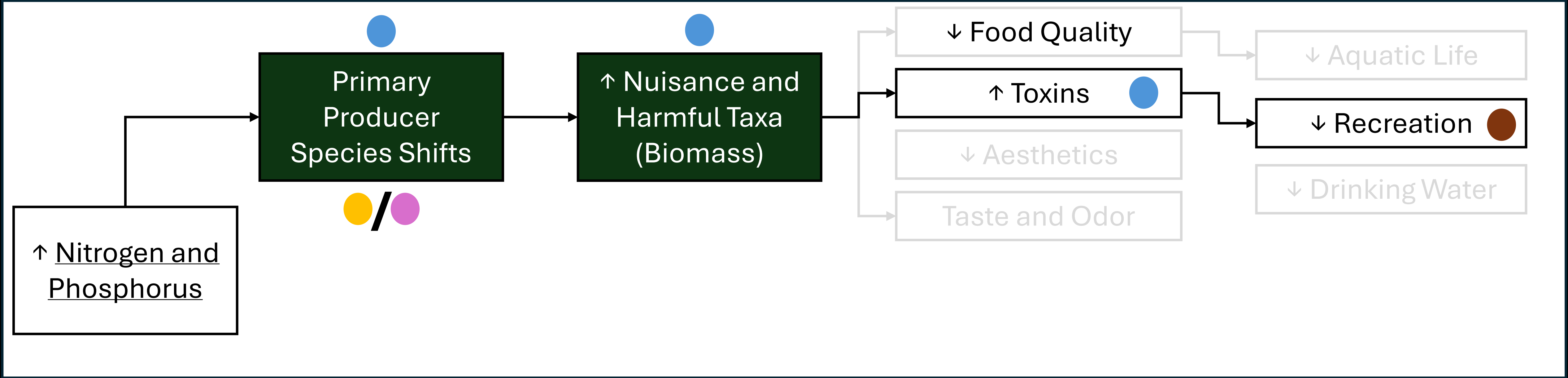
Nuisance/Harmful Algae

Biomass

Chlorophyll a, N and P values

Term	Definition
Management Goal	Narrative reflective of protecting a designated use
Assessment Endpoint	Ecological entity/attribute to be protected
Measure	Measurable attributes of an assessment endpoint
Water Quality Target	Numeric value assuring management goal attainment

Management: Developing numeric nutrient criteria (4)



Recreation

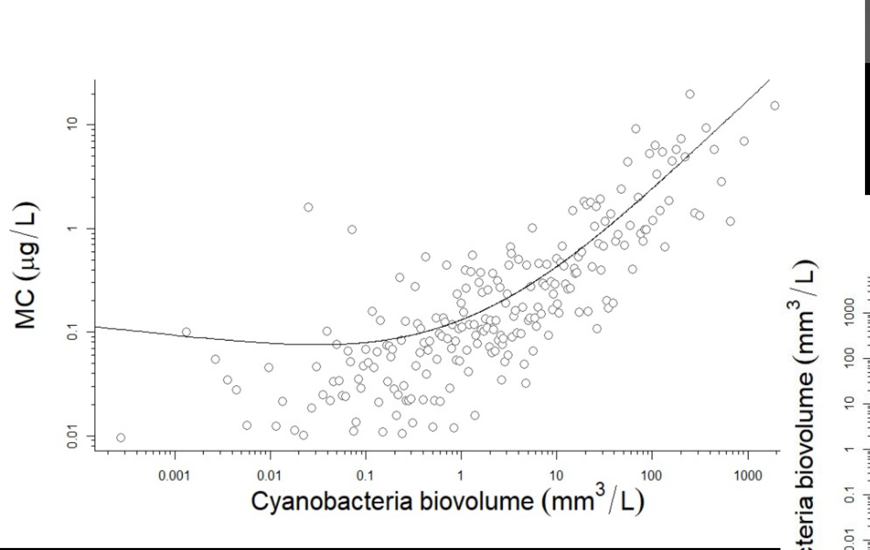
Nuisance/Harmful Algae

Biomass

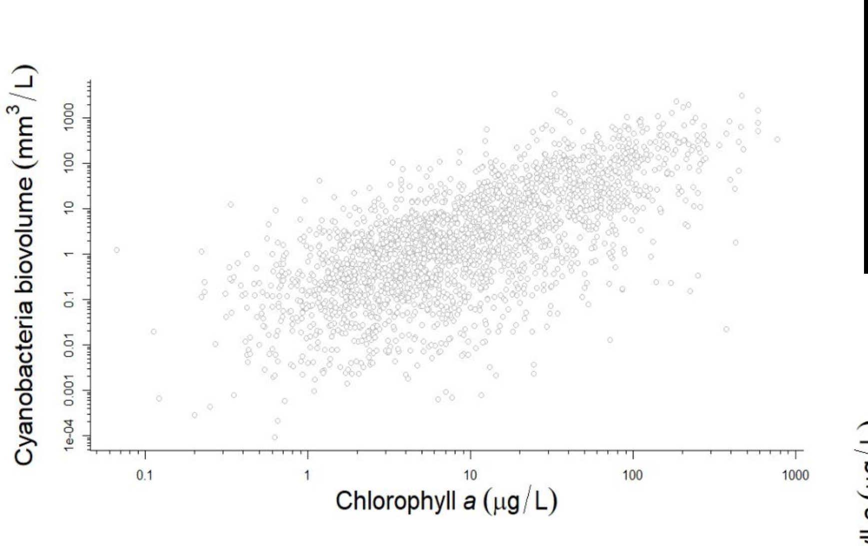
Chlorophyll a, N and P values

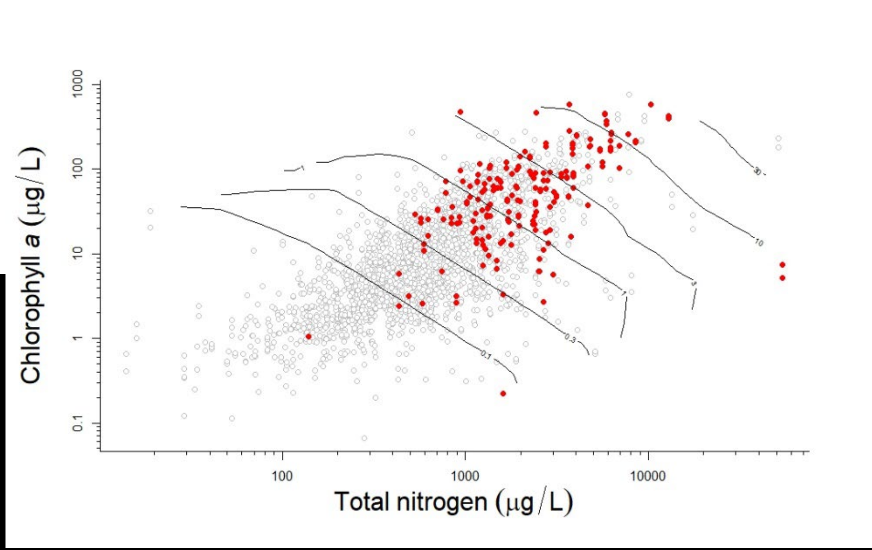
Term	Definition
Management Goal	Narrative reflective of protecting a designated use
Assessment Endpoint	Ecological entity/attribute to be protected
Measure	Measurable attributes of an assessment endpoint
Water Quality Target	Numeric value assuring management goal attainment

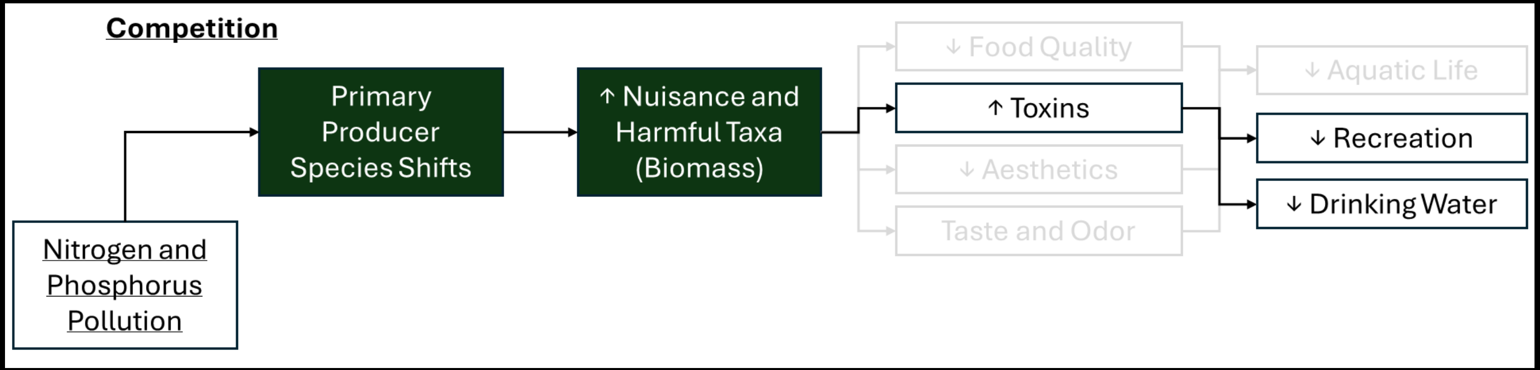
Management: Developing numeric nutrient criteria (5)



