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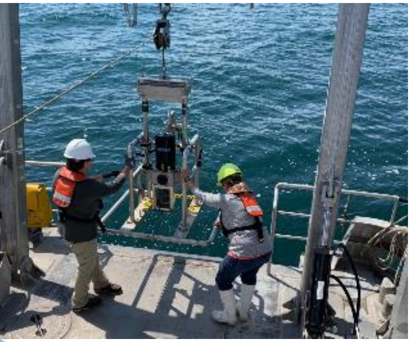
Safe and Sustainable Water Resources Research Program




Research Area 5:
Science to Support Nutrient-Related Water Quality Goals

BOSC SSWR Subcommittee Meeting on Nutrients and HABs

December 1-2, 2021

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication.

EPA

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BOSC Meeting SSWR Nutrients and HABs
December 1-2, 2021

Background and Research Overview and Highlights

Heather Golden, Ph.D.

Center for Environmental Measurement and Modeling (CEMM)

Background

- Nutrient pollution: widespread water quality problem with consequences for human and environmental health, environmental condition, and the economy.
- ORD research: supports the development of new information and tools for OW, 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

Research Area 4: Assessment and Management of HABs

Research Area 5: Science to Support Nutrient-Related Water Quality Goals

Research Area 6: 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 determine nutrient-related impacts in watersheds and water bodies, which helps determine protective endpoints for aquatic life.

Relates the condition of watersheds and water bodies to nutrient loading, water quality, and aquatic life.

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

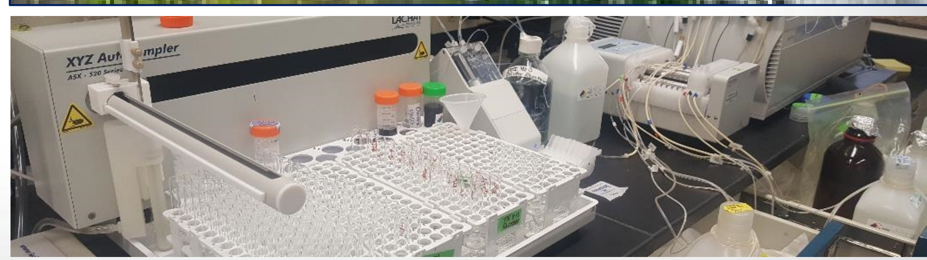
Approaches and Partnerships

- **Approaches**: Monitoring (e.g., nutrients, DO, sediment profiles), laboratory analyses (e.g., DNA metabarcoding), remote sensing (e.g., of seagrass distributions), modeling (e.g., statistical/process-based), and decision-support tools synthesizing several approaches.

- **EPA-Based Collaborations**: Research Centers (CESER, CPHEA, CEMM), Office of Water, Regions

- **External Collaborations**: States, Tribes, other federal agencies (e.g., USGS, USDA), academic institutions, NGOs

Source:www.lakesuperiorstreams.org



Characterizing Nutrient-Related Impacts Across Multiple Spatial Scales

Overview:

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

Research Products:

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.

Example Research Projects

- Quantifying dissolved oxygen and ecosystem metabolism in estuaries across space and time using data and models.
- Characterizing nutrient-enhanced acidification and hypoxia (NECAH) in space and time and assessing vulnerability to acidification.
- Using remote sensing to map seagrass distribution and response to anthropogenic alterations.
- Expanding the development of DNA Nutrient-Indicator metabarcoding for biota to improving temporal monitoring under changing nutrient conditions.

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-occurring 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 developed will provide science to support CWA decisions related to TMDLs, nutrient reduction projects, and nutrient criteria development.

Research Products:

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 .

Example Research Projects

- Modeling to improve prediction of nutrient-related water quality responses.
- Using molecular biological response variables to evaluate water quality.
- Assessing benthic invertebrate responses to nutrient-associated stressors in estuaries.
- Developing national index of estuarine vulnerability to nutrient-enhanced coastal acidification.

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

Overview:

- 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 produced within this Output 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 Products:

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.

Example Research Projects

- Expanding a Decision Support System to determine cost-effective nutrient reduction strategies in sub-watersheds.
- Quantifying the spatial and temporal effects of wetlands on large river basin nutrient delivery.
- Using a recently develop national nutrient inventory to link historic nutrient surpluses to water quality conditions across the US.
- Applying nutrient spiraling and other process measurements to characterize how an aquatic ecosystem may respond to stream restoration.

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Research Focused on Novel Methods to Assess Nutrient Indicators

Cheryl Brown, Ph.D.
Center for Public Health and Environmental Assessment (CPHEA)

Research for Characterizing Nutrient-Related Impacts Across Multiple Spatial Scales

Research Products/Focal Areas:

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.

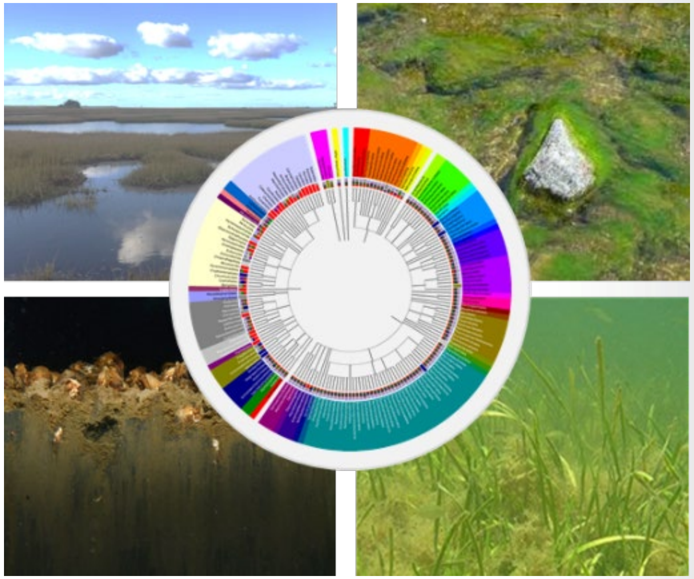
Tools to support nutrient criteria development and attainment of water quality goals.

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

Issue: 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.

Approach: 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.



Agency Research Driver(s):

- CWA
- N-STEPS (nutrient monitoring)

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

Approaches to Identify Drivers of Carbonate Chemistry in Estuaries

Issue: Approaches are needed to quantify the impacts of climate change and land-based sources of acidification in estuarine systems.

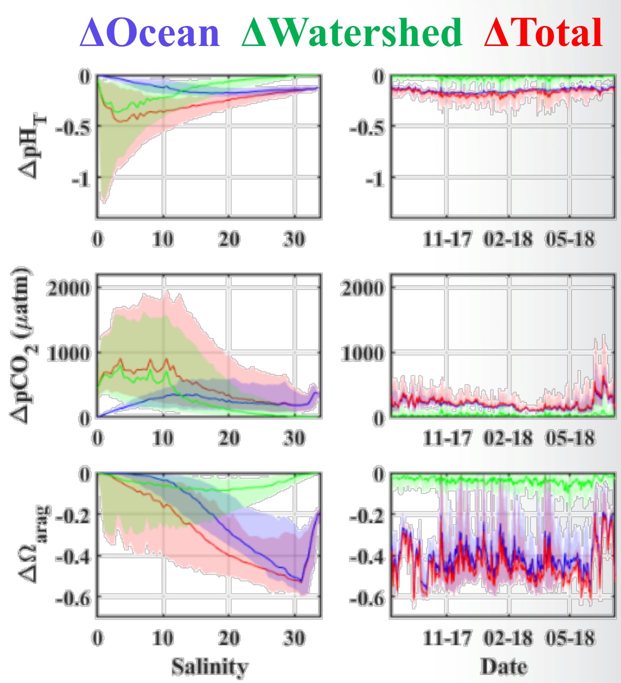
Approach:

- Combined continuous monitoring data with targeted synoptic sampling of coastal ocean, estuary, and watershed biogeochemistry.
- Parsed out present-day impacts of climate change and anthropogenic land use to estuary acidification dynamics.
- Identified acidification "hotspots" in time and space.

