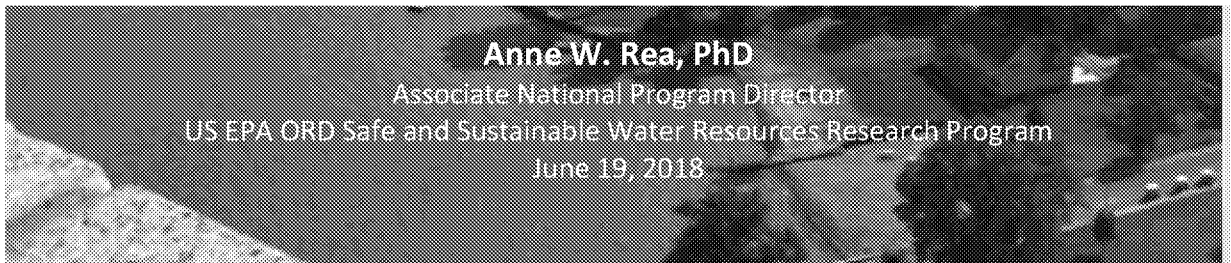
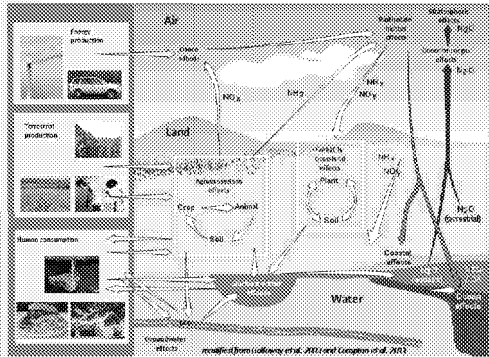


Nutrients and Harmful Algal Blooms





Managing Nutrients in New England

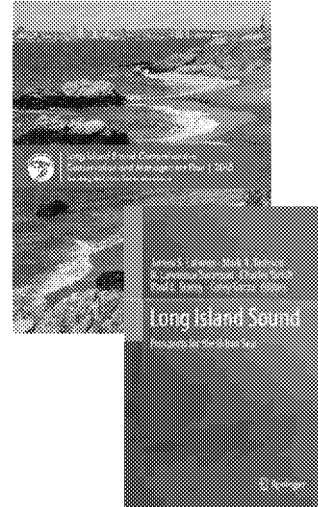


- Excess nitrogen & phosphorous decreases the quality of fresh & estuarine waters, impacting their use by people
- Nutrient management involves multiple environmental media, work by multiple agencies & management interventions at multiple points
- ORD has assisted New England states by
 - Informing nutrient criteria development
 - Evaluating approaches to nutrient management & mapping
 - Evaluating the effects of excess nutrients on aquatic resources
 - Using data-intensive models to predict occurrences of harmful algal blooms & methods for cyanotoxins
 - Encouraging development of nutrient sensors



Nutrient Criteria: Technical Support to CT, ME & NH

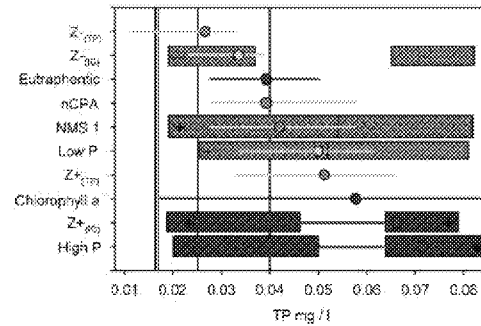
- New England states need technical advice on nutrient related issues for estuarine systems to inform nutrient management & criteria development
- ORD is providing expertise to the Long Island Sound (LIS) Study (CT, NY), Suffolk County (NY), and the Great Bay Estuary (NH/ME) to inform development of nitrogen thresholds for embayments
- This work continues
 - 25 year synthesis of LIS research, monitoring & assessment (2014)
 - Update of the 24 year old Comprehensive Conservation and Management Plan for Long Island Sound (2015)
 - Draft of technical report for Great Bay Estuary expected summer 2018