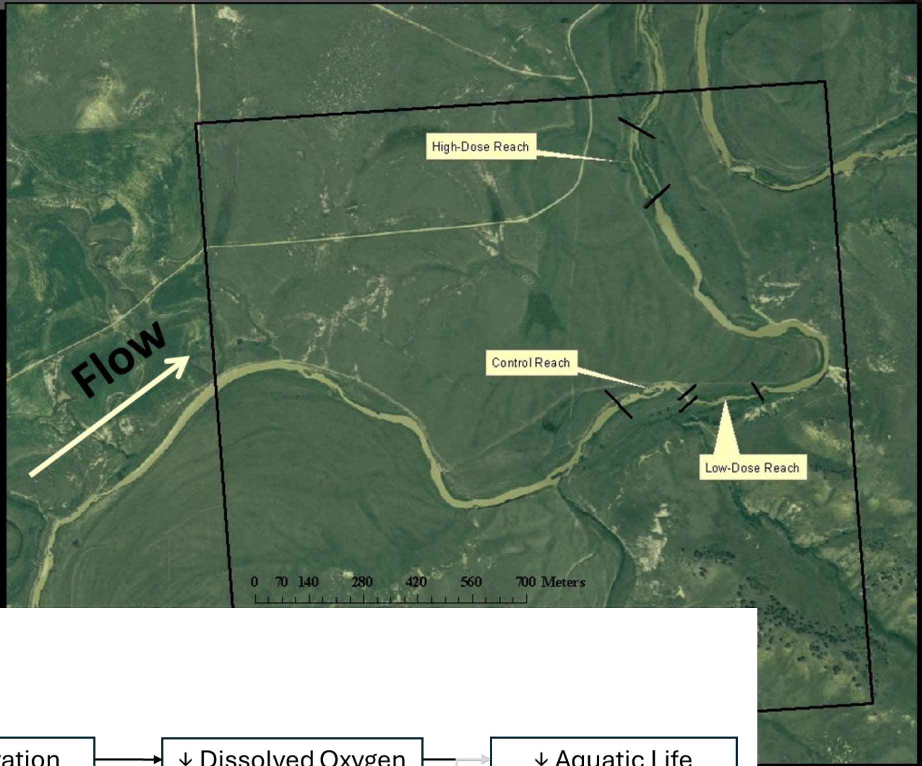
L. Yuan, U.S. EPA



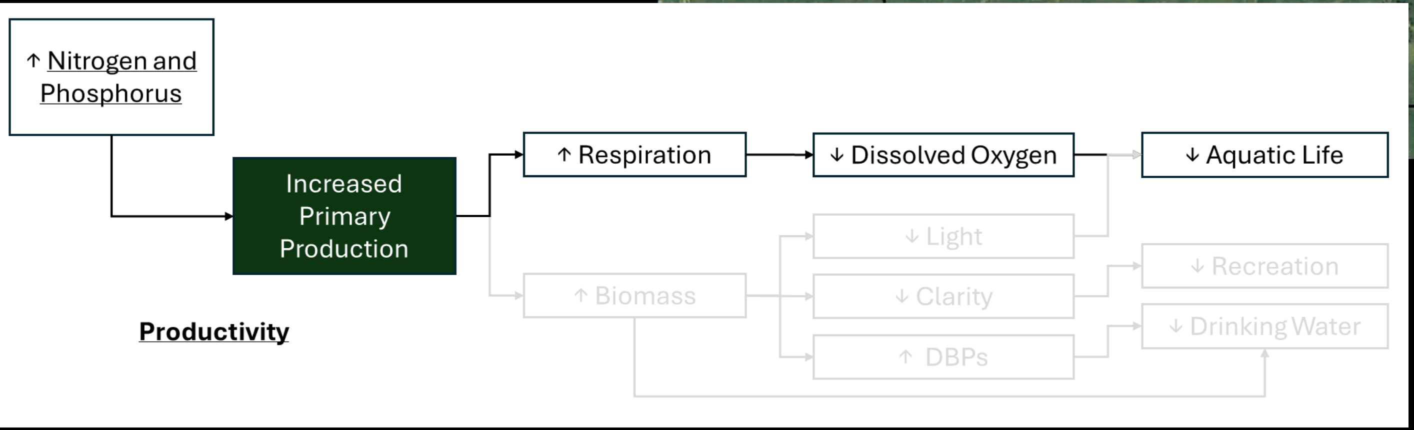




Management: Developing numeric nutrient criteria (5)

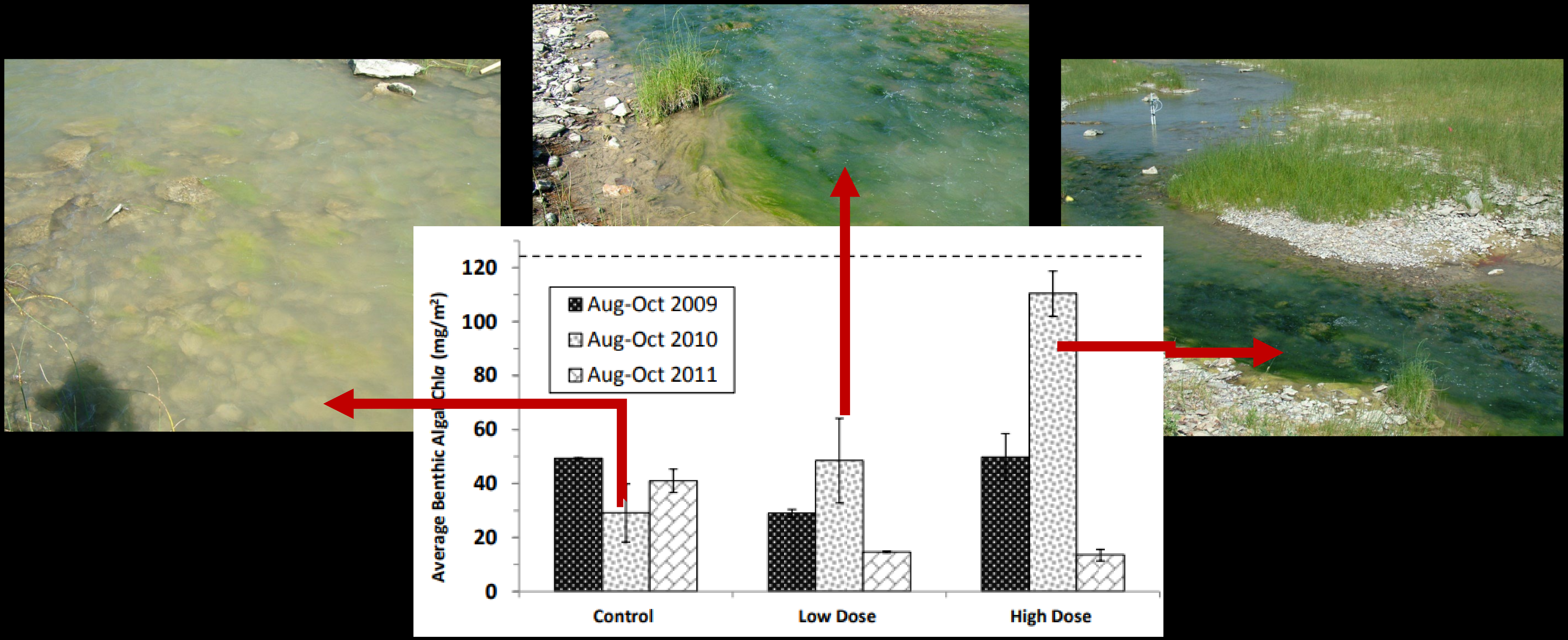


Box Elder Creek, MT



https://deq.mt.gov/files/Water/WQPB/Standards/NutrientWorkGroup/PDFs/BoxElderTechRprt_FNL.pdf