Results:

- Publications/presentations: 2019 ASLO Meeting; 2020 EPA Numeric Nutrient Criteria Webinar; Publication and EPA Report on OA monitoring in 7 NEPs; Manuscript on climate change and watershed impacts.
- Ongoing work: Supporting OR DEQ with development of ocean acidification and dissolved oxygen assessment method; Analysis of threshold exceedances for endemic organisms.

Future Directions: Assessment of acidification drivers and biological impacts across all NEP OA monitoring sites.



Partners: Tillamook Estuaries Partnership, EPA Office of Water, Region 10, Oregon Department of Environmental Quality

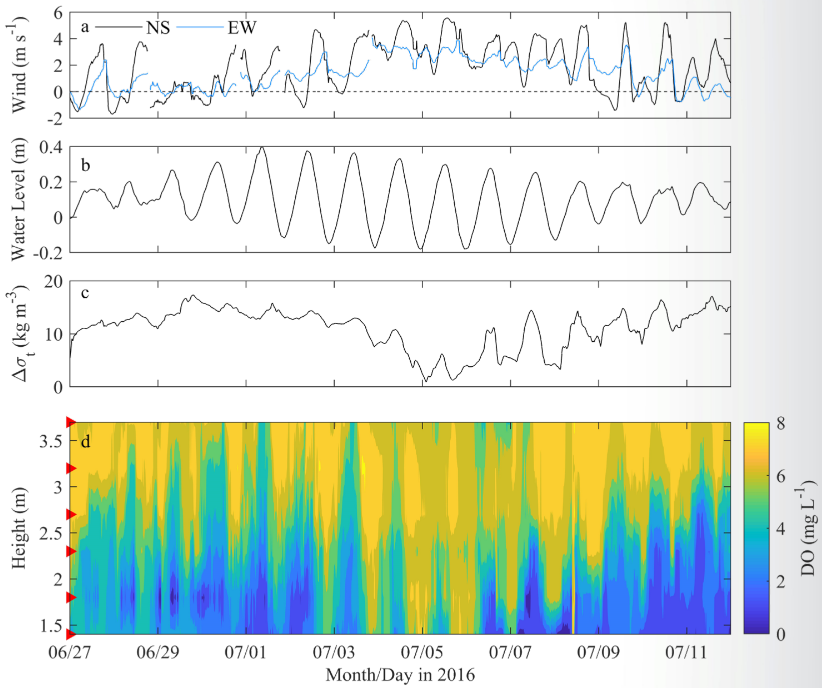
Evaluating Dissolved Oxygen Variability and Effects

Issue: Dissolved oxygen is spatially and temporally variable, making it difficult to characterize and to associated impacts with causes.

Approach:

- Evaluate time series of bottom water oxygen and biophysical drivers using continuous wavelet transforms to relate drivers and responses.
- Collect continuous DO time series at New England sites with nutrient restoration efforts.
- Currently evaluating ecosystem metabolism and DO effects at sites, while building new analysis methods.

Results: Article submitted (Duvall et al., *in review*)



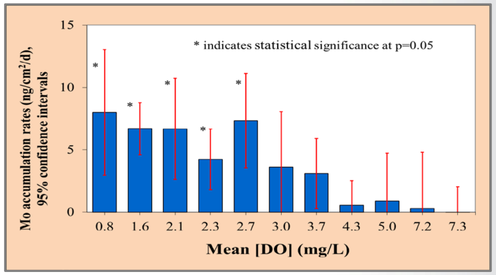
Complex patterns of DO in Pensacola Bay, FL are related to physical and biological drivers using continuous wavelet transforms. From Duvall et al. (in review)

Using Molybdenum (Mo) in Sediments to Establish Relationship Between Nitrogen Loading and Frequency of Hypoxia

Issue: Managers need integrated measures to assess frequency of hypoxia and relate to nitrogen loading.

Approach: To establish hypoxic threshold of nitrogen loading…

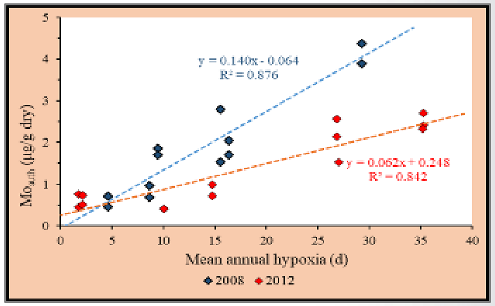
- Determine quantitative relationship between Mo in surface sediments and mean annual duration of hypoxia in field sediments.
- Use relationship to map occurrence, duration of hypoxia; relate to N load estimated from land use model, normalized for dilution and tidal flushing.
- Derive limit to N loading based on reference/threshold approach.



Status:

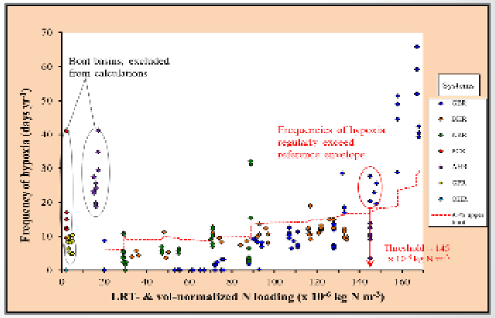
<u>Publications/presentations:</u>

- Boothman W. S. and Coiro L. L. (2009) Laboratory Determination of Molybdenum Accumulation Rates as a Measure of Hypoxic Conditions. *Estuaries and Coasts* **32**(4), 642-653
- Boothman, W.S., Coiro, L.L., Abdelrhman, M., and Nelson, W.G., "Assessing the prevalence of hypoxia via Mo accumulation in coastal sediments: the influence of N loading and local residence time," Coastal and Estuarine Research Federation, 22nd Biennial Conference, San Diego, November 2013



<u>Ongoing work:</u>

- Boothman W. S., Coiro L. L., and Moran, S. B (in prep) Molybdenum accumulation in sediments: a quantitative indicator of hypoxic water conditions in Narragansett Bay, RI. *Estuarine and Coastal Shelf Science*.



Future Directions:

- Use of molybdenum accumulation in sediments to develop hypoxia-based limits for nitrogen loading to coastal embayments.
- Develop a modern history of hypoxia in Narragansett Bay.

Monitoring Seagrass with Satellites

Issue: Monitoring of seagrass change is difficult and infrequent.

Approach: Quantify seagrass with machine learning and satellite data

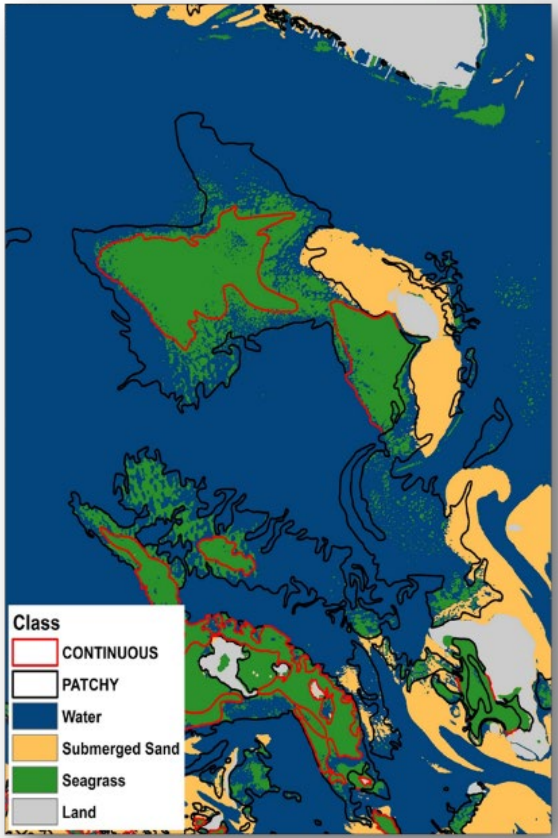
- Semi-automated method to quantify seagrass area, leaf area, and carbon.
- Use of free government satellites include Landsat and Sentinel-2.
- Use of commercial satellites including WorldView and Planet Scope.
- Developing solutions for quality control such as sediment, glint, and organic matter flags.