Nutrient Criteria: CT Streams

- CT required quantitative information on nutrient-response relationships to support stream nutrient criteria development
- ORD worked with CT Department of Energy and Environmental Protection to analyze state monitoring data and develop ecological & non-ecological approaches for setting criteria
- Resulting in scientifically defensible & ecologically relevant total phosphorous criteria
- Analyses informed stream nutrient criteria development for phosphorus



4

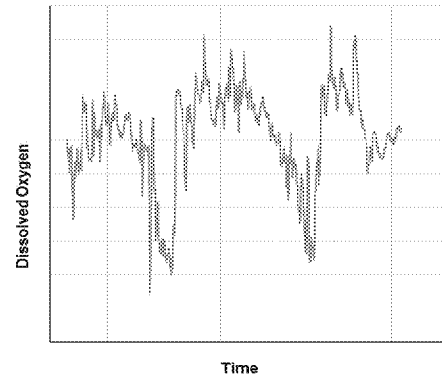
Results: Scientifically defensible and ecologically relevant TP criteria were identified at (1) 0.020 mg/l for designating highest quality streams and restoration targets, above which sensitive taxa steeply declined, tolerant taxa increased, and community structure changed, (2) 0.040 mg/l, at which community level change points began to occur and sensitive diatoms were greatly reduced, (3) 0.065 mg/l, above which most sensitive diatoms were lost and tolerant diatoms steeply increased to their maxima, and (4) 0.082 mg/l, which appeared to be a saturated threshold, beyond which substantially altered community structure was sustained.

Figure: Summary of change points and threshold generated from non-ecological approaches (vertical black line from left to right are modeled TP and t25th percentiles of study sites, ecoregion, and nutrient region XIV) and ecologically based approaches. Circles represent change points and horizontal lines are 90th percentiles. Textured boxes represent ranges of TP within which metrics had substantial changes as indicated by boosted regression trees, and symbols represent steep sections of response curves where the greatest increases (+) or decreases (-) occurred. The 90th percentile (0.222mg TP/l) of chlorophyll a is beyond



Dissolved Oxygen Standards for MA & NH

- MA and NH are reevaluating their marine dissolve oxygen standards
- ORD provided technical assistance through Region 1 for the application of EPA's saltwater dissolved oxygen criteria and its implementation with time-varying dissolved oxygen in MA & NH marine waters
- Assistance increased confidence in how the 2000 Virginian Province criteria document was created & its applicability to MA & NH
- Anticipated improvement to MA & NH dissolved oxygen standards





Managing Phosphorus: Monponsett Ponds, MA

- Water supply management of Monponsett Ponds in Halifax, MA increased retention time of phosphorus, resulting in extended blue-green algal blooms
- ORD worked with local watershed group to apply Watershed Management Optimization Support Tool (WMOST*) to evaluate solutions to meet water demands while minimizing interbasin transfers
- WMOST identified need to reduce interbasin transfers, with green infrastructure best management practices (BMPs) a common element in least cost solutions
- Halifax Board of Health used results in applying for grants to implement stormwater BMPs in watershed to increase infiltration (water supply) & reduce runoff to ponds



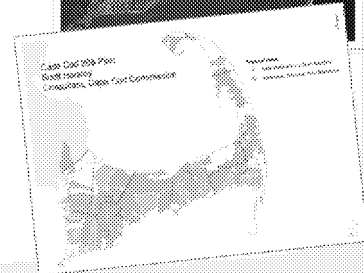
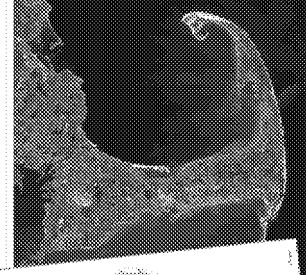
*<https://www.epa.gov/ceam/wmost>