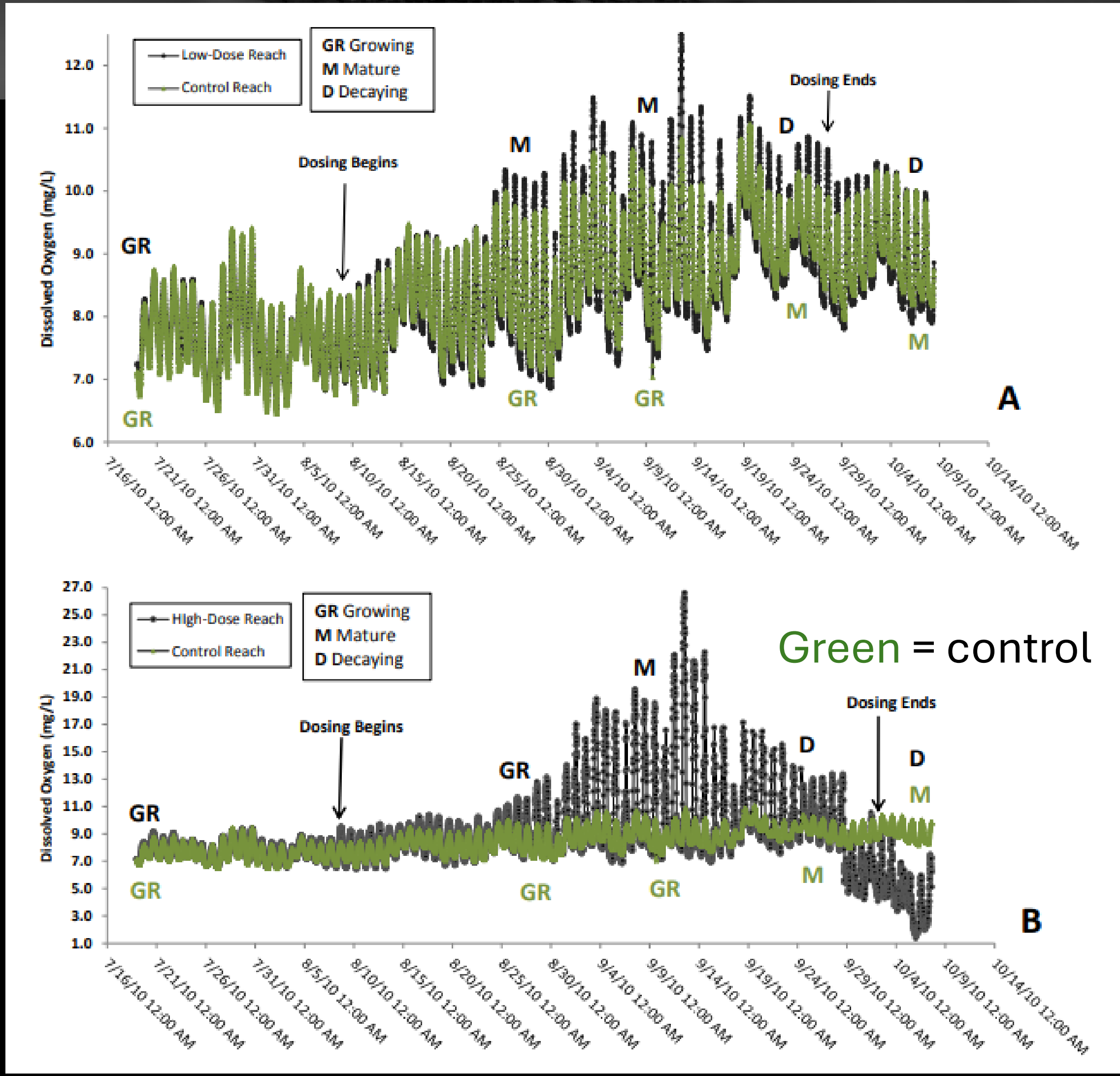
Management: Developing numeric nutrient criteria (6)



https://deq.mt.gov/files/Water/WQPB/Standards/NutrientWorkGroup/PDFs/BoxElderTechRprt_FNL.pdf

Management: Developing numeric nutrient criteria (6 continued)

Low Dose



High Dose

- Metabolism increased with enrichment
- Oxygen declines with decay
- Below state DO criterion

https://deq.mt.gov/files/Water/WQPB/Standards/NutrientWorkGroup/PDFs/BoxElderTechRprt_FNL.pdf

Management: Developing numeric nutrient criteria (7)

Reference condition model and data quantity

Selection criteria (examples):

Forested land cover
No human hydrologic alterations (e.g., dams, canals)
No NPDES discharges
No documented CWA 303(d) listings
Biological evidence of aquatic life support

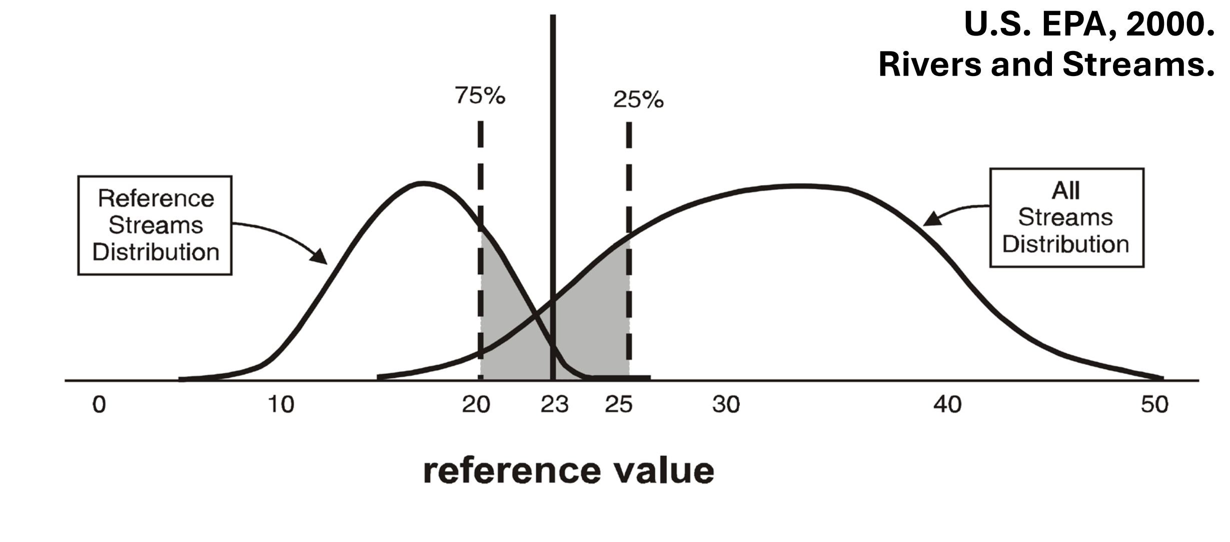
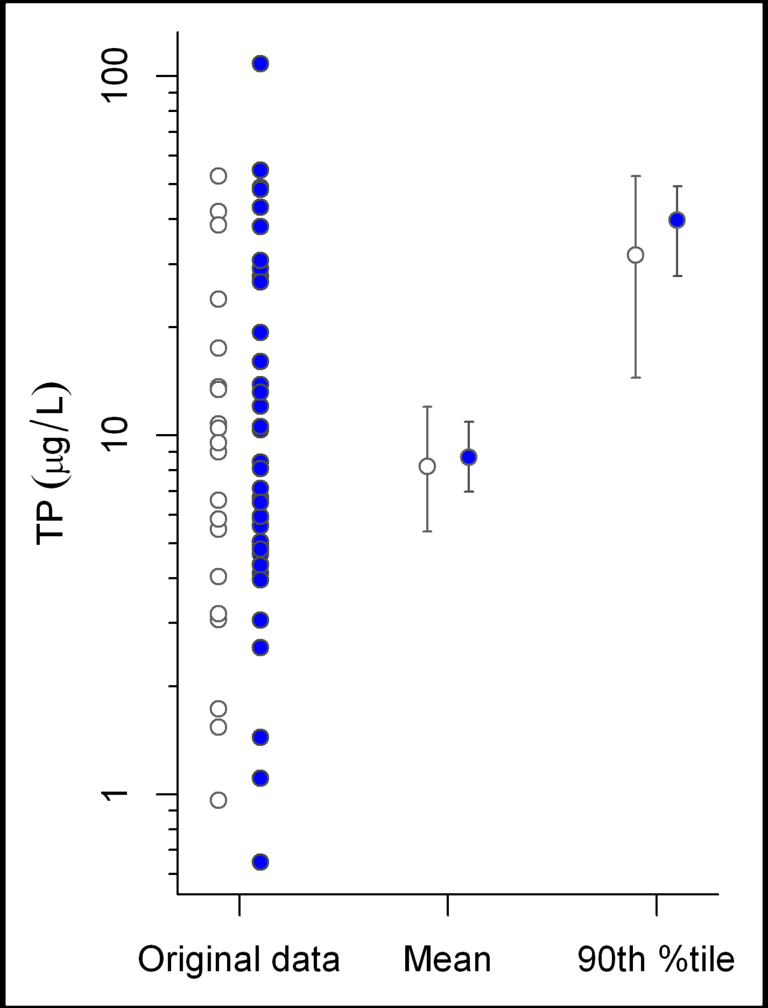