Partners: Old Dominion University, NASA Commercial Smallsat Data Acquisition Program, Maxar, Planet, National Geospatial Intelligence Agency, EPA Regions 1, 2, 3, and Chesapeake Bay Program SAV Workgroup

Status:

Publications: Methods published (3 papers, 3 conf. proceed., tech report) and time series analysis and broad geographic examples are ongoing.
Future directions: Transition from research to applications. Improved automation and broader applicability including more location types and different water conditions.

Deep Convolutional Neural Network classification of Back Sound, NC with WorldView-2 satellite.



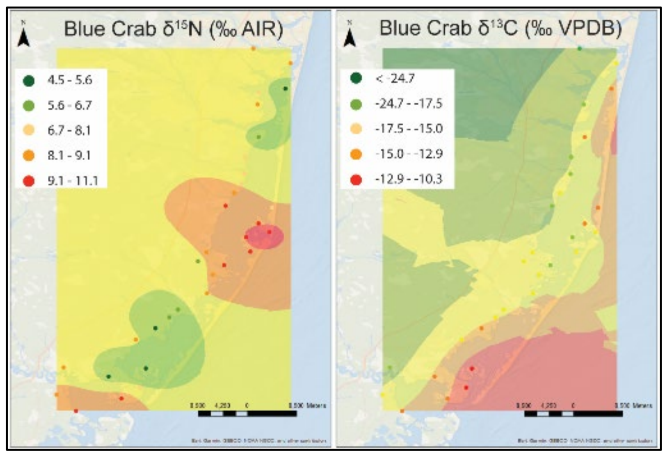
The Role of Eutrophication in Coastal Wetland Fragmentation, Barnegat Bay, New Jersey

Issue: Local managers are concerned that nutrient driven eutrophication is causing salt marsh fragmentation which, in turn, is affecting coastal food webs.

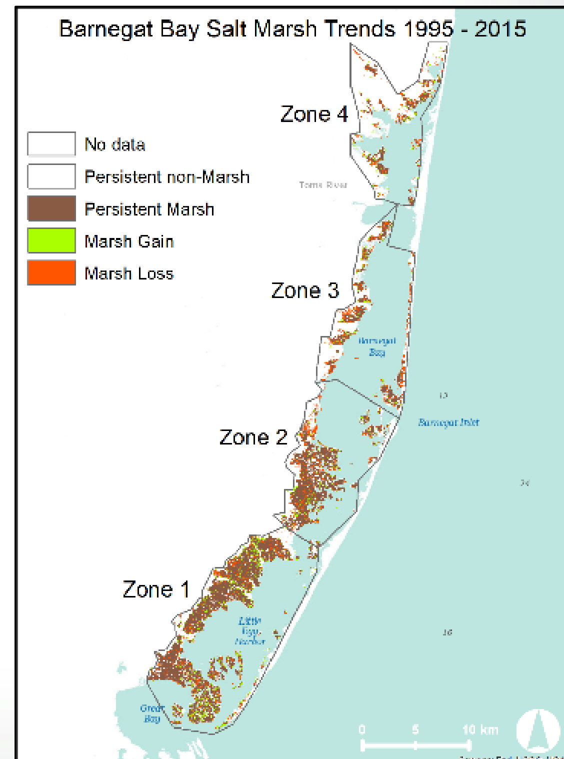
Approach: By integrating biogeochemical indicators, remote sensing technologies, stable isotope analyses, and nutrient stoichiometry, coastal marsh fragmentation and linkages with eutrophication will be documented.

Status:

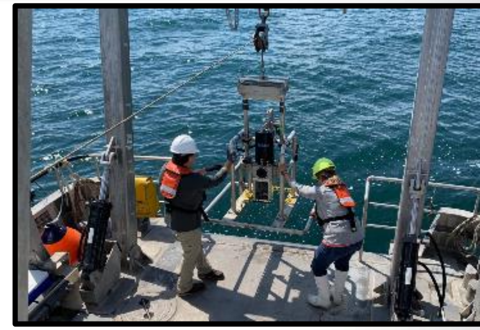
- Manuscript in preparation on remote sensing observations.
- Manuscript in preparation on stable isotope work.
- Archival and modern shells are being processed for shell bound nitrogen content and isotope composition.



Partners: Region 2, Barnegat Bay Partnership, & NRCS Soil Science Division

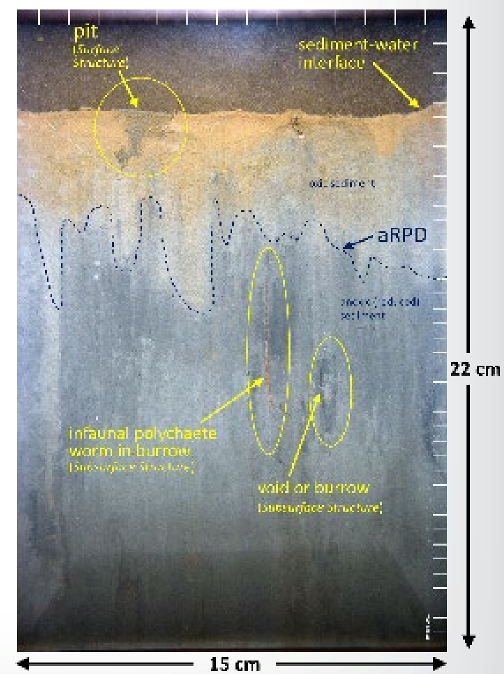


Development of a Consistent Methodology for Assessments using Sediment Profile Imagery (SPI)



Issue: There is a need for consistency in Sediment profile imagery (SPI) analysis and interpretation for biological assessment applications.

Approach: Research uses a combination of methods and tools to evaluate the benthic community responses to stressors in marine and freshwater systems; SPI data collected from these and past studies to be assembled into an image and feature reference library to facilitate consistency in SPI data analysis and interpretation.



Status:

Presentations: CERF'19, CERF'21; IAGLR '19; Papers in preparation
SPI surveys completed in Lake Ontario (2018), Pensacola Bay (2019), Three Bays (2020); Analysis ongoing; Additional SPI surveys planned for Lake Erie (Summer 2022).
Ongoing work: Development of a guidance document, incorporating the image reference library, to achieve greater comparability and reduce variation in environmental assessments using sediment profile cameras, with a focus on image analysis.

Partners: Great Lakes National Program Office/EPA R5, Gulf of Mexico Division/ EPA R4, Pensacola and Perdido Bays Estuary Program (FL), Nutrients Solutions-Driven Research Pilot (MA)

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

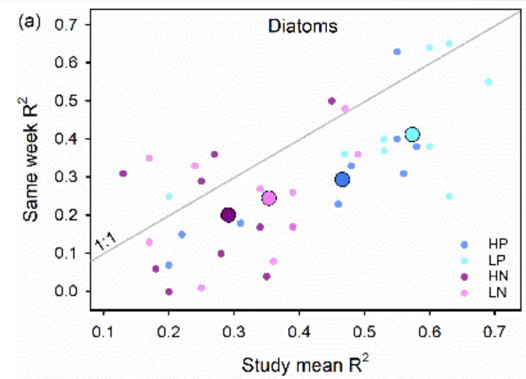
Issue: Temporal variability and antecedent nutrient conditions could confound nutrient biota relationships and affect monitoring and assessment outcomes.

