EPA

Office of Research and Development

SAFE AND SUSTAINABLE WATER RESOURCES RESEARCH PROGRAM




Science to Support Nutrient-Related Water Quality Goals

July 6, 2020

Background

- Nutrient pollution is a widespread water quality problem with consequences for human and environmental health, environmental condition, and the economy.
- Research can support the development of new tools for EPA, states, tribes, and local decision-makers to establish and achieve water quality goals.
- Science can inform recommendations to protect different types of waters and different designated uses (e.g., aquatic life, recreation, and drinking water source protection)

ORD's Nutrients and HABs Research

SAFE AND SUSTAINABLE WATER RESOURCES RESEARCH PROGRAM

Assessment and Management of Harmful Algal Blooms

Science to Support Nutrient-Related Water Quality Goals

Nutrient Reduction Strategies and Assessment

Science to Support Nutrient-Related Water Quality Goals

This research advances the science to inform decisions related to nutrient and co-pollutant water quality goals.

Provides information, methods, or approaches to characterize nutrient-related impacts in watersheds and water bodies, to help determine protective endpoints for aquatic life.

Assesses the responses of aquatic ecosystems to nutrient pollution.

Links these results in approaches that identify areas that may most effectively respond to restoration and recovery.

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Research for Characterizing Nutrient-Related Impacts Across Multiple Spatial Scales

Research Output 1

Research for Characterizing Nutrient-Related Impacts Across Multiple Spatial Scales

Output 1 Overview:

- Advances understanding of nutrient related impacts across waterbodies and watersheds
- Will help determine protective endpoints for aquatic life in different waterbody types for a range of endpoints and range of scales
- Products will provide tools that allow partners to more effectively assess nutrient-related impacts

Research Priorities:

Approaches for Understanding Nutrients and Impacts Across Space and Time

Novel Methods to Assess the Status of Nutrient-Sensitive Aquatic Life Endpoints and Nutrient Indicators

Tools to Support Nutrient Criteria Development and Attainment of Water Quality Goals

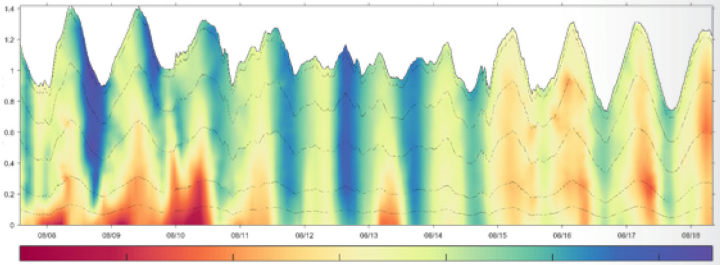
Approaches for Understanding Nutrients and Impacts Across Space and Time

Problem: Nutrient reduction strategies seek to minimize the frequency, duration and spatial extent of estuarine acidification and hypoxia. Characterizing temporal and spatial distributions of water quality is challenging and limits the ability to relate water quality drivers and responses.

Action: Methods will be developed to combine continuous data, discrete data and simulation model results to characterize hypoxia and acidification in space and time, and relate to water quality drivers.

Result: New data analysis methods will leverage different data types (continuous, discrete) and additional information (drivers, models) to improve water quality characterizations.

Impact: EPA and its state and tribal partners can make more accurate water quality assessments using the range of available data and other information.



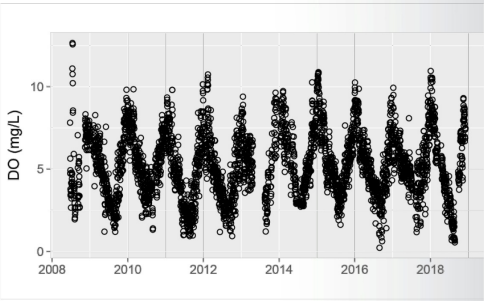
Agency Research Driver(s): Clean Water Act (CWA), Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA)

- Internal partners: EPA Office of Water (OW), EPA Regions 1, 3, 10
- External collaborators: Tillamook Estuaries Partnership, Massachusetts Bay National Estuary Program (NEP), Oregon Dept of Env. Quality

Approaches for Understanding Nutrients and Impacts Across Space and Time

Research Highlight: Quantifying dissolved oxygen & ecosystem metabolism in estuaries across space and time using data and models

Characterizing dissolved oxygen & ecosystem metabolism in estuaries is complicated by complex spatial and temporal patterns. Research will develop hybrid modeling-data analysis methods and related ideas to improve space-time extrapolation for water quality assessment.