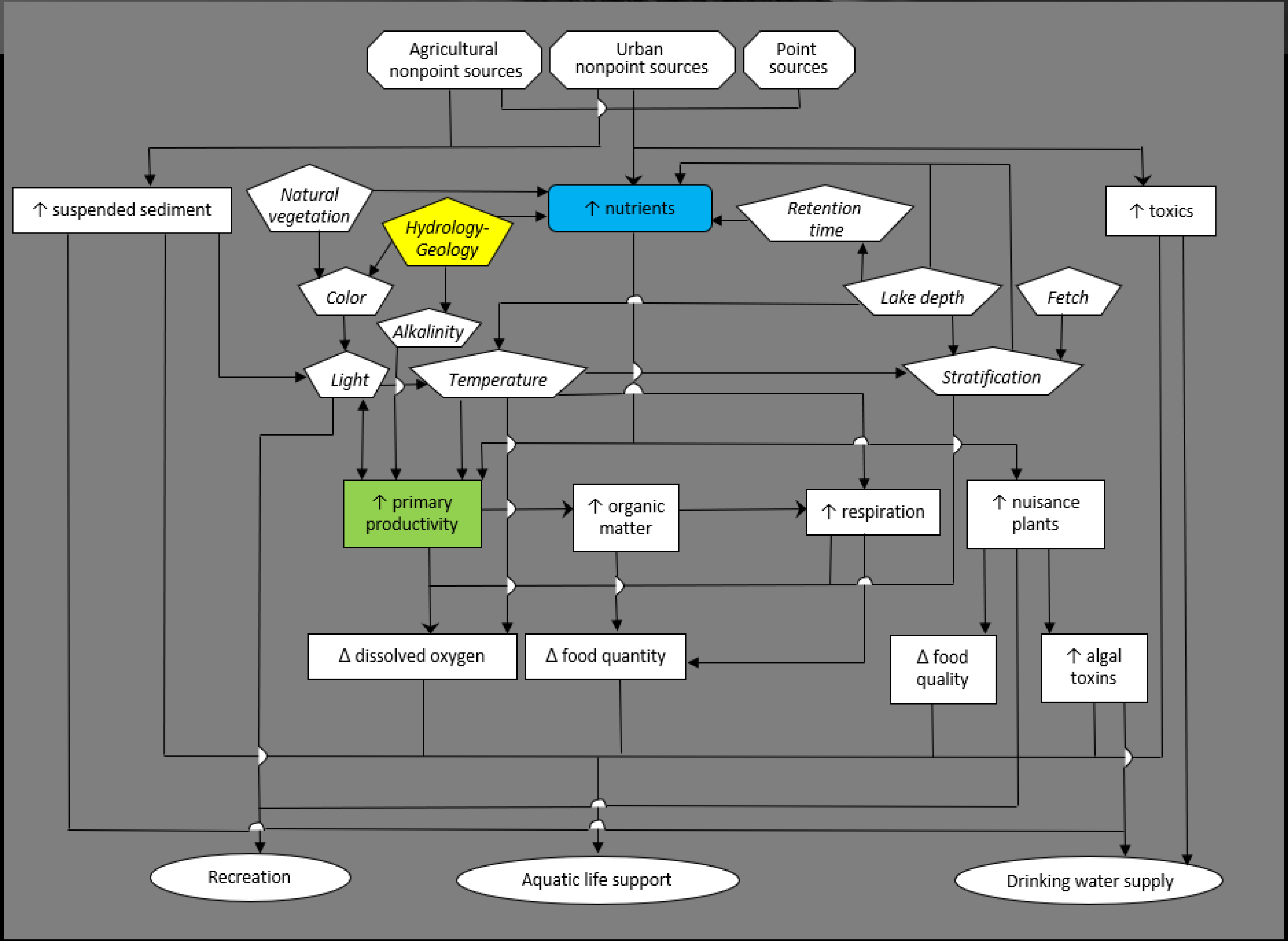
Figure 8. Selecting reference values for total phosphorus concentration (μg/L) using percentiles from reference streams and total stream populations.

L. Yuan, U.S. EPA



Management: Developing numeric nutrient criteria (8)

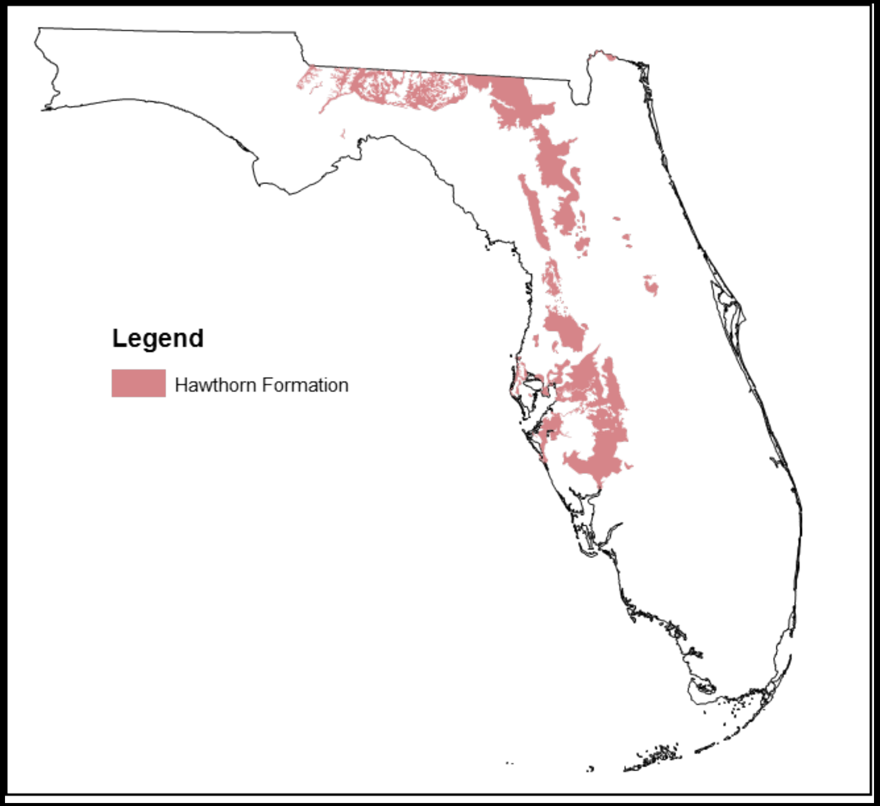
Lake Conceptual Model

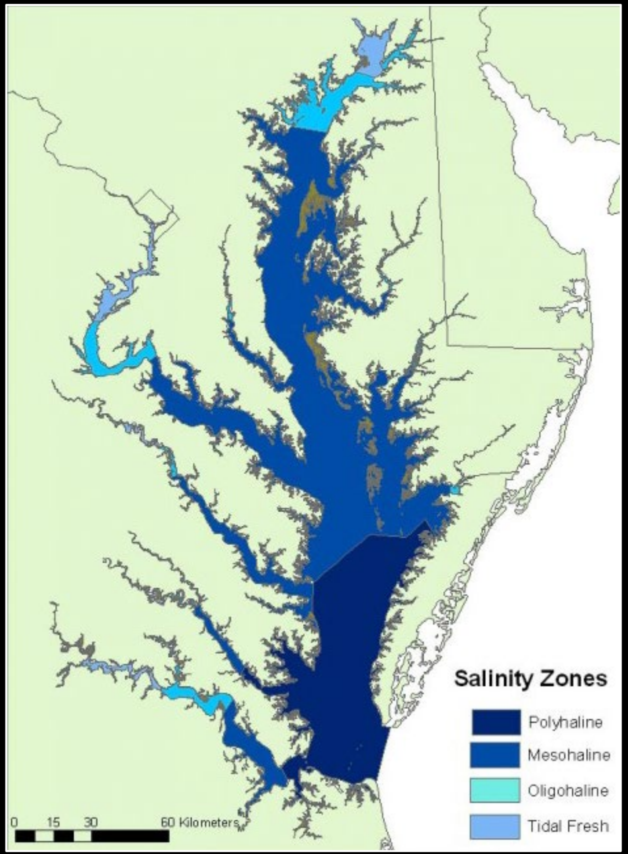


L. Yuan, U.S. EPA

Management: Developing numeric nutrient criteria (9)