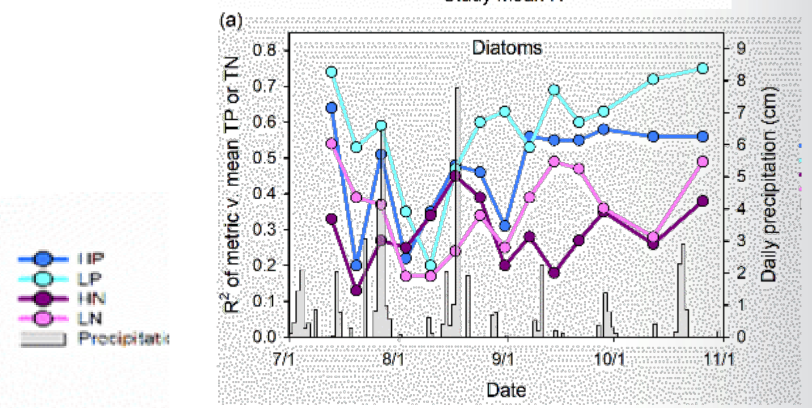
Approach: Characterizing how diatom and bacterial assemblages integrate nutrient effects over time can strengthen interpretations of monitoring results and inform decision making.

- Document weekly variability in nutrients and use DNA metabarcoding to characterize biota at 25 stream sites.
- Identify what factors affect temporal variability
- Summarize how this variability might affect nutrient-biota relationships and monitoring and assessment outcomes.

Status: 2 journal articles (published/in press) and 2 in preparation, 7 presentations.

Future Directions: Effects of nutrient concentration and ratios on ecosystems and DNA metabarcoding indicators. Analysis of NARS DNA metabarcoding with focus on regional differences in indicators and nutrient effects.





Partners: EPA Office of Water; EPA Office of Wetlands, Oceans, and Watersheds; EPA Region 5; USDA-Natural Resources Conservation Service; USACE Louisville District; Ohio EPA; 3 Ohio Soil and Water Conservation Districts

Nutrient Dosing Studies in Stream Mesocosms

Issue: Developing the rationale for nutrient reduction goals in TMDLs by using dose-response studies in experimental streams to make better linkages among nutrients, periphyton, and macroinvertebrates.

Approach: Stream mesocosm nutrient studies.

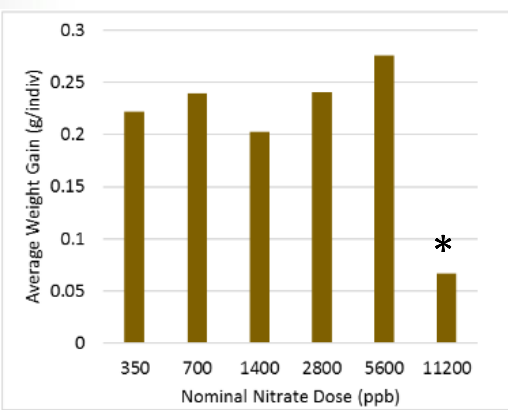
1) Nitrate Study – Nitrate doses 350, 700, 1400, 2800, 5600, 11200 ppb. Phosphate held at 60 ppb.
2) Phosphate Study – Phosphate doses 15, 40, 100, 300, 600, 1200 ppb; Nitrate held at 100 ppb.
3) N+P Study – N|P doses: 240|40, 500|60, 750|90, 1500|180, 2500|300, 3300|400.
4) N:P ratio – P Threshold Study – 2x2 factorial – Low and High N:P ratio x above and below phosphate threshold.

Status:

- Ongoing work: Testing completed, papers in presentation.
- Future directions: Analysis of stream mesocosm results to understand effects on indicators developed using DNA barcoding.

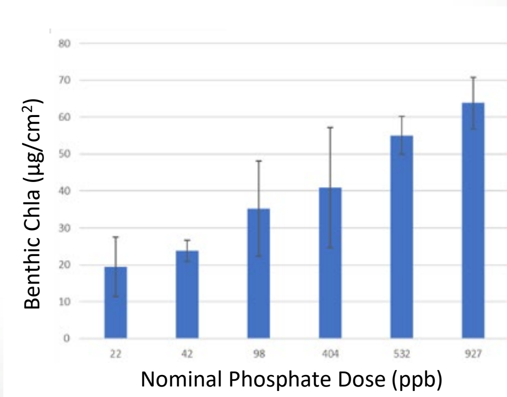
Partners: Regions 5 and 8, and Ohio EPA; EPA OW-OST, OWOW

Example Dose-Responses



1) Bivalve wt. gain vs NO_3 dose

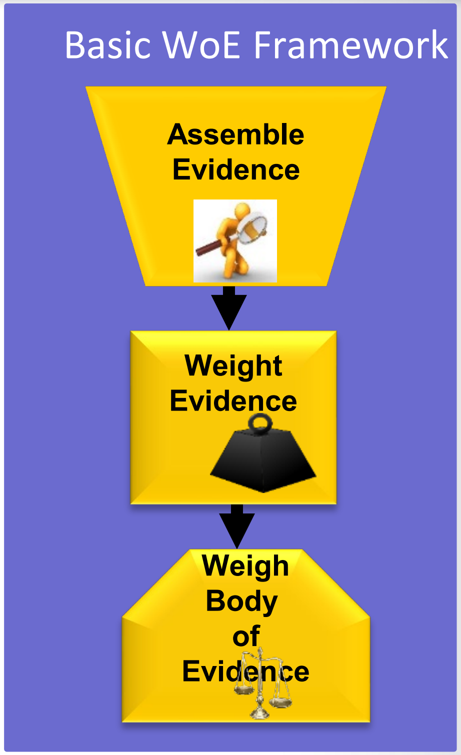
2) Benthic Chlorophyll vs P dose



Using Weight-of-Evidence to Combine Diverse Data to Inform Nutrient Criteria Development

Issue: States face challenges integrating diverse sources of evidence (e.g., analysis of field samples and/or experiments; literature-based evidence) when developing numeric nutrient criteria (NNC).

Approach: Develop materials with definitions, best practices, and examples to show how a weight-of-evidence (WoE) approach can be used to combine diverse data under a variety of evidence, resource, and time constraints to produce defensible and transparent nutrient criteria.



Status:

Publications: Ridley et al. 2021. Application of weight of evidence approaches for decision making related to protecting aquatic life from excess nutrients. Ecological Society of America.

Ongoing work: Summarizing WoE methods for evidence assembly, evidence weighting, and weighing bodies of evidence for NNC (including visual communication options); developing examples of how to select and apply appropriate WoE methods in situations inspired by real states; presenting results to states.

Future directions: Publish EPA report; develop online materials.

Partners: Office of Water, Office of Science and Technology, Health and Ecological Criteria Division; state water quality managers (e.g., ME, CO, AR)

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Research Focused on Vulnerability to and Recovery from Excess Nutrients

Kate Schofield, Ph.D.