Research Highlight: Develop simple empirical models of relationships between watershed land use and nutrients and co-pollutants

Nutrients often enter waterbodies with other co-pollutants. We are developing regression models between land use and nutrient and carbon in streams, which can be used to prioritize watersheds.

Research Highlight: Characterizing nutrient-enhanced acidification and hypoxia (NECAH) in space and time & assessing vulnerability to acidification

Nutrients and other land-based inputs can enhance the acidification in coasts and estuaries. We are developing approaches to identify the factors contributing to NECAH including tracking sources of carbon and nitrogen and linkages between ecosystem metabolism and NECAH.

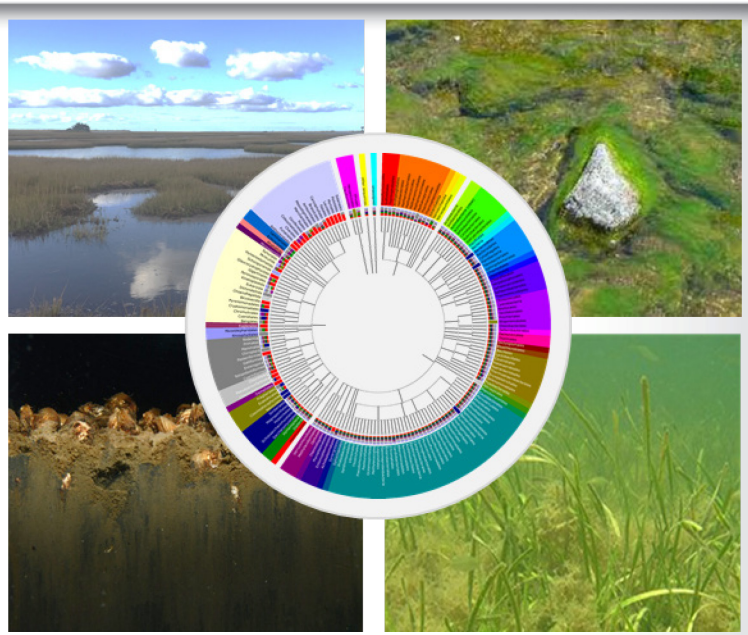
Novel Methods to Assess the Status of Nutrient-Sensitive Aquatic Life Endpoints and Nutrient Indicators

Problem: There is a need for meaningful and cost-effective measures to assess environmental responses to nutrient pollution and eutrophication for compliance monitoring and to improve nutrient reduction strategies.

Action: We use a combination of methods and tools to examine responses to nutrient inputs, including biogeochemical indicators, molecular approaches, and remote sensing technologies to examine environmental responses to nutrients in estuarine and freshwater systems across a range of temporal and spatial scales.

Result: Tools developed will improve the consistency and speed of identification of nutrient indicators and nutrient-sensitive biota that respond to changing nutrient conditions in watersheds.

Impact: Resource managers are equipped with novel and refined approaches to gather information to make sound decisions toward addressing eutrophication problems.



Agency Research Driver(s): CWA

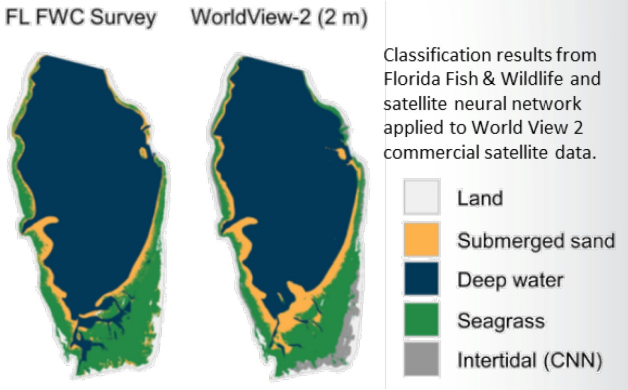
- Internal partners: EPA OW, EPA Regions 1, 2, 3, 4, 5, 10, Chesapeake Bay Program Office, Great Lakes National Program Office (GLNPO), Gulf of Mexico Division
- External collaborators: NASA, DOD, USDA, USGS, Ohio EPA, Pensacola-Perdido Bays Estuary Program, Barnegat Bay Partnership

Novel Methods to Assess the Status of Nutrient-Sensitive Aquatic Life Endpoints and Nutrient Indicators

Research Highlight: Using remote sensing to map seagrass distribution and response to anthropogenic alterations

Developing a method to quantify seagrass extent using high satellite imagery and machine learning.