Classification: Geographic (spatially-variable factors)





Management: Developing numeric nutrient criteria (10)

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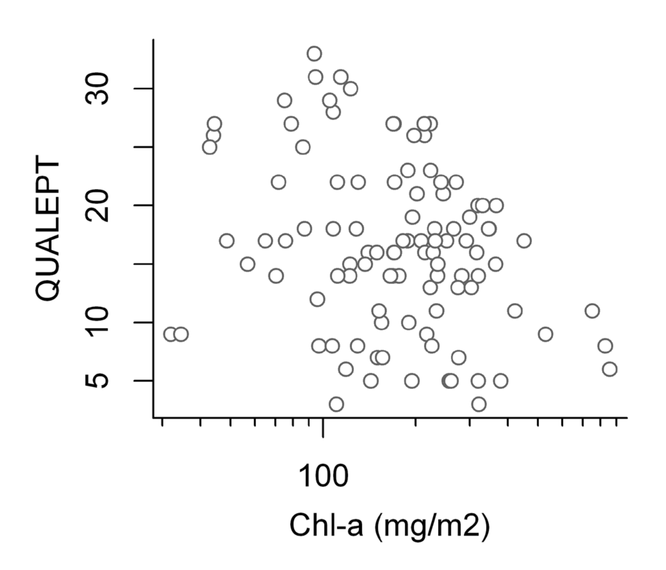
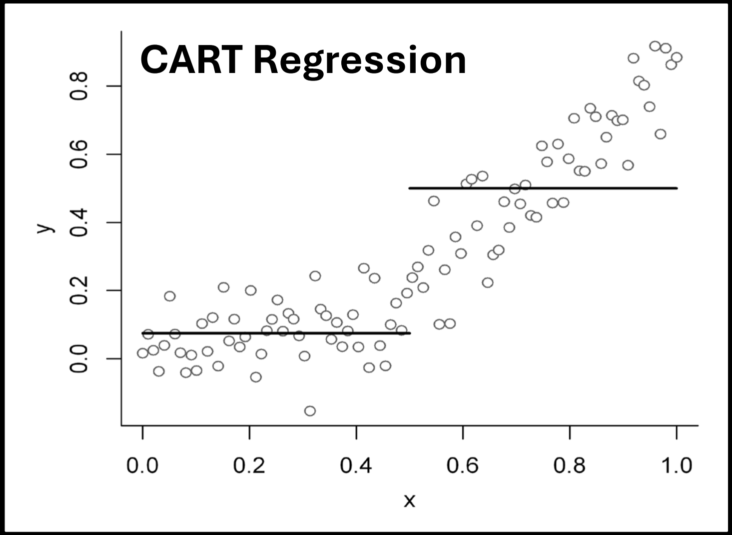


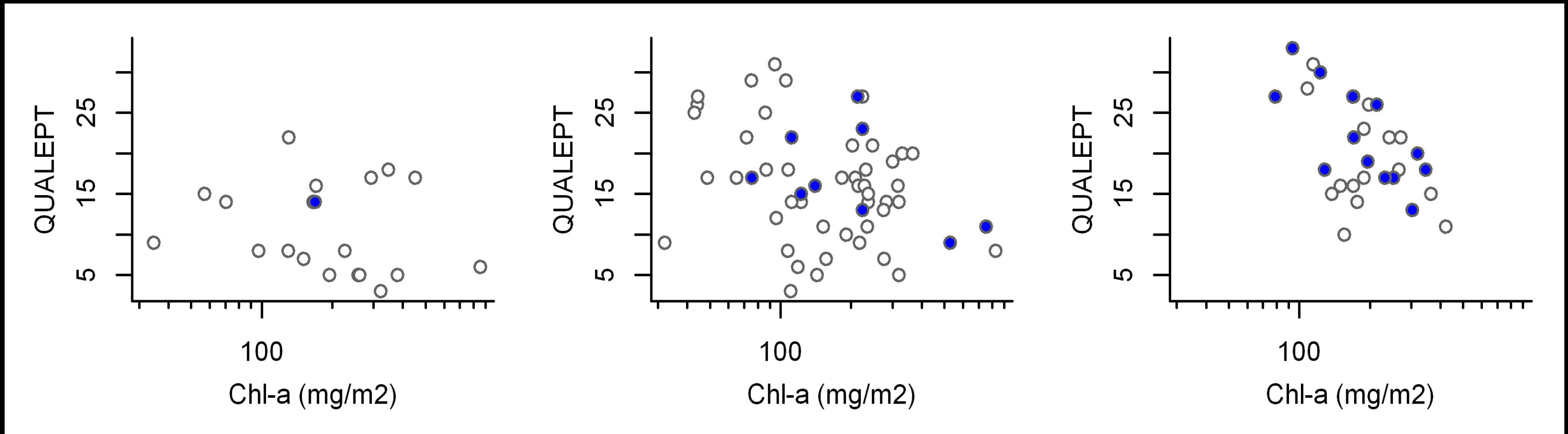
Classification: Functional

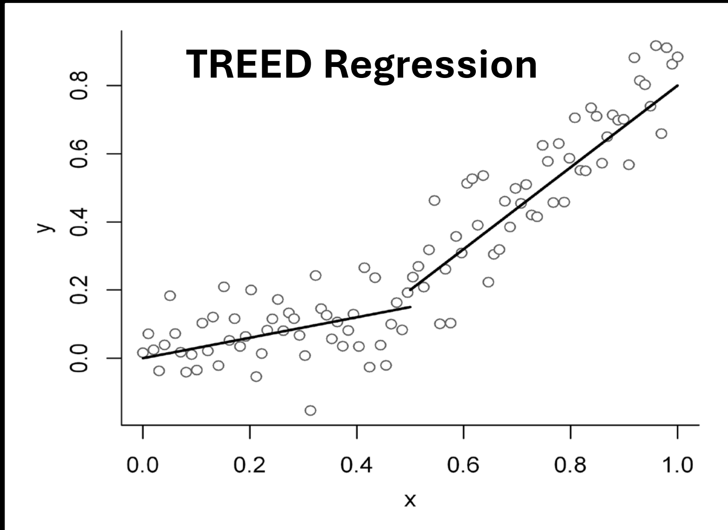


Habitat poor

Habitat fair

Habitat good





Management: Developing numeric nutrient criteria (11)

Estimating Duration and Frequency

Toxic pollutants

- Controlled laboratory experiments (removes confounding variables)
- Dose-response (gradient)
- Lethal effects
- Length of exposure: hours–days
- Frequency of exposure: weeks–months (recovery time)

Management: Developing numeric nutrient criteria (12)

Estimating Duration and Frequency

Toxic pollutants

- Controlled laboratory experiments (removes confounding variables)
- Dose-response (gradient)
- Lethal effects
- Length of exposure: hours–days
- Frequency of exposure: weeks–months (recovery time)

Nutrient pollution

- **Field monitoring of WQ (includes confounding variables)**
- **Correlations, not dose-response**
- **Sub-lethal effects**
- **Length of exposure: weeks–months+**
- **Frequency of exposure: months–years (recovery time)**

Management: Developing numeric nutrient criteria (13)

Distinguishing Criteria Duration and Frequency

Criteria (defines protection)

Length and frequency of *exposure* to a pollutant, or pollutant parameter, magnitude

WQ Monitoring/Sampling

Length of time and frequency of *observations* needed to detect exceedance of the criteria

Assessment Period

Length of time and frequency over which exceedance of the criteria is *concluded*

Management: Developing numeric nutrient criteria (14)

Distinguishing Criteria Duration and Frequency

Criteria (defines protection)

Length and frequency of *exposure* to a pollutant, or pollutant parameter, magnitude

WQ Monitoring/Sampling

Length of time and frequency of *observations* needed to detect exceedance of the criteria