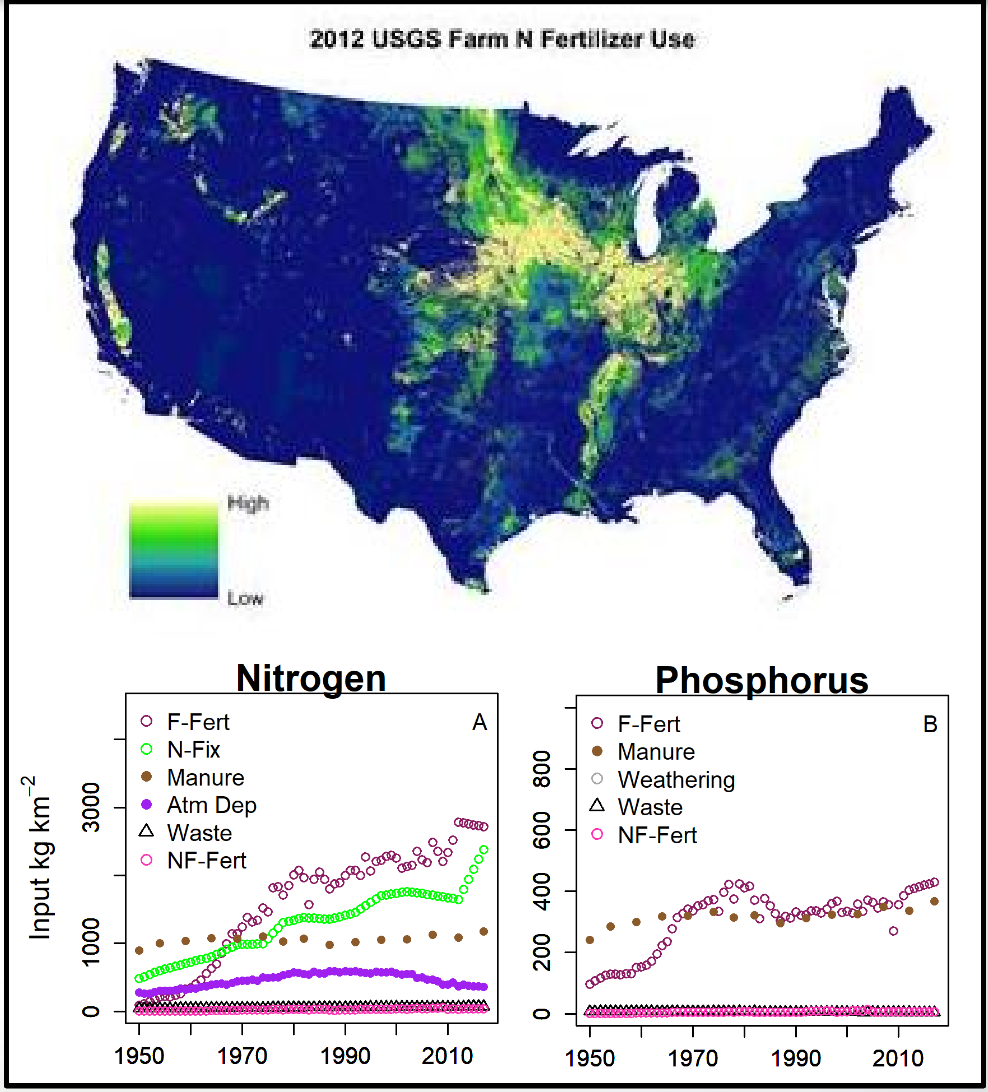
Center for Public Health and Environmental Assessment (CPHEA)

National Nutrient Inventories

Issue: Limited resources need to be leveraged efficiently and effectively to prioritize watersheds for restoration and target management actions to achieve nutrient reduction goals.

Approach:

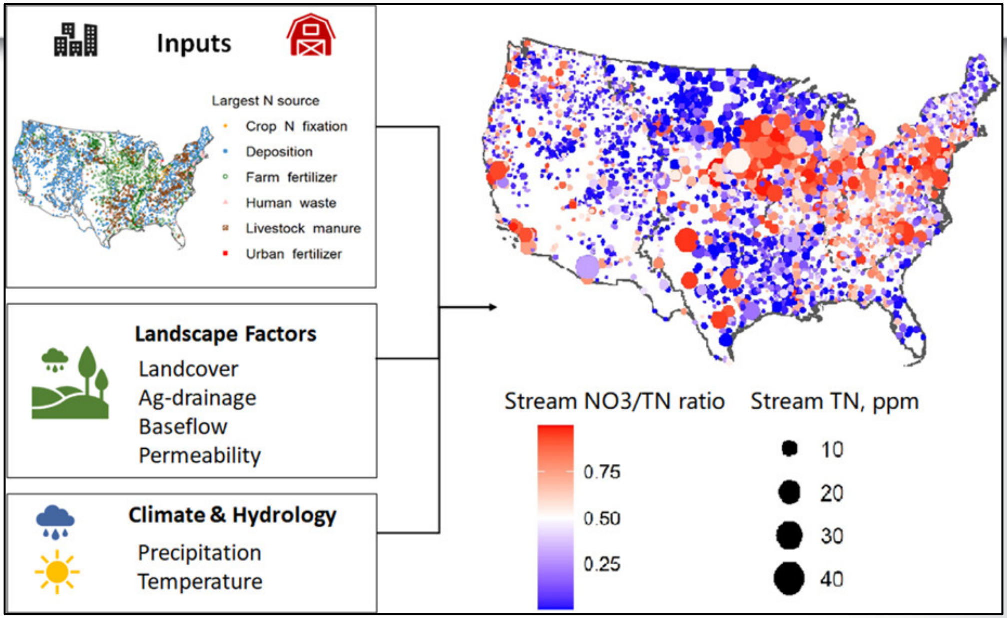
1. Develop nitrogen and phosphorus inventories to track point and non-point source pollution across the United States at multiple scales (primarily 1987-2017).
2. Use empirical models to relate shifts in inventories and other environmental factors to spatiotemporal variability in surface water and groundwater quality.
3. Work with partners to develop management-relevant metrics, based on inventories and models, to communicate with stakeholders and improve prioritization of watershed restoration actions.



National nutrient inventories

Publications:

- Stackpoole et al. 2021. Long-term Mississippi River trends expose shifts in the river load response to watershed nutrient balances between 1975 and 2017. *Water Resources Research* e2021WR030318.
- Lin et al. 2021. Context is everything: Interacting inputs and landscape characteristics control stream nitrogen. *Environmental Science & Technology* 55(12): 7890-7899.
- Sabo et al. 2021. Considerations when using nutrient inventories to prioritize water quality improvement efforts across the US. *Environmental Research Communications* 3(4): 045005.
- Sabo et al. 2021. Phosphorus inventory for the conterminous United States (2002-2012). *Journal of Geophysical Research: Biogeosciences* 126(4): e2020JG005684.



Partners: USEPA Office of Water and Region 5, USGS, USDA, Chesapeake Bay Program, University of Maryland Center for Environmental Science

Ongoing work: Finalize next-generation nutrient inventories for US and Chesapeake Bay; develop machine learning model to predict annual nutrient loads; develop application to better visualize datasets.

Future directions: Update inventories to 2022; incorporate future projection scenarios; incorporate nutrient-related BMPs, update/test existing water quality models; explore nutrient trading schemes.

Drivers of Lake Ontario Nearshore Phosphorus (P)

Issue: Need to understand and predict nuisance and toxic algae blooms in the Great Lakes.

Approach: Application of a nutrient mathematical model to understand sources of P, an important driver of nearshore algae in the Great Lakes.

Status:

- Publications/presentations: Presentation at the *State of Lake Ontario Conference*; peer-reviewed article in the *Journal of Great Lakes Research.*
- Ongoing work: Extend to other Great Lakes; explore drivers of Great Lakes algae, limitations of existing models, and potential model improvements.
- Future directions: Investigate impact of climate change on P and algae; collaborate with ecologists to improve HABs/*Cladophora* modeling in the Great Lakes.

Partners: USEPA Great Lakes National Program Office and Region 2, State of New York, University of Buffalo.

Drivers of Lake Ontario Nearshore Phosphorus (P)

Methods: A mathematical model was developed and applied to explore interbasin (from Lake Erie) and intrabasin (local Lake Ontario rivers) P loading to southwestern nearshore areas of Lake Ontario.

Results: The Niagara River is the dominant P source for the southwestern nearshore of the lake. However, the Genesee River strongly impacts the adjacent beach where significant *Cladophora* blooms have been reported; other local rivers may have similar impacts on the very nearshore areas. Uncertainty of Niagara River loading estimates and insufficient daily/weekly tributary load estimates limit accurate nearshore P concentration and ultimately *Cladophora* bloom predictions.