This approach will improve the consistency & speed of estimating the extent of seagrass habitat in response to nutrients & anthropogenic alterations in watersheds.

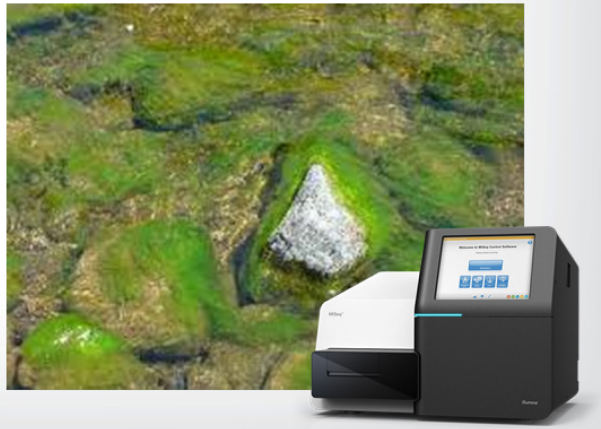


Research Highlight: Further Development of DNA Metabarcoding of Nutrient-Indicator Biota to Improve Temporal Monitoring for Changing Nutrient Conditions

Identification of the biota in found in periphyton in streams is either very challenging and time consuming.

Understanding which biota are present at a site is key for use as indicators of changing nutrient condition.

Tools developed will improve the consistency &speed of identification of nutrient indicator biota.



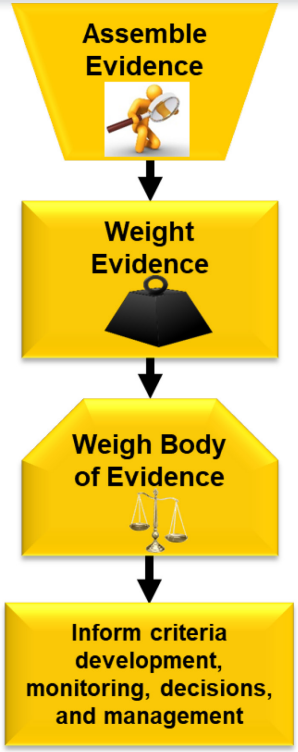
Tools to Support Nutrient Criteria Development and Attainment of Water Quality Goals

Problem: State and regulatory agencies face uncertainty when developing nutrient targets, TMDLs, or other nutrient reduction programs for streams and lakes.

Action: Analyze the weight-of-evidence from literature, field data, case studies, and experiments to provide scientific rationale that more directly links nutrient targets to ecological responses.

Result: Reports and web resources for using weight-of-evidence approaches and validate nutrient targets in a pilot watershed study using experimental and process-level data.

Impact: States will have tools and examples that can be used to more quickly and effectively develop robust and transparent nutrient targets that protect aquatic life, a pilot example for Ohio's "New Vision" TMDL process.



Agency Research Drivers: CWA

- Internal partners: EPA Regions 5, 7, 9, EPA Office of Water
- External collaborators: Ohio EPA, USDA-NRCS, USACE Louisville District, Wright State University, 3 Ohio SWCDs

Tools to Support Nutrient Criteria Development and Attainment of Water Quality Goals

Using weight-of-evidence to combine diverse data to inform nutrient criteria development

Literature review

Nutrients
Ecological responses
Types of relationships

Field datasets

Nutrients
Ecological responses
Types of relationships

Summarize and synthesize results
Assemble and weight evidence
Weigh the body of evidence/support
Identify support for indicators and nutrient targets

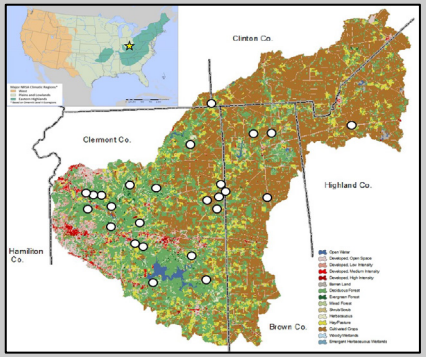
Integrating monitoring, modeling, and experiments to rationalize nutrient reduction goals