6



Managing Nitrogen on Cape Cod, MA

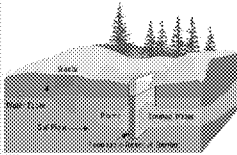
- Approximately 34 watersheds on Cape Cod, MA with Total Maximum Daily Loads for nitrogen not being met currently
- 2014 Conservation Law Foundation sued US EPA for not meeting the Clean Water Act limits for nitrogen in Cape Cod's estuaries
- Responsibility had been delegated to the state of Massachusetts
- The state had delegated responsibility to the Cape Cod Commission
- Organizations & communities are revisiting their roles & how to address the loading limits





How ORD Is Helping MA & Cape Cod Communities

- Integrating social and ecological data
- Evaluate effectiveness of alternative solutions
- Support towns to weigh the tradeoffs & co-benefits of alternative solutions
- Customized solutions appropriate for communities to achieve Clean Water Act goals



Decision support tool—approach to evaluate different solution sets on alternatives

Evaluating peoples' acceptance of various alternative approaches

Alternative septic systems such as permeable reactive barriers (PRBs) can offer an efficient means of controlling nitrogen loads in areas where N inputs are dominated by septic systems

In coastal areas, PRBs may be most beneficial (most bang for the buck) in densely populated near-shore locations where they may also be susceptible to seawater intrusion

Our experiment examined how saltwater intrusion affects the nutrient removal capacity of woodchip-based PRBs

Preliminary results (for one species of nitrogen, nitrate) suggest that nitrogen removal efficiency is not substantially impacted by episodic seawater intrusion

Results will help to inform decisions to install woodchip-based PRBs in coastal areas prone to episodic flooding events by providing data on their potential efficiency in these environments

10/19/2017



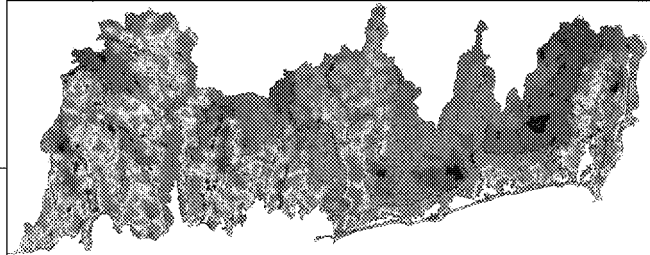
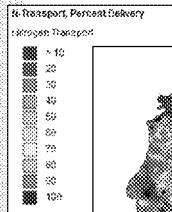
Mapping Nutrients: N-SINK

Purpose

- N-Sink is a useful web-based decision support tool built on biogeochemistry, hydrology, and GIS that shows locations sensitive to nitrogen pollution within a watershed
- N-Sink uses hydrology, land-cover, and best available biogeochemistry data to estimate Nitrogen retention along the flowpath
- Developed in collaboration with University of Connecticut and the University of Rhode Island

Application

- N-Sink is used by land use planners and managers as a planning and prioritization tool for N decision making in watersheds
- Web based with maps for users
- Provides insight to decision makers about nitrogen retention and locations sensitive to nitrogen loading



Heat map of nitrogen retention in some New England HUC 12 "watersheds." Red indicates N is not retained with watershed. Blue indicates low N delivery or high retention of N.

<http://clear.uconn.edu/projects/nsink/>

9

ORD continues N-Sink Tool Development with U Conn, ORD, and R1 EPA

N-Sink team works with R1, U Conn, and ORD on watersheds for inclusion in the current N-Sink web tool. Available now for watersheds in New England.

Applying N-Sink in its current form to new watersheds of interest. The goal is to improve the web tool and make heat maps for more watersheds.

Cooperative Agreement funded to expand N-Sink platform for broader application.