Assessment Period

Length of time and frequency over which exceedance of the criteria is *concluded*

Nutrient Criteria Duration/Frequency	Criteria Monitoring Period (Index Period) Sampling Frequency	Criteria Assessment Period
Instantaneous [chl-a] shall not exceed 40 µg/L over the year, more than 10% of the time	Monitor over growing season (140 days) Sample once per week (n=20)	303(d) Assessment: Every two years Multiple annual assessment periods
Magnitude: 40 µg/L Duration: Year (365 days) Frequency: ≤ 10%		

Making a difference: EPA-State partnerships (N-STEPS Program) (1)

State Projects

- ✓ Data acquisition and preparation
- ✓ Classification analysis
- ✓ Modeling
  - ✓ Conceptual
  - ✓ Stressor-response
  - ✓ Reference condition
  - ✓ Mechanistic
- ✓ Technical reports
- ✓ Technical literature reviews
- ✓ Peer reviews

National and Regional Projects

- ✓ Webinars
- ✓ White Papers
- ✓ Online Technical Resources
- ✓ National Meetings
- ✓ Regional Workshops
- ✓ 304(a) Criteria Recommendations
- ✓ Consultation with CWA 303(d), 402 programs

Making a difference: EPA-State partnerships (N-STEPS Program) (2)

Streams

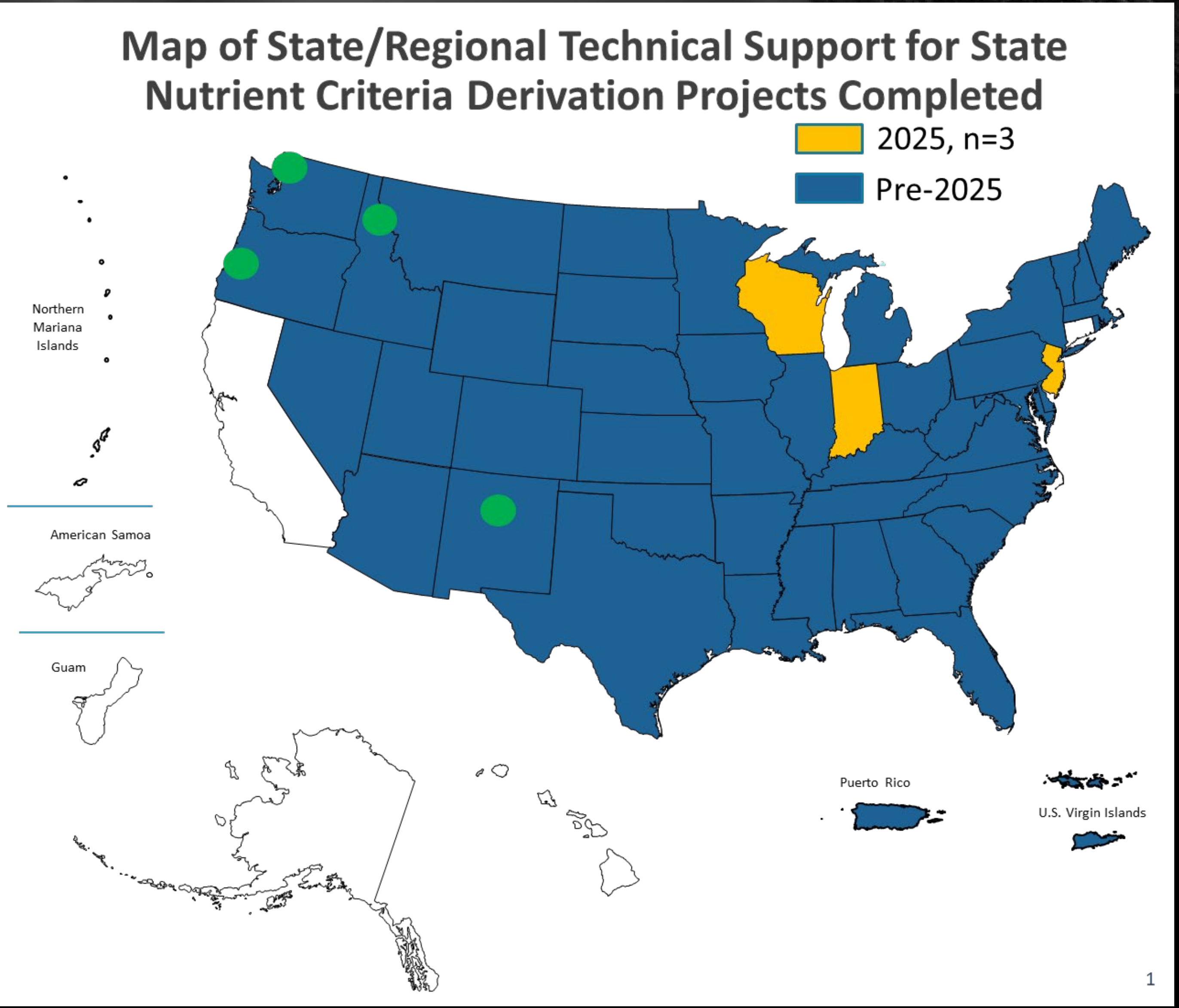
Rivers

Lakes

Reservoirs

Wetlands

Estuaries



- Tribes include:
  - Coeur d'Alene Tribe
  - Confederated Tribes of the Coos, Lower Umpqua and Siuslaw Indians
  - New Mexico Pueblo Tribes
  - Lummi Nation

Additional technical resources

N-STEPS Online (2021)

Primer on user perception surveys (2021)

Ambient Water Quality Criteria to Address Nutrient Pollution in Lakes and Reservoirs (2022)

Questions and Discussion

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Acknowledgments

- ❖Jacques Oliver, Ph.D., U.S. EPA, Office of Water
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- ❖Galen Kaufman, U.S. EPA, Office of Water
- ❖Michael Suplee, Ph.D., Montana Department of Environmental Quality

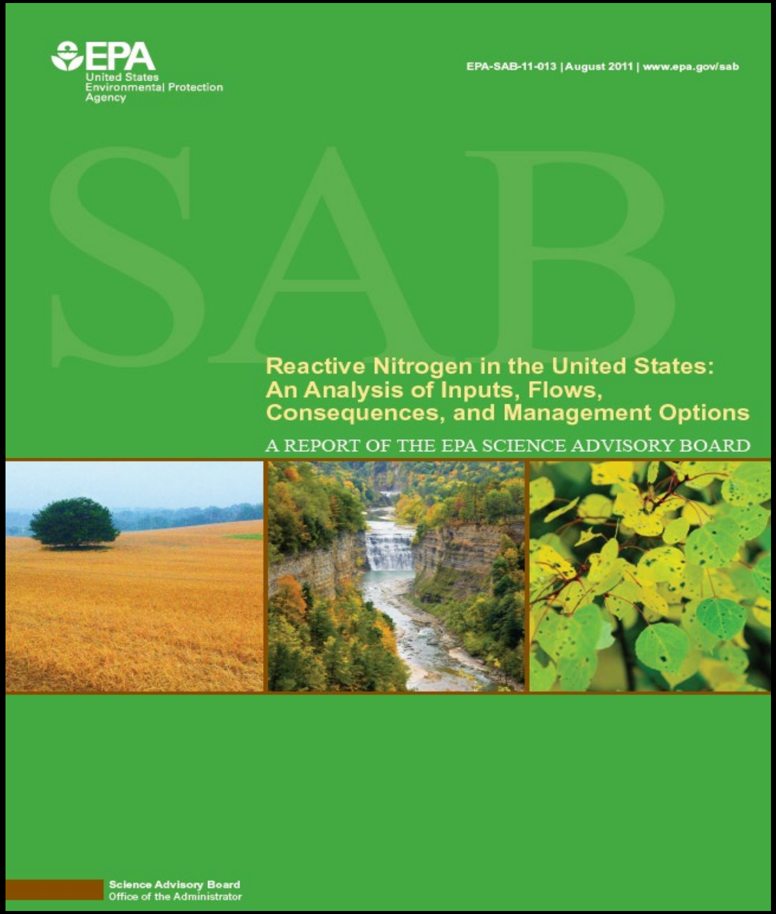
Further Reading (1)

Phosphorus: Past and Future, by Jim Elser and Phil Haygarth

The Nitrogen Bomb, by James Worrell, David E. and Marshall Jon Fisher

The Swamp: The Everglades, Florida, and the Politics of Paradise, by Michael Grunwald