Experiments

Stream Mesocosms

- Experimental combinations of nitrogen/phosphorus concentrations/ratios
- Suite of ecological responses
- Analysis and synthesis

Watershed case study



- Long-term nutrient monitoring (streams/lake)
- Watershed modeling of nutrient loads and BMPs
- Local BMP partnerships
- Survey using periphyton DNA metabarcoding

EXPECTED OUTCOMES AND IMPACT:

Support for methods and strategies used to develop criteria
Improve monitoring, modeling, and N&P reduction efforts
Evaluation of the responsiveness of indicators
Advancement of new methods and indicators

Overview of sub-products

United States Environmental Protection Agency

Trajectories of Aquatic Ecosystem Responses to and Recovery from Nutrient Pollution

Research Output 2

Trajectories of Aquatic Ecosystem Responses to and Recovery from Nutrient Pollution

Overview:

- Assesses the responses of freshwater and coastal ecosystems to nutrients and related co-occuring stressors (e.g., nuisance algae, hypoxia, acidification) and the processes and trajectories associated with recovery from those stressors.
- Research focuses on the development, use, and analysis of model results, experiments, existing datasets, and published literature.
- Products will provide science to support CWA decisions related to TMDLs, nutrient reduction projects, and nutrient criteria development.

Research Priorities:

Assessment of nutrient transport to, fate within, and effects on related stressors within freshwater and coastal ecosystems

Assessment of how freshwater and coastal ecosystems respond to nutrient reductions

Assessment of Nutrient-Related Stressors and Responses in Freshwater and Coastal Habitats

Problem: Effective reduction strategies for nutrient pollution requires knowledge of how diverse aquatic ecosystems respond to nutrients and related stressors.

Action: Use models, experiments, and existing datasets to assess nutrient transport to, fate within, and effects on related stressors in freshwater and coastal ecosystems.

Result: Improved understanding of how freshwater and coastal ecosystems are affected by nutrients and related stressors.

Impact: Use knowledge gained from experimental and model results to inform nutrient reduction methods and plans.

Agency Research Driver(s): CWA, HABHRCA + more

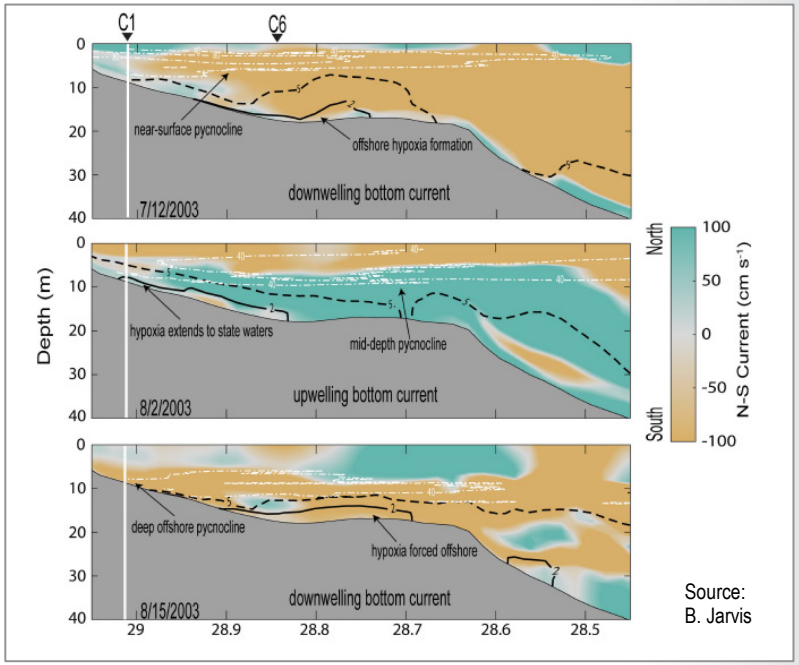
- Internal partners: EPA OW, EPA Office of Air and Radiation (OAR), multiple Regions and NEPs, GLNPO + more
- External collaborators: NOAA, Gulf of Mexico Program, Ohio EPA, multiple universities + more

Aquatic Ecosystem Responses to and Recovery from Nutrient Pollution

Research Highlights: Product 2.1

Modeling to improve prediction of nutrient-related water quality response

- Use multiple EPA ecosystem models to quantify nutrient effects on water quality and aquatic life use in hypoxic coastal systems.
- Compare model performance to reduce uncertainty in water quality simulations and inform nutrient reduction decisions.