Convert N-Sink to support greater spatial coverage. Go national. Requires further model development (Vector based to Raster based for broader application)

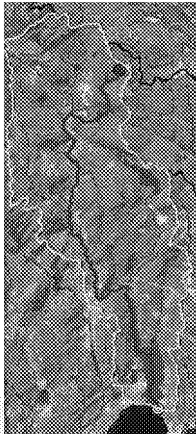
Evaluating inclusion of BMP's, other nutrients like P, and export layers for other applications

Continued outreach for community input to improve the tool.

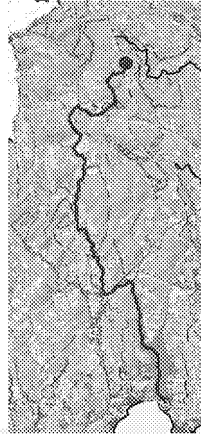


N-SINK Case Study: Niantic River Watershed, CT

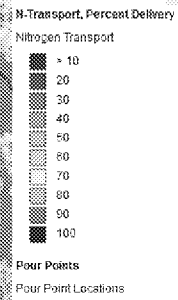
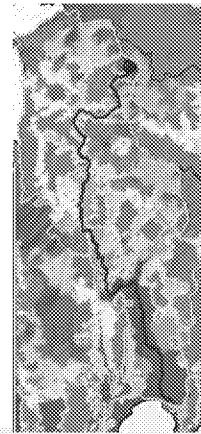
1) Start with hydrology in a watershed (e.g. Niantic R.)



2) Move water and N where landscapes remove N along path. (e.g. 93% N removed 7% remains)



3) Repeat every grid cell to see where N is and is not retained to generate a "heat map".



How: N-sink step by step:

Water moves down hill. Water transport is used as N transport (that is ok because Nitrate is mobilized by water)

Nitrogen is retained by each landscape feature at a certain biogeochemical rate x duration of water/nitrogen staying in that feature as it moves out of the watershed. Back calculate to the original location and assign a %retention and %exit.

Repeat for every grid cell in the watershed and you have a retention surface that tells users where the sensitive areas are and where the robust areas are located.

What: So far we have funded URI and Uconn to produce reports on case study use of the tool, the limitations of the tool, and feasibility of expansion. Part of this work included heat maps that are now expanded to the entire study area.

Based on published science, nationally available data, and best available Biogeochemical functions ported to a web-based tool.

Uconn and URI are our partners and have an outreach component that we can tap directly into for tool development and enhancement.

<http://clear.uconn.edu/projects/nsink/index.htm>

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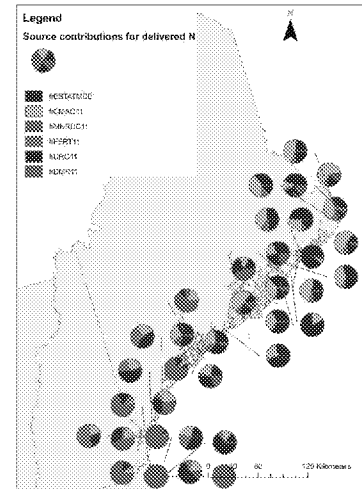
Evaluating inclusion of BMP's, other nutrients like P, and export layers for other applications

Continued outreach for community input to improve the tool.



Mapping Nutrients: Estuary Data Mapper

- Status & trends of nitrogen loads & sources to estuaries are needed to inform Comprehensive Conservation and Management Plans, Coastal Zone Management Plans & Total Maximum Daily Loads
- ORD developed a virtual data portal for information on estuaries & coastal watersheds of the US
- Existing data on nitrogen sources & loadings to estuarine watersheds added to Estuary Data Mapper
- When combined with regional SPARROW* models, Estuary Data Mapper can inform managers about relative sources, loads & trends in their estuaries