Publications:

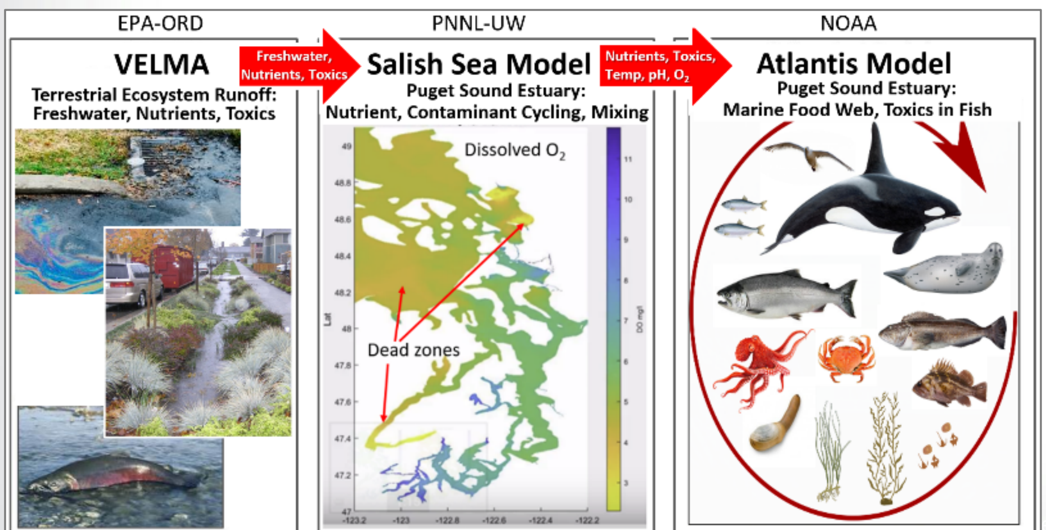
Pauer et al. 2021. A modeling study to determine the contribution of interbasin versus intrabasin phosphorus loads on the southwestern nearshore of Lake Ontario. *Journal of Great Lakes Research*.

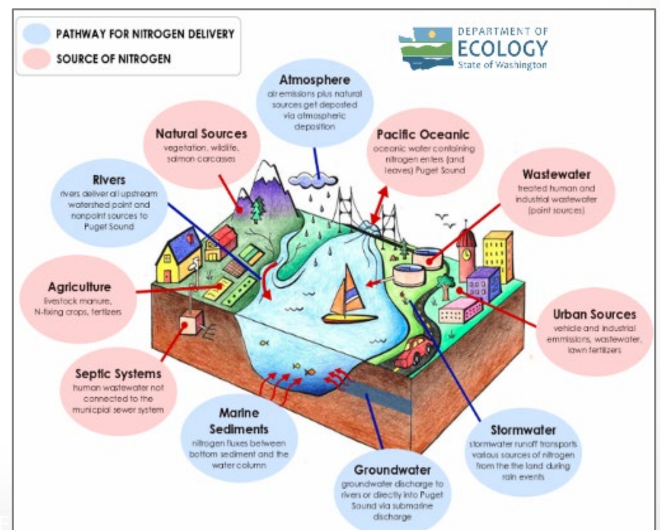
A Puget Sound Whole-Basin Decision Support Framework for Modeling Biophysical Controls and Transfers of Water, Nutrients, and Contaminants Across Terrestrial-Marine Boundaries

Issue: The Puget Sound National Estuary is experiencing major declines in endangered salmonids, orca, and supporting food web species. No integrated terrestrial-marine modeling frameworks exist to support whole-ecosystem recovery planning.

Approach: Develop and apply a coupled terrestrial-marine modeling framework to identify and prioritize nutrient and contaminant reduction strategies for accelerating recovery of the Puget Sound ecosystem.

Partners: Pacific Northwest National Laboratory; University of Washington; NOAA; EPA Region 10; tribal, community, state and federal members of the Puget Sound Partnership.





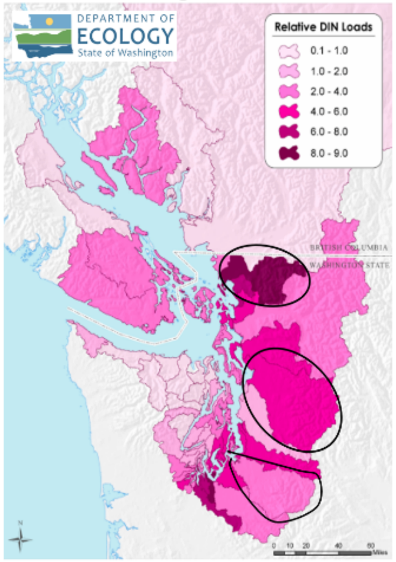
A Puget Sound Whole-Basin Decision Support Framework for Modeling Biophysical Controls and Transfers of Water, Nutrients, and Contaminants Across Terrestrial-Marine Boundaries

Status:

Publications/presentations:

- Barnhart et al. 2021. Modeling the hydrologic effects of watershed-scale green roof implementation in the Pacific Northwest, United States. Journal of Environmental Management 277:111418.
- McKane et al. 2020. An integrated multi-model decision support framework for evaluating ecosystem-based management options for coupled human-natural systems. Pp. 255-274 in: Ecosystem-based Management, Ecosystem Services and Aquatic Biodiversity: Theory, Tools, and Applications. Springer Nature.
- McKane et al. 2021. Model analysis and visualization of 6PPD-quinone fate and transport in Longfellow Creek watershed, Seattle, USA. EMCON 2021, The 7th International Conference on Emerging Contaminants.

Amounts, sources of nitrogen loads to Puget Sound are highly variable



"River loads contribute the second largest local input of inorganic nitrogen to Puget Sound (after wastewater loading). There are about 15 major rivers that discharge to Puget Sound."
https://www.arcgis.com/apps/MapSeries/index.html?appid=907dd54271f44aa0b1f08efd7efc4e30

Nooksack River N Loads
- Main sources: ag, CAFO, N dep
Annual DIN load (kg/day) 4,175
Summer DIN load (kg/day) 1,065

Snohomish River N Loads
- Main sources: ag, urban, alder
Annual DIN load (kg/day) 5,945
Summer DIN load (kg/day) 1,600

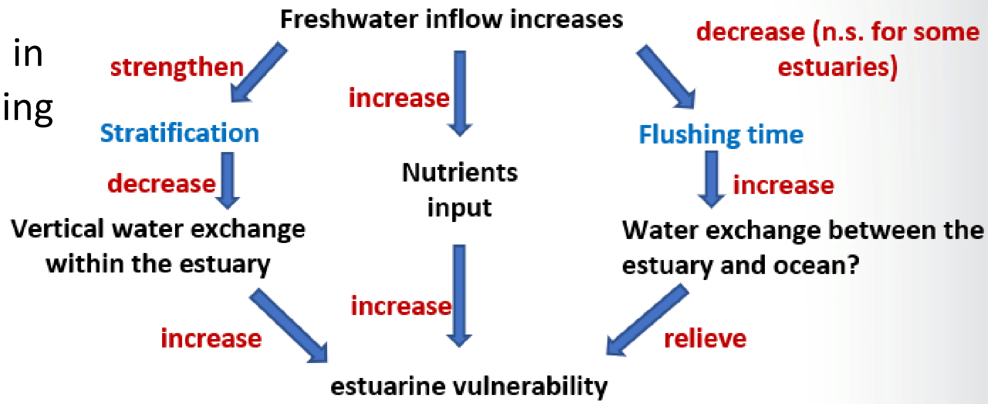
Nisqually River N Loads
- Main sources: septic, alder
Annual DIN load (kg/day) 1,425
Summer DIN load (kg/day) 440

Ongoing Work: Proof-of-concept applications of ORD's VELMA watershed model for quantifying land use and climate impacts on runoff of water, nutrients, and contaminants for 3 of 15 major river sub-basins draining to the Puget Sound estuary.

Future Directions: Apply whole-basin (13,700 mi^2) alternative future scenarios to the coupled VELMA/Salish Sea Model/Atlantis framework. Engage stakeholders and decision makers in prioritizing pollutant reduction and climate mitigation strategies for accelerating Puget Sound ecosystem recovery.

Assessing the Sensitivity and Resilience of Estuaries to Nutrient Loading

Issue: Analysis of estuarine response to decreases in loading, within national framework of factors affecting sensitivity to nutrient loading.



Approach:

- Classification framework for estuarine sensitivity to nutrient loads.
- Compile national database of factors affecting sensitivity of estuaries to nutrient loads (inter- and intra-annual variation in stratification indices, flushing time).
- Combine sensitivity and loading measures to generate exposure indices.
- Compile national databases of nutrient response endpoints (chlorophyll, submerged aquatic vegetation (SAV), sediment particle-size to total organic carbon).
- Analyze endpoint responses for selected systems with documented nutrient load changes.