Using molecular biological response variables to evaluate water quality

- Develop qPCR assays that can quickly and accurately identify an array of nutrient-related water quality indicators.
- Provide methods for regional and state monitoring programs.

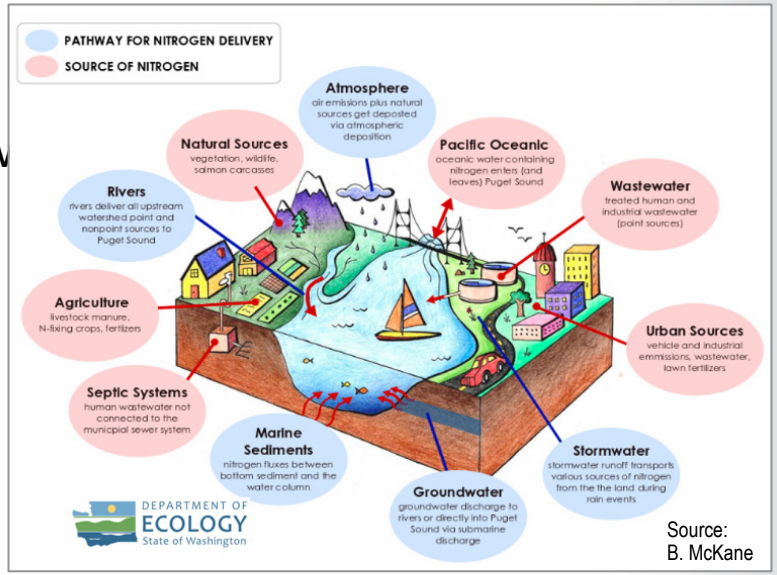
Assessment of Ecosystem Recovery from Nutrient-Related Sources and Stressors in Freshwater and Coastal Habitats

Problem: To assess the effectiveness of different nutrient reduction actions, we need to understand how diverse aquatic ecosystems respond.

Action: Use models, field sampling, existing datasets and published literature to assess spatial and temporal patterns in vulnerability to and ecosystem recovery from nutrient-related sources and stressors in freshwater and coastal ecosystems.

Result: Identify which ecological parameters are sensitive to point and non-point source nutrient reductions, and at what temporal and spatial scales.

Impact: Assess effectiveness of nutrient reduction strategies and potential barriers to ecosystem recovery.



Agency Research Driver(s): CWA, HABHRCA + more

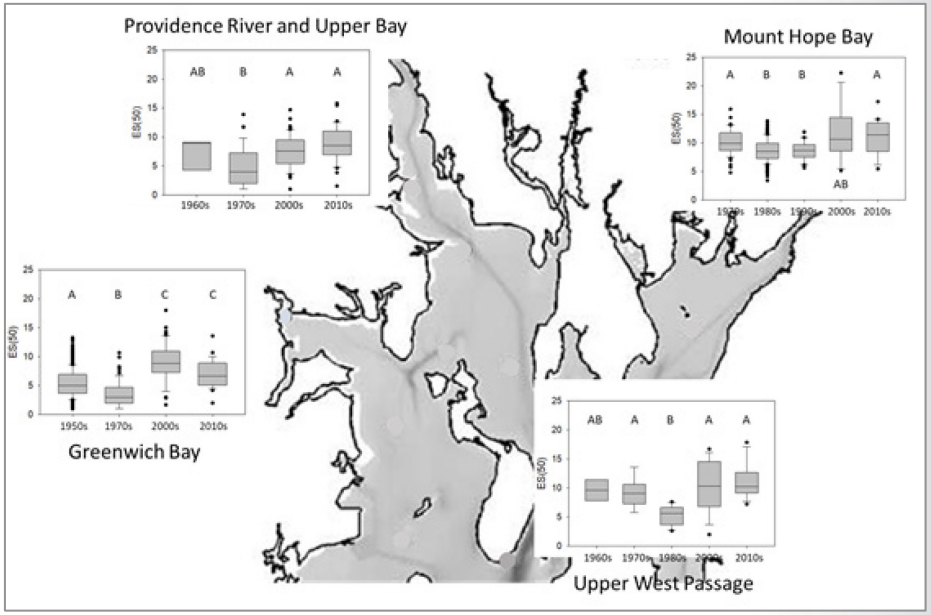
- Internal partners: EPA OW, Narragansett Bay NEP, multiple Regions + more
- External collaborators: NOAA, Lake Champlain Basin Program, Rhode Island DEM, multiple universities and states + more

Aquatic Ecosystem Responses to and Recovery from Nutrient Pollution

Research Highlights: Product 2.2

Benthic invertebrate responses to nutrient-associated stressors in estuaries

- Examine spatial and temporal trends in nutrient-related degradation and recovery in Narragansett Bay.
- Quantify DO-benthic invertebrate relationships in Narragansett Bay and Pensacola Bay.