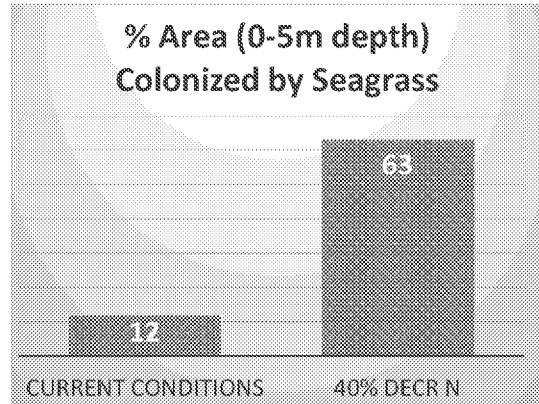


*USGS Spatially Referenced Regression On Watershed Attributes (SPARROW)



Evaluating Effects of Nitrogen on Eelgrass

- Changing nutrient loads, in combination with other moderating factors, will affect eelgrass recovery in Narragansett Bay, RI
- ORD developed predictive seagrass presence/absence model accounting for spatial autocorrelation
- The Narragansett Bay Seagrass Model produced robust predictions of eelgrass extent
- Model provides ability to discriminate factors, predict recovery & potential factors limiting recovery (e.g., tidal currents) at specific sites in the Bay

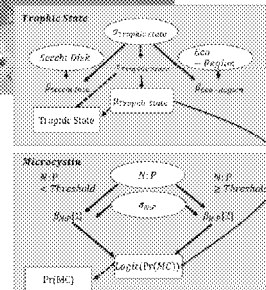
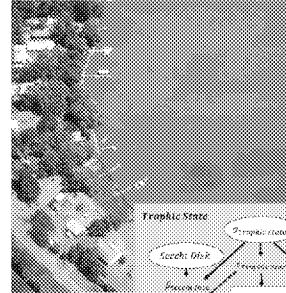


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Predicting Occurrences of Harmful Algal Blooms

- Harmful algal blooms of cyanobacteria are occurring more frequently, and are more severe, in New England lakes and reservoirs, with potential ecological, human health & economic consequences
- ORD is developing data-intensive statistical models to predict the likelihoods of bloom events and of microcystin in individual water bodies
- Modeled relations developed between landscape characteristics & lake trophic state, and between trophic state & presence of microcystin
- Modeled results can inform management of conditions (e.g., nutrient loads) influencing bloom occurrence, and can direct routine monitoring for harmful algal blooms





Analytical Methods for Cyanotoxins in Drinking & Ambient Waters

Microcystins and Nodularins

- **Method 544:** Determination of microcystins and nodularins in drinking water by LC/MS/MS
- **Method 546:** Determination of microcystins and nodularins in drinking water and ambient water by enzyme-linked immunosorbent assay (ELISA)
- **Single Laboratory Validated Method:** Determination of microcystins and nodularins in ambient freshwaters by LC/MS/MS

Cylindrospermopsin and Anatoxin-a

- **Method 545:** Determination of cylindrospermopsin and anatoxin-a in drinking water by LC/ESI-MS/MS
- **Single Laboratory Validated Method:** Determination of cylindrospermopsin and anatoxin-a in ambient freshwaters by LC/MS/MS

Domoic Acid

- **Methods Development:** Determination of domoic acid for marine waters (RI)

www.epa.gov/water-research/methods-models-tools-and-databases-water-research#cyanotoxins



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EPA Method 544: Determination of Microcystins and Nodularin in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) This method is used to determine six microcystins (including MC-LR) and nodularin in drinking water using solid phase extraction and liquid chromatography tandem mass spectrometry (SPE-LC/MS/MS). The advantage of this SPE-LC/MS/MS is its sensitivity and ability to speciate the microcystins. This method development task establishes sample preservation techniques, sample concentration and analytical procedures, aqueous and extract holding time criteria and quality control procedures.