Status:

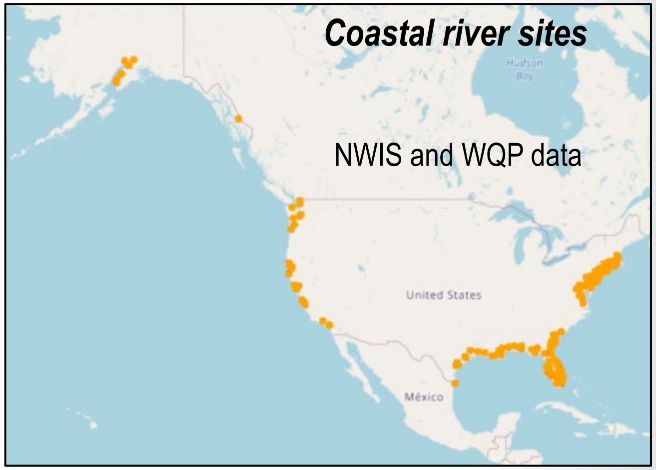
- Publications/presentations: Databases in Estuary Data Mapper (epa.gov/edm); 5 presentations 2019-21.
- Ongoing work: Invited manuscript on nationwide estuarine classification framework (in revision).
- Future directions: Incorporate data on chlorophyll time series from remote sensing into analysis of estuarine responses; meta-analysis of changes in SAV coverage over time; Evaluate climate change effects.

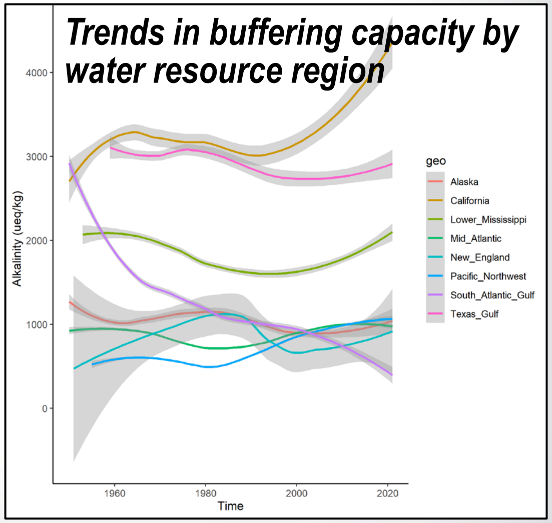
Vulnerability to Land-Based Sources of Acidification in U.S. Estuaries

Issue: Characterizing sensitivity of U.S. estuaries to land-based sources of acidification.

Approach:

- Synthesize existing coastal/riverine pH, alkalinity, temperature datasets.
- Quantify sensitivity of coastal waters to CO2 addition/removal via calculation of "buffer" factors.
- Trend analysis of acidification sensitivities and potential land-based drivers (e.g., changes in nutrient loading, land cover).
- Nationwide classification system for estuarine acidification vulnerability and trends.





Status:

Presentation: 2020 EPA Numeric Nutrient Criteria Webinar Series.
Ongoing Work: Manuscript preparation on sensitivity of U.S. estuarine waters to acidification.

Future Directions:

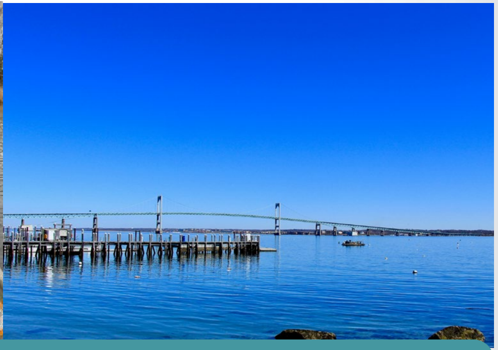
- Updated carbon and alkalinity export budget for conterminous U.S.
- Suitability analysis of carbon dioxide removal and "blue carbon" strategies, including coastal alkalinity enhancement.

Partners: EPA Office of Water, EPA Region 10.

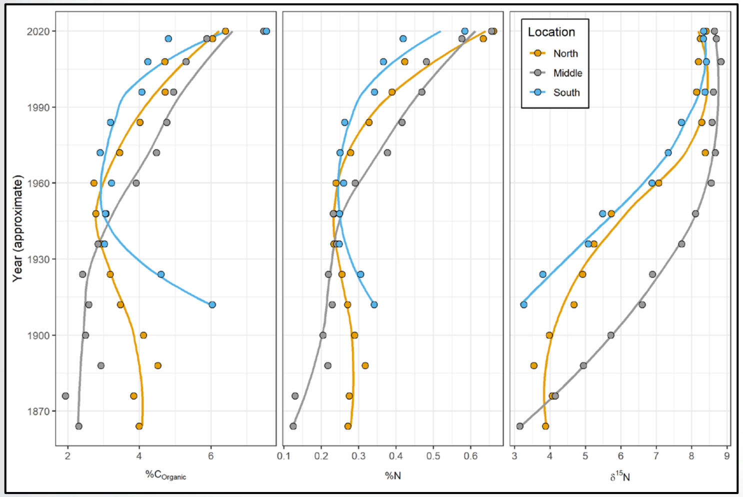
Assessing Ecosystem Responses to Reductions in Point and Non-Point Source Nitrogen Across Spatial and Temporal Scales

Issue: Coastal ecosystem response to management-led nutrient reductions is not well known, particularly for estuary-scale and non-point source reductions.

Approach: To document recovery, frequent water quality measurements and ecological assessments are undertaken in ***Narragansett Bay***, RI, which has seen an 82% reduction in sewage nitrogen loads since 2008, and in ***Wickford Harbor***, RI, where local homes and businesses have been converting from septic to sewer system over the past three years.



Partners: EPA Region 1, the Town of North Kingstown, the North Kingstown Free Library, Narragansett Bay Estuary Program, RI Department of Environmental Management.



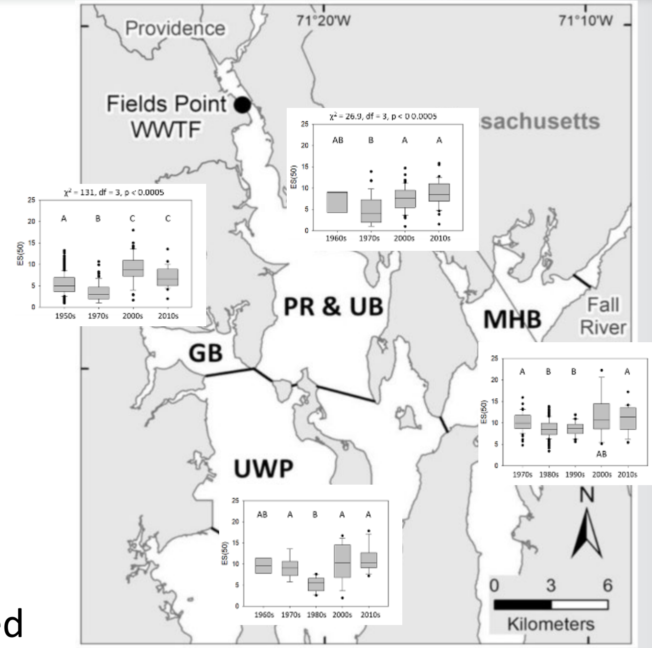
Status:

- Dissolved oxygen impairments in the Wickford Harbor coves have been identified and the linkages between hypoxia and extensive benthic macroalgae will be addressed.
- Core data reflect clear changes in trophic state in the coves and are consistent with records of geomorphic perturbations.
- Nearby Little Narragansett Bay may be included in future research as it similarly has water quality impairments, with low dissolved oxygen and extensive benthic macroalgal cover.

Trends of Benthic Invertebrate Response in Narragansett Bay

Issue: Need to document biological responses to nutrient-related stressors and resulting management actions.