Estuarine vulnerability to nutrient-enhanced coastal acidification

- Combine synthesis of land-based acidification impacts in US estuarine waters with a newly created nationwide index of estuarine vulnerability to coastal acidification, to identify and rank systems that are both vulnerable and facing acidification pressures.

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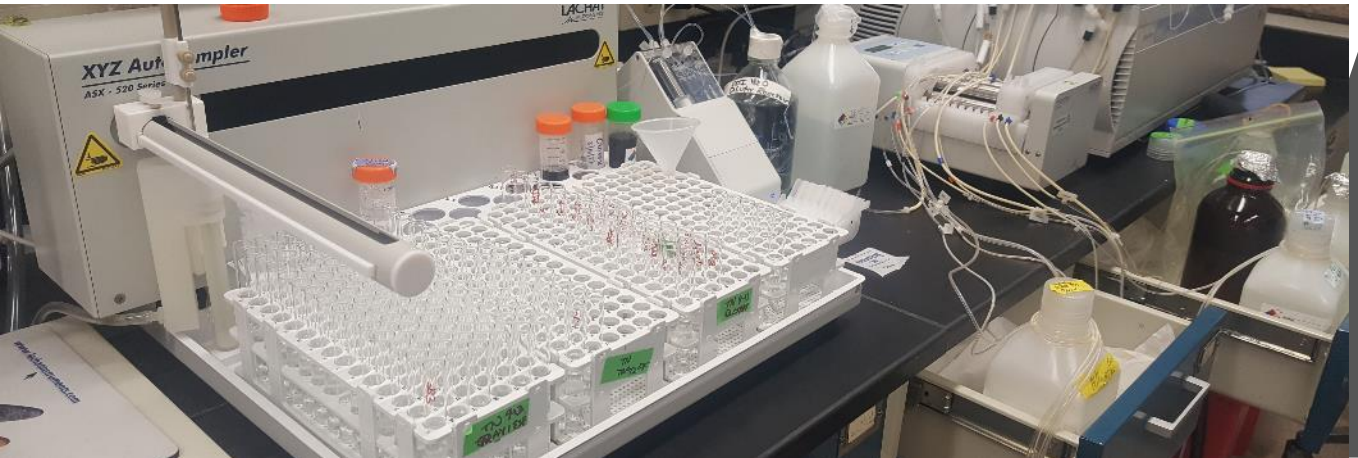
Scientific Approach for Identifying Which Watersheds and Water Bodies May Most Efficiently Attain Water Quality Goals



Research Output 3

Scientific Approach for Identifying Which Watersheds and Water Bodies May Most Efficiently Attain Water Quality Goals

Overview:

- This research advances the science needed to inform decisions to prioritize watershed nutrient sources for reduction options.
- Data, models, and tools are used to identify watersheds and water bodies that may most effectively respond to restoration and recovery efforts.
- Products will provide science to support CWA decisions related to TMDLs, nutrient criteria development, and recently prioritized market-based programs (e.g., water quality trading).

Research Priorities:

Large-Scale Watershed Assessments to Characterize Potential Gradients of Nutrient Sources and Sinks

Landscape-Scale Tools and Data to Identify Watershed Locations for Targeting Nutrient Reduction, Phase 1

Landscape-Scale Tools and Data to Identify Watershed Locations for Targeting Nutrient Reduction, Phase 2