EPA Method 545: Determination of Cylindrospermopsin and Anatoxin-a in Drinking Water by Liquid Chromatography Electropray Ionization Tandem Mass Spectrometry (LC/ESI-MS/MS) This method is used for the determination of the algal toxins, cylindrospermopsin and anatoxin-a, in finished drinking water. Method 545 requires the use of MS/MS in Multiple Reaction Monitoring (MRM) mode to enhance selectivity. It is intended for use by analysts skilled in the operation of LC/ESI-MS/MS instrumentation and the interpretation of the associated data.

EPA Method 546: Determination of Total Microcystins and Nodularins in Drinking Water and Ambient Water by Adda Enzyme-Linked Immunosorbent Assay (ELISA) This method is used for the determination of total microcystins and nodularins in finished drinking water and in ambient water using ELISA. It measures the total concentration based on detection of a characteristic feature common to microcystin and nodularin congeners (structural variants).

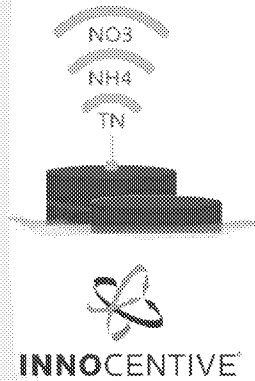
Single Laboratory Validated Method for Determination of Cylindrospermopsin and Anatoxin-a in Ambient Freshwaters by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) This standardized, single laboratory validated liquid chromatography/tandem mass spectrometry (LC/MS/MS) method is used for the detection of

cyanotoxins—cylindrospermopsin and anatoxin-a (combined intracellular and extracellular)—in ambient freshwaters. It requires the use of very small volumes of organic solvent and very small quantities of pure analytes, thereby minimizing potential hazards to both the analyst and the environment as compared to the use of large volumes of organic solvents in conventional liquid-liquid extractions.

Single Laboratory Validated Method for Determination of Microcystins and Nodularin in Ambient Freshwaters by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) This standardized, single laboratory validated liquid chromatography/tandem mass spectrometry (LC/MS/MS) method is used for the detection of cyanotoxins—microcystins and nodularin (combined intracellular and extracellular)—in ambient freshwaters. It requires the use of very small volumes of organic solvent and very small quantities of pure analytes, thereby minimizing potential hazards to both the analyst and the environment as compared to the use of large volumes of organic solvents in conventional liquid-liquid extractions.



Advanced Septic System Nitrogen Sensor Challenge



- Region 1, Cape Cod Commission (MA) & Suffolk County (NY)
 - Significant nitrogen pollution from 360,000 cesspools/conventional septic
 - 210,000 need to be replaced
- Innovative/Alternative Onsite Wastewater Treatment System
- Sensor challenge to develop a cost-effective septic system nitrogen sensor
- Status
 - Phase I: proposals
 - Phase II:
 - MA Alternative Septic System Test Center (MASSTC) field testing, verification 2018-19
 - Order for 200 sensors by The Nature Conservancy, Spring 2020

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innovative/alternative onsite wastewater treatment system (I/A OWTS)

The current cost of monitoring one I/A OWTS during the four and half years of the MA permitting process is \$4,500. It costs \$300 to sample 1 system and run the lab tests. For an I/A OWTS manufacturer to monitor the required 50 systems in MA over 4.5 years, it costs \$155,250 for the sampling.

Sensor challenge to develop a cost-effective septic system nitrogen sensor

Assures long-term system functionality & evidence for recommendation

Lower data collection costs

Performance and maintenance

Verification and reduce field testing costs; improve performance

Aid in streamlining permitting process over time

Workshop/webinar: 7/12/2018

1st no risk one month test: 10/1/2018

2nd no risk one month test: 1/7/2019

By invitation only, 6 month field verification test: 5/13-11/15/2019

Awards: ISO ETV 14034 verification reports, 2/21/2020

Proposed TNC order for 200 sensors: Spring 2020

All the sensor testing will be conducted at the MA Alternative Septic System Test Center (MASSTC) on Cape Cod. Our Technical Panel for the prototype testing includes the following people from the R1 area: George Loomis (URI professor, advanced septic system expert & advisor to RI), George Heufelder (Head of MASSTC) and Brian Dudley (MA DEP).