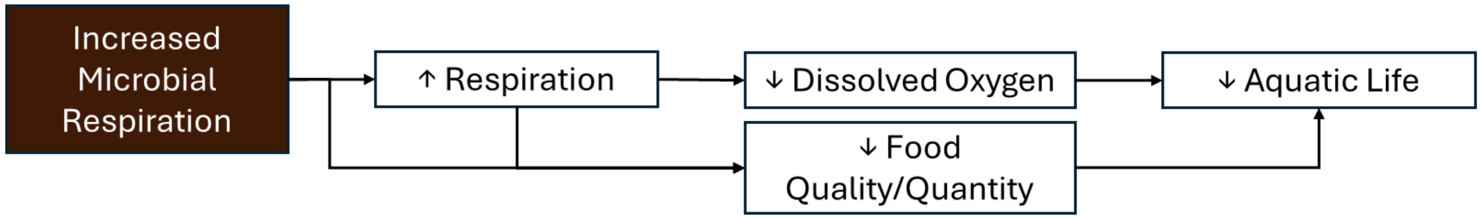
Cooperative Federalism, Nutrients, and the Clean Water Act: Three Cases Revisited, by Oliver Houck



U.S. EPA, 2011, EPA-SAB-11-013

Further Reading (2)

Productivity



Experimental nutrient additions accelerate terrestrial carbon loss from stream ecosystems

Amy D. Rosemond,[1*] Jonathan P. Benstead,[2] Phillip M. Bumpers,[1] Vladislav Gulis,[3] John S. Kominoski,[1†] David W. P. Manning,[1] Keller Suberkropp,[2] J. Bruce Wallace[1]

Rosemond et al. 2015. Science 347:1142

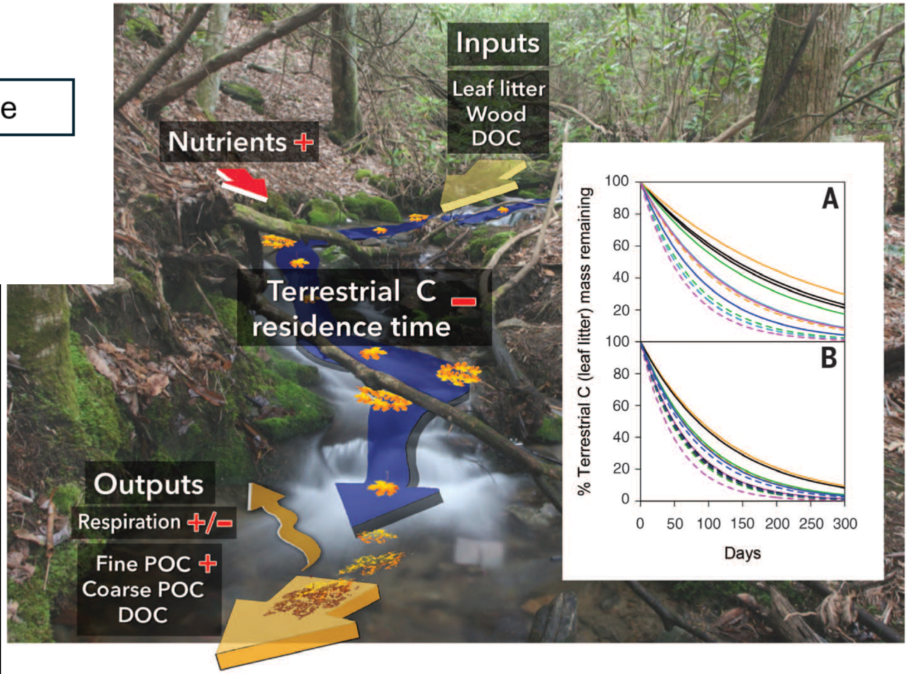


Fig. 1. Terrestrial C residence time was approximately halved with experimental nutrient enrichment. Increased nutrient inputs (+) reduced terrestrial particulate C residence time (–) and increased export of fine detrital particles (+) and respiration rates [which increased on C substrates (*11*) but decreased at reach scales; +/–]. Inset graph: Reach-scale leaf litter loss rates were faster in enriched (dashed lines) than in reference (solid lines) streams; the inverse of these rates is residence time. Colors correspond to the same years in (**A**) (reference versus enriched streams; N+P experiment; $n = 12$ annual rates) and to the same streams in (**B**) (pretreatment versus enriched years; N×P experiment; $n = 15$ annual rates). Data shown for litter loss are untransformed but were natural log–transformed for analyses and the calculation of loss rates (k, per day). The larger image depicts terrestrial organic C inputs, which enter as leaf litter, wood, and dissolved organic carbon (DOC), and outputs as hydrologic export (fine and coarse particles, DOC) and respired CO_2 in deciduous forest streams, using an image of one of the N×P experimental stream sites.

Further Reading (3)

Coastal eutrophication as a driver of salt marsh loss

Linda A. Deegan[1], David Samuel Johnson[1,2], R. Scott Warren[3], Bruce J. Peterson[1], John W. Fleeger[4], Sergio Fagherazzi[5] & Wilfred M. Wollheim[6]

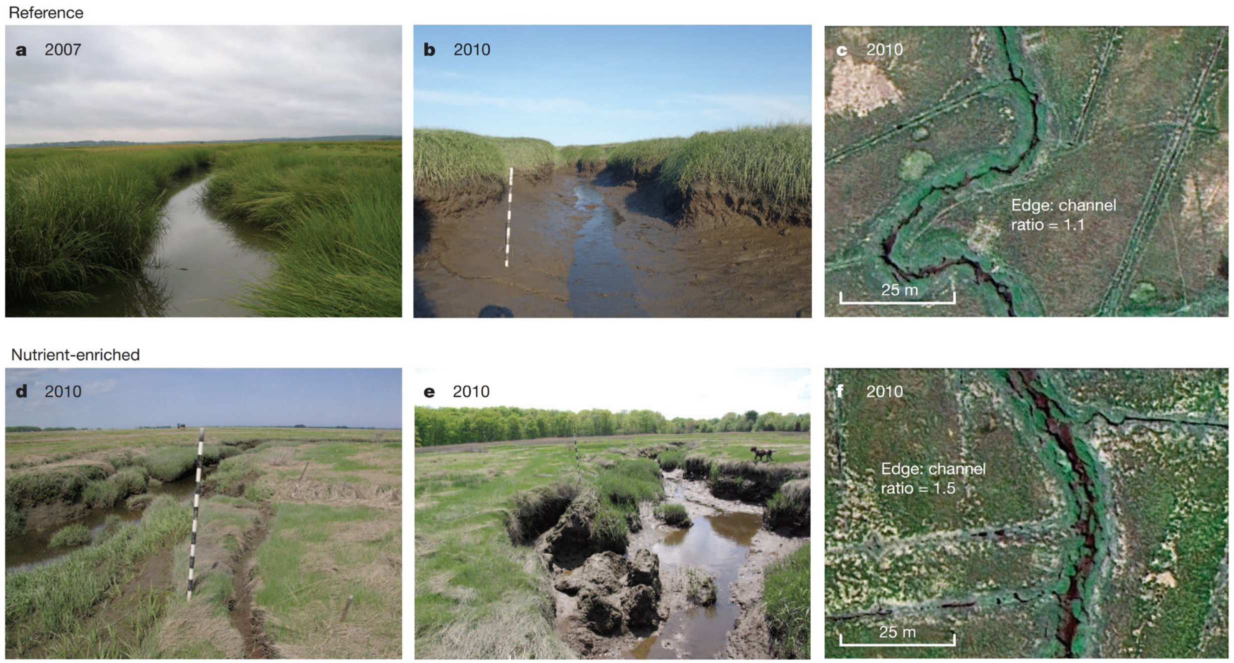
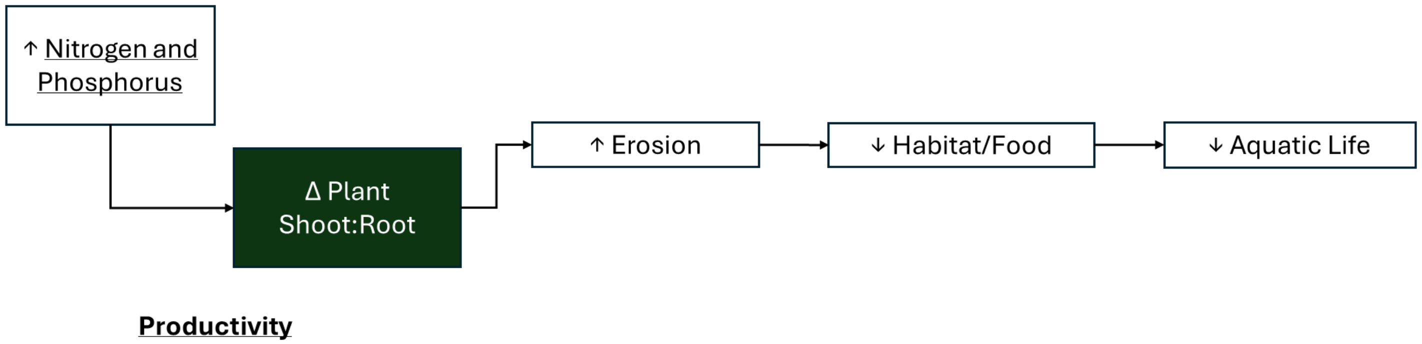


Figure 1 | Comparison photos of the marshes from the ecosystem nutrient-enrichment experiment. **a–c**, Reference. **d–f**, Nutrient-enriched. Photo credits: **a**, **b**, **d** and **e**, L.A.D.; **c** and **f**, Google Earth (19 June 2010 image, copyright 2012 Google).