Approach: Analyze qualitative and quantitative data to examine environmental patterns over time. 1. Assemble all available benthic invertebrate data in the Bay (1951-2015). 2. Subset by area. 3. Statistically analyze for decadal patterns. 4. Assemble environmental and management information to explain patterns.



Status:

Publications/Presentations: Pelletier et al. 2021. Benthic macroinvertebrate community response to environmental changes over seven decades in an urbanized estuary in the northeastern United States. Marine Environmental Research 169:105323.

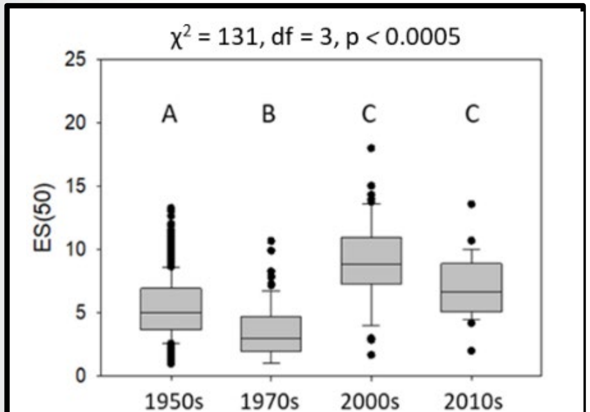
Pelletier et al. 2021. Seven decades of benthic community change in an urbanized estuary: a historical ecology approach. CERF 26th Biennial Conference.

Partners: EPA OW; RI Dept of Environmental Management

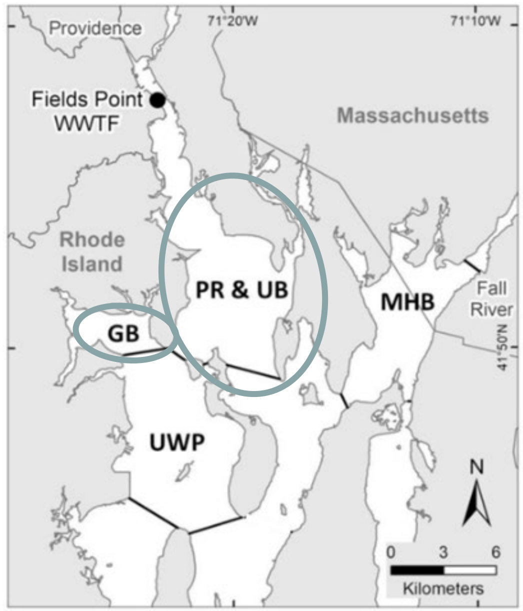
Ongoing Work: Additional data have been collected in the Bay to capture recent management changes.

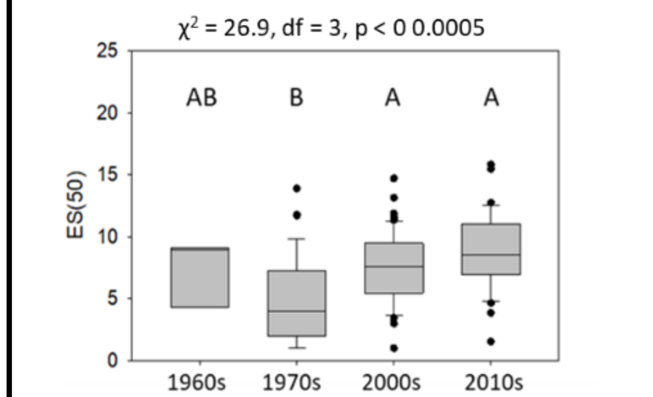
Future Directions: Analysis will focus on (1) more recent decades (more consistent data collection and increased availability of associated environmental data) and (2) interacting climate and management changes.

Trends of Benthic Invertebrate Response in Narragansett Bay: Sewage and Eutrophication



Greenwich Bay (GB)
(1951-2015)

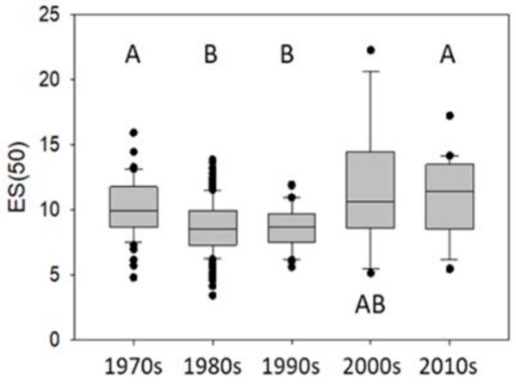




Providence River & Upper Bay (PR & UB)
(1967-2015)

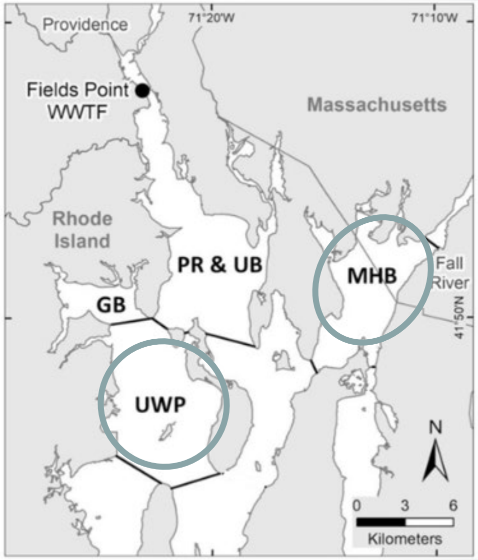
- Low diversity in the 1970s corresponds to when Fields Point, the largest WWTF in the bay, was releasing raw sewage.
- Clean Water Act upgrades completed in the early 1990s and CSO diversion tunnels completed in the late 2000s and mid-2010s, along with implementation of biological controls in the mid-2010s, led to improved condition.
- The benthic community reflected the decline and eventual improvement of the sewage treatment facility.

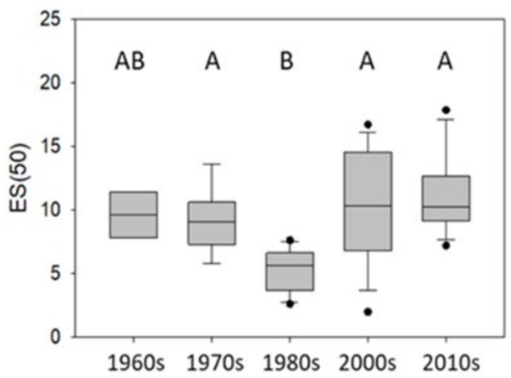
Trends of Benthic Invertebrate Response in Narragansett Bay: Temperature and Climate



Mount Hope Bay (MHB)
(1975-2015)

- A dip in diversity in the 1980s and 1990s in MHB was due to a dramatic increase in cooling water, which led to plummeting fish stocks.
- In 2011, a cooling tower went on-line to remove the thermal stress to the bay.
- Observed benthic impact due to food web changes.





Upper West Passage
(1967-2014)

- A similar diversity decrease in UWP corresponded to an ecosystem shift in Narragansett Bay.
- After 1980 there was a loss of the winter-spring bloom, and shifts in the phytoplankton, zooplankton and fish communities.
- Recovery of the benthos by 2000 was aided by cooler temperatures and a ctenophore that decreased grazing copepod populations.
- Cooler temperatures promoted winter-spring blooms, while low numbers of zooplankton populations allowed these blooms to persist and senesce, providing a source of labile carbon to the benthos.

Questions?

Charge Question 1

Nutrient pollution is the most widespread water quality problem facing the United States, with far-ranging consequences for environmental condition, economic prosperity, and human health and well-being. Current SSWR in Research Area 5 focuses on nutrient-related impacts in watersheds and waterbodies to support determining protective endpoints for aquatic life in different water body types.

What suggestion(s)/ recommendation(s) does the Subcommittee have on ORD's implementation of this research area and on

a) any new or emerging sensitive aquatic life endpoints, and
b) methods, sensors, and/or nutrient indicators for assessing aquatic life endpoints, particularly under changing climate conditions?