Tel Labs is also developing a very low cost nitrate and ammonium sensor for the Advanced Septic System Nitrogen Sensor Challenge. Mark Bowkett, CEO of Tel Labs, will be speaking next Monday at the showcase meeting in Woods Hole.



Assisting New England with Nutrient Issues

- Informing development of nutrient and related criteria & standards
- Evaluating approaches to nutrient management & mapping
- Evaluating the effects of excess nutrients on aquatic resources
- Using data-intensive models to predict occurrences of harmful algal blooms, and developing methods for quantification of cyanotoxins in drinking water
- Encouraging development of nutrient sensors



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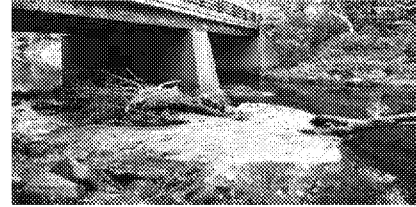
Questions?

Anne W. Rea, PhD
Associate National Program Director
US EPA ORD Safe and Sustainable Water Resources Research Program
rea.anne@epa.gov
919-541-0053



Managing Nutrients: Upper Taunton Watershed, MA

- Taunton River watershed is one of the fastest developing watersheds in MA, with eutrophication-related 303d listings for lakes & streams, and a need to control nitrogen loading to Narragansett Bay, RI
- ORD worked with consortium of NGOs & planning groups to apply the Watershed Management Optimization Support Tool (WMOST*) to determine most cost-effective management actions to meet multiple loading targets
- Results demonstrated that green infrastructure best management practices & riparian buffer restorations could be most cost effective solutions in reducing non-point source phosphorus loads to lakes & nitrogen loads to Narragansett Bay
- Consortium requesting additional funds to apply WMOST to future growth/climate scenarios in watershed & to inform municipal managers



*<https://www.epa.gov/ceam/wmost>

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303d listings driven by phosphorus



Nutrient Sensor Challenges

**EPA-led interagency collaboration
on prize challenges to address
nutrients** www.challenge.gov



CHALLENGE	GOAL	RESULT/STATUS
Nutrient Sensor Challenge	Affordable nitrogen and phosphorous sensors to market	3x price reduction sensors on the market
Visualize Nutrients	Effective communication/visualization of nutrient data	Award winning video
Smart Septic Sensor Challenge	Nitrogen sensors to monitor septic system integrity	Breakthrough technology for low-cost nitrogen sensors (U. Connecticut)
Nutrient Reduction Challenge	Recover nitrogen/phosphorous from pork and dairy manure	Prototypes in development
Nutrient Sensor Action Challenge	Demonstrated use of nitrogen/phosphorous sensor data for use in decision making	Stage 1 - 11 teams participated Stage 2 - launch February 2018

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In 2013 a coalition of agencies agreed to work together on issues pertaining to nutrient pollution.

EPA, USGS, NOAA, NIST and USDA; The Agencies convened a Visioneering with experts from different sectors and disciplines to identify barriers; from those barriers a set of challenges grew that the agencies worked on together.

This list is some of the activities by the coalition;

Nutrient Sensor Challenge – low cost sensors for N and P; there is now a sensor on the market and other companies have reduced their prices

Visualize Nutrients Challenge – challenge to create effective examples of visualizing data from nutrient sensors; help turn data into information

Smart Septic Challenge – with Massachusetts, Suffolk County NY -serious issues with N from failing septic systems; needed a small and affordable sensors; breakthrough technology identified from U Conn.