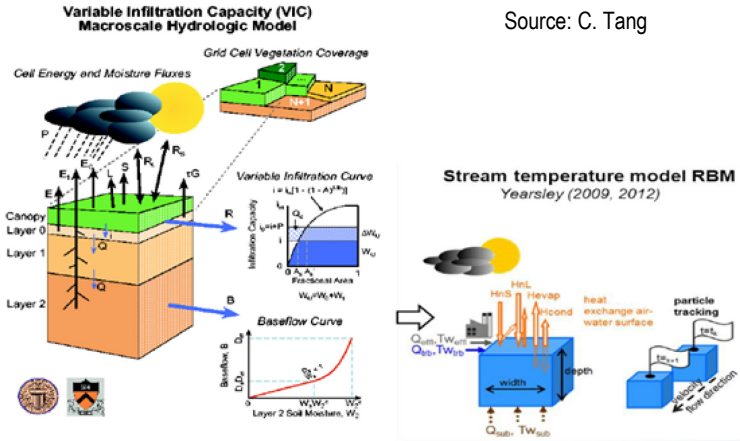
Large-Scale Watershed Assessments to Characterize Potential Gradients of Nutrient Sources and Sinks

Problem: Uncertainty remains on how different portions of the landscape are contributing to and processing nutrients entering surface water systems, particularly at large spatial scales (regions, nation).

Action: Characterizing the spatial and temporal patterns of nutrients across large river basins and providing an inventory of US watersheds currently not attaining nutrient-related water quality goals.

Result: Identifying high-yield nutrient locations at large spatial scales and broad-scale measures for mediating nutrient-based water quality.

Impact: Targeting regional and national areas of high nutrient loads and the effects wetlands may have on mediating them.



Agency Research Driver(s): CWA, HABHRCA & others

Internal partners: EPA OW; EPA Regions 3, 5, 7, and 10 + more

External collaborators: Upper Mississippi River Basin Association (UMRBA) ++

Landscape-Scale Tools and Data to Identify Watershed Locations for Targeting Nutrient Reduction, Phase I

Problem: Challenges remain for identifying locations within watersheds where nutrients may be most efficiently reduced.

Action: Expanding a decision support system and N and P inventories across the US, as well as implementing field methods to the characterize how spatial patterns of stream intermittency affect nitrogen loads.

Result: Identifying areas across the country where nutrient reduction strategies may be most efficient, and how temporal variability of precipitation and other factors affect these sites' potential for nutrient processing

Impact: Large-scale identification of potential areas to target for nutrient reduction.

Source: N. Detenbeck

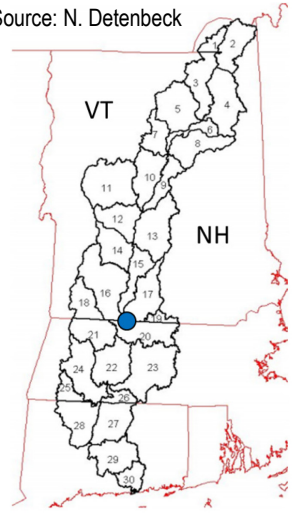
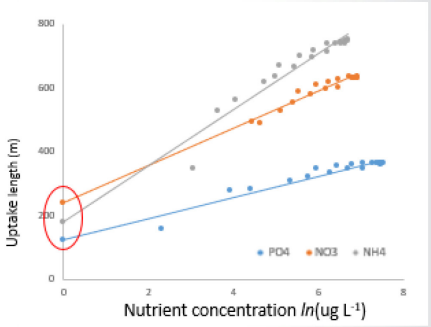


Figure 2. Sub-basins within Connecticut River Basin.

Source: T. Jicha



Agency Research Drivers CWA, HABHRCA & others

- Internal partners: EPA Regions 1, 3
- External collaborators: USGS, USFS, USDA

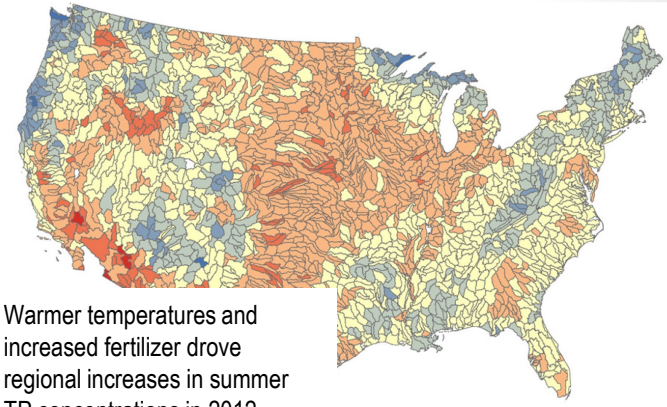
Landscape-Scale Tools and Data to Identify Watershed Locations for Targeting Nutrient Reduction, Phase 2

Problem: Challenges remain for identifying where in watersheds nutrients may be most efficiently reduced.