Deegan et al. 2012, Nature 490: 388



Further Reading (4)

Reversal of a cyanobacterial bloom in response to early warnings

Michael L. Pace[a,1], Ryan D. Batt[b], Cal D. Buelo[a], Stephen R. Carpenter[c,1], Jonathan J. Cole[d], Jason T. Kurtzweil[c], and Grace M. Wilkinson[a]

Pace et al. 2017. PNAS 114:352

Recovery time after exposure to a nutrient supply

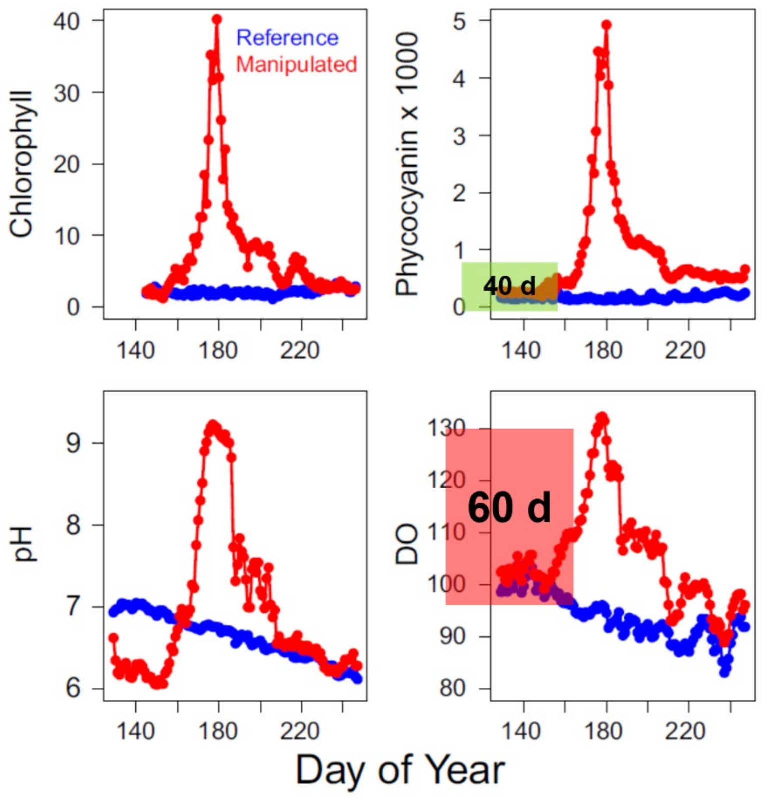
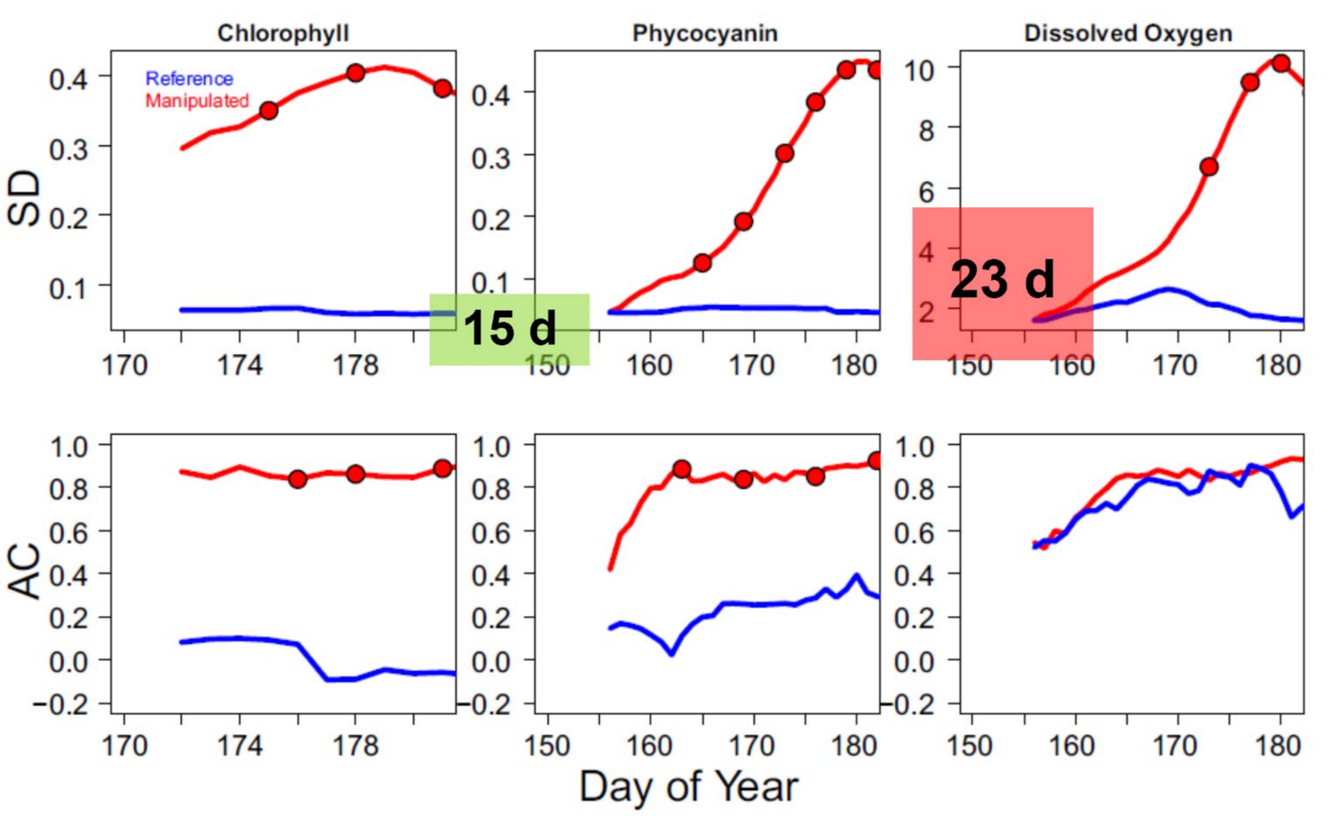


Fig. 1. Dynamics of (*Upper Left*) chlorophyll *a* ($\mu g \cdot L^{-1}$), (*Upper Right*) phycocyanin (fluorescence units), (*Lower Left*) pH, and (*Lower Right*) dissolved oxygen (DO; percent saturation) in the unenriched reference and enriched manipulated lakes. Nutrients were added to the manipulated lake from day of year 151–180.

Exposure to a nutrient supply over time



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  - Amino acids: By Dan Cojocari - Own work, CC BY-SA 3.0
  - Light-dependent reactions: By Somepics - Own work, CC BY-SA 4.0
  - Calvin-Benson Cycle: By Mike Jones - Own work, CC BY-SA 3.0

Image Credits Continued

- Slide 8
  - Lake Erie algal bloom: NASA Earth Observatory, image taken on Sept. 13, 2013 by MODIS on NASA's Aqua satellite
  - *Microcystis cf. aeruginosa*: (Kützing) Kützing. Sample from epilimnion of Lake Mahopac, NY. Source: John D. Wehr, Professor, Fordham University
  - Microcystin molecule: Wikipedia
  - Nutrient Loading to Gulf maps from USGS
  - Gulf of Mexico hypoxia map, NOAA media release from EPA Hypoxia Task Force