Nutrient Reduction Challenge – Office of Water challenge with extensive public/private partnership to find cost effective solutions for N and P recovery from pork and dairy

Nutrient Sensor Action Challenge – Proof of concept challenges for communities/organizations to demonstrate added value and opportunity for N/P sensor data to be used in decisions

Here are the two companies from the sensor challenge that now have low cost sensors on the market. I know Systema has sensors collecting data in New England and in Ohio – I don't know exactly who are the partners but am trying to find out .

Systema – WIZ probe

http://www.systema.it/index.php?option=com_k2&view=item&layout=item&id=223&Itemid=175&lang=en

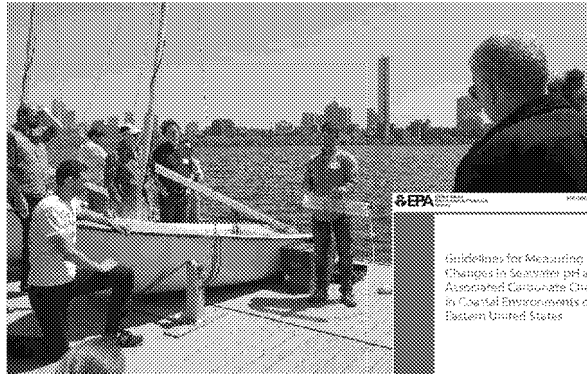
Tel Labs – Lowcost sensor for nitrate, nitrite, ammonium and phosphate for open waters: <http://www.aquamonitrix.com/>

Also there is a 4th sensor for nitrate, nitrite, ammonium and phosphate for open waters: <http://www.aquamonitrix.com/> It was developed by Tel Labs. They were involved in the Nutrient Challenge, but the Aquamonitrix was not commercial ready until recently, and I think it costs \$5-6K.



Near-Coastal Acidification & Hypoxia – CT, MA & ME

- Nutrient-enhanced near-coastal acidification has the potential to adversely affect shellfish
- Changes in pH in near-coastal waters currently are difficult to measure
- ORD developed monitoring guidelines & demonstrated their application during citizen science workshops with a range of stakeholders
- Organizations now coordinating monitoring efforts, equipment & data



ORD scientist Adam Pimenta demonstrating seawater sampling methods in Boston

<https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100UDMR.txt> 20

Coastal communities are concerned about coastal acidification, which has been difficult to monitor with traditional open water sensors because it is influenced by dynamic eutrophication processes and pulses of freshwater after storm events.

EPA recently published coastal acidification monitoring guidelines, which are written for a wide variety of audiences concerned about impacts. The guidelines can be found here:
<https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100UDMR.txt>.

Science partners held citizen science workshops in Connecticut, Maine, and Massachusetts focusing on the guidelines and on strengthening regional connections among researchers, citizen scientists, and other stakeholders. EPA staff served as 'science advisors' during the workshops.

Workshop participants included shellfish growers, educators, and representatives of municipal shellfish commissions, watershed associations, state agencies, regional organizations (e.g., NEIWPCC, Save the Bay, Harbor Watch, etc), land trusts, and research organizations. These organizations resolved to coordinate their efforts, share data, equipment and lessons learned, and have begun to discuss quarterly sampling "blitzes" and shared calibration exercises.

EPA's recently released coastal acidification monitoring guidelines lay out the relationships with nutrient enrichment and may be of interest (<https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100UDMR.txt>). The document also contains a bunch of info on methods. There has been a ton of interest; Adam and I served as 'science experts' during three citizen science workshops funded by NOAA and held in May in Connecticut, Maine, and Massachusetts. The guidelines served

as the 'jumping off' point for the workshops, where we gave an overview and demonstrated some of the methods and equipment. You are welcome to use any of the slides in the 'gear' file you attached, but my guess is that they would take too much explanation to be of value for state the commissioners meeting, perhaps with the exception of the ones with pictures of shellfish experiments.

Note that Maine and Rhode Island both have legislative commissions on ocean acidification. Not sure about MA and CT and NH.