Action: Field data collection, large river basin modeling and multi-media modeling systems, and tier two expansion of a Decision Support System to identify regional and national focal areas for nutrient reduction.

Result: Phase 2 results of identifying areas across the country where nutrient reduction strategies may be most efficient and how temporal variability of precipitation and other factors affect these sites' potential for nutrient processing.

Impact: Large-scale identification of potential areas to target for nutrient reduction strategies.



Warmer temperatures and increased fertilizer drove regional increases in summer TP concentrations in 2012

Source: R. Sabo

Agency Research Driver(s): CWA, HABHRCA & others

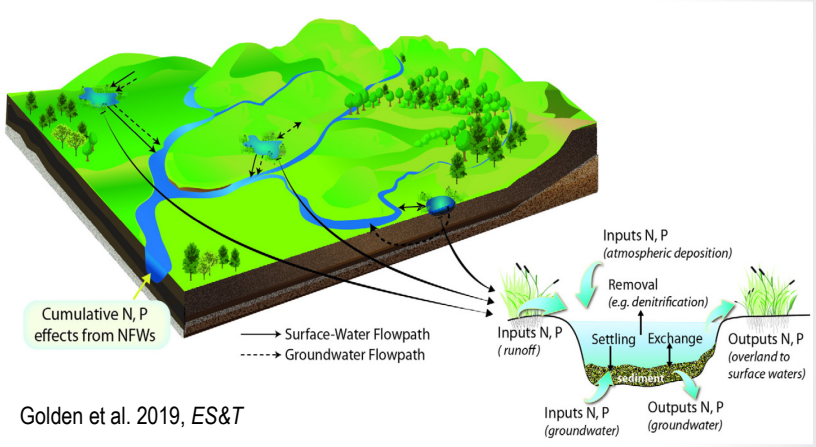
- Internal partners: EPA OW, EPA OAR, EPA Regions 1, 3, 5, 7, 10
- External collaborators: PNNL, UMRBA, USGS, USDA

Identifying Areas for Efficiently Attaining Nutrient Water Quality Goals

Research Highlights: Output 3

Expand a Decision Support System to determine cost-effective nutrient reduction strategies in sub-watersheds

- Optimization program and associated databases will be expanded using regional SPARROW models to determine the most cost effective suite of BMPs to decreases downstream nitrogen loading.



Golden et al. 2019, *ES&T*

Quantify the spatial and temporal effects of wetlands on large river basin nutrient delivery

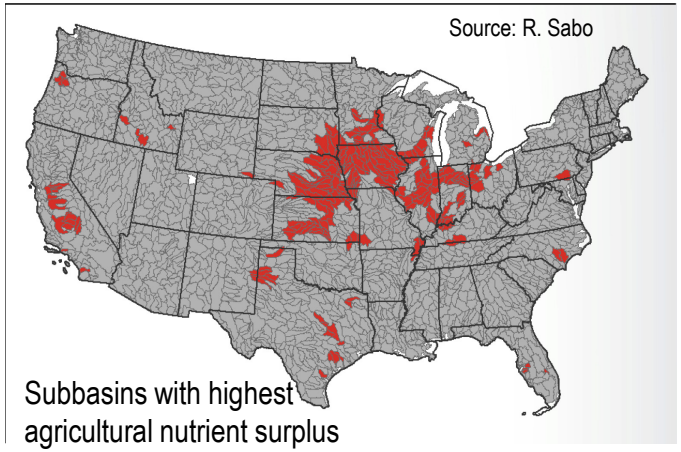
- Using combined "big data" (spatial, remote sensing) and modeling (statistical, process-based) approach to identify where and when wetlands mediate nutrient-based water quality across large river basins.

Identifying Areas for Efficiently Attaining Nutrient Water Quality Goals

Research Highlights: Output 3

Update recommendations for watersheds to meet water quality goals based on local responsiveness to changes in major drivers

- Integrate a suite of statistical water quality models of aquatic nutrient concentrations into an online nutrient inventory tool and provide new recommendations for watershed restoration.



Apply a multi-media modeling system to identify nutrient hotspots across the Mississippi River Basin

Apply nutrient spiraling and other process measurements to characterize how an aquatic ecosystem may respond to stream restoration

United States Environmental Protection Agency

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Links:
EPA Water Research:
https://www.epa.gov/water-research

SSWR Strategic Research Action Plan:
https://www.epa.gov/research/strategic-research-action-plans-2019